The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

2025 ANNUAL REPORT

FOREWARD

The past year has been one of meaningful progress for the ASSURE and our partners. Together with the FAA, we continue to deliver research needed to inform the policies, regulations, and standards that guide the safe and efficient integration of unmanned aircraft systems into the national airspace. As the use of unmanned systems expands into more complex and high-value missions, these technologies are proving their worth in the places they're needed most—supporting commerce, enhancing public safety, and improving daily life across the nation.

Over the last year, our research teams have completed several projects that directly address some of the most pressing challenges in UAS integration. These include validation of Detect and Avoid (DAA) risk ratios to ensure the safe coexistence of manned and unmanned aircraft; studies of collision severity between small UAS and manned helicopters in critical flight zones; and analysis of UAS operations for disaster preparedness and emergency response, which expands our research on how UAS can safely and effectively support first responders. We also advanced research on cybersecurity oversight and risk management, emphasizing the need for system-level resilience as UAS become increasingly connected, and DAA track classification and filtering, improving the accuracy of detection and avoidance algorithms. These findings, along with workforce and outreach efforts that continue to strengthen the next generation of aviation professionals, reflect the practical, applied focus that defines ASSURE's work.

While the pace of new research tasking has slowed as the FAA refines its priorities for the next phase of UAS integration, ASSURE has continued to use this time to strengthen our foundation; validating data, refining methodologies, and preparing for the next generation of research that will shape the future of unmanned and autonomous systems.

ASSURE's mission also continues to grow beyond traditional research boundaries through expanded collaboration with our partners across government, academia, and industry. Our work with the DHS, FEMA, and NIST has supported ongoing efforts to better integrate UAS into public safety infrastructure. These partnerships, strengthened under the 2024 FAA Reauthorization Act, formalize ASSURE's broader role through the ASSUREd Safe program, which now serves as a foundation for standardized UAS training, credentialing, and operational safety across federal, state, and local agencies. This recognition affirms the FAA's and Congress's shared confidence in ASSURE's ability to bridge research, policy, and practice for national benefit.

In addition to our research and interagency work, ASSURE continues to play an active role in shaping global standards. Our researchers have contributed to ASTM International task groups developing guidance for Beyond Visual Line of Sight (BVLOS) operations and DAA performance, critical pieces of the regulatory and technical framework that will enable expanded operations and Advanced Air Mobility (AAM). Across the country, our universities have supported multiple flight test campaigns to inform the safe implementation of UAS detection systems, to help ensure a safer operating environment for all airspace users.

With the addition of the University of Oklahoma and Oklahoma State University to our coalition, ASSURE's reach and technical capacity continue to grow. The breadth of expertise within our 32 member universities and over 100 partners underscores the strength of this coalition and its ability to address complex challenges through collaboration and innovation.

As you explore the 2025 Annual Report, I invite you to review the results of our projects, connect with our teams, and share your perspectives on the path ahead. The challenges facing our industry are significant, but the work reflected in these pages demonstrates the continued strength of our partnerships and the collective determination to move forward—safely, efficiently, and together.

HANNAH THACH
Executive Director
ASSURE

MISSISSIPPI STATE UNIVERSITY

FEDERAL AVIATION ADMINISTRATION

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**The photographs and images used throughout this report are not representative of the equipment used in testing.*

ASSURE LEADERSHIP

OVER THIRTY OF THE WORLD'S LEADING RESEARCH INSTITUTIONS
AND MORE THAN A HUNDRED LEADING INDUSTRY AND GOVERNMENT PARTNERS COMPRISE
THE ALLIANCE FOR SYSTEM SAFETY OF UAS THROUGH RESEARCH EXCELLENCE

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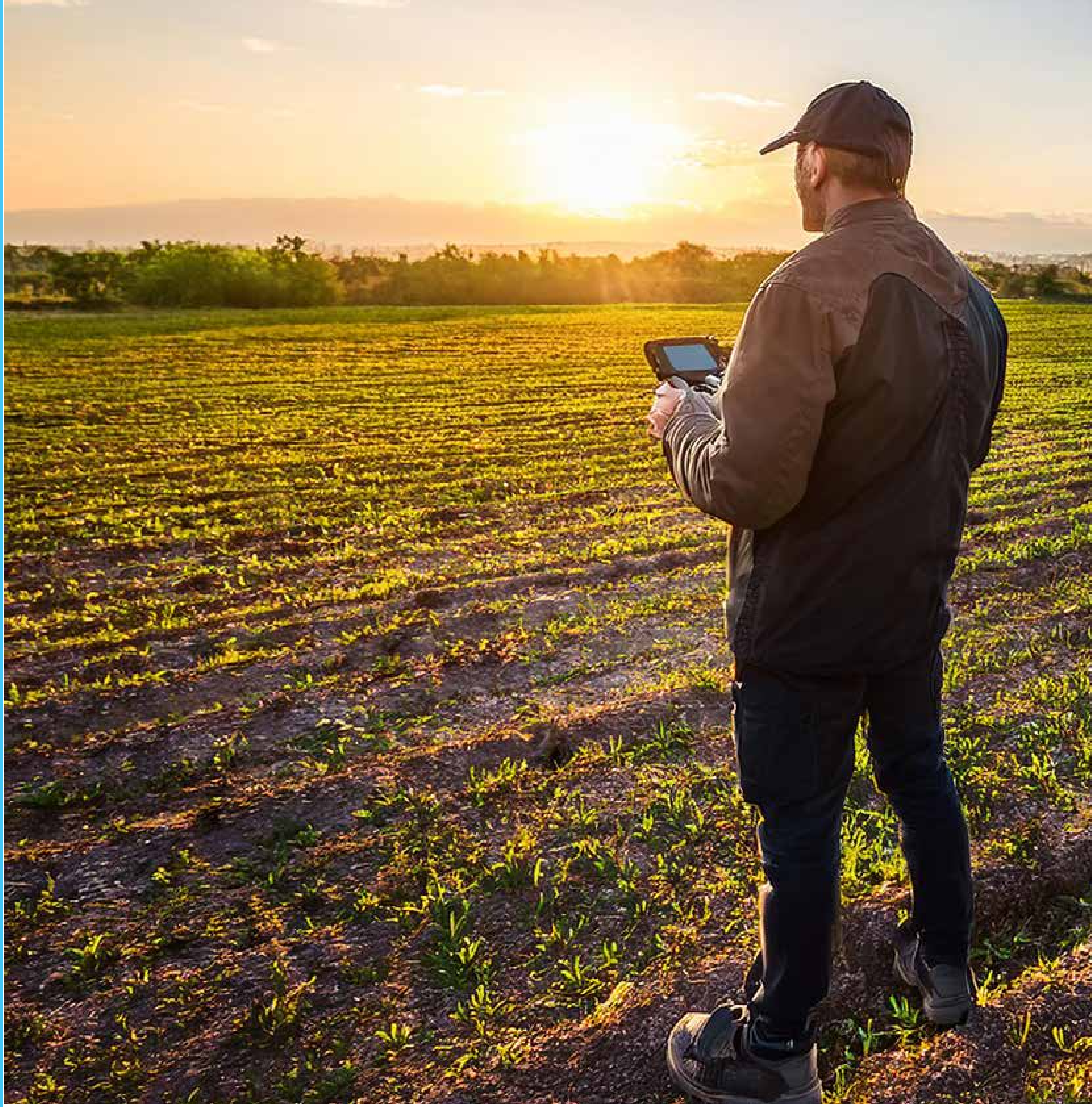
MISSION: Provide high-quality research & support to autonomy stakeholders both within the US and beyond to safely & efficiently integrate autonomous systems into the national & international infrastructure, thereby increasing commerce and overall public safety and benefit.

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.



INFORMING UAS POLICY THROUGH RESEARCH

The FAA's Center of Excellence for UAS Research
ASSURE
Alliance for System Safety of UAS through Research Excellence

ACKNOWLEDGMENTS

This year has been one of transition and perseverance for ASSURE and our partners. I want to start by thanking Stephen Luxion for his years of dedicated service to the coalition and his leadership in advancing our research mission, both within the United States and internationally, to safely and efficiently integrate UAS into the national airspace system. I'm grateful for the opportunity to continue that work as Executive Director and to help carry forward the vision that he and so many others have built.

ASSURE's progress comes down to the people who make it happen every day. Our researchers across the coalition continue to produce work that directly shapes policy, regulation, and standards for the safe integration of UAS. Their dedication, innovation, and professionalism keep this program moving forward, even in the face of change. To all of you, thank you for continuing to promote and strengthen ASSURE's mission through your hard work.

This year also brought some key transitions within the FAA leadership team. After many years of service to the Center of Excellence, Karen Davis, the COE for UAS Program Manager, has accepted a new position as Acting Grants Management, Branch Manager within the Office of NextGen. Her leadership and guidance have been invaluable to the success of this program, and she will be greatly missed. We're excited to welcome Hector Rea as our new Program Manager to take her place. Having served as Deputy, Hector's leadership and insight have already made an impact.

On behalf of the entire ASSURE team, I want to thank the FAA for its continued partnership and sponsorship, and to recognize Karen, Hector, Bill Oehlschlager, and their team of program managers and the project sponsors for their continued support and collaboration.

Finally, I want to thank the ASSURE team, our staff, researchers, and leadership, for your resilience, patience, and trust through this period of transition. Your commitment to our mission and to one another is what keeps this program strong.

With sincere thanks,

HANNAH THACH
Executive Director
ASSURE

FINANCES

ASSURE FY25 FUNDING SUMMARY

TOTAL FUNDING : $105,477,685.43

	AWARD AMOUNT	EXPENDITURES	REMAINING	COST SHARE	COST SHARE REQUIRED	COST SHARE %
PROGRAM OFFICE	$11,653,728.12	$10,257,800.12	$1,395,928.00	$7,666,640.31	$8,494,764.12	90%
CORE SCHOOLS	$93,823,957.31	$74,470,642.94	$19,353,314.37	$50,934,713.50	$64,877,823.56	79%
Drexel University	$3,563,116.69	$3,066,119.80	$496,996.89	$1,565,425.69	$2,924,257.16	54%
Embry-Riddle Aeronautical University	$9,826,269.13	$6,284,867.12	$3,541,402.01	$3,931,050.66	$7,303,924.17	54%
Kansas State University	$5,565,872.00	$4,328,370.43	$1,237,501.57	$3,343,316.04	$5,411,691.53	62%
Mississippi State University	$11,794,235.04	$8,689,176.04	$3,105,059.00	$5,766,879.11	$8,167,845.79	71%
Montana State University	$709,062.28	$709,062.28	$0.00	$599,958.32	$555,653.03	108%
New Mexico State University	$8,136,193.33	$6,625,441.07	$1,510,752.26	$3,339,949.48	$3,907,863.51	85%
North Carolina State University	$1,844,740.39	$1,545,031.66	$299,708.73	$1,089,437.31	$1,297,225.96	84%
Ohio State University	$6,013,698.21	$5,588,883.79	$424,814.42	$4,271,974.42	$3,936,191.09	109%
Oregon State University	$3,507,173.00	$3,505,569.28	$1,603.72	$1,304,470.37	$1,376,323.00	95%
Sinclair Community College	$1,691,000.00	$1,146,968.88	$544,031.12	$1,506,534.24	$1,691,000.00	89%
University of Alabama-Huntsville	$7,992,660.86	$6,844,304.63	$1,148,356.23	$5,103,389.54	$5,516,074.09	93%
University of Alaska-Fairbanks	$7,518,589.39	$4,032,526.87	$3,486,062.52	$1,997,031.29	$3,890,347.96	51%
University of California-Davis	$144,730.00	$144,730.00	$0.00	$93,287.00	$144,730.00	64%
University of Kansas	$3,281,155.33	$2,914,810.94	$366,344.39	$2,048,508.87	$2,278,500.09	90%
University of North Dakota	$12,272,846.78	$10,152,227.91	$2,120,618.87	$5,733,523.61	$6,513,581.30	88%
University of Vermont	$1,713,600.00	$1,262,909.49	$450,690.51	$1,731,583.94	$1,713,600.00	101%
Wichita State University	$7,521,674.88	$7,158,059.54	$363,615.34	$6,823,513.99	$7,521,674.88	91%
Virginia Tech University	$727,340.00	$471,583.21	$255,756.79	$684,879.62	$727,340.00	94%
TOTALS	$105,477,685.43	$84,728,443.06	$20,749,242.37	$58,601,353.81	$73,372,587.68	80%

ASSURE FY25 FUNDING SUMMARY

TOTAL FUNDING $105,477,685.43

	Award Amount	Expenditures	Remaining	Cost Share	Cost Share %
PROGRAM MANAGEMENT	$11,882,250.31	$10,486,322.31	$1,395,928.00	$7,893,247.68	90%
PROJECTS	$93,595,435.12	$74,242,120.75	$19,353,314.37	$50,708,106.13	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	$284,186.01	$284,186.01	$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	$2,203,376.77	$1.02	$2,357,156.77	126%
A17: Airborne Collision Severity Evaluation - Engine Ingestion	$1,532,132.43	$1,532,132.43	$0.00	$1,580,974.27	164%
A18: Small UAS Detect and Avoid Requirements Necessary for Limited BVLOS Operations: Separation Requirements and Training	$1,199,608.51	$1,199,608.51	$0.00	$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	$291,681.65	$0.00	$396,319.22	136%

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	$1,379,521.49	$1,379,521.49	$0.00	$472,732.10	95%
A24: UAS Safety Case Development, Process Improvement, and Data Collection	$1,046,436.98	$1,046,436.98	$0.00	$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	$1,721,897.39	$1,721,897.39	$0.00	$962,923.16	144%
A29: STEM Outreach- UAS as a STEM Outreach Learning Platform for K-12 Students and Educators (STEM III)	$466,014.56	$466,014.56	$0.00	$130,269.09	57%
A31: Safety Risk and Mitigations for UAS Operations On and Around Airports	$1,858,861.97	$1,858,859.01	$2.96	$549,086.15	111%
A33: Science and Research Panel (SARP) Support	$43,160.74	$43,160.74	$0.00	$31,839.61	74%
A35: Identify Wake Turbelance and Flututer Testing Requirements for UAS	$1,479,132.51	$1,479,132.51	$0.00	$976,301.92	95%
A36: Urban Air Mobility (UAM): Safety Standards, Aircraft Certification and Impact on Market Feasibility and Growth Potentials	$1,099,164.36	$1,099,164.28	$0.08	$728,097.70	104%
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	$0.00	$164,745.33	63%
A40: Validation of American Society for Testing Materials (ASTM) Remote ID Standards-Safety Research Center	$451,209.48	$451,209.48	$0.00	$250,000.00	100%
A41: Air Carrier Operations-Investigate and Identify the Key Differences Between Commercial Air Carrier Operations and Unmanned Transport Operations	$677,062.49	$677,062.49	$0.00	$228,471.01	34%
A42: UAS Cargo Operations-From Manned Cargo to UAS Cargo Operations: Future Trends, Performance, Reliability, and Safety Characteristics Towards Integration into the NAS	$791,164.00	$791,156.80	$7.20	$224,582.33	84%
A43: High-Bypass UAS Engine Ingestion Test	$506,774.02	$506,343.18	$430.84	$213,333.33	100%
A44: Mitigating GPS and Automatic Dependent Surveillance- Broadcast (ADS-B) Risks for UAS	$811,308.02	$809,689.65	$1,618.37	$255,769.67	93%
A45: Shielded UAS Operations-Detect and Avoid (DAA)	$925,608.55	$925,607.71	$0.84	$365,617.33	119%
A46: Validation of Visual Operation Standards for Small UAS (sUAS)	$500,185.35	$500,184.63	$0.72	$246,666.88	100%

FUNDING BY PROJECT

	Award Amount	Expenditures	Remaining	Cost Share	
A47: Small UAS (sUAS) Mid-Air Collision (MAC) Likelihood	$960,786.14	$960,786.14	$0.00	$715,801.48	
A49: UAS Flight Data Research in support of Aviation Safety Information and Sharing (ASIAS)	$348,899.37	$348,899.37	$0.00	$152,047.43	97%
A50: Small Unmanned Aerial Systems (sUAS) Traffic Analysis	$2,178,786.41	$2,178,786.41	$0.00	$908,833.00	
A51: Best Engineering Practices for Automated Systems	$3,621,915.74	$3,488,106.03	$133,809.71	$1,372,756.36	98%
A52: Disaster Preparedness and Emergency Response Phase II	$3,465,954.87	$3,427,294.15	$38,660.72	$669,237.68	61%
A53: UAS Advanced Materials Investigation	$314,425.22	$314,425.10	$0.12	$317,223.50	99%
A54: Propose UAS Right-of-Way Rules for UAS Operations and Safety Recommendations (ERAU, KU, UND)	$1,625,445.81	$1,600,074.32	$25,371.49	$688,574.86	32%
A55: Identify Flight Recorder Requirements for UAS Integration into the NAS	$1,089,090.00	$1,089,076.18	$13.82	$695,136.60	
A56: Evaluate Unmanned Aircraft Systems (UAS) Electromagnetic Compatibility (EMC)	$975,872.17	$975,872.17	$0.00	$325,315.29	
A57: Investigate Detect and Avoid (DAA) Track Classification and Filtering	$1,513,441.00	$1,482,415.53	$31,025.47	$966,890.29	97%
A58: Illustrate the Need for UAS Cybersecurity and Risk Management	$1,869,991.00	$1,716,552.07	$153,438.93	$559,135.95	88%
A60: Evaluation of Unmanned Aircraft Systems (UAS) Integration Safety and Security Technologies in the National Airspace System (NAS) Program	$13,972,343.80	$9,073,446.54	$4,898,897.26	$3,590,024.64	77%
A61: STEM Outreach	$174,881.68	$174,881.68	$0.00	$197,374.26	113%
A62: Disaster Preparedness and Emergency Response Phase III	$2,789,141.12	$2,733,285.35	$55,855.77	$2,845,011.21	102%
A64: Identify Models for Advanced Air Mobility (AAM)/Urban Air Mobility (UAM) Safe Automation	$1,614,226.00	$1,601,450.65	$12,775.35	$1,441,700.49	89%
A65: Detect and Avoid Risk Ratio Validation	$1,990,971.45	$1,990,971.45	$0.00	$1,662,368.60	83%
A67: Determine the Collision Severity of small Unmanned Aircraft Systems (sUAS) in Flight Critical Zones of Piloted Helicopter	$1,795,948.00	$1,795,947.71	$0.29	$1,795,947.71	
A66: Develop Methodolgies to Inform the Integration of Advanced Air Mobility (AAM) into the National Air Space System (NAS)	$2,000,000.00	$1,214,193.60	$785,806.40	$1,332,581.84	67%
A68: Validate sUAS Well Clear Definition	$2,124,949.44	$1,730,800.84	$394,148.60	$1,512,210.58	71%
A71: Conduct Safety Risk Management Analysis on small Unmanned Aircraft Detect and Avoid Systems	$1,048,601.84	$774,573.35	$274,028.49	$759,873.00	72%
A73: STEM Outreach to Minority K-12 Students Using UAS as a Learning Platform	$368,239.27	$367,591.94	$647.33	$368,344.37	100%
A74: Increase Small UAS Conspicuity in Terminal Environments	$2,182,754.32	$966,801.90	$1,215,952.42	$1,232,717.98	56%
A81:Develop small Unmanned Aircraft DAA Human Factors Requirements	$1,717,868.00	$648,567.44	$1,069,300.56	$732,353.88	43%
A82:Develop a Data Driven Framework to Inform Safety Risk Management Mitigation Credit	$1,679,486.00	$413,103.38	$1,266,382.62	$679,274.76	40%
A83: Analyze Drone Traffic	$4,031,239.05	$542,907.96	$3,488,331.09	$947,002.05	23%
A84: Disaster Preparedness and Emergency Response Phase IV	$6,456,511.39	$949,705.49	$5,506,805.90	$1,821,610.54	28%
Totals	**$105,477,685.43**	**$84,728,443.06**	**$20,749,242.37**	**$58,601,353.81**	**80%**

COST SHARE SUMMARY

COST SHARE SUMMARY BY CONTRIBUTORS

Adaptive Aerospace Group, Inc.	$5,897.34
Advanced Thermoplastic Composites	$400.00
AIM Institute	$5,090.00
Airbus	$2,255,176.00
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
CAN Corporation	$722,798.86
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	$1,326,415.69
Embry-Riddle Aeronautical University	$3,101,208.00
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 Automation	$71,000.00
Jaunt Air Mobility	$500.00
K.I.M. Inc.	$85,280.00
Kansas Department of Commerce	$647,382.09
Kansas State University	$3,360,470.96
Keysight Technologies	$566,690.00
Keystone Aerial Surveys	$1,750.00
Kongberg Geospatial	$40,000.00
Mike Toscano	$147,500.00
Misc. External Match - Industry Funds	$310,605.12
Mississippi State University	$3,587,045.64
Montana Aircraft	$6,000.00
Montana State University	$521,387.68
911 Security	$88,781.54
Navmar Applied Sciences Corporation	$2,833,570.87
New Mexico State University	$3,339,949.48
North Carolina Department of Transportation	$459,549.74
North Carolina State University	$1,314,381.67
North Dakota Department of Commerce	$3,066,191.10
Novotech	$500.00
NUAIR	$20,923.02
Ohio State University	$1,686,390.87
Ohio/Indiana UAS Center (ODOT)	$1,813,116.32
Oregon State University	$1,229,470.37
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 Community College	$2,436,353.64
State of Kansas	$91,604.83
Skyfire Consulting	$350,480.00
Solvay	$254.00
Technion Inc	$4,260,468.43
Teijin Carbon America, Inc	$500.00

(CONTINUED ON NEXT PAGE)

COST SHARE SUMMARY

COST SHARE SUMMARY BY CONTRIBUTORS

The Cirlot Agency	$120,237.56
Transport Canada	$531,654.00
Unifly, LLC	$32,000.00
University of Alabama in Huntsville	$3,179,309.00
University of Alaska Fairbanks	$1,997,031.29
University of California Davis	$93,287.00
University of Kansas Center for Research, Inc.	$1,394,500.25
University of North Dakota	$1,947,446.17
University of North Dakota Aerospace Foundation	$44,649.20
University of Vermont	$1,402,253.93
Unmanned Systems Group	$34,565.64
USRA, Inc	$500,467.00
Virginia Polytechnic Institute & State University	$877,138.65
Wichita State University	$4,586,073.28
Total	**$58,601,353.81**

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
FY24 Cost Share	$9,564,387.00
FY25 Cost Share	$7,612,353.43
Cumulative Cost Share	**$58,601,353.81**

SUMMARY BY SOURCE

Universities	$37,479,617.11
State Contributions	$6,077,844.08
3rd Party Contributions	$15,043,892.62
Total	**$58,601,353.81**

RESEARCH PROJECTS

HIGH-BYPASS TURBOFAN UAS ENGINE INGESTION TEST

A11L.UAS.85_A43

PARTICIPANTS

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WICHITA STATE UNIVERSITY

High-Bypass Turbofan UAS Engine Ingestion Test

Background:

The 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 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 are crucial for future FAA regulatory and policy development surrounding safe UAS integration into the NAS.

Approach:

The research was carried out in close collaboration with the test partner and the FAA. The team informed and reviewed the test plan created by the test partner. The test partner provided the team with rough scans of the fan blade used in the experiment. A Finite Element (FE) model was created using material models developed by the FAA in previous research programs, and are the closest openly available pre-existing material models. These models were also used in 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, were shared with the team for independent analysis. The team ran computational simulations at the test conditions 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 provided 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 provided a final test report and their analysis of the test event, which the research team reviewed and provided feedback based on their expertise and independent analysis. Finally, the research team completed their own analysis and report, validating the overall computational modeling approach and demonstrating the effectiveness of the representative fan assembly model developed in the previous computational engine ingestion research program.

PROJECT HIGHLIGHT

THE COMPLETION OF THIS RESEARCH PROGRAM HAS VALIDATED THE OVERALL COMPUTATIONAL MODELING APPROACH FOR THE INGESTION OF A UAS INTO A FAN ASSEMBLY MODEL. MOREOVER, THE OPEN REPRESENTATIVE FAN ASSEMBLY MODEL THAT WAS PREVIOUSLY DEVELOPED WAS COMPARED WITH A FAN ASSEMBLY RIG MODEL OF AN ACTUAL ENGINE IN SERVICE (CFM56-7B) AND FOUND TO BE IN GOOD AGREEMENT.

Task 1: Testing Oversight

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

Sub-Task 1.1: Test Plan Input and Review

The objective of this task was to ensure a test plan that produced a valuable data set for answering current and future research questions related to UAS engine ingestions. This task included coordinating with the ongoing computational research and the FAA to provide the test partner with input on the test plan. The test plan included the planned conditions for the test (i.e., operating conditions of the engine, launch speed, location, and orientation of the UAS). The test partner, in consultation with the FAA/ASSURE team, selected an operational engine for the test. The test plan also included planned measurement instrumentation and setup location. Scans of the blades pre- and post-test were also produced by the research team for use in the computational studies. The research team provided additional input on the measurement data that should be taken and recommendations for the setup to obtain the needed data for the initial analysis and potential future work. The test partner was responsible for the overall test plan, 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 was to conduct an independent post-test analysis of the engine ingestion test. The test partner conducted their own analysis of the engine ingestion and provided the reduced and processed measurement data from the experiment. This task 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 fan, was performed to evaluate damage in the blades of the fan section. The damage from the computational simulation was compared to the experiment. Elastic material properties were used for the casing and nose cone to provide appropriate boundary conditions and to determine secondary impacts and loading patterns.

Sub-Task 1.3: Final Test Report and Modeling Validation

The objective of this task was to provide a final test report on the research program that includes the results of both the research team and the test partner, as well as the conclusions from analyzing the engine ingestion test. Moreover, the work was also used to validate the modeling approach used in the recently completed computational engine ingestion research. In particular, a comparison of the computational simulation of the ingestion with the full-scale test was conducted. Differences in the response and damage were 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 and the representative fan UAS ingestion cases from the computational research were also 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 was 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 required 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 the engine operating at takeoff conditions, being ideally suited to understand a critical impact case. The test partner has successfully completed the test per the agreed-upon test plan. The completion of this research program has validated the overall computational modeling approach for the ingestion of a UAS into a fan assembly model. Moreover, the open representative fan assembly model that was previously developed was compared with a fan assembly rig model of an actual engine in service (CFM56-7B) and found to be in good agreement. This gives high confidence in using this open representative fan assembly model in future foreign object ingestion studies in industry and academia to improve models and compare results with prior work. The test partner has successfully completed the test per the agreed-upon test plan. Preliminary analysis of the computational simulation results qualitatively matches the data from the experiment.

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SMALL UAS TRAFFIC ANALYSIS

A11L.UAS.91_A50

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Small UAS Traffic Analysis

Background:

To effectively manage the safety of UAS operations within the National Airspace System (NAS), the FAA must identify, assess, mitigate, and monitor safety hazards and risks on an ongoing basis. Additionally, the FAA should proactively plan for the continued growth of small Unmanned Aircraft Systems (sUAS) operations and anticipate emerging aviation risks associated with integrating UAS into low-altitude airspace. A 2018 report by the National Academies of Sciences, Engineering, and Medicine (NASEM) recommended that the FAA expand its quantitative data collection to better assess risk in UAS integration, noting that existing qualitative risk management approaches produced results that lacked repeatability, predictability, scalability, and transparency. The NASEM (2018) report "Assessing the Risks of Integrating Unmanned Aircraft Systems into the National Airspace System" indicated there was an inherent need for an empirical, data-driven approach to inform UAS policy decision-making. The report ascertained that successful UAS integration into the NAS was 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).

The purpose of this research was to leverage near-real-time and historical sUAS traffic data collected from emplaced Remote Identification (RID) sensors across the NAS at various convenience sample airport locations. This analysis proved useful for monitoring UAS traffic activity, forecasting future traffic trends, identifying and assessing sUAS hazards, measuring NAS risk, and evaluating the effectiveness of existing sUAS regulations. Ultimately, this effort provides valuable data for establishing effective UAS risk management policies and informing future NAS integration of advanced aviation operations like Advanced Air Mobility (AAM).

PROJECT HIGHLIGHT

THE COMPLETED PROJECT PROVIDED SEVERAL RECOMMENDATIONS FOR IMPROVING SAFE AND EFFICIENT INTEGRATION OF sUAS INTO THE NAS.

Approach

Remote Identification data was collected at select locations across the United States. Specific emphasis was 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
- Providing findings and recommendations that may inform the development of Unmanned Traffic Management (UTM) requirements and UAM route design

Task A: Analysis Tool Development

This task focused on developing analytics tools, enabling them to integrate, process, and display new Remote ID datasets. These tools enabled the research team to monitor the implementation of Remote ID at the project's several sampling locations. The research team partnered with Unmanned Robotics Systems Analysis (URSA), Inc. to aid in developing the analytics tools. Pierce Aerospace, Inc. furnished the Remote ID collection technology and conducted device installation, support, and routine data extraction.

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

In this task, the research team provided a descriptive analysis of current sUAS traffic based on Remote ID data trends. The research used Remote ID data to address questions surrounding traffic attributes in urban areas, estimated registration rates, and flight patterns. The team leveraged cloud storage, software, and digital analysis tools furnished by URSA, Inc. to support data aggregation, analysis, synthesis, and visualization.

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

For this task, the focus shifted to assessing operator compliance. The research team assessed sUAS operations adherence and exceedances to various provisions of Title 14 CFR, with emphasis on Parts 107 and 48. The researchers identified 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

In this task, the research team evaluated sUAS operations conducted in proximity to aerodromes. The team sought to provide insight into the likelihood of near encounters between sUAS and manned aircraft, and identify high-risk areas or 'hotspots' where sUAS operations may be particularly problematic to air traffic.

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

During this task, collected data was used to make informed predictions about sUAS industry growth. The research team assessed strategies to improve sUAS integration and safety within the NAS. Potential implications to advanced aviation operations, such as AAM and UTM, were also assessed.

Task F: Communicating Findings

This task focused on communicating the study's findings, culminating in a final written report, formal sponsor briefing, and dissemination to external stakeholder groups. The final report was completed in March 2025.

Key Findings

The research team identified several key findings from the completed project:

Remote ID Adoption and Detection:

- Remote ID adoption remained relatively low during the study period. As of mid-April 2025, Remote ID equipage was reported as 50.03% for Part 107 registrants (207,665 of 415,095 total) and 30.51% of recreational registrants (139,166 of 456,169 total).
- Remote ID detection was determined to be effective only within a limited range (approximately 3 NM in urban/suburban areas; and, up to 7 NM in rural settings), which created challenges for large-scale airspace surveillance.

Platform and Manufacturer Trends:

- Usage trends were primarily comprised of DJI products, making up more than 86.3% of detected platforms based on correlation to the FAA Declaration of Compliance database.
- Approximately 12.8% of serial numbers within the dataset could not be correlated to a model in the FAA Declaration of Compliance database, likely representing Remote ID Broadcast Modules.
- Lightweight sUAS platforms continued to gain popularity, with approximately 95.4% of detected sUAS weighing less than 2.5 lbs, and more than a third of those weighing less than 0.55 lbs.

Operational Activity Patterns:

- During the sampling period, Remote ID data showed generally increasing levels of flight operations.
- More than 90.0% of detected UAS platforms were operated during a single calendar month, reinforcing previous research suggesting that sUAS operators—particularly recreational operators—exhibited initial high-frequency utilization and subsequent discontinuation.
- More than 88% of detected sUAS flights lasted less than 30 minutes, with 37.6% lasting less than 5 minutes.
- An evaluation of nearly 2.6 million Remote ID messages indicated more than 52% of sUAS operators flew their platforms within 0.1 NM from the operator location. The research team acknowledged that this finding may have been skewed due to the relatively low effective detection range of Remote ID signals at longer ranges.

Altitude and Compliance:

- Most sUAS operations flew at compliant altitudes, with more than 79.2% of detected sUAS platforms flown at maximum altitudes of less than 400 feet AGL.
- Approximately 2.4% of detected sUAS flights were flown at altitudes in excess of 1,000 feet AGL, presenting a potential threat to aviation operations.
- A substantial number of sUAS flights occurred near airports and heliports, with some exceeding altitude limitations.
- While UAS Facility Map maximum altitudes were designed to segregate sUAS traffic operating in controlled airspace from manned aviation operations, data suggested a sizable proportion of sUAS operations exceeded UASFM grid maximum altitudes, in some cases by up to 500 feet.

Temporal and Environmental Patterns:

- The majority of sUAS operations detected in the sample occurred during daylight hours, with peak operations times occurring between 12:00 p.m. – 9:00 p.m., local time.
- Most sUAS flights occurred in calm weather conditions, with few operations conducted during precipitation or high winds, suggesting that adverse weather naturally limited sUAS activity.
- Current nighttime operations remained minimal but could increase with the expansion of commercial applications, such as package delivery.

Safety and Security Concerns:

- Operations were concentrated in residential neighborhoods, suggesting primarily recreational operations.
- Short flight durations presented transient risks but also limited opportunities for intervention.
- The recent removal of DJI's geofencing system raised additional safety and security concerns, potentially increasing incursions into controlled airspace and over protected facilities and critical infrastructure, including prisons, military installations, critical infrastructure, airports, heliports, and special use airspace.
- A discrepancy existed between Low Altitude Authorization and Notification Capability (LAANC) approvals and detected sUAS operations, highlighting that a disproportionate number of flights were likely being carried out under certificates of authorization or airspace authorizations.

Recommendations for Future Operations:

The completed project provided several recommendations for improving safe and efficient integration of sUAS into the NAS:

- Expand research efforts to better understand Remote ID effectiveness, including its range, signal interference, and coverage limitations.
- Broaden data collection efforts to improve statistical reliability and better inform national airspace risk assessment (planned for inclusion in follow-on ASSURE A83 project).
- Enhance situational awareness through heliport plotting on sectional charts.
- Air Traffic Control broadcast of known sUAS traffic alerts to manned aircraft.
- Update FAA guidance on collision avoidance and conspicuity.
- Expand training opportunities for sUAS operators via the FAA WINGS program.
- Consolidate critical flight reference materials into a singular, centralized online hub.
- For AAM operations, recommend operations at altitudes above 500 feet AGL and avoid overflights of residential neighborhoods.
- Implement Remote ID or detect-and-avoid technologies for AAM to enhance safety by reducing potential conflicts with sUAS flights.

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BEST ENGINEERING PRACTICES FOR AUTOMATED SYSTEMS

A11L.UAS.92_A51

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Best Engineering Practices for Automated Systems

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 reusable 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 considering these findings.

PROJECT HIGHLIGHT

THIS PROJECT HAS JUST BEEN COMPLETED AND PROVIDED GUIDANCE FOR SAFE, AUTONOMOUS OPERATION OF SMALL UAS ACROSS SEVERAL AREAS: PERCEPTION, SENSORS, CONTROL ARCHITECTURES, RUNTIME VERIFICATION, CYBER-PHYSICAL SECURITY, PROBABILISTIC RISK ASSESSMENT, ROBUST INFERENCE, ENVIRONMENTAL MODELING, AND FLIGHT TESTING.

The investigators and structured interviews with SMEs serving as consultants on the project identified existing mitigations for the identified root causes and contributing factors. The existing methods can be very roughly divided into specific 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 developed new guidance and engineering best practices for autonomous UAS and put into practice new guidance for specific automated functions of UAS.

Task 4: Validation of Design Guidance

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

Key Findings:

This project has just been completed and provided guidance for safe, autonomous operation of small UAS across several areas: Perception, Sensors, Control Architectures, Runtime Verification, Cyber-Physical Security, Probabilistic Risk Assessment, Robust Inference, Environmental Modeling, and Flight Testing. Summarytements of recommended guidance are found below.

1. Perception: The recommended guidance emphasizes enhancing long-range drone detection by expanding datasets like LRDDv2 to include diverse conditions and accurate distance annotations. It suggests using advanced detection methods such as SAHI to improve performance at longer ranges, while also exploring lightweight alternatives like contrastive models to reduce computational demands. The guidance highlights the need for onboard image quality assessment metrics—specifically, no-reference methods like BRISQUE and DBCNN—to help UAS systems evaluate visual reliability in real time. These metrics can inform decisions about whether to continue or terminate operations under degraded conditions. Overall, the guidance supports safer and more efficient UAS perception through improved data, detection algorithms, and self-assessment tools.

2. Sensors: To achieve the desired levels of safety in a grid airspace using the above combination of localization technology and infrastructure, the team recommends:

a. Pilot deployments of 3D cubic cell systems: Begin with grid sizes of approximately 20 meters x 20 meters x 20 meters for suburban and rural trials and 10m x 10m x 10m in urban corridors or high-density UAS routes.

b. Develop Artificial Intelligence-powered geofencing managers that integrate signal mapping and sensor health indicators to enforce dynamic no-fly zones.

c. Standardize sensing fault classification protocols across UAS platforms and encourage FAA and International Civil Aviation Organization alignment in fault management documentation.

d. Incorporate multi-sensor feedback loops where redundancy is shared across swarm participants via local mesh networks.

e. Promote open data formats and Application Programming Interfaces to integrate RIS-enhanced infrastructure sensing into both commercial and public UAS operations.

3. Control Architectures: The team recommends using AI and machine learning to improve UAS flight control and dynamic modeling, emphasizing the importance of robust, adaptive techniques and validating them through real-world flight tests rather than relying solely on simulations.

a. AI-based flight control provides a promising method for passive fault-tolerant control in UAS, offering improved performance compared to traditional techniques. These controllers can adapt to changing flight conditions and maintain stability even when faults occur, without needing prior knowledge of specific failure types. Additionally, AI-based methods show potential for controlling multiple aircraft with varying dynamics, making them versatile across different platforms. This adaptability enhances safety and reliability in autonomous UAS operations.

b. Machine learning offers approaches for improving UAS dynamic models.

i. The cross-entropy method is introduced as a promising approach for real-time adaptation of aircraft control systems during flight. It enables dynamic modeling by continuously updating system parameters based on incoming flight data, allowing the controller to respond effectively to unexpected changes in aircraft behavior. This technique supports robust inference under adverse onboard conditions, such as component failures or environmental disturbances. Its ability to operate online makes it suitable for enhancing the resilience and safety of autonomous UAS operations.

ii. Machine learning techniques using prior flight test data can be used to model the lateral-directional dynamics of UAS more effectively. This approach allows for improved dynamic modeling without requiring complex or specialized flight maneuvers. Leveraging existing data enhances the accuracy and adaptability of control systems. This method supports safer and more efficient UAS operations by enabling better prediction and response to flight conditions.

c. Robust and adaptive control techniques can be developed to tackle the impact of adverse onboard conditions, such as weather.

d. Performing flight test validation of UAS systems is essential. Only relying on simulations is not sufficient since simulations do not accurately represent the actual flight test environment.

4. Runtime Verification: The team proposes that every UAS have onboard runtime monitors for continuous checking of its own health and operations, including distance to (static and moving) obstacles. These on-board monitors ought to be synthesized automatically from the formal requirements to avoid human coding errors (the team notes in passing that generative artificial intelligence cannot yet provide code correctness guarantees, in the sense of fidelity to designer intent). For monitoring inter-UAS operation, the team needs research on establishing the degree to which clock drift can affect UAS operations for common UAS platforms with off-the-shelf components and developing a regulatory framework for inter-UAS communication on safety-critical tasks (such as monitoring).

5. Cyber-Physical Security:

a. Updated thread and defense assessment: The team updated the threat assessment of attacks based on the severity of outcomes and likelihood. Based on this, the team recommends a practical set of minimal defenses with large coverage that most practitioners should consider using (e.g., sensor fusion, fuzz testing, safety mode). On top of this, depending on the use case, the team provides recommendations for various levels of additional defenses.

b. Recommended Guidance for defense assessment: Based on the updated list of widely available attacks, the team recommends the use of the following defenses that provide wide coverage of attacks: sensor fusion and redundancy, a safety mode, rapid message validation, software testing and requirement validation, path planning and navigation algorithms, adversarial training for computer vision algorithms, and delay handling.

c. Safety and Robustness of UAS swarms: The team developed open-source code for tuning flocking distributed swarms. The team developed methods and a recipe for robust tuning and evaluation, including a novel attack, focusing on low-latency avoidance and the Vicsek algorithm. Lastly, the team identified limitations and areas for future work as well as guidance for when and how low-latency tuned d-swarms should be used in their current state.

d. Recommended guidance for swarms: While path planning and collision avoidance methods are recommended for many use cases, no matter what methods are chosen, the limits of these should be identified, and fallback modes of operation should be used in the case of attacks or challenging scenarios. The team recommends a hierarchical fallback mode structure. The first level is a simple fallback mode, like hovering or landing. In cases where these are not appropriate (such as unavailability of a good landing spot for a large number of drones), the team recommends that different settings of swarm parameters be stored, to choose the best adapted to the current flight situation, thus allowing minimal continued operations while maintaining a tolerable safety standard. The next level is to use a slow swarm velocity or hybrid flocking-pathfinding methods. Finally, and as a last resort, it is worth exploring the use of UAS tolerate some light collisions or bumps.

6. Probabilistic Risk Assessment (PRA): The team proposes that reachability-based PRA, such as demonstrated in PRREACH, become a required part of the evidence submitted by a UAS operator for approval of their CONOPs, at least as long as reliable, clean data on hazard outcomes and hazard causes remain scarce. In the absence of such low-data risk assessments, assurance cases remain severely incomplete and qualitative at best. The team proposes that a low-data risk analysis tool, such as PRREACH, become a standard part of the authorities' own certification efforts for autonomous UAS operations.

7. Robust Inference: The team recommends that UAS developers and relevant certification authorities leverage the identified set of moderate sensor spoofing attacks and their simulator; the developers to test their UAS in relevant contexts, and the certification authorities to evaluate the evidence submitted by a UAS operator in support of a CONOPs safety (e.g., "Did they submit evidence that they are resilient against the following attacks?"). The team recommends the use of physical watermarking techniques by UAS developers to enhance resilience against more sophisticated sensor spoofing attacks, like replay attacks, especially when the UAS are planned to be deployed to an adversarial environment. The watermarking-based detector can potentially detect covert sensor spoofing attacks that were designed to avoid detection by passive anomaly detectors.

8. Environmental Modeling: Based on the CFD simulations of urban wind fields, the following guidance strategies are recommended to improve UAS safety in complex urban environments.

a. Operators should maintain a horizontal standoff distance from building corners and walls as discussed in the University of Kansas findings to avoid zones of accelerated flow, vortex formation, and shear layers identified in the simulations.

b. Sharp 90-degree turns near building corners should be avoided. Instead, smooth arc trajectories or offset corners should be used to reduce exposure to complex wind patterns revealed by the CFD.

c. Before flight, operators should perform pre-flight assessments of wind conditions using available hyperlocal sensors or real-time forecast tools to anticipate gust potential and identify periods of calmer conditions.

d. This guidance can be integrated into distance recommendations and real-time UAS decision support systems. It also aligns with the FAA's urban integration goals, offering a scientifically grounded roadmap for enhancing urban UAS safety and reliability.

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PROPOSE UAS RIGHT-OF-WAY RULES FOR UAS OPERATIONS AND SAFETY

A11L.UAS.97_A54

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Propose UAS Right-Of-Way Rules for UAS Operations and Safety

Background:

Right-of-way rules govern the interactions between aircraft to maintain safe interactions. Right-of-way rules were derived partly from the See-and-Be-Seen safety concept, the maneuverability limitations of aircraft types to give way, and other safety considerations. This research effort is to develop safety-based recommendations to the FAA for UAS right-of-way rules 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-of-way 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
    - o Examples include: UAS waiver assessments, policy development, rulemaking, etc.
- Industry standards development
    - o Examples include: design standards, training standards, operations and procedure standards, etc.

Approach:

Task 1: Background Report

The performer has completed 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, including 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, including 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 Advanced Air Mobility (AAM)/Urban Air Mobility (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.

PROJECT HIGHLIGHT

THIS APPROACH AIMS TO ENABLE SAFE BVLOS sUAS OPERATIONS WHILE MAINTAINING FAIR ACCESS AND PROTECTING NON-COOPERATIVE AIRCRAFT IN LOW-ALTITUDE AIRSPACE. FURTHERMORE, THE RESEARCHERS RECOMMEND THE SYSTEM AS A NEAR-TERM SOLUTION TO ENHANCE AIRSPACE SAFETY AND ENABLE BROADER UAS INTEGRATION.

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 led 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-up research tasks, and be used as a reference for safety recommendations developed by the project.

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, the ability of the researchers to provide 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 schedules, industry needs, safety considerations, and other applicable criteria that are 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 included:

- 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 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 focused on three areas:
    - o General Interactions - specifically related to existing right-of-way rules, determined the effectiveness of those rules related to interaction with UAS and crewed aircraft.
    - o Reserved Airspace Concept (RAC) or Non-ADS-B Reserved Airspace (NARA) – 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 was primarily conducted through physics-based simulations.
    - o 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 were developed from the initial flight test plan for the General Interactions area. The flight tests (Task 4) were to 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 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 developed a comprehensive flight test plan for testing sUAS and crewed aircraft encounters across multiple locations. Each team created specific flight test cards to execute tests at their sites, focusing on refining and validating initial recommendations.

Three rounds of testing were conducted:

- Round 1: Focused on standard geometric encounters (e.g., head-on, converging, overtaking) between various combinations of sUAS and crewed aircraft, following proposed right-of-way rules.
- Round 2: Tested the RAC/NARA.
- Round 3: Focused on RID, using simulation and flight testing to address gaps.

The research team identified and proposed the following themes that would influence the final recommendations:

- Specifications on the maneuverability and handling characteristics of small UAS (sUAS) to ensure separation standards are met.
- Specifications on the accuracy of sUAS technology for BVLOS operations, such as maintaining altitude or location accuracy.
- Specifications on crew reaction times to perform collision avoidance maneuvers, such as a descending turn to remain well clear.
- Specifications on separation standards for DAA systems to provide adequate collision warnings based on the speed of two aircraft, whether between two sUAS or an sUAS and a crewed aircraft, to prevent Near Mid-Air Collisions (NMAC) or well-clear violations.
- Specifications for reserving certain airspace to allow short-term commercialization of sUAS operations while ensuring fair airspace use for all users.
- Current minimum regulatory requirements for RID systems to adequately separate sUAS from other sUAS traffic in BVLOS scenarios.
- Well-Clear (WC) and small NMAC distances, both vertically and horizontally, need to be defined for sUAS when passing crewed aircraft and other sUAS.
- Crewed aircraft cannot effectively visually identify sUAS, placing the burden of detection and avoidance on BVLOS sUAS aircraft.

Task 5: Final Briefing and Final Report

The performer summarized and aggregated all of the previous papers and reports into a final report package for the overall project. The final report focused on updating right-of-way rules for sUAS in the NAS, for operating BVLOS below 400 feet. Through literature reviews, gap analyses, simulations, and flight tests, the report provided data-driven recommendations to assist in validating and revising existing right-of-way rules to accommodate modern UAS technologies including DAA systems and RID. A key proposal was the creation of NARA to segregate UAS from non-cooperative aircraft, ensuring safety and equitable access. The report outlined over 40 right-of-way recommendations, addressing various encounter scenarios, including head-on, overtaking, and emergencies involving sUAS, swarms, and crewed aircraft. For each recommendation, a rationale was given that provided the justification and reasoning behind the recommendations, alongside the specific data source from the published reports of previous tasks. It also identified regulatory gaps and called for further research to support safe UAS integration, with a focus on BVLOS operations. In summary, the report offered practical guidelines for enhancing airspace safety while promoting the efficient integration of sUAS into the NAS.

KEY FINDINGS

Reserved Airspace Concept or Non-ADS-B Reservable Airspace

The research team developed the RAC, also referred to as NARA, to create segregated airspace below 400 feet AGL for safe UAS and crewed aircraft operations. This concept enables equitable access to airspace for both sUAS and non-ADS-B-equipped crewed aircraft through preflight reservations.

Key aspects of the concept include:

- Airspace Reservation: sUAS or non-ADS-B crewed aircraft can reserve airspace, preventing interactions between aircraft that cannot detect each other.
- Safety: UAS flying BVLOS must have systems to detect non-cooperative aircraft, or if in a NARA reserved by UAS, the UAS would only have to identify crewed aircraft transmitting ADS-B out.
- Equitable Access: Both sUAS and crewed aircraft can reserve airspace on a first-come, first-served basis, ensuring balanced use.
- Implementation: The system could be integrated with existing tools like LAANC or NOTAMs, enhancing airspace management and safety.
- Right-of-Way: Standard right-of-way rules remain unchanged by the NARA system

This approach aims to enable safe BVLOS sUAS operations while maintaining fair access and protecting non-cooperative aircraft in low-altitude airspace. Furthermore, the researchers recommend the system as a near-term solution to enhance airspace safety and enable broader UAS integration.

Right-of-Way Safety Hierarchy

The research team proposed the following safety hierarchy and applied it to right-of-way evaluations:

- Protection of human life—An sUAS may not allow a human onboard or in another aircraft to be harmed through maneuvering or inaction.
- The burden to avoid shifts to the aircraft or person who can see/sense and avoid.
- Ensures consistency with existing right-of-way rules and allows safe integration of the sUAS into the NAS.
- Considers environmental/external influences, such as the boundary of operations.

Recommendations for RoW Rules

The performers presented specific recommendations that provide standardized rules for general interaction scenarios, including head-on, converging, overtaking, and in-distress situations between sUAS, swarms, and crewed aircraft. Additionally, the research team addressed right-of-way influencers such as the use of RID, human factors, safety volumes like sNMAC, and various technology improvements. Other key considerations include RAC/NARA airspace recommendations, operations above 400ft AGL, GPS accuracy, and handling characteristics of sUAS, such as speed, rate of turn, vertical speed, as well as environmental conditions such as wind and turbulence. The rationale for each of those recommendations clarifies the logic, addresses challenges, and supports the recommendations with evidence from detailed research references.

Future Research Recommendations

The researchers proposed several recommendations for improving right-of-way in BVLOS operations below 400 feet AGL. These include developing standards for minimum GPS accuracy, terrain data integration, and RID capabilities. The team also evaluated small NMAC requirements and identified considerations for small WC standards for sUAS, establishing performance standards for sUAS handling, and requiring specific reaction times for avoidance maneuvers. Additionally, the team recommended expanding ADS-B requirements, improving DAA interface designs, and conducting further research on multi-robot and swarm response scenarios, as well as for AAM/UAM vehicles and larger than small UAS.

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INVESTIGATE DETECT AND AVOID (DAA) TRACK CLASSIFICATION AND FILTERING

A11L.UAS.100_A57

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Investigate Detect and Avoid (DAA) Track Classification and Filtering

Background:

Developing robust Detect and Avoid (DAA) systems is a key requirement for enabling routine beyond visual line of sight missions in the national airspace system. A hurdle to their widespread adoption is a lack of track classification performance requirements related to the 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 research task will therefore focus on developing 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. Briefly, the proposed 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 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 1: Literature Review & Risk Identification.

The team conducted 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 assigned a likelihood and severity of the risks identified in Task 1. These metrics were 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 functional hazard analysis, failure modes, effects, criticality analysis, or fault trees were used. Additionally, categorization and identification of the impact of misleading information on overall system risk was investigated.

Mitigations to the prioritized risks were developed. The mitigations were sorted into categories like the risks and assessed for feasibility, utility, and effectiveness at a qualitative level.

The risk prioritization and mitigation development tasks heavily informed requirements and metrics development. Specifically, the team developed requirements/metrics to guide air picture cleanliness, classification performance requirements, data filtering, and human factors for DAA systems. These requirements/metrics were 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 was provided with key recommendations regarding prioritization, mitigation, and requirements outlined.

Task 3: DAA System Performance and Test Planning.

A test plan was developed focusing on air picture modeling. Scenarios were 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 was used to characterize DAA system performance and help evaluate the developed air cleanliness, classification performance, and data filtering requirements.

Task 4: Peer Review / Feedback from Standards Bodies.

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

PROJECT HIGHLIGHT

THIS APPROACH AIMS TO ENABLE SAFE BVLOS sUAS OPERATIONS WHILE MAINTAINING FAIR ACCESS AND PROTECTING NON-COOPERATIVE AIRCRAFT IN LOW-ALTITUDE AIRSPACE. FURTHERMORE, THE RESEARCHERS RECOMMEND THE SYSTEM AS A NEAR-TERM SOLUTION TO ENHANCE AIRSPACE SAFETY AND ENABLE BROADER UAS INTEGRATION.

Task 5: Scenario and Subsystem Model Refinement.

Phase 1 of this project culminated with an 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 reviewed feedback and updated risks, risk mitigations, and requirements/metrics accordingly.

After the team developed mature risks/metrics for DAA system and associated performance, the team developed encounter scenarios to fully understand and exercise the interaction of developed performance requirements/metrics and risks to DAA systems. The encounter scenarios were tailored to align with the prioritization of risks, risk mitigations, and requirements/metrics. Encounter scenarios covered 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 were exercised in a variety of airspace densities (sparse to dense) and misleading surveillance information rates (low to high) to understand the impact on 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 were used to develop representative sensor models for ground and airborne DAA systems. These were 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 was collected from representative DAA systems currently emplaced to assess clutter performance, track classification and filtering performance, and provide repeatable test scenarios for evaluation in the modeling and simulation framework. These clutter representations were 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 were 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 was generated. The results cover the verification/validation of developed requirements/performance metrics relating to air picture usability and 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 that 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 capture 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 midair collision, Loss of Well Clear, etc. as a function of the superimposed clutter density. In parallel with this effort, ERAU 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.

In the last year, the team has refocused on capturing impacts on airspace usability and safety in the terminal environment. The team has utilized the MIT terminal encounter dataset to select 20,000 encounters (both alerting and non-alerting) to capture clutter impacts on Instrument Flight Rules (IFR) approaches. These tests use a similar fast-time simulation environment to that previously outlined, with the addition of a DADELUS DAA system to enable the ownship to return to course after an avoidance maneuver. Initial results indicate that even small levels of clutter have a dramatic impact on the number of missed approaches and NMACs occurring in the constrained environment of an IFR approach. The team is currently finalizing the statistics for these encounters for inclusion in the final report.

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ILLUSTRATE THE NEED FOR UAS CYBERSECURITY OVERSIGHT AND RISK MANAGEMENT

A11L.UAS.95_A58

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Illustrate the Need for UAS Cybersecurity Oversight and Risk Management

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 cybersecurity gaps. This project addresses the need for UAS Cybersecurity Oversight and Risk Management as it pertains to the relationship between the national airspace system and FAA systems.

Approach:

Task 1: Literature Review and Industry Engagement

Review all publicly available information concerning the IG, GAO, and other reports that delineate risk management assessment elements, concerns, and best practices. Example: In GAO-19-105, the executive summary highlighted five core security functions that federal agencies were evaluated on (Identify, Protect, Detect, Respond, and Recover). The team worked from the GAO-19-105 with additional emphasis on cyberphysical issues common in UAS environments. The team worked with industry partners in the early stages of the effort to explore standards and processes common to their workflows.

Task 2: UAS Cybersecurity Oversight and Risk Management

The performers created 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 researchers mapped static analysis, dynamic analysis, and code retargeting to UAS-specific cybersecurity tasks. The resulting framework provides a roadmap for applying a framework to operational systems.

Task 3: Test Cybersecurity Oversight Tool or Process

The team tested the UAS Cybersecurity Oversight and Risk Management Tool or Process created in Task 2. Researchers developed cybersecurity scenarios to be tested against the Tool or Process in either a table-top simulation or live-test event. To achieve this, researchers engaged in several demonstrations during technical interchange meetings with sponsors. These demonstrations showed cyberattacks ranging from sensor spoofing to malware injection applied to various aerospace platforms. These demonstrations are included in the framework as examples linked to both attacks and mitigation tools.

Task 4: Peer Reviewed Final Report and Final Briefing

The performers wrote a final report documenting:

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

The framework takes the form of attack descriptions, attack mitigations, and links to tools. The objective was to provide a map from known cyberattacks to mechanisms – tools, redesign, models – for mitigating the attack.

KEY FINDINGS

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

The framework starts from the A38 report detailing risks and addresses attacks associated with those risks that: (i) impact the airspace; and (ii) were judged most serious and most common. Researchers augmented the A38 report findings with additional information from the literature survey and industry interactions. With a set of attacks in hand, the team set about defining each attack in a manner approachable by UAS engineers. Specifically, the team sought to provide a high-level description of the attack mechanism, its impacts on airspace, and identify flight operations where the UAS is vulnerable to the attack.

Each attack is linked to one or more known mechanisms for mitigation. These may include static analysis, dynamic analysis and observation, and code refactoring. Static analysis techniques include the application of tools that treat software as a mathematical object to infer properties. Such techniques include symbolic theorem proving, model checking, SAT/SMT solving, memory usage analysis, and type checking. Dynamic techniques include those approaches that monitor executing systems through simulation, testing, or monitoring. Such techniques directly observe the properties of running systems. Finally, code refactoring involves bug fixing and replacing existing code. Such techniques include using modern languages and environments, rewriting vulnerable code, and replacing libraries.

Each mitigation is linked to existing tools implementing the technique. Tool descriptions include links to available public domain and commercial software implementations, as well as tutorials and usage guides. Where available, the team included presentation materials and demonstrations from technical interchange meetings that demonstrate mitigation in action. These demonstrations also serve as a means for demonstrating the framework on actual systems and subsystems.

Results from the investigations clearly demonstrate the need for a framework that mitigates cyberattacks impacting UAS in public airspace. Furthermore, they show a need to consider cybersecurity issues from high-level requirements through implementation.

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EVALUATION OF UAS INTEGRATION SAFETY AND SECURITY TECHNOLOGIES IN THE NAS PROGRAM

A11L.UAS.90_A60

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Evaluation of UAS Integration Safety and Security Technologies in the NAS Program

Background:

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 misuse, 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.

This research will support development aimed at solutions for critical national security problems associated with the hazardous and malicious operation of UAS. This development of a solution is in the form of cross-agency standards against which to test UAS integration safety and security technologies.

The updated priorities of the A60 project are as follows:

1. Determine the interference of CNS of air and ground components and ATM (UART, ADS-B, VOR, TACAN, VORTAC, ILS, and RADAR). Identify the types and levels of interference, including distance from the DTI system, if any.
2. Determine if DTI systems cause interference with First Responder radio communications and emergency navigation systems, and if First Responder radio communications interfere with the DTI systems themselves. In addition, if testing multiple DTI systems at one time, do these systems interfere with each other.

PROJECT HIGHLIGHT

AT THIS TIME, THERE IS NO EVIDENCE OF A SIGNIFICANT IMPACT ON THE NATIONAL AIRSPACE SYSTEM BY ANY OF THE VENDOR DRONE DETECTION SYSTEMS THAT WE HAVE TESTED. FURTHERMORE, THERE IS NO APPARENT IMPACT ON FIRST RESPONDER (POLICE, FIRE, AND EMS) RADIO AND DATA COMMUNICATIONS FROM THE SAME VENDOR SYSTEMS, BASED ON DATA ANALYSIS AT THIS TIME.

3. Evaluate impacts of DTI systems on remote identification (Remote ID) systems and technologies. How can DTI and RID be used to differentiate authorized vs unauthorized UAS? MSU conducted testing of transmission ranges within the A56 project. Suggest leveraging existing data and systems of external RID and internal RID (aircraft with built-in RID), and the effects of the DTI systems on the RID transmission.
4. Document impacts of lost UA link impacts (1) the DTIs ability to continue to detect, track, and identify; and (2) does 'loss of link' change what the DTI systems (depending on the system) report to the operator.
5. Human Factors Issues: Document and determine human interface issues and system false alarm rates (FARs) and the impacts on operators' confidence levels of each system.
6. Test systems in high-density WI-FI or other high-frequency noise environments (specifically, Urban environment) to determine any performance impacts to the DTI systems. Please provide information on what kind of frequency "noise" and physical infrastructure, if any, would limit or interfere with the detection system.
7. Analyze any impacts to the DTI systems associated with high electromagnetic interference and provide options to lessen and alleviate interference impacts.

a. The FAA requests the ASSURE Team, if possible, to test how the equipment may operate during times of high electromagnetic interference, such as during and after various solar events. Document any impacts to the system itself, if there are any impacts to the system calibration that need to be adjusted, any impacts to the type of UAS it can identify, etc.

b. The FAA requests the ASSURE team as part of their analysis to provide recommendations for minimizing the impacts of electromagnetic interference on these systems, as well as any suggestions on how to respond to an electromagnetic event.

8. Determine the probability of detection by platform as well as by frequency, including false alarm detection rates. Provide information on what factors impacted the probability of detection.
9. Determine if moisture content in the soil and in the air impacts the detection systems. Identify any potential impacts to system operability and data identification.

10. Compare flight log information (downloaded from UAS) to what the DTI system recorded. Evaluate aircraft position reporting performance by comparing onboard data of UAS flight logs to an independent flight tracking system. (Altitude, airspeed, location/position). May illustrate requirements for RID accuracy and return to home functions.

The ASSURE A60 project successfully completed four flight campaigns during FY2025. The flight campaigns were completed in Cape May, New Jersey; Santa Teresa, New Mexico; Camp Grafton-South, North Dakota; and Starr Forest, Mississippi.

Cape May, New Jersey

The Cape May flight campaign was scheduled to take place between April 14th-25th, 2025. Due to windy, rainy weather, researchers lost one full day of flying on the 16th, and two half days on the 14th and 15th. The campaign was completed on Friday, the 25th. The event was held at the Delaware River and Bay Authority (DRBA) Ferry Terminal in Cape May, New Jersey. The area encompasses the Delaware River Bay and the Cape May Canal with beaches, protected sand dunes, marshes, and a riverfront surrounding the Cape May Ferry Terminal. The DRBA Ferry runs at least four times daily between Cape May, New Jersey, and Lewes, Delaware. The ferry traffic, US Coast Guard ship movement, and civilian boat traffic provide the background maritime traffic needed for this event.

There were five vendors that participated in this flight campaign. They were Robin Radar, Squarehead (acoustic), remote ID vendors: AeroDefense, Pierce Aerospace, DroneSpotter.

The team did not fly the Tigershark (Group 3) due to a Form FAA 7460-1 - Notice of Proposed Construction or Alteration being requested by the airport manager the day before the scheduled flight. The team met with the airport manager during the site survey visit in December 2024, and this issue was never brought up. There were potential alternatives to relocate the NMSU trailer that would not require the permit, but ultimately, these alternatives put the flight team in an unsafe situation. The decision to scrap the Tigershark was made, leaving Cobalt as the only other Group 3 aircraft to fly during this campaign.

There were two small quad drones that made unscheduled hard landings due to engine failure. These were very minor incidents because the first incident happened within seconds of take-off due to an engine failure. The second flight was moved to a secure area in anticipation of a possible motor failure, as it was a backup aircraft to the first drone failure. The second drone crashed due to a motor failure and was recovered without incident. The two drones were identical and used the same motors. These were inexpensive DIY aircraft. A handful of aircraft used the same motors and were removed from service.

Researchers had six different military and general aviation manned aircraft transit the NOTAM-specified drone operational area through the flight campaign. These instances required our drone pilots to recover the aircraft and make radio contact over the Common Traffic Advisory Frequency (CTAF). No issues came from these transitions.

UAH and NMSU collected background RF information throughout the flight campaign. UAH concentrated on collecting background environmental information from several sites around the operational area. NMSU collected RF information from each vendor during each test card flight. The RF information collected from NMSU is in the process of being analyzed.

The team completed 155 flights for a total of 30 hours, 15 minutes of flight time. Researchers collected 27.4 GB of data to process from the drone detection system vendors. 90 Aircraft were flown during the campaign.

Santa Teresa, New Mexico

The New Mexico flight campaign was scheduled for June 16th through June 27th, 2025, in Santa Teresa, New Mexico. The flight campaign was conducted at the Old Rio Grande Speedway, located 8.7 miles west of the original Doña Ana Community College - Sunland Park Center location. Rio Grande Speedway opened in 1998, featuring a 3/8-mile dirt oval speedway hosting numerous varieties of racing. The venue had plans to construct a one-mile paved circuit and to add a drag strip, but it closed just a few years later in 2001. There was no vehicle traffic to and from the Speedway due to its closed nature; however, U.S. Highway 9 north of the Speedway remains an active highway. The Old Rio Grande Speedway northern parking lot served as the primary launch and recovery point. The parking lot encompasses just over two acres of flat asphalt. The parking lot did not have any amenities to support flight operations; all power and shelter were brought in to support the campaign. The northern edge of the parking lot acted as a staging area for the support trailers.

The New Mexico flight campaign highlighted hot and dry weather as well as a higher density altitude. These conditions

required an early morning start for each flying day.

There were a total of 195 flights and 121 test cards completed during the flight campaign. Total flight time was 35 hours, 4 minutes, and 22 seconds. This was a noticeable increase from the New Jersey flight campaign of 30 hours, 14 minutes, and 50 seconds while conducting 155 flights.

There was a significant change in how the test cards were flown between the two campaigns. In the New Jersey flight campaign, each aircraft flew just Test Card 1 (Long Distance) before switching to the next aircraft. The rest of the test cards would be completed after all aircraft completed Test Card 1. The intent was to ensure that there would be some signal representation for each aircraft in the event of a shortened flight campaign due to bad coastal weather. This created a significant burden for the flight teams to prepare several aircraft for flights each day, only to have them brought out again later in the flight campaign. For the New Mexico flight campaign, it was decided that each aircraft would fly Test Cards 1, 2, and 4 in order. This allowed the aircraft to be put away in storage once the flight cards were completed, easing the burden on the flight teams. This

increased the frequency of flights by removing the constant preparation time needed for several aircraft. Test Card 3 was removed as a required card because it was not flown in New Jersey due to bad weather and time constraints. Test Card 5 (Multiple aircraft) did not need to be flown by all aircraft.

Visual Observers (VOs) were switched out every 45 minutes to an hour during the very hot parts of the day. VO selection was again informally done here, as it was in NJ, by identifying .

better to have a defined daily schedule with people's IDs before the start of the day's operations. A VO schedule with set times should be developed at the start of each flight day to allow for personnel changes.

Because of the heat, the density altitude for the fixed wings proved a challenge to obtain enough lift. This was noted on several aircraft. Future flight campaigns need to ensure a wider open space for launch and ascent. Also, there needs to be personnel in the landing area standing and not sitting for these launches, so they can react as needed.

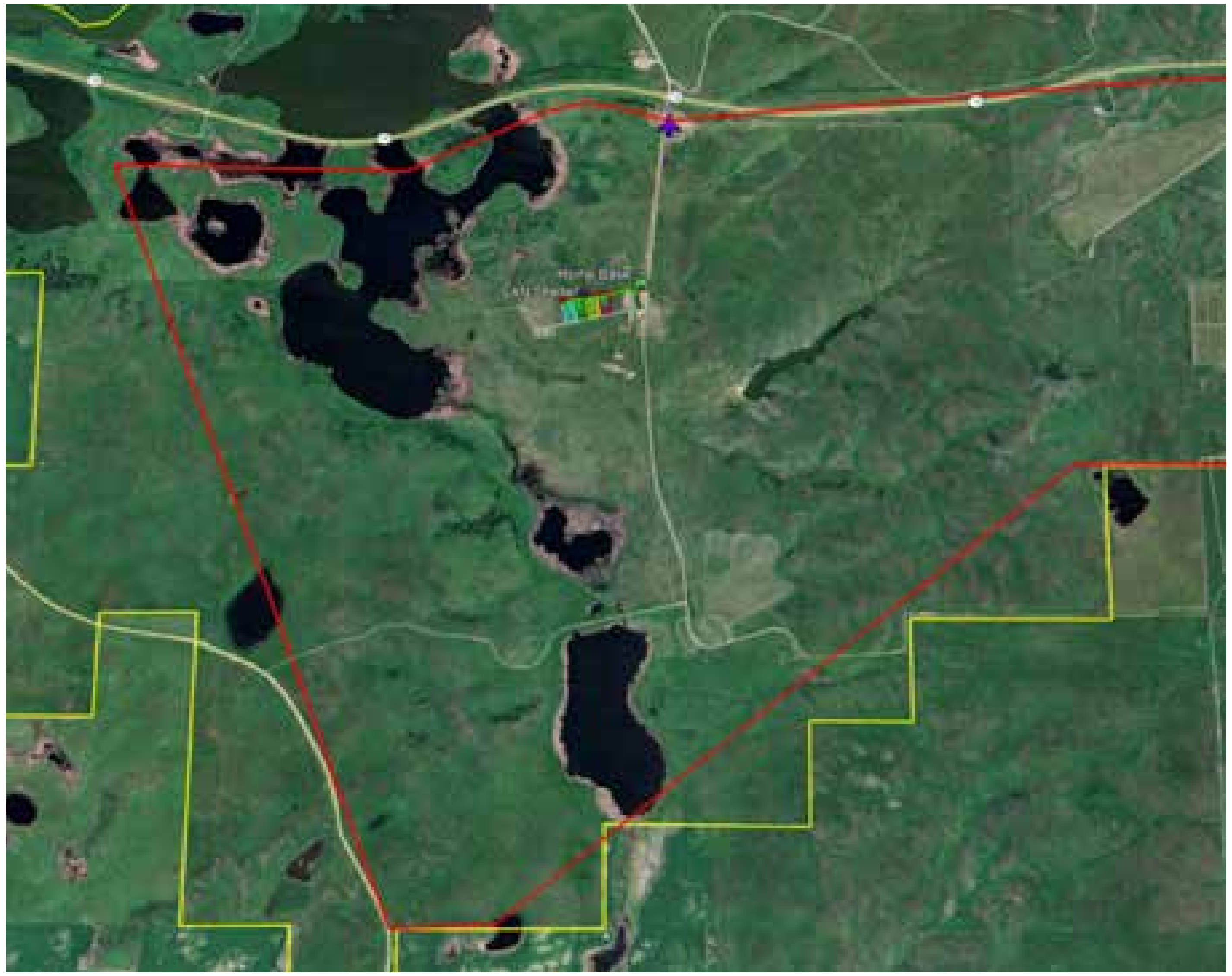
There was a safety-related issue at the end of the UAH Fixed Wing flight. As the aircraft was on final approach, a member of the team started walking across the tarmac toward the restroom area. The landing was aborted, came around, and then safely landed. After the event, fights were stopped, and everyone was brought in for a safety brief. Adequate overwatch of the landing zone was not provided. The root cause of this issue is the camp layout with the facilities placed well away from the flight areas to avoid the potential odor on the very hot days, and personnel needing to cross this area to access the facilities. Changes made include a spotter with the pilot to ensure the landing area is clear, added cones to designate the area (completed before next flight), and a person on site to approve crossing this area during operations. This only impacted the few fixed-wing operations, but measures were in place for all flights. If possible, future camp setup should eliminate this potential issue.

A small racing drone presented an error and was intentionally landed in the field before there was a loss of control. Unfortunately, the exact location of the drone was not readily apparent due to the vegetation. A search was conducted and took longer than expected to recover the drone. The lesson learned was that a coordinated plan must be in place for a downed aircraft incident. Most aircraft are easily identifiable when they land in the field. The New Mexico campaign illustrated the need for a plan to recover all aircraft with respect to the heat and vegetation. A plan was developed and used for all flights and future campaigns moving forward.

"Bogey" or Dark drones are non-participating aircraft that enter the operational area. Specific to the New Mexico flight campaign, many were crossing the international border with Mexico. These events occurred many, many times. Some flew directly across the test area. Any violation of the airspace by a dark drone, at any altitude, was a "knock off" and shut down the test operation. The only impact dark drones had to testing were operational shutdowns.

Camp Grafton-South, North Dakota

The North Dakota flight campaign was scheduled to take place



August 11th-27th, 2025 at the Camp Grafton-South test range. Camp Grafton South Training Range, located in Eddy County in east central North Dakota, is approximately 11,000 acres of transitional grassland, interspersed with lakes and wetlands. The installation has maneuver space as well as live fire weapons ranges. The real property is owned by the State of North Dakota and used primarily as a training range for the North Dakota National Guard (NDNG). This area is the live fire weapons complex and consists of several range towers, multiple classrooms, and modern restrooms.

The vendors present for this flight campaign were: Remote ID- AeroDefense, Pierce Aerospace, DroneSpotter, RADAR- DeTect Harrier, Acoustic- Squarehead, Hyperion FireFLY, EO/IR- Axis Q8752-E (part of DeTect Radar).

The weather during the flight campaign was good overall with average temperatures in the high 70's to low 80's. Wind was the biggest factor especially in the late afternoon shortening some flight days. Gusting winds prevented fixed wing aircraft from flying on a few days.

Campaign total Time: 28hrs 43min 12 sec. Total of 184 flights over the course of the flight campaign. 151 Test Card flights out of a scheduled 141 TCs = 107% completion rate. There were 20 meteorological drone flights and 15 meteorological balloon launches.

A fixed wing Skyhunter aircraft was lost during a test card flight. It appeared a wing came off. It was later determined that winds aloft had increased and exceeded the aircraft rating. Flight operations were suspended, and the downed drone recovery procedures were implemented. Multiple personnel saw it go down and had a general location for the vehicle. Two ATVs and four personnel went out for recovery. The wings and fuselage pieces were found quickly. The battery had ejected from the aircraft. A sweep line was formed by the four personnel to search for the battery. An M30T (thermal camera) was launched by UAF to support the search. It was not effective in supporting the search because the thermal background was very varied and would not support location. The battery was not recovered at that time. AccessND (range operations) noted the location and accepted responsibility for the battery recovery at a later time.

Test Card 7 was developed for aircraft that do not have enough endurance to complete the regular test cards (1,2, and 4). Several smaller aircraft completed this card during this campaign. Test Card 8 was developed for long distance flights. A fixed wing aircraft was flown by NMSU along the very straight ND Highway 15. The aircraft was programmed to take off from Camp Grafton-South, fly 10 miles west along the highway, conduct a U-turn and return to Camp Grafton-South. NMSU crew followed the aircraft along the planned route in a chase vehicle. The pilot was the front passenger accompanied by the driver and a visual observer. The flight was successful without any issues. A second Test Card 8 was completed by the UAF team. The flight team conducted pop-up flights from launch points that would increase by 2-mile increments from Camp Grafton-South out to 10 miles. The team flew a Matrice 30T up to an altitude of 400 feet at each launch

point. The flight was successful without any issues.

Weather conditions on Wednesday, August 20th had predicted with winds 10mph gusting to 15mph at the start of the day, increasing to 30mph+. This provided a limited window for flight operations. Weather for Thursday, August 21st, was forecasted to be worse with higher winds and possible rain clouds. The team had completed all the flight cards by the end of day on the 20th. Researchers collectively did not see a benefit in trying to fly Thursday or Friday the 22nd in any available flight windows. The team accomplished the goals early and were content with ending on that note.

Starr Forest, Mississippi

The Mississippi flight campaign took place at the John W. Starr Forest, located South of KSTF airport in Starkville, Mississippi, scheduled for October 13th – 24th, 2025. Starr Forest is located approximately 10 miles south of Starkville along Highway 25. The John W. Starr Memorial Forest borders the Sam D. Hamilton Noxubee National Wildlife Refuge and serves as a living laboratory for demonstration and research in forestry and wildlife management.

The primary goal of the Mississippi flight campaign was to conduct flight operations around an active wildland fire. The MSU Forestry department conducts yearly controlled burns on designated parcels within the Starr Forest. The controlled burn was under the control of the Forestry Department, and they maintained full responsibility for the planning off and execution of the burn plan. The FAA and ASSURE teams were not involved in the wildland fire operations. The ASSURE team was present at Starr Forest to conduct flight operations separate from and adjacent to the wildland fire operations without any direct involvement.

It was not known what parcel was going to be selected for the control burn at the time Starr Forest was selected as a test location. The ASSURE universities developed several test plans to cover all possible burn parcel locations. The burn parcel was identified two weeks before the flight campaign started. The operations area was identified as the Dorman Lake Cabin, Site 5 in the test developed test plans. Site 5 was the closest location for vendors and flight operations relative to the burn parcel. It is approximately 3,000 feet to the burn parcel from Site 5. Unfortunately, the trees surrounding the Dorman Lake Cabin were as high as 150 feet tall. The MSU Raspet team secured scissor lifts and telescoping boom lifts that were 60' and 80' tall respectfully. These lifts allowed the sensors and visual observers to be elevated, making for a better line of sight for flight operations.

Vendors for the Mississippi Flight Campaign

System	Descriptions
Pierce Aerospace Flight Portal ID	**Flight Portal ID (FPID) uses broadcast Remote ID signatures to detect, track, and identify RID-equipped drones.**
Echodyne EchoFli-ght	**A small airborne-based radar used to track airborne objects such as traditional aircraft and drones.**
Echodyne EchoShield	**A small ground-based radar used to track airborne objects such as traditional aircraft and drones.**
Hyperion FireFLY	**Acoustic sensor and signal processing algorithm to detect and track unauthorized movement of rotary and fixed-wing aircraft**
OneRadio	**Passive Coherent Location (PCL) Radar. This technology detects drones by sensing the drone's reflection of existing, ambient broadcast radio signals (like TV and FM radio).**
uAvionix Casia G	**An AI enhanced ground-based EO/IR UAS DAA system for both cooperative and non-cooperative aircraft detection 24/7.**
DroneSpotter Drone Spotter Receiver	**Rugged RemoteID receiver with IP66 rated enclosure designed to be mounted outdoors for opti-mal drone detection**
Thalrix Sentinel	Advanced visual threat detection platform featuring highly efficient, low-compute algorithm.
WATC Infrasound	**Seismoacoustic technology uses two novel processing schemes to detect the acoustic waves from UAS and locate them**

Weather was overall very good for the Mississippi flight campaign. Daily temperature highs were in the mid 80's during the first week dropping down to the mid 70's during the second week. There were predicted thunderstorms for the first weekend. The Forestry Department made the decision to move the burn day up from Monday the 20th to Friday the 17th due to the predicted weather.

Flight teams headed out to the burn parcel on the morning of Thursday the 16th to conduct reconnaissance on the flight area. Switzer Road is along the eastern boundary of the burn parcel, and it runs north-south. Flight teams identified two operational areas on Switzer Road to conduct flight operations from. Fire behavior on the day of the burn would dictate which location the teams would operate from. Test flights were conducted with mixed results from the vendors detecting the aircraft operating at 400 feet AGL. The test team had a discussion on any potential changes to the operational plan based on the preliminary data from the vendors during the test flights for the burn parcel. It was determined that the distance from the burn parcel to Site 5 is the underlying reason for the lack of consistent detection by the vendors. It was not possible to move the vendors closer to the burn parcel as trees would obstruct any line of site to the drone aircraft. The team decided to move forward with the flights on the burn day.

The controlled burn was initiated by the Forestry Department on the morning of Friday the 17th. Test card flights were initiated about an hour and a half after the fire was started. This ensured that there was a dense cloud of smoke between the vendors and the test aircraft. Test flights progressed over the next three hours while the wildland fire was burning. All test aircraft successfully completed their flights without incident. Operations were shut down for the day once all test aircraft completed their flights. All test card goals identified for the controlled burn were met.

All fire test cards were repeated on the following Monday after the fire had gone out. The same test aircraft repeated the flights they had conducted on Friday. The intent was to replicate the flights to see if the smoke had any impact on the vendors' systems performance. The data is still being analyzed with no conclusions at this time.

Test card flights were scheduled to continue for the rest of the week. Flight operations were canceled on Tuesday the 21st due to heavy rain and thunderstorms. All flights for the campaign were completed on Wednesday the 22nd. In summary, 250 Flights were conducted totaling over 27hours, 8 minutes and 31 seconds. 221 test cards were completed with 18 drone meteorological flights and 12 meteorological balloon launches.

Urban Spectrum Assessment:

Each test site location had a background spectrum assessment completed. This will identify the baseline spectrum present at the test site prior to any introduction of a DTI vendor. The background spectrum survey was conducted by NMSU while UAH conducted Radio Frequency survey of each flight campaign location. The analysis of the RF data from NMSU will be included in the final A60 report. UAH completed their background analysis of all the campaign locations. The summary for North Dakota is included here to illustrate that process used to collect the data and the analysis.

North Dakota

The UAH test team participated in Unmanned Aerial System (UAS) tests in North Dakota. As part of ensuring a safe operational test environment, the UAH test team measured Radio Frequency (RF) characteristics at the 7 locations shown in figure 1.

Figure 1. North Dakota Test Area RF Environment Measurement Points.

These points were chosen to obtain RF environmental data over the maximum accessible extent possible around the test event. The purpose of these measurements is to provide the FAA with a comparison baseline against FCC regulated communication environments and allocated RF signal bands to minimize potential interference issues during testing events in addition to imposing minimal impacts to normal RF communications within the surrounding community.

These locations were chosen to map the RF signal environment characteristics over the test area and perform comparisons against the spectrum. For this test, the RF signal measurements were obtained over the Wi-Fi, cellular, and GNSS frequency bands.

Figure 1. North Dakota Test Area RF Environment Measurement Points.

A Robin Radar IRIS radar was also operating during test operation for the purpose of demonstrating the capabilities of the radar to detect UAS (Unmanned Aerial Systems). The FCC allocated operating parameters of the Robin radar along with the frequency spectrums of the Wi-Fi, Cellular, and GNSS bands are summarized in the next sections.

Robin Radar IRIS Frequency STA Summary

For operations at Cape May, NJ (NL 38-58-06; WL 74-57-40), the FCC issued an STA for operations between April 12, 2025, to September 13, 2025. The STA authorizes operations at this test location under the following requirements.

- Frequency: 9500 – 9800 MHz
- Bandwidth: 50.0 MHz
- Modulation Type: Frequency
- ERP: 1175 W

Wi-Fi Operational Frequency Bands

The UAH team measured RF signals operating over the Wi-Fi frequency bands, defined by the IEEE 802.11 standards. These signals are implemented in a variety of communications scenarios including UAS control and data sharing along with common network communications within the surrounding community. Figure 2 summarizes these Wi-Fi frequency bands.

Figure 2. Wi-Fi Operational Frequency Bands.

Cellular Communications Frequency Bands

The UAH team measured RF signals in the ranges typically used in cellular communications. The approximate frequency ranges for these RF communication bands are shown in Figure 3.

Figure 3. Cellular Operational Frequency Bands.

GNSS Frequency Bands

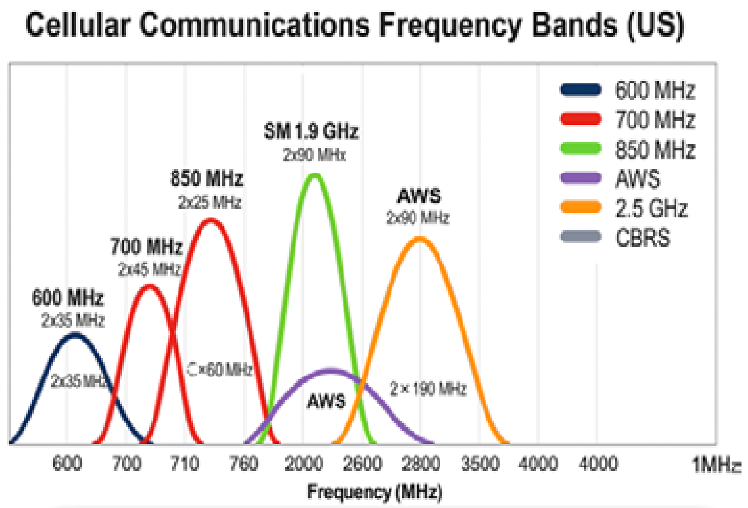


Figure 2. Wi-Fi Operational Frequency Bands.

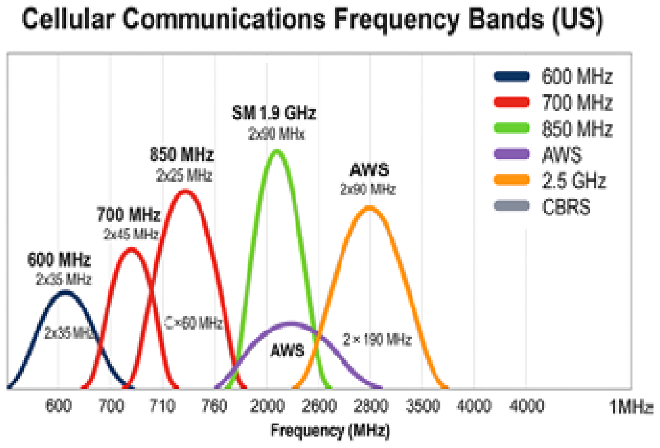


Figure 3. Cellular Operational Frequency Bands.

The UAH team measured RF signals in the frequency ranges typically used by GNSS systems. The approximate frequency ranges for these RF systems bands are shown in Figure 4.

Figure 4. GNSS Operational Frequency Bands.

RF Environment Measurement Results

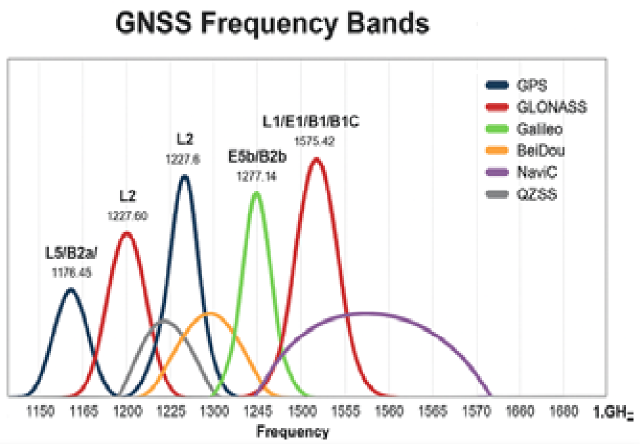


Figure 4. GNSS Operational Frequency Bands.

The UAH RF environment spectrum measurements taken over the first week of the testing at Cape May, New Jersey is summarized in Figure 5. These measurements summarize the received power over this time period in the frequency range from approximately 400 MHz to 6.3 GHz. This range covers the communication bands summarized in the previous paragraphs.

The GNSS and cellular signal spectrums measured at the test site indicate measured power levels at frequencies typically associated with navigation signals and cellular communications. The GNSS signals fall within the cellular bands and the measurements shown in Figure 5 indicates signal spectrum characteristics that match the cellular and GNSS bands discussed in the previous paragraphs.

The measured spectrum in the Wi-Fi bands indicate a portion of the Wi-Fi band crosses into the upper frequency region of the cellular band.

Figure 5. UAH Spectrum Measurements and Allocated Frequency Bands.

Conclusion

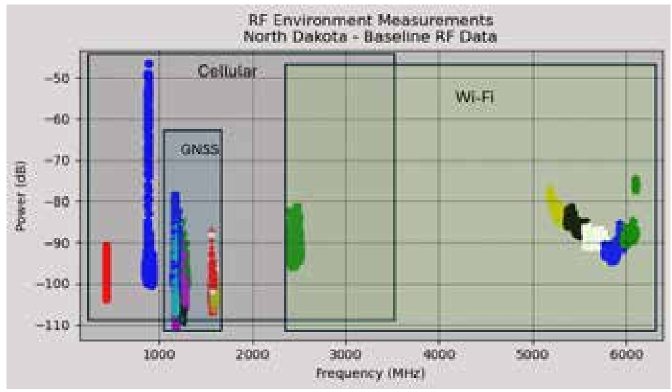


Figure 5. UAH Spectrum Measurements and Allocated Frequency Bands.

The spectrum measurements performed by the UAH test team covering the common communication and navigation frequency bands indicate the expected distribution of frequencies and power levels. The Wi-Fi, cellular, and GNSS systems can operate at required power levels and sufficient spectrum for proper operations within FCC allocations.

Therefore, the RF spectrum measurements obtained by UAH indicate that test operations exhibit a minimal impact on communication and navigation operations around the test site.

DTI Vendors:

Thirteen different drone detection systems were fielded over the course of all five flight campaigns for A60. Four different modalities were fielded, Remote ID, Acoustic, RADAR, and EO/IR. Five of the systems were operated by universities to ensure the system participation.

Vendor Data Processing:

The ASSURE A60 data management team has developed a software data processing pipeline to handle the data generated from the DTI vendors and the truth ground data from the

Modality	Number	System	University
Remote ID	1	AeroDefense	
	2	DroneSpotter	
	3	Pierce	
Acoustic	4	SquareHead	
	5	FireFLY-Hyperion	
	6	WATC Infrasound	UAF
RADAR	7	Robin	
	8	DeTect Harrier	UND Aerospace
	9	Echodyne - EchoFlight	UAF
	10	Echodyne - EchoShield	UAF
	11	OneRadio – Passive	
EO/IR	12	uAvionix	MSU
	13	Thalrix Sentinel	

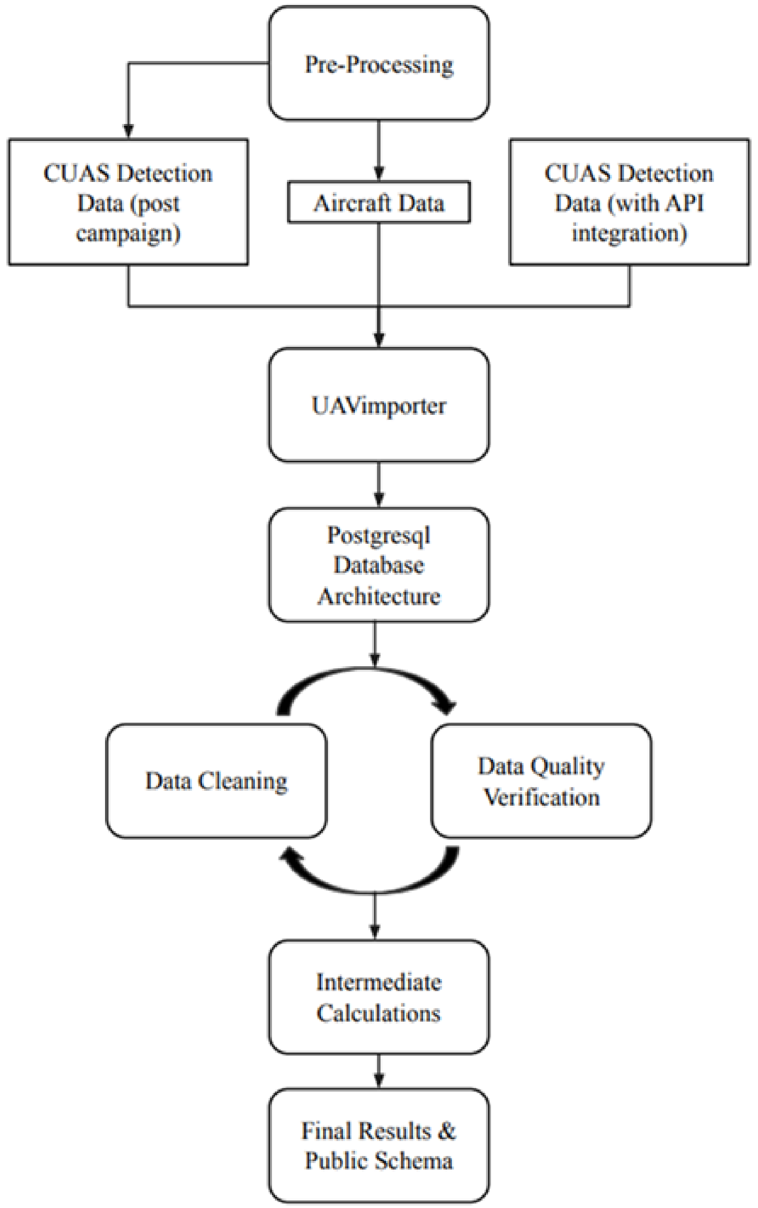
UAS. This will allow the team to process data generated each day during the flight campaigns, significantly reducing the data processing time.

All A60 campaign vendor data and UAS telemetry logs will be imported, processed, and analyzed using the ITS-toolkit module. This model design details the vendor data integration plan and UAS data integration plant using the ITS-toolkit. Figure 6 illustrates the top-level schematic of the ITS-toolkit data flow architecture.

Next Steps:

The analysis of the vendor data from the flight campaigns is ongoing. A preliminary report for each flight campaign summarizing the vendor data was submitted. Radio frequency data will continue to be processed over the next few months, with the findings included in a final report.

At this time, there is no evidence of a significant impact on the National Airspace System by any of the vendor drone detection systems that we have tested. Furthermore, there is no apparent impact on First Responder (Police, Fire, and EMS) radio and data communications from the same vendor systems, based on data analysis at this time.



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DISASTER PREPAREDNESS AND EMERGENCY RESPONSE – PHASE III

A11L.UAS.68_A62

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Disaster Preparedness and Emergency Response – Phase III

Background:

There is a need for research that explores 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 the Department of the Interior and Homeland Security (including the Federal Emergency Management Agency), as well as local and state disaster preparedness and emergency response organizations, to ensure proper coordination during those emergencies. The results help inform requirements, technical standards, and regulations needed to enable disaster preparedness and emergency response and recovery operations for UAS. This research also developed a database with data collected during the project to be analyzed to produce various key performance measures and metrics that characterize overall pilot proficiency in a flight environment.

Key Findings:

This project completed several analyses and trade studies focused on supporting technological solutions enabling expanded operations and looking at additional use cases, legislative policies, data sharing and storage, and domestic and international outreach. There has also been a database collection and more flight testing and exercises focused on disasters.

Some findings include the completion of a peer review focusing on the need for technological advancements (Common Operational Pictures, Radars, and Internet Capabilities such as Starlink), exercises including tornado drills, hurricane drills, coverage of music festivals, the development of a Minimum Operational Proficiency Standards exercise, and the development of a prototype database collector. During this time, some of the team supported the response to real-life floods and tornadoes. The team also supported the development of Future Proof, a summit focusing on airspace awareness and Drones as a First Responder (DFR). The team also identified new UAS disaster use scenarios:

- Animal, Agricultural, and Food Related Disasters,
- Site protection (recovery),
- Debris management (safety and recovery),
- Water, wastewater, dams (seepage and internal erosion – subset of flooding or unique use case),
- Coastal hazards (response),
- Addressing vulnerable populations (people with disabilities, pediatrics, children, seniors, etc.),
- Evidence collection,
- Historic preservation considerations/compliance,
- Highway disasters (iced roads, fog, sinkholes, etc.),
- Bridge collapse,
- Landslide, and
- Avalanche (both natural and human-caused).

PROJECT HIGHLIGHT

THIS PROJECT COMPLETED SEVERAL ANALYSES AND TRADE STUDIES FOCUSED ON SUPPORTING TECHNOLOGICAL SOLUTIONS ENABLING EXPANDED OPERATIONS AND LOOKING AT ADDITIONAL USE CASES, LEGISLATIVE POLICIES, DATA SHARING AND STORAGE, AND DOMESTIC AND INTERNATIONAL OUTREACH.

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IDENTIFY MODELS FOR ADVANCED AIR MOBILITY (AAM)/URBAN AIR MOBILITY (UAM) SAFE AUTOMATION

A11L.UAS.98_A64

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Identify Models for Advanced Air Mobility (AAM)/Urban Air Mobility (UAM) Safe Automation

Background:

Advanced Air Mobility (AAM) and Urban Air Mobility (UAM) operations are expected to involve significant amounts of machine automation 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 UAM core technology 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 four 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, regulations, certification, and policy. This report has been completed.
- **Task 2:** Risk and Technology Assessments. A range of alternative safety risk assessment methods was applied to develop case studies for different UAM/AAM subsystems to help evaluate their use in addressing UAM automation capabilities. This experience was then 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. This report has been completed.
- **Task 3:** Forming Recommendations. Gaps and roadblocks to realizing future AAM/UAM operational capabilities have been identified. A technology path, a standards development path, and an FAA policy and standards path were each developed to enable the advancement from current capabilities to future AAM/UAM capabilities at full maturity. This report has been submitted, and final revisions are underway.
- **Task 4:** Final Report. Task 4 will summarize all of the previous reports into a final report package for the overall project. The Final Report will answer the knowledge gaps and include research findings from the project tasking. The report will provide clear recommendations to the FAA and UAS standards development organizations. The report will highlight areas of future research needed to address remaining gaps in right-of-way rules.

KEY FINDINGS

The Task 3 Report was submitted. It includes a focus on technologies and standards relevant to separation assurance, communications, and vertiports, as well as preflight planning, strategic deconfliction, and preflight checks. Issues concerned with airspace design, human-automation interaction, and cybersecurity are noted within these categories. The primary focus is on flights with remote pilots. Appendix A of this report identifies 62 gaps concerning the development and use of technologies to provide safe automation that need to be addressed in the transitions from Initial to Midterm to Mature Operations.

The major focus of the Task 3 report is UAM flights with remote pilots in airspace with moderate to high volume. Detailed analyses are provided, organized around the following areas:

- Separation assurance.
- Communications
- Vertiports.
- Preflight planning, strategic deconfliction, and preflight checks.

Some of the major gaps identified are:

- Separation assurance:
  - o Rorie (2023) recommends that the DAA software needs to be incorporated into a configuration that "requires the pilot to switch ACAS Xr from the nominal operating mode into a 'TA Only' [Traffic Advisory only] operating mode to reduce the likelihood of nuisance RAs in the vicinity of a vertiport. The TA Only mode suppresses RAs [Resolution Advisories] entirely, limiting all alerting to TAs, regardless of the severity of the conflict." This raises important questions about how to provide safeguards to ensure separation in approach airspace.
  - o Rorie further reports that "rates of losses of DAA well clear were found to be substantially higher in the Hover scenario compared to Cruise. Pilots failed to fully comply with RAs at a rate of 0.10-0.18 in all conditions except for the DAA configuration in the Hover scenario, which was associated with a higher non-compliance rate of 0.4 due to Descend RAs issued at low altitudes." These findings indicate a need for further evaluation to ensure designs that support effective performance by the remote pilots in response to Ras from the DAA software.
  - o Software needs to provide the RPIC with situation awareness regarding other traffic and obstacles in the area (eVFR operations).
  - o DAA software must support detecting and responding to cooperative and non-cooperative aircraft and obstacles.
  - o Software needs to support return to mission after a maneuver is completed to avoid a conflict.
  - o DAA software needs to support safe autoflight for an autonomous landing if there is a loss of communication for command and control by the remote pilot.

- Communication:
  - o To prescribe the communications requirements necessary to support remote pilots and, when necessary, autonomous control of UAM aircraft, an evaluation needs to be completed that:
  - o Identifies the full range of communications (content and originators/recipients) that need to be supported.
  - o Identifies architectures to provide seamless transition to backup systems for communications if the primary support for communications is lost.
  - o Defines the procedures and required supporting technologies if there is a loss of communications supporting these communications.
  - o To support performance if there is an LC2L (Loss of Command and Control Link), preflight, the full 4D trajectory needs to be stored onboard by the avionics and sent to all relevant parties. While communications are functioning, this flight plan needs to be updated. This standard needs to deal with a range of scenarios:
  - o Loss of all communication for command and control for a single aircraft.
  - o Loss of communication for command and control for all of the aircraft under control by a flight operations center.
  - o Loss of communication provided by a specific vertiport to coordinate sequencing and spacing for a specific vertiport with the RPICs.
  - o Loss of communication for command and control for all aircraft in an urban area.
  - o The software also needs to determine whether the flight has a sufficient power supply to fly the computed 4D trajectory and have a contingency plan to deal with a scenario where the power supply is not adequate to land and the planned destination vertiport.
  - o Detailed analyses are necessary to determine the reliability of the primary and backup communications systems. Examples of scenarios where a LC2L event could occur that merit consideration are:
  - o Hardware or software failures.
  - o Direct attacks on the communications infrastructure itself.
  - o Emergency evacuation of a flight operations center, leaving all of its flights unattended.
  - o Spoofing of GPS is impacting C2 systems that rely on GPS for encryption. This could also include an indirect attack on those C2 systems that make use of GPS to support encryption. This concern is encompassed by the Presidential Memorandum on Space Policy, Directive 7 (Presidential Memo, 2021)
  - o Performance-based standards need to be specified to define acceptable performance for alternative communication network and architecture designs. These standards need to consider requirements relative to:
  - o Capacity and latency.
  - o Reliability.
  - o Security.
  - o As indicated in Figure 9, 5G networks are considered a primary approach to support UAM communications. Performance standards need to be developed and applied for 5G, 6G, and SATCOM communications systems. SATCOM capabilities could be designed to provide a supplement or backup for cellular 5G+ networks or could be developed as a separate communications network

- Vertiports:
  - o The vertiport flight manager needs to be provided with the software and procedures necessary to:
  - o Maintain situation awareness regarding vertiport status (including weather as well as traffic on the ground and in the airspace).
  - o Coordinate with the ATC traffic manager regarding the determination of vertiport arrival capacity, including decisions to initiate arrival ground stops and to communicate this information to flight operators.
  - o Coordinate with ATC to clear flights for departure. Again, responsibility for delivering a clearance to depart will be dependent on the airspace classification for the vertiport. For example, for a private vertiport in Class G airspace, the vertiport flight manager might be responsible for clearing a flight to depart, while for a vertiport in Class B airspace, ATC would be responsible.
  - o Requirements for automation to help ensure landing pads are clear for safe landings need to be developed, potentially including use of downward-facing cameras on the aircraft (McNab 2023).
  - o Requirements for a vertiport ground station to support the vertiport flight manager need to be established.
  - o The vertiport flight manager needs access to weather information.
  - o The vertiport flight manager needs to have the ability to coordinate with the FAA traffic manager (or some other appropriate authority for vertiports that are not in ATC-controlled airspace) to provide information relevant to determining arrival capacity or to request a vertiport departure or arrival stop.
- Preflight Planning and Strategic Deconfliction
  - o The process for managing arrivals at a vertiport needs to be defined, including assignment of roles and responsibilities and requirements for procedures and automation support (to prevent overloading an arrival fix and necessitating an undesirable amount of holding or diversions). This includes software to support the responsible party or parties.

The Task 4 final report will be submitted in November 2025. It summarizes important findings based on Tasks 1-3. Based on the gaps identified in Report 3, it further presents recommendations for the FAA and standards organizations, specifying areas that need further research and development, as well as standards development for safety automation to support UAM operations.

. It also indicates the current status of relevant standards and prioritizes the importance of the development of standards in specific areas.

The focus areas covered in the Task 4 report include:

- Support for UAM weather decision making.
- Traffic Flow Management for UAM operations.
- Separation assurance for UAM operations.
- Communication, navigation, and surveillance for UAM operations.
- Vertiport operations.

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DEVELOP METHODOLOGIES TO INFORM THE INTEGRATION OF ADVANCED AIR MOBILITY (AAM) INTO THE NATIONAL AIR SPACE SYSTEM (NAS)

A11L.UAS.106_A66

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Develop Methodologies to Inform the Integration of Advanced Air Mobility (AAM) into the National Air Space System (NAS)

Background:

The Office of Aviation Policy and Plans (APO) has a commercial-aviation forecasting process and methodology – known as the Terminal Area Forecast – Modernized (TAF-M). Overall, TAF-M projects airport enplanements and operations based on a flow of passengers passing through a network of airports with substantial commercial activities. The forecast currently assumes that the network of passenger flows and aircraft serving them, drawn from these 230 airports that form the nodes of the network, does not change over the horizon of the forecast. In other words, the underlying network in TAF-M is assumed to be fixed. Under the current structure of the aviation industry, this assumption is reasonable, but as Part 135 Advanced Air Mobility (AAM)/Urban Air Mobility (UAM) commercial transportation services begin to merge with traditional aircraft, the industry will mature with new entrants proposing services across the National Air Space System (NAS). Activities at smaller regional airports at the periphery of metropolitan areas (e.g., Class D airports) are likely to see rapid increases in commercial activity in support of the expanding network. This could push smaller airports over the TAF-M commercial activities' threshold of 100,000 annual Part 121 enplanements. Alternatively, as regional airports begin expanding services due to emerging Part 135 AAM/UAM commercial transportation operations, Part 121 services in established core commercial airports could decline. Furthermore, this could flex the nodes at established TAF-M airports. These, in turn, will result in a network that is flexible. From a research perspective, it is important to understand the extent to which such maturation (i.e., Class D airports qualifying to become a node in TAF-M commercial airport network; and/or commercial airport losing services due to expanding Class D airport services, thus losing their previous node positions) is likely via Part 135 AAM/UAM activities in the NAS.

PROJECT HIGHLIGHT

THE INTEGRATED FRAMEWORK DELIVERS COMPREHENSIVE 25-YEAR PART 121 ENPLANEMENT FORECASTS FOR TARGETED US CSAS, PROVIDING A ROBUST FOUNDATION FOR INFORMED DECISION-MAKING ON PART 135 AAM/UAM TRANSPORTATION SERVICE INTEGRATION, RESOURCE ALLOCATION, AND LONG-TERM SYSTEM SAFETY MANAGEMENT. RESULTS INDICATE THAT PART 135 AAM/UAM TRANSPORTATION SERVICE INTEGRATION COULD SUBSTANTIALLY RESHAPE PASSENGER FLOW PATTERNS, WITH SMALLER AIRPORTS GAINING ENPLANEMENTS WHILE MAJOR HUBS EXPERIENCE MODERATED GROWTH.

Based on the empirical research and findings of this grant, APO plans to improve, implement, and incorporate the forecasting model that is dedicated to predicting commercial-aviation network expansion and contraction by accounting for Part 135 AAM/UAM commercial transportation service activities. The new model would allow inactive nodes – airports without substantial economic activities – to become active, as well as active nodes to become inactive, due to Part 135 AAM/UAM commercial transportation services attracting and dispersing passenger flows respectively. The flexibility of the network, the key research focus, will facilitate relaxing of the assumption that the network does not change over the forecast time horizon. This will allow FAA to account for the growth of AAM and its impact on NAS and help assist FAA with resource allocation and continued safe integration.

Approach:

The approach to this project includes the following tasks:

Task 1: Flexible Network Analytical Framework

Task 2: Develop a Flexible Network Commercial-Aviation Methodology

Task 3: Develop an A66 AAM/UAM Transportation Integration Forecast Methodology

Task 4: Review and Expansion of A36 Metropolitan Ranking Methodology

Task 5: Integration of Metro-Specific Parameters into A66 AAM/UAM Transportation Integration Forecast Methodology

Task 6: Generate Analytical Framework for the A66 AAM/UAM Transportation Integration Forecast Methodology

Task 1 FY24 Activities:

The research team conducted a thorough review of the current TAF-M Methodology utilized by the FAA to project future Part 121 air traffic and operations. This process involved identifying and understanding the underlying principles, assumptions, and parameters that govern the TAF-M Part 121 forecasts. As part of this process, the research team reproduced TAF-M operations using Python scripts to ensure the methodology could be applied programmatically and accurately replicated. Subsequently, the research team also conceptualized the input and output structure for the proposed Terminal Area Forecast – Modernized 2 (TAF-M2) model, which would account for potential Part 121 enplanement shifts resulting from the introduction of Part 135 AAM/UAM commercial transportation services into the NAS. Through this exercise, a comprehensive conceptual framework was developed to demonstrate how Part 135 AAM/UAM commercial transportation services could potentially interact with the TAF-M2 model.

Task 2 FY24 Activities:

The research team archived data pertaining to the TAF-M2 Methodology developed through Task 3. These data were utilized by the research team to conduct a limited implementation of the TAF-M2 Methodology to produce a 25-Year Forecast of Part 121 Enplanements for the Los Angeles Combined Statistical Area (CSA).

Task 3 FY24 Activities:

The research team conducted a literature review pertaining to passenger choice modeling related to ground transportation access and airport preference. Upon completion of this literature review, the research team developed a three-phase methodology to assess how the introduction of Part 135 AAM/UAM commercial transportation services as an airport access mode may shift Part 121 enplanements among airports within select US CSAs. The phases, outlined below, collectively reflect the proposed TAF-M2 Methodology. Through this process, the research team identified appropriate data sources for each variable involved in the methodology.

Phase I: TAF-M Part 121 Enplanement Forecasts

Utilizing the existing TAF-M Methodology, 25-Year Forecasts of annual Part 121 enplanement estimates were constructed for each selected US MSA, as well as for each airport within each selected US MSA. These forecasts served as a baseline of annual Part 121 enplanement estimates through 2050 based on the assumption that Part 135 AAM/UAM airport access services are not introduced within the selected US MSA during the forecast period.

Phase II: AAM/UAM Transportation Integration Forecasts

Next, the A66 AAM/UAM Transportation Integration Forecast Methodology was applied to determine the extent of potential annual Part 121 enplanement shifts between airports within each selected US metropolitan area due to the introduction of Part 135 AAM/UAM airport access services into respective metropolitan urban transportation systems. To this end, a nested logit model was utilized to estimate the appropriate weights of annual Part 121 enplanement shifts for each airport within each selected US CSA based on factors which influence discrete passenger choices pertaining to airport access mode and airport preference.

Phase III: TAF-M2 Part 121 Enplanement Forecasts

Finally, TAF-M2 25-Year Forecasts of annual Part 121 enplanement estimates were constructed for each airport within each selected US CSA by utilizing a forward induction approach. Annual airport-level weights developed through the A66 AAM/UAM Transportation Integration Forecast Methodology were iteratively applied to annual MSA-level Part 121 enplanement estimates developed through the TAF-M Methodology. The TAF-M2 forecasts serve as a counterfactual of annual Part 121 enplanement estimates through 2050 based on the assumption Part 135 AAM/UAM airport access services are introduced in the immediate future within the selected US CSAs.

In addition to the above methodology, the research team submitted sample flight telemetries which would accompany the TAF-M2 25-Year Forecasts, as well as documentation containing explanations of the parameters and assumptions used to generate the sample flight telemetries. As the TAF-M2 Methodology was not yet implemented, the research team utilized TAF-M Part 121 enplanement projections and A36 Part 135 enplanement projections to develop the sample flight telemetries.

Task 4 Activities:

The research team conducted a literature review pertaining to existing methodologies and variables which should be considered when ranking US CSAs based on potential for Part 135 AAM/UAM commercial transportation service integration and expansion, concluding the project would adopt an expanded version of the A36/A41 Simple Multi-Attribute Rating Technique (SMART) to reassess Part 135 AAM/UAM site suitability. In doing so, key variables pertaining to urban structure, economic scale, congestion and travel time, market readiness, and existing short-haul markets were retained from the A36/A41 projects. Additional variables identified by the literature as important indicators of Part 135 AAM/UAM commercial transportation service adoption, such as average personal income, were noted for inclusion within the expanded site suitability analysis. Through this process, the research team identified appropriate data sources for each variable and conducted an expanded site suitability analysis.

Task 5 Activities:

The research team archived data pertaining to the TAF-M2 Methodology developed through Task 3 for the six target US CSAs selected for full implementation (i.e., New York, Los Angelos, San Francisco, Chicago, Miami, and Washington D.C.). These data were utilized by the research team to conduct implementation of the A66 AAM/UAM Transportation Integration Forecast Methodology developed in Task 3 to obtain the necessary parameters for full implementation of the TAF-M2 Methodology across the six target US CSAs within Task 6.

Task 6 Activities:

The research team executed full implementation of the TAF-M2 Methodology developed through Task 3 to generate a 25-Year forecast of Part 121 enplanements for each airport within the six target US CSAs. In doing so, all necessary Python scripts and data sources were packaged and documented to ensure replicability.

Furthermore, the research team developed, packaged, and delivered a data generator which would enable FAA sponsors to easily generate counterfactual data from official data sources to assess how hypothetical scenarios would potentially influence Part 121 enplanements within the TAF-M2 framework.

KEY FINDINGS

The project identified several metropolitan areas with strong potential for Part 135 AAM/UAM adoption and successfully developed a functional TAF-M2 methodology, supported by optimization analyses which generated reliable parameters for metropolitan-level forecasting. The integrated framework delivers comprehensive 25-Year Part 121 enplanement forecasts for targeted US CSAs, providing a robust foundation for informed decision-making on Part 135 AAM/UAM transportation service integration, resource allocation, and long-term system safety management. Results indicate that Part 135 AAM/UAM transportation service integration could substantially reshape passenger flow patterns, with smaller airports gaining enplanements while major hubs experience moderated growth.

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COLLISION SEVERITY OF SUAS IN FLIGHT CRITICAL ZONES OF PILOTED HELICOPTER

A11L.UAS.115_A67

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Collision Severity of sUAS in Flight Critical Zones of Piloted Helicopter

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 Advanced Air Mobility (AAM)/Urban Air Mobility (UAM) operations into the National Airspace System (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 investigated 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, focused on larger Part 29 helicopters encountering relatively small sUAS (2.7lb (Quadcopter) and 4lb (Fixed Wing)). Research conducted under this current requirement addresses 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. Vertical Stabilizer
3. Mast
4. Main Blade
5. Windshield
6. Nose

Three different collision speed scenarios were considered:

1. Forward flight at a collision speed of 94 kts. (Medium).
2. Cruise flight at a collision speed of 149 kts. (Max).
3. Hover condition with a speed of collision of 39 kts.

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

Approach:

Task A16 focused on Part 29 helicopters encountering smaller 2.7 and 4 lbs sUAS. This phase addressed those same size sUAS (2.7 and 4 lbs) and larger sUAS (10, 25, and 55 lbs) impacting a medium-sized Part 27 helicopter, specifically looking at windshields, main rotor blade, rear servo, cowling, nose, and horizontal stabilizer structures.

Task 1 – Research Task Plan and Helicopter Purchasing Process.

NIAR located and purchased a structurally complete medium-sized Part 27 helicopter (Robinson R44).

Task 2 – Helicopter Reverse Engineering.

The medium-sized Part 27 helicopter purchased during Task I was reverse-engineered to create a Computer Aided Design (CAD) and Finite Element (FE) model representing its major structural components. The reverse engineering process was divided into five major tasks:

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

Task 3 – Helicopter Finite Element Model.

The 3D CAD model of the medium-sized Part 27 helicopter developed on Task II was used to generate the detailed FEM for collision severity analysis. NIAR's internal processes and the building block approach were used to generate the detailed finite element model 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 set up and evaluated load cases for 2.7, 10, 25, 55 lbs quadcopters and 4, 12, 25, 55 lbs fixed-wing sUAS in these tasks. Six impact locations and three impact velocities were considered for each sUAS, resulting in a total of 144 collision cases.

A set of criteria was established to categorize the results of each collision 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 criterion followed for Task A16 was used to evaluate the level of damage on the main rotor blade for this Part 27 helicopter.

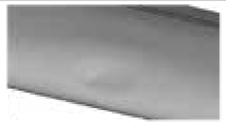
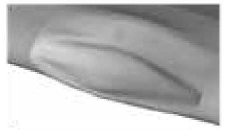
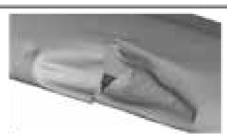
Severity	Description	Example
Level 1	• The airframe is undamaged. • Small deformations.	
Level 2	• Extensive permanent deformation on external surfaces. • Some deformation in internal structure. • No failure of skin.	
Level 3	• Skin fracture. • Penetration of at least one component into the airframe.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

Figure 2. Severity Levels.

Task 8 – Final Report – Collision Evaluation.

The research completed throughout Tasks 1 to 7 was summarized into one single project report delivered on August 2024.

KEY FINDINGS

The results of the 135 impact scenarios analyzed corresponding to the quadcopter and fixed-wing sUAS architectures from 2.7 lbs. to 55 lbs. are summarized in Figure 3. Nine cases were not analyzed because the collision was not geometrically feasible. An example of mid-air collision evaluation analysis is shown in Figure 4. The following key findings affect the severity classification of the impact events:

1. There is a clear trend with the increase of sUAS mass and impact velocity on the severity outcome. There is less severity for smaller mass sUAS and lower impact velocities.
2. Nonetheless, it should be noted that the architecture and construction of the sUAS also influence the severity levels significantly:
   a. Direct impact with stiff components (i.e., the motors) increases stress concentration and larger damage to the impacted structure.
3. From a severity level point of view, the most critical impact location is the windshield. All sUAS impacts result in severity level 4 when the speed is greater than 39 knots (hover). Some sUAS (F12, Q55, and F55) produced a level 4 severity at hover speed. This is related to the fact that conventional Part 27 rotorcraft windshields are not bird-strike resistant.
4. The main source of severity for main rotor blade impacts is the weight and size of sUAS. This is due to the blade rotational speed being the largest component of the relative impact velocity.
   a. Larger sUAS impacts do not result in direct damage to the blade, as opposed to small-size UAS with their stiff components (i.e., motors). However, they create excessive blade bending and twisting, which could lead to unrecoverable loss of control.
5. Any impact on the tail rotor will likely result in the tail rotor skin debonding, leading to loss of control. This occurred even on secondary impacts with the foam wings of the 4 lbs. fixed-wing sUAS.
6. Impact with the nose at hover speed (39 knots) is the least severe. All sUAS were deflected at hover speed, which resulted in minimal damage to the rotorcraft skin.
   a. However, impacts at higher speeds (149 knots) with the larger sUAS (25 and 55 lbs.) result in loss of structural integrity in the forward fuselage.
7. Impacts with the mast do not result in sUAS penetration or severe structural damage. However, A level 4 severity was assigned to cases where the swash plate links are pinched or compressed, which could interfere with pilot control of the aircraft.

Impact cases on the windshield and the main rotor blade were compared to actual sUAS mid-air collisions. The observed damage in the analysis correlates well with the actual event observations, as highlighted in Figure 5. These events are used as additional validation data points and add confidence to the analysis results.

Overall, the small size and type of construction utilized in the Part 27 rotorcraft results in severe damage when there is a mid-air collision with larger sUAS (25 and 55 lbs.). Conversely, impacts with sUAS less than 10 lbs. are less severe, even at higher speeds (149 knots). The findings from this research may be used to conservatively define airborne hazard severity thresholds for collisions between sUAS of several sizes and weights and a Part 27 rotorcraft.

UAS\Impact Area	Horizontal Stabilizer			Vertical Stabilizer			Mast			Nose			Windshield			Blade		
	Hover	Medium	Cruise	Hover	Medium	Cruise	Hover	Medium	Cruise	Hover	Medium	Cruise	Hover	Medium	Cruise	Hover	Medium	Cruise
Q2.7	1	2	3	1	2	3	1	2	2	2	3	3	1	4	4	2	2	2
F4	2	2	3	4	4	4	1	2	3	2	3	3	1	4	4	3	3	3
Q10	2	3	4	2	3	4	2	2	3	2	3	3	4	4	4	3	3	3
F12	-	-	-	4	4	4	2	2	3	2	3	3	2	4	4	4	4	4
Q25	2	4	4	2	3	4	2	3	4	2	3	4	2	4	4	4	4	4
F25	-	-	-	4	4	4	2	3	4	2	3	4	3	4	4	4	4	4
Q55	3	4	4	4	4	4	3	4	4	2	4	4	4	4	4	4	4	4
F55	-	-	-	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4

Figure 3. Simulation Severity Matrix – Summary.

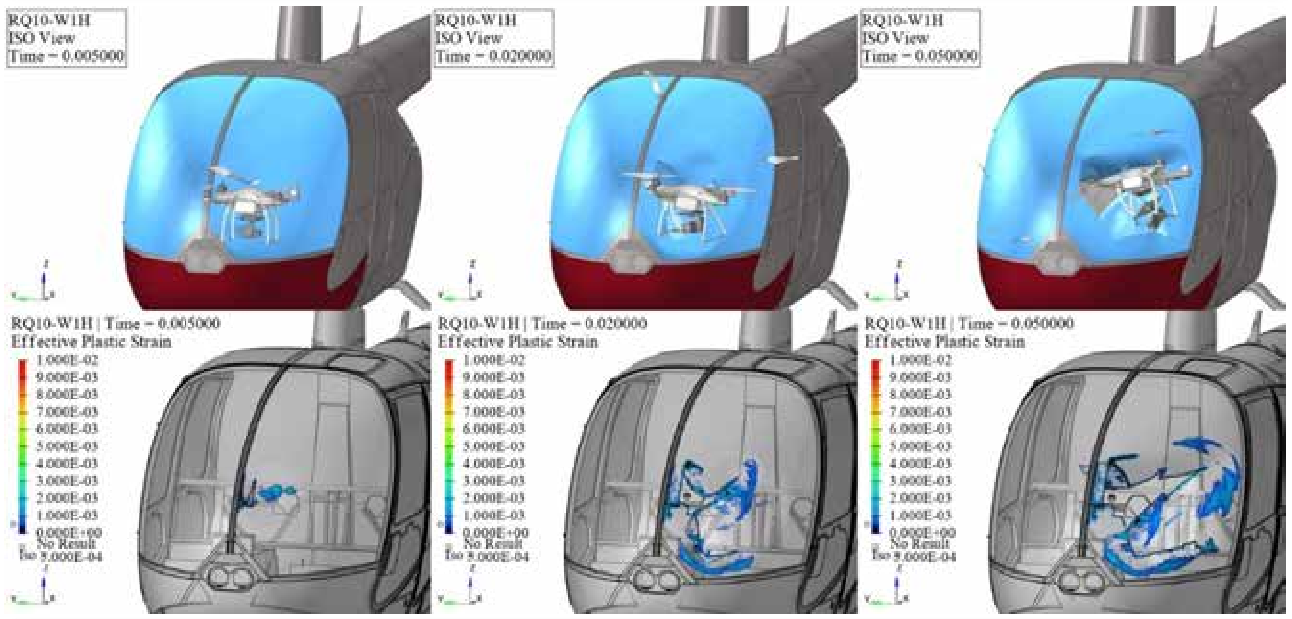


Figure 4. Simulation Severity Matrix – Summary.

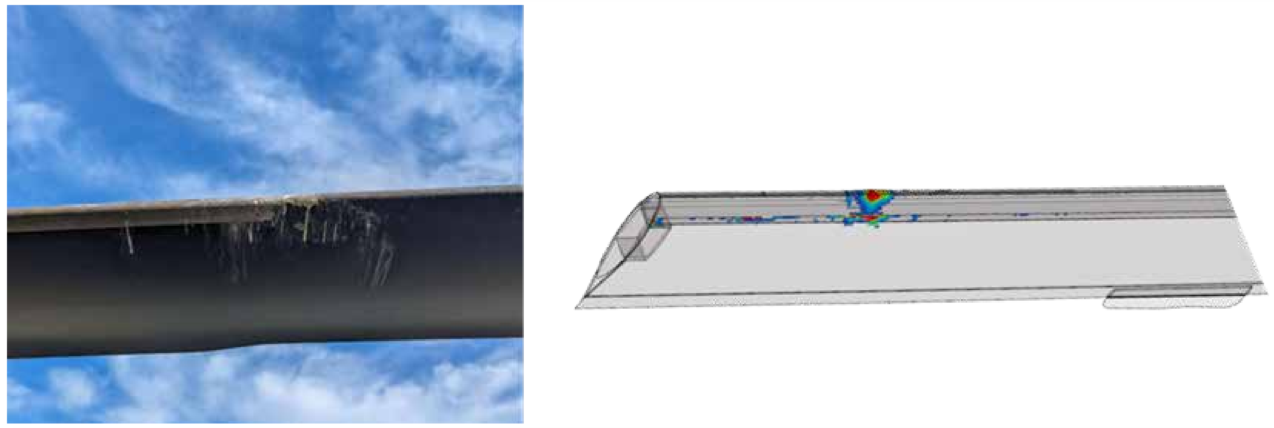


Figure 5. Comparison of an actual mid-air collision event vs. FE Analysis.

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VALIDATE sUAS DAA WELL CLEAR REQUIREMENTS

A11L.UAS.117_A68

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UNIVERSITY OF KANSAS

Validate sUAS DAA Well Clear Requirements

Background:

sUAS Detect and Avoid (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 are suitable for interactions between two sUAS for a variety of interactions near and away from flight obstacles at low altitudes.

Main tasks:

- Task 1: sUAS Well Clear Volume Validation
- Task 2: Right of Way Quantification
- Task 3: Remote Identification Field Testing
- Task 4: UTM Service Field Testing

Key Findings:

- **Task 1:** Monte Carlo Simulations (evaluated ASTM 2000 ft horizontal and 500 ft vertical well-clear volume; tested safety vs. Well Clear Volume (WCV)

  → ASTM well-clear volume is safe; moderate reductions below 2000 ft may still maintain safety.

PROJECT HIGHLIGHT

THIS PROJECT WILL ASSESS, REFINE (IF NECESSARY), AND VALIDATE WELL-CLEAR SEPARATION CRITERIA FOR A VARIETY OF SUAS OPERATIONS THAT AVOID CREWED AIR TRAFFIC.

- **Task 2:** VR simulations and flight tests (measured RoW impact and pilot perception thresholds; spotting/maneuver vs. 2000 ft horizontal and 500 ft vertical).

  → Pilots spotted sUAS ~2,000 ft (day), ~6,500 ft (night); rarely requested maneuvers above 300 ft vertical.

  → RoW impact became significant at ~281 ft vertical separation

  → Potential to reduce the 2000 ft horizontal well clear separation threshold to 1500 ft using Group 3 UA.

- **Task 3:** RID field testing (evaluated DB120 Wi-Fi, DB120 Bluetooth, DroneTag Mini for PRR, accuracy, and speed effects)

  → RID feasible but limited (missing accuracy fields, variable reliability)

  → Need to account for positional error in RID signals

- Task 4: Flight test encounters and simulations
  - o Demonstrated UTM-enabled separation using multiple data sources (ADS-B, Radar, Cellular)
  - o Determined detection distances required to maintain WC

    → Required detection distances 8–14k ft to maintain 2000 ft

  - o UTM-enabled encounter simulations and flight tests with RID integration

    → Single sUAS vs sUAS encounter required ~3.5–4k ft detection to maintain 500 ft separation

    → **Multi-sUAS** corridor encounter simulations required ~14,300 ft detection to maintain WC

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CONDUCT SAFETY RISK MANAGEMENT ANALYSIS ON SMALL UNMANNED AIRCRAFT DETECT AND AVOID SYSTEMS

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Conduct Safety Risk Management Analysis on Small Unmanned Aircraft Detect and Avoid Systems

Background:

Safety management policy and requirements established by the FAA are mandated in FAA Order 8000.369: Safety Management Systems. FAA Order 8040.4B: Safety Risk Management (SRM) Policy establishes the requirements for an SRM program and conducting SRM within an organization. According to the National Academies of Sciences (2018), the systematic approach to safety risk management has achieved a high level of safety for all users of the National Airspace System (NAS). Unfortunately, the agency's current safety risk management approaches are qualitative and subjective. Additionally, most safety risk management processes currently used in aviation to create a Safety Risk Management Document (SRMD) analysis were initially intended for the safety assurance of crewed aircraft and not unmanned systems. Proposed methodology refinements when creating an SRMD are needed to support risk management for UAS and Detect and Avoid (DAA) Systems. The project will focus on SRM processes for UAS with a primary lens on DAA risk assessment to propose recommendations towards refined SRM processes and SRMD for DAA systems.

Knowledge Gaps/Research Questions

1. Through a sensitivity analysis, what portions of a DAA system design are most critical when it comes to mitigating collision risks?
2. Does this change for different DAA architectures or operations such as Airborne DAA, Ground Based DAA, UAS traffic management Surveillance Services as part of a DAA system, automated or manual DAA maneuvers, and Multi-vehicle DAA architectures and operations?
3. What risk assessment tools are recommended for industry DAA risk management?
4. Are they [risk assessment tools] different than the risk assessment tools recommended for FAA use?
5. What does a sensitivity analysis reveal about the effects of loss of link on DAA performance when considering different DAA architectures and operations?

Examples include Ground Based vs Airborne, Manual vs Automated avoidance, en-route vs terminal operations, etc.

6. How should a suitable standard/accepted risk assessment on a DAA system be structured to provide meaningful insights into system design, performance, and safety optimization?
7. What variables or aspects of system design have the greatest impact?
8. What safety metrics are recommended for meaningful DAA system safety assessments? Consider assurance, performance, and system-to-system interactions.
9. What input-processing-output models or diagrams are most useful for identifying potential hazards?
10. How could guidance for SRMD assessments and UAS SRM policy be updated to satisfy the original intent of safety risk management and the risk management cycle?
11. What risk assessment tools and metrics are recommended for DAA system safety assessments?
12. What guidance is recommended for distinguishing between system safety and system-of-systems safety?
13. What risks are unique or more critical to different DAA systems? Consider a variety of different DAA systems and DAA operations.
14. How can SRM assessments better inform DAA standards and DAA development (as intended in the SRM cycle) rather than be an activity that is conducted after the design standard or system development is complete?

Approach:

Task 1: Issue Report

This issue paper explored DAA system functions and operations against the backdrop of the SRM process to identify issues and gaps that pose challenges to assessing risks associated with DAA systems. Framing this issue paper in terms of the SRM process – describing the system, identifying hazards, assessing risk, analyzing risk, and controlling risk – provides a rational way to look for issues and gaps that challenge effective SRM for DAA systems in each process step. This approach identified issues and gaps that may be considered and addressed during the development of a DAA risk assessment framework in future research tasks.

Issues and gaps identified within this issue report can be listed in seven key points. These points are distilled from issues and gaps identified in each step of the SRM process and summarized for brevity. Issues and gaps identified within this issue report are listed below in the key findings section.

While this issue paper did not address all possible issues and risks associated with DAA systems, it has highlighted some of the most prominent barriers to identifying hazards and assessing risk. The issues and gaps identified in this issue paper will inform the identification of hazards and the development of a risk assessment framework in future research tasks. Additionally, the issues and gaps identified here may inform other research efforts and serve as a starting point for identifying essential characteristics of DAA systems.

Task 2: Draft Hazard Identification and Risk Assessment Processes for DAA Systems and Operations

Task 2-1 identifies two proposed alternative Probabilistic Risk Assessment (PRA) methods suitable for use in the context of DAA systems and operations.

Proposed risk assessment method #1: The proposed exposure-based approach to PRA expands traditional two-variable models by incorporating exposure, the duration a UAS is subjected to a hazardous condition, as a third critical dimension alongside potentiality (the likelihood of a condition occurring at a specific moment) and severity (the potential consequences of an event). This approach allows for a more nuanced and dynamic understanding of risk by recognizing that the longer a UAS remains in a risky environment, the greater the overall threat becomes. Exposure is quantified in real time during potential conflict windows, such as proximity to other aircraft, and is considered only when potentiality is greater than zero. By framing risk as a point in three-dimensional space, represented by the Risk Assessment Point (RAP), this model provides a visualization of operational risk, which can be applied at both micro (individual encounters) and macro (fleet or mission-wide) levels. This method supports better-informed decision-making for both automated systems and human operators by capturing the time-dependent nature of real-world UAS risk scenarios.

Proposed risk assessment method #2: DAA timing distribution approach to PRA. The probability that a DAA system does not detect the other aircraft before a Near Mid-Air Collision (NMAC) in a Concept of Operations (CONOPS) is a vitally important but difficult to estimate risk measure. It is vitally important because DAA system performance (e.g., the distribution of detection delay) is difficult to contextualize and interpret outside of specific CONOPS. That is, knowing the median and standard deviation of the detection delay are m and s seconds, respectively, does not by itself convey anything about the risk associated with using that DAA system. Rather, the risk acquires meaning only within the specific CONOPS, which includes i) characteristics of the flight of the ownship (the vehicle on which the DAA is mounted) and the intruder (the vehicle to be detected) such as the separation distance, ii) system characteristics (e.g., the camera resolution), and iii) operating conditions (e.g., fog and visual clutter). By leveraging probabilistic mathematical modeling, realistic flight trajectories, detailed detection algorithm simulation, machine learning techniques, and efficient Monte Carlo simulation, the proposed approach yields credible estimates of this risk measure.

Task 2-2 studied the sensitivity of the proposed risk measures. Specifically, the approach described in proposed risk assessment method #2 in Task 2-1 yielded a parameterized model for the instantaneous detection probability as a function of the instantaneous separation distance between the two aircraft, where the parameters capture system characteristics (e.g., the camera resolution), and operating conditions (e.g., fog and visual clutter). This model is obtained by using standard machine learning techniques on datasets that combine realistic flight trajectories with a detailed detection algorithm simulation. Specifically, there was a parameter space for system characteristics and operating conditions sampled to estimate the probability of instantaneous detection under those particular conditions, and the machine learning algorithm yields a model of that detection probability over the entirety of the parameter space. The focus of this component of Task 2-2 was to explore the dependence risk measures of interest (e.g., the instantaneous detection probability, the detection delay distribution, and the probability of detection before NMAC) upon operating conditions (camera resolution, fog, and visual clutter).

Task 3: DAA Hazard Identification and Risk Assessment

Task 3 incorporates the findings of Task 2, Draft Hazard Identification and Risk Assessment Processes for DAA Systems and Operations, into a simulation environment to evaluate risk assessment processes and determine the impact of key variables in a simulated environment. This task uses advanced simulation techniques to model environmental conditions, DAA system functions, timing, and other variables relevant to DAA system function and risk. This task will inform a broader safety risk management analysis document that summarizes findings as part of subtask 3-2 and the final report (Task 4).

KEY FINDINGS

Task 1:

- There are no universally accepted reliability metrics for DAA systems.
- There are currently no accepted standards for assessing the risk associated with DAA systems.
- Data required to assess the risk associated with DAA systems is often incomplete, inaccurate, or unavailable.
- Models driven by reliable data and a robust analytical framework are essential to assessing the risk associated with DAA systems.
- The evolution of DAA technologies is occurring rapidly and extends beyond the current UAS operational guidance.
- Effective verification and validation of DAA systems are needed to ensure reliability.
- Guidance and standards are needed to define and apply risk controls for DAA systems.

Task 2:

- Exposure-Based PRA:
    - o Added exposure as a third risk factor.
    - o Showed that encounters with longer time in conflict have a much higher risk if the likelihood/severity are the same.
    - o Timing-Distribution PRA:
    - o Produces credible detection delay and NMAC probability estimates via simulation + ML + Monte Carlo.
    - o Demonstrated that detection probability drops sharply under degraded conditions (e.g., in moderate/heavy fog, detections are often missed, raining NMAC risk).
- Detection Rate: >98.6% in clear/light fog ⍰ ~12.82% in heavy fog.
- Detection Distance: 1447.38m (clear), 87.49m (heavy fog).
- NMAC Risk: NMAC risk stays very low (<0.22%) for fog <0.01, then climbs sharply – about 1.04% at 0.013, 2.7% at 0.015, and reaches 13.48% in heavy fog.

Task 3

- Migration from Gazebo Classic to Gazebo Sim (Ignition) is completed.
- The Waypoint follower is completed to smoothly work in Gazebo Classic.
- A custom launcher is generated to simulate different MIT encounters in Gazebo Classic.
- Customizable frequency for the detection measurements coming from YOLO vision detection system.
- To have more detection data, YOLO detection process has been changed from the CPU to the GPU.

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

A11L.UAS.53_A73

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VIRGINIA TECH

Conduct Science, Technology, Engineering, and Math (STEM) Outreach to K-12 Students Using Unmanned Aircraft Systems (UAS) as a Learning Platform

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 meeting this demand. To make STEM opportunities more accessible and to contribute to creating the next generation's interest in the UAS field, the FAA UAS Center of Excellence (COE)/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, cybersecurity, 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 1-4 of the STEM efforts funded by the FAA through ASSURE, each school was in control of their own specific approach to address the two 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 continued to serve as the lead University for Phase V and handled the programmatic support for the project through technical interchange meetings and program management review updates. Building on activities supported during the previous STEM grant, the team was active in partnerships both on and off campus with the NC Department of Transportation's Division of Aviation (DOA) and several programs within The Science House and the TRIO Early College Program.

For the third year, NC State was able to support the DOA's Aviation Career Education (ACE) Academy grant program, which hosts middle and high school students at local public airports in North Carolina. During the summer 2024 camps, the University took on a larger role, aiding with both the drone flight demonstrations as well as providing the bulk of the DOT's career opportunity presentation. Camps were offered to select hands-on experiences from the following options: indoor flying with small trainer drones, indoor (hangar) or outdoor flights with a small UAS, and drone simulators deployed via laptops. There were eight total awards provided to seven unique airports across the state. Each camp was individually organized, and the support from this program makes up only a small portion of the total curriculum. Some of the other activities the students got to participate in include crewed aircraft tours in hangars and first flights in smaller general aviation planes.

Through the TRIO program, one of the new highlights for this year was a curriculum involving block programming for command and control. Students were tasked in small groups with exploring basic commands to navigate the aircraft through a series of increasingly difficult prompts. Finally, each student was required to design and run a program on their own that would spell out the first letter of their first name. This open-ended mission allowed for creativity and problem-solving skills development, and quite a lot of trial and error.

In support of all outreach activities under this award, the university was able to make capital improvements to the UAS fleet through the acquisition of aircraft and supporting supplies to provide students with the best and latest technologies.

Oregon State University

Oregon State University (OrSU) hosted several outreach events focused on providing both hands-on activities using drones and participating in various career fairs and open houses, where the OrSU team introduced drone use for various civil and construction engineering applications. Overall, over 1,050 students attended these events.

The hands-on activities include assembling drones from the components, test-flying the assembled drones, and spoofing the onboard sensors of drones. The activities are designed to provide K-12 students with opportunities to learn the basic principles of drone flight as well as the security concerns related to sensor spoofing attacks on drones. Oregon State supported the STEAM Night event at Blodgett Elementary School (Philomath, OR) by providing hands-on activities to K-4 students. Blodgett Elementary School serves the community in a rural area and has a small enrollment (fewer than 40 students in total). In the Beaver Achiever Camp hosted at the Oregon State Corvallis campus, Oregon State provided the hands-on activities to African American middle school students and their teachers. In the Engineering Migrant Institute program hosted at the Oregon State Corvallis campus, high school migrant students participated in our hands-on activities. In the Oregon State Juntos program, Latinx high school students were introduced to drones by participating in our hands-on activities.

In partnership with OrSU outreach programs, our team participated and presented at various career fairs and open houses in Corvallis, Salem, and Portland, Oregon. The OrSU team prepared a poster, fliers, and a presentation describing various drone applications in the construction industry, such as construction progress monitoring, aerial surveying, safety inspections, and structural inspections, among others. Some of these career events were organized by trade associations, while some of them were organized by various high schools in Oregon and OrSU.

Virginia Tech

This summer, Virginia Tech's Mid-Atlantic Aviation Partnership (MAAP) engaged in several STEM outreach activities, using UAS as a platform to ignite interest in STEM fields.

Summer Camps: MAAP conducted two week-long summer camps, each hosting approximately 40 students. One camp took place on Virginia Tech's Blacksburg campus, in partnership with the VT Center for the Enhancement of Engineering Diversity (CEED), Wing Aviation, VT's Engineering Department, and VT Institute for Critical Technology and Applied Science (ICTAS). This residential camp allowed students to fully immerse themselves in the university experience. The other camp was held in Alexandria, VA, in collaboration with the K-12 programming at the VT Innovation Campus and industry sponsors. While the students in Alexandria returned home each evening, the camp maintained a strong focus on UAS and STEM education.

Both camps were designed to engage communities. Students had the unique opportunity to build their own drones from individual components and earn their FAA TRUST certification. Throughout the week, they also heard from speakers in the drone industry, toured drone-related businesses, and spent significant time flying drones under the supervision of Part 107-certified pilots. The culmination of both camps was a showcase event at the VT Drone Park, where students test-flew their custom-built drones and participated in a flight competition.

Outreach Events: In addition to the summer camps, the team conducted a presentation for around 80 students at Christiansburg Middle School, introducing them to UAS technology and the cutting-edge research MAAP is involved in. The team also hosted a site visit at Wing Aviation for a local Cub Scout Pack, which includes youth from kindergarten to fifth grade.

The combination of hands-on learning, industry exposure, and mentorship through these programs is designed to foster a long-term interest in UAS and STEM fields.

KEY FINDINGS

NC State University

- Completed eight aviation camps with NC DOT at airports across the state, highlighting aviation career opportunities with specific emphasis on rural areas. This program reached a total of 260 students.
- Supported multiple NC State initiatives, including the Catalyst program for high school students with disabilities, the TRIO Pre-College Program, and the Drone Wolves camp.
- Over the duration of the A73 STEM V effort, NCSU had 586 students/contacts.

Oregon State University

- Completed two hands-on activities using drones, where middle school African American and Hispanic students participated.
- Supported six career fairs and open houses hosted by various trade associations, high schools, and OrSU, highlighting drone use for various applications in the construction industry, including progress monitoring and inspections.
- Over the duration of the A73 STEM V effort, OrSU had 897 students/contacts.

Virginia Tech

- Completed two weeklong summer camps for middle school-aged students.
- Presented to local middle school robotics students on research in the drone industry.
- Over the duration of the A73 STEM V effort, VT had 179 students/contacts.

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INCREASE SMALL UAS CONSPICUITY IN TERMINAL ENVIRONMENTS

A11L.UAS.128_A74

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SINCLAIR COLLEGE

Increase Small UAS Conspicuity in Terminal Environments

Background:

Remote Pilots, visual observers, and air traffic controllers must be able to clearly see UAS in operation to support the safe separation of the UAS from manned aircraft. UAS operations are increasing in frequency in FAA terminal environments. The operation of small Unmanned Aircraft Systems (sUAS) within an airport's terminal area poses an added risk of hazardous encounters with air traffic. The concentration of air traffic arrivals, departures, overflights, and other near-airport aircraft operations necessitates rapid visual detection and recognition of all aerial traffic—including sUAS—to enable effective see-and-avoid by other aircraft crews and de-confliction by air traffic controllers.

The purpose of this human factors research is to identify factors that increase the human visual conspicuity of sUAS operating within the terminal area of an airport. Williams et al. (2022) performed a computer-based study evaluating a series of independent variables, including sUAS lighting colors, flash rates, background environment, relative movement patterns, time of day, environmental conditions, and other factors.

A comprehensive literature review revealed 11 general factors that influenced visual conspicuity, including: 1) Background conditions; 2) Environmental lighting; 3) Light flashing frequency; 4) Light intensity; 5) Light color; 6) Meteorological conditions; 7) Movement/Hovering; 8) [Vehicle] size; 9) Vehicle color; 10) Visibility distance (as perceived from the ground); and, 11) Visibility distance (as perceived from an elevated tower). Based on the factors identified in the literature review, the research team recommends prioritization of seven consolidated variables for field testing: 1) Environmental Conditions; 2) Light Flashing Frequency; 3) Light Intensity; 4) Lighting Color; 5) Meteorological Conditions; 6) Human Factors; and 7) Night Operations.

PROJECT HIGHLIGHT

IT IS ANTICIPATED THAT THE FINDINGS OF THIS HUMAN FACTORS RESEARCH PROJECT WILL PROVIDE SCIENTIFIC BENCHMARKS FOR VARIOUS FACTORS THAT INFLUENCE sUAS VISUAL CONSPICUITY AND INFORM THE DEVELOPMENT OF UAS POLICY FOR sUAS OPERATIONS CONDUCTED WITHIN THE TERMINAL ENVIRONMENT, THEREBY ENHANCING OPERATIONAL SAFETY FOR sUAS OPERATING IN THE NATIONAL AIRSPACE SYSTEM.

Approach:

The research project addresses the critical need for enhanced sUAS conspicuity to ensure safety and prevent collisions, especially given the increasing presence of sUAS in FAA terminal environments. Current studies indicate a low probability of detection for sUAS by air traffic controllers, pilots, and observers. This research is guided by a quantitative, quasi-experimental design, with controlled field studies conducted across multiple institutions. This methodology aims to improve environmental validity by conducting tests under real-world conditions, extending prior computer-based research. The team will identify and analyze key factors affecting sUAS conspicuity. Outcomes will support the development of refined FAA guidelines and best practices for improving sUAS conspicuity. The study will leverage Signal Detection Theory (SDT) to analyze data collected on detection rates and response times. SDT metrics used for analysis include hit rate, false alarm rate, and d-prime. This analysis structure ensures rigorous evaluation of how different factors impact sUAS conspicuity, focusing on the dependent variables of detection rate and response time. Participants, recruited via convenience sampling, include sUAS operators and observers from testing institutions including: Virginia Tech, Kansas State University (KSU), New Mexico State University (NMSU), and Sinclair Community College (SCC). Participants will be pre-tested for study eligibility, based on visual acuity, color vision, and contrast sensitivity.

Detailed testing conditions, testing locations, sampling, and other methodological and analytical procedures have been established and approved by the FAA for the flight-testing phase of the project. It is anticipated that the findings of this human factors research project will provide scientific benchmarks for various factors that influence sUAS visual conspicuity and inform the development of UAS policy for sUAS operations conducted within the terminal environment, thereby enhancing operational safety for sUAS operating in the National Airspace System.

Project Status

The foundational planning and documentation phases, including the literature review and gap analysis, are complete. Literature review and gap analysis identified eleven factors influencing visual conspicuity for further prioritization and formed the basis for subsequent field testing. The methodology and detailed experimental design have been formalized in an approved research task plan and subsequent flight testing plan. The project is currently conducting field testing to gather data on detection rates and response times using SDT metrics.

This project includes the following phased progression benchmarks:

Task A: Literature Review and Gap Analysis

The project team updated the existing Annotated Bibliography literature search published by the Civil Aerospace Medical Institute (CAMI), which focused on methods to increase the conspicuity of sUAS by manipulating lighting schemes (colors and flash rates) on the UAS. This task identified 11 factors influencing visual conspicuity for further prioritization.

Task B: Identify Effects of Fixed Distances and Positions to Observer

Researchers conducted flight testing to determine the threshold and the parameters affecting sUAS conspicuity in the terminal environment from fixed viewpoints at varying distances. The fixed viewpoints included perspectives from a Visual Observer and an Air Traffic Controller operating from an elevated tower. Flight testing for this task is currently underway. Preliminary results suggest the visibility to most sUAS platforms diminishes considerably at distances exceeding 0.3 NM.

Task C: Identify Effects of sUAS Vehicle Size and Weight

Flight testing will be conducted to identify the sUAS vehicle physical parameters' impact on the vehicle's conspicuity and its ability to hover for a quadcopter or similar rotorcraft configuration. This testing is projected to begin in early 2026.

Task D: Identify Effects of the sUAS Lighting System

The research team will perform flight testing to identify the impact of the sUAS lighting system on its conspicuity, including vehicle color, color patterns, light intensity, and light flashing frequencies. This testing is projected to begin in early 2026.

Task E: Identify Effects of Observer Environmental Lighting

Flight testing is being performed to identify the effects of observer ambient environmental lighting conditions on sUAS conspicuity, such as day, night, civil twilight light, nautical twilight light, and astronautical twilight lighting. Flight testing for this task is currently underway and projected to continue through mid-2026.

Task F: Identify Effects of Observer Environmental Meteorological Conditions

The research team is conducting testing to identify the effects of observer environmental meteorological conditions, such as clear skies, overcast conditions, and other atmospheric obscurations, on UAS conspicuity in the terminal environment. Flight testing for this task is currently underway and anticipated to conclude in late 2025.

Task G: Identify Effects of Observer Visual Background Conditions

The project team will determine the effect of observer visual background conditions on sUAS conspicuity in the terminal environment, such as in the presence of blue sky, grey sky, night sky, green landscape, brown landscape, and other related factors. Flight testing for this task is currently underway and anticipated to conclude in late 2025.

Task G: Final Reporting on sUAS Conspicuity

The research team will aggregate and summarize the findings of flight testing into a comprehensive report, providing recommendations to inform the FAA about conditions that influence the visual conspicuity of small unmanned aircraft systems to support the safe integration of these platforms into the National Airspace System. Final reporting for this project is projected to conclude in late 2026.

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DEVELOP SMALL UNMANNED AIRCRAFT DETECT AND AVOID HUMAN FACTORS REQUIREMENTS

A11L.UAS.114_A81

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VIRGINIA TECH

Develop small Unmanned Aircraft Detect and Avoid Human Factors Requirements.

Background:

ASTM Detect and Avoid (DAA) industry standards contain little information on Human Factors requirements. Because there is a large diversity of possible DAA systems and their operations, DAA user interface design guidance needs to be highly adaptable. With the overarching goal of integrating sUAS into Beyond Visual Line of Sight (BVLOS) operations, the development of robust DAA systems to ensure safe airspace management is required. While industry standards typically define technical performance requirements for DAA systems, they tend to provide minimal guidance on human factors considerations—this mainly applies to Human-Machine Interface (HMI) design. This research project aims to bridge this gap by identifying key human factors requirements for sUAS DAA systems.

The project objective is to develop human factors-related guidance and requirements for DAA systems. The research team has and continues to leverage existing literature on aviation human factors, interface design, and system usability. These findings will inform future industry standards and regulatory frameworks that support safe and efficient BVLOS operations.

Approach:

Task 1: Literature Review and Initial Ris Assessment Report (Complete)

Sub-Task 1-1: Literature Review

The findings from the literature review served as a critical foundation for shaping the subsequent research tasks and risk assessments within this project. By synthesizing existing research on human factors in DAA systems, this review highlighted key considerations that must inform the development of evaluation frameworks, testing methodologies, and risk mitigation strategies. Given the complexity of integrating DAA into sUAS for BVLOS operations, understanding human-machine interactions, cognitive workload, interface usability, and situational awareness is essential for ensuring safe and efficient operations.

One of the primary contributions of the literature review was its identification of knowledge gaps in the current human factors research related to DAA systems. These gaps guide the formulation of specific research questions and hypotheses that will be addressed in the experimental and simulation-based research tasks outlined in the project's research task plan and as a component of subsequent tasks. For example, the review highlights that existing DAA interface designs primarily cater to larger UAS and are not fully optimized for the operational constraints and cognitive demands of sUAS pilots. This insight necessitates targeted investigations into designing and implementing HMIs tailored for sUAS applications. Future research tasks will examine how different HMI configurations influence pilot situational awareness, response times, and decision-making accuracy in BVLOS scenarios.

Another critical aspect informed by the literature review was the development of a robust risk assessment framework for BVLOS operations. The review identified cognitive overload, automation bias, and loss of situational awareness as significant risk factors that can compromise the effectiveness of DAA systems. The research tasks incorporated structured risk assessment methodologies based on the FAA's 8040.6A risk matrix and other established frameworks to assess these risks. This approach will systematically evaluate human factors-related hazards and their impact on BVLOS safety. By integrating these findings into risk assessment models, the project aims to develop actionable mitigation strategies that enhance the reliability and usability of DAA technologies.

Sub-Task 1-2: Risk Assessment and Gap Analysis

To support the safe integration of DAA systems into sUAS operations, this project aims to address the current lack of human factors guidance in existing industry standards. The overarching goal was to develop HMI design guidance and human factors requirements that enhance usability, situational awareness, and error mitigation, while informing FAA evaluations and accelerating industry standardization.

PROJECT HIGHLIGHT

A KEY OBSERVATION FROM THIS ANALYSIS IS THAT HAZARDS ARE NOT STATIC, BUT EVOLVE WITH THE INCREASING AUTOMATION AUTHORITY REPRESENTED BY AL1, AL2, AND AL3. ACROSS ALL THREE LEVELS, ONE HAZARD REMAINS UNIVERSAL: THE DEGRADATION OF OPERATOR SITUATIONAL AWARENESS WHEN THE HMI FAILS TO PRESENT INFORMATION TRANSPARENTLY, PRIORITIZE EFFECTIVELY, OR SURFACE UNCERTAINTY.

Within this broader effort, Task 1.2 focused on identifying critical HMI design elements and associated human factors hazards that should be prioritized for evaluation, using a modified Operational Risk Assessment (ORA) approach developed in response to data gaps uncovered during the Task 1.1 Literature Review.

Due to the variation between BVLOS operations within the UAS industry, the scope for this task needed to be narrowed. Limiting the flight operations to a BVLOS, head-on collision only, and only a horizontal avoidance maneuver helped ensure a worst-case scenario, focusing on a simple avoidance maneuver either executed by the pilot or confirmed before the automation executes the avoidance maneuver. For the automation, no errors with the suggested or directed avoidance maneuver were considered to help keep the focus on the information delivered to the user and limit secondary effects.

With this more focused scope, the research team executed a four-step approach to the task. This approach is depicted in the Figure 1.

The first step was to complete a Hierarchical Task Analysis (HTA) to help specify core functions that must be performed by either the human or the autonomous agents, independent of any specific operating platform or DAA system. The output from the HTA helps set the DAA tasks and minimum HMI requirements for this report. This flows right into the second step, the Task Allocation Analysis (TAA), which aimed to better align the tasks and HMI design requirements to specific automation levels that would be analyzed through this study. With the tasks and requirements now mapped to automation levels, hazard identification was the third step in the process. By identifying HMI hazards associated with different tasks at different automation levels, the team created a hazard register that contained hazards that represent conditions that increase the likelihood of Remote Pilot in Command (RPIC) error or delayed response. Finally, once the high-level tasks, subtasks, and HMI hazards were identified, multiple scenarios were created for each subtask, which introduced one or more HF hazards within them. These hazards were then mapped to each subtask to aid in designing a scenario for said subtask. These scenarios are subtask-specific and are based on real-world scenarios one would expect to see within a DAA system. All scenarios were presented with only the task and subtask specifically being scored, and they were clearly labelled to reduce confusion.

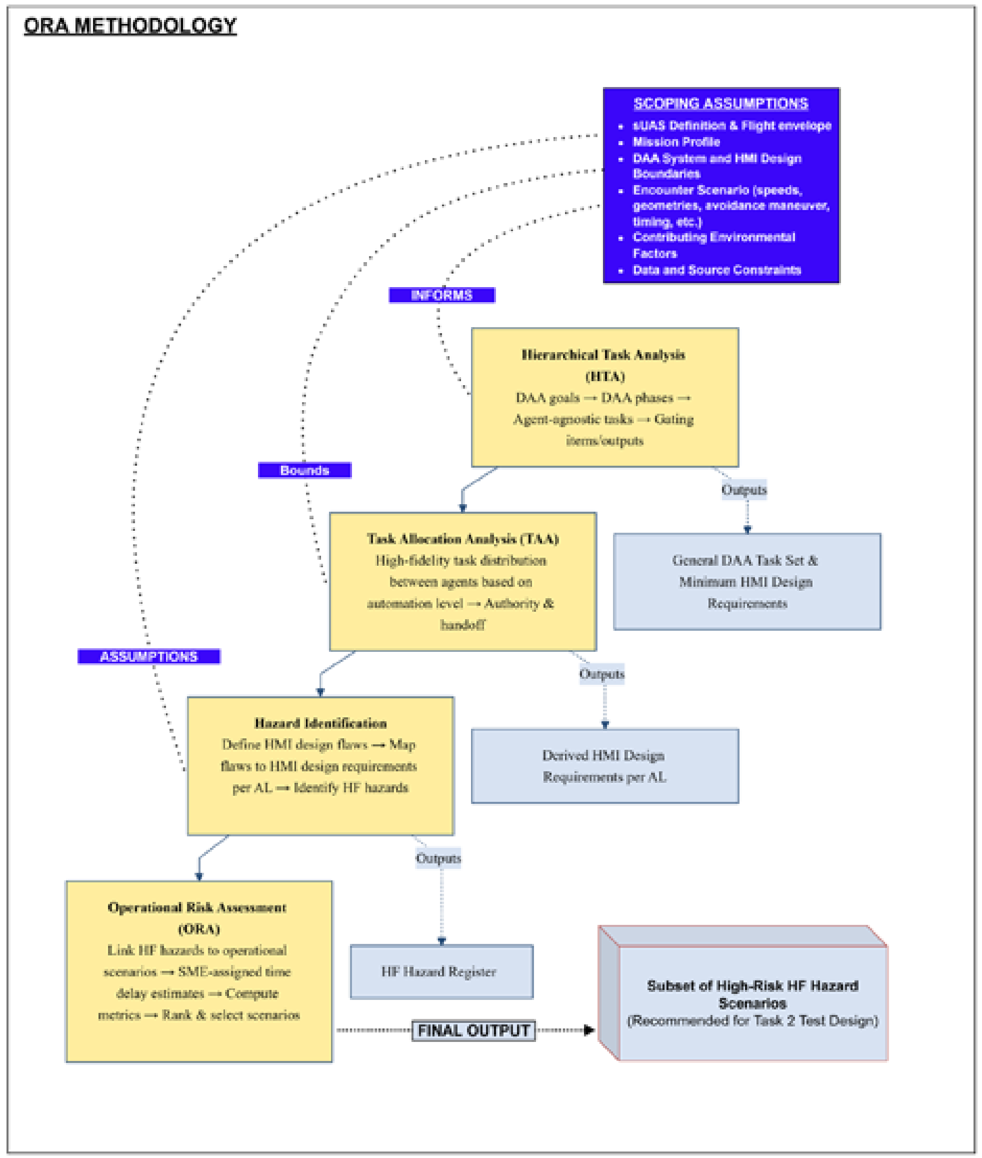

Figure 1. ORA Methodology Approach

To assess and prioritize the hazards, the research team utilized Subject Matter Experts (SMEs) to consider each scenario and determine, to the best of their ability, the likely minimum and maximum delay caused by the hazard (bounded between 1 – 30 seconds). They were also asked to consider how likely this scenario would be given a typical DAA system during a typical BVLOS flight. The SMEs are all pilots, both crewed and uncrewed, with a wealth of knowledge focused on a variety of airframes, DAA systems, and mission profiles. The delays were averaged and fit within a specified category, which was then influenced by the likelihood category selected by the SME. The severity is expressed as the amount of delay the pilot is expecting to encounter, on average, when faced with the scenario within the risk assessment window. With the likelihood and severity scored, they were multiplied together to result in a final determination for this exercise. Twenty-one HMI hazards were included within the eleven scenarios selected, with the highest latency times calculated with the method outlined above. Of these specific HMI hazards, display latency, ambiguous indication, and information masking and occlusion appeared most often within the selected scenarios.

While more hazards were identified, these three should be the priority for further examination in Task 2 of this ASSURE project. Additionally, there may also be value in exploring the DAA/UAS combinations, which may have a direct effect on the HMI hazards identified, depending on the tested scenario. The scenarios used to identify these hazards can be leveraged in the test design of Task 2 as well, though that will be dependent upon the capabilities of the testing equipment.

Task 2: Initial Requirements Development and Planning Activities

The research team will develop an evaluation framework and a set of simulated encounter scenarios for testing a variety of User Interface (UI) design parameters using a sUAS Ground Control Station (GCS) software with a pool of sUAS pilots of varying operational experience levels. This evaluation framework aims to capture the human factors considerations when interacting with a sUAS HMI during DAA operations and will form the foundation for human factors testing planned in Task 3 of this effort.

The research team has identified the HMI developer Parallax Advanced Research as a partner for developing the simulated scenarios for testing with sUAS pilots using the Vigilant Spirit UAS operator control interface, shown in Figure 2, originally developed by the United States Air Force Research Laboratory (AFRL). This HMI was ultimately chosen for its high configurability and scalability across a large variety of UAS from Group 1 - Group 5.

The software also supports multi-UAS operations as well as logging and playback features that allow researchers to examine elements of the UI that affect a pilot's ability to efficiently and accurately execute BVLOS missions under varying levels of automation with a DAA system. An example of a scripted three-aircraft scenario is shown in Figure 3. The top portion of the figure shows the map view with each aircraft's Attitude and Heading Reference System (AHRS); the bottom portion displays the scriptable playback timeline for creating simulated scenarios.

Utilizing the findings from Tasks 1 and 2, the team plans to develop

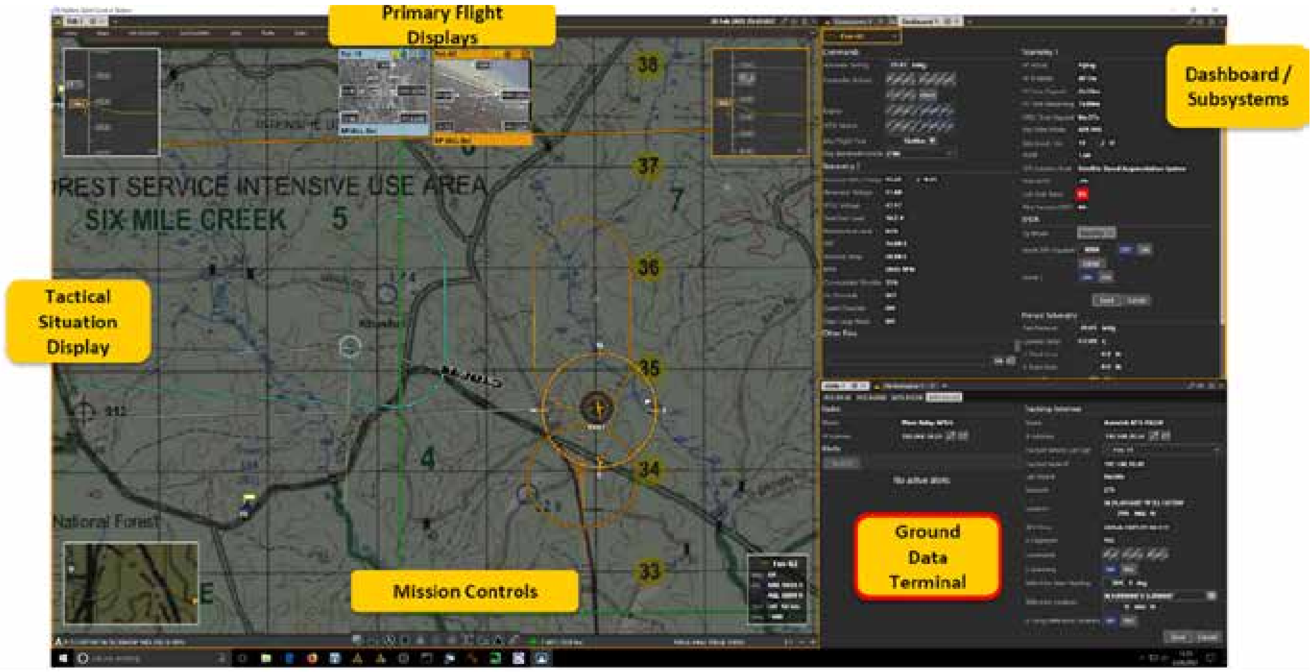

Figure 2. Vigilant Spirit UAS HMI

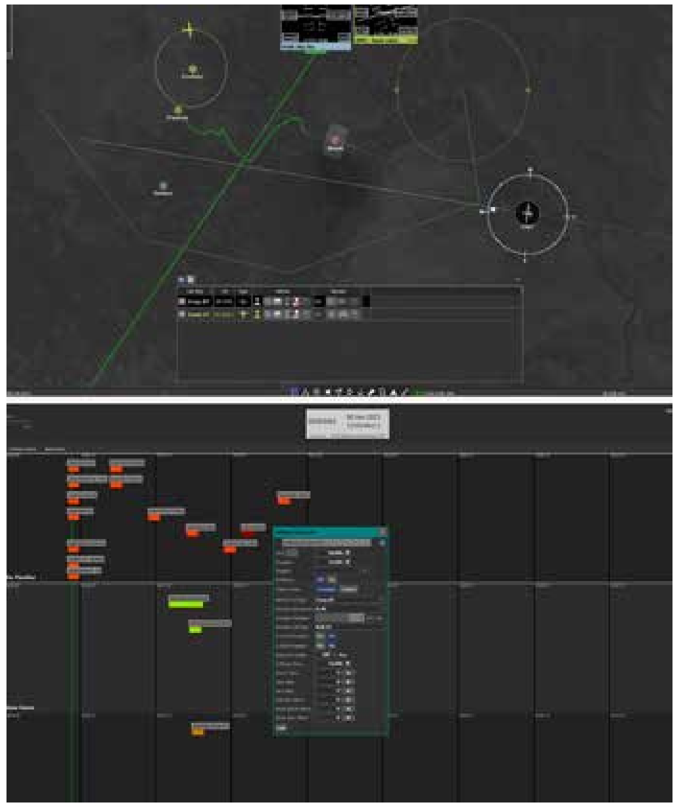

Figure 3. Vigilant Spirit Multi-UAS and Playback Features.

approximately 11 testable scenarios that can be simulated with the sUAS pilots acting as test participants for the human factors study. The team has worked to identify the most impactful UI elements that affect pilot performance in DAA operations. Some of the variables of interest include automation level (low, medium, high), variable alerting modality (aural and visual), and alert conspicuity as event severity varies. Parallax is currently updating the Vigilant Spirit software to include the autonomy features necessary to perform the human factors study, as well as adding ease-of-use features for researchers to tune UI elements in the system between tests.

The outputs of this task will yield an evaluation framework that allows the research team to test scenarios and make determinations on which features of the HMI are most critical to operator decision-making for safe operations. This framework will allow for standardized procedures that ensure consistency in the testing methodology across the four participating universities. The team will develop a multi-university institutional review board submission detailing the data collection plan and protocols to ensure that all data is captured in accordance with approved methods determined by the board. The team is anticipating approximately 120 participants for the execution phase in Task 3 of this research effort.

Task 3: DAA Hazard Identification and Risk Assessment

The requirements and test plans developed in Task 2: Initial Requirements Development and Planning Activities will be executed and regularly reported on. Plans will be executed by multiple performers to increase the amount of data collected. Before testing, an Institutional Review Board will need to ensure compliance with regulations and ethical standards regarding human research participants. Each performer will be responsible for recruiting the participants for their testing, whether internally or externally. The performers will work with UAS operators to test the HMI in a series of simulated DAA encounters. There may be an overlap between the requirements development and planning in Task 2 and the execution of those plans in this task. This will allow for a staggered approach where earlier tests can inform the design of later tests and their needs.

Reports will be written that detail the completed testing and results. These reports are meant as short-form summaries of the procedure and analysis. Lessons learned throughout testing should be contained in the report and thoroughly communicated with the other performers to ensure testing can be completed with minimal issues. These reports will be shared between the research performers and reviewed by subject matter experts.

KEY FINDINGS

Task 1.1: Literature Review

- DAA design interfaces that are adapted from larger systems may fail to address unique cognitive and operational challenges associated with sUAS operations.
- While DAA technologies and systems have matured, human factors considerations for these systems remain underdeveloped.
- The possibility of cognitive overload must be a consideration for sUAS DAA interfaces.
- Gaps exist in standardized human factors testing frameworks for sUAS DAA systems.
- Significant human factors challenges for sUAS DAA systems remain unaddressed.

Recommendations:

- Minimize cognitive workload.
- The implementation of automation must be balanced to prevent a loss of operator engagement.
- Standardization across systems (architectures) is essential. Alerting, symbology, etc., should be standardized.
- Human-in-the-loop testing is essential for validating HMI effectiveness.

Additional recommendations and discussion may be found within the literature review document.

Sub-Task 1-2: Risk Assessment and Gap Analysis

Hazards identified and categorized according to six human factors dimensions:

- Situation Awareness
- Cognitive Load
- Decision-Making
- Automation Trust
- Attention Management
- Mode Awareness
- A key observation from this analysis is that hazards are not static, but evolve with the increasing automation authority represented by AL1, AL2, and AL3.
- Across all three levels, one hazard remains universal: the degradation of operator situational awareness when the HMI fails to present information transparently, prioritize effectively, or surface uncertainty.

The list below provides an example of hazards that fall within the aforementioned categories as listed above.

- Accidental Activation of HMI Navigation/Manipulation
- Alarm/Alert Criticality and Salience Compatibility
- Alarm/Alert Criticality and Salience Incompatibility
- Alarm/Alert Saturation
- Ambiguous Command/Recommendation
- Ambiguous HMI Control/Target Indication
- Ambiguous Indication (of Responsibility)
- Ambiguous/Lack of Feedback of Control Input
- Display Latency
- Inconsistent Command Escalation
- Ineffective Automated Command Execution
- Inefficient Control Accessibility
- Information Accessibility - Keyhole Effect
- Information Masking and Occlusion
- Information and Recommendation Priority and Salience
- Lacking Alert or Salient Indication
- Layout Inconsistency
- Map Distortion
- Missing Uncertainty Indication
- Spatial Display Distortion (2D & 3D distortion)
- Visual Accessibility - Color Blindness

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DEVELOP A DATA-DRIVEN FRAMEWORK TO INFORM SAFETY RISK MANAGEMENT (SRM) MITIGATION CREDIT ESTIMATES

A11L.UAS.112_A82

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Develop a Data-Driven Framework to Inform Safety Risk Management (SRM) Mitigation Credit Estimates

Background:

Safety Risk Management Panels (SRMPs) currently do not have an objective way to evaluate the likelihood credit given to a proposed risk mitigation, or a combination of risk mitigations, that are proposed for different types of UAS operations. This typically leads to a more subjective evaluation process, which can lead to inconsistent estimates - both overestimates and underestimates - of likelihood credits. SRMPs often resort to subjective evaluations for the amount of likelihood credit to grant each mitigation proposed in an operation. The inconsistency of these estimates requires research to provide data-driven estimates for at least the commonly proposed mitigations. The goal of this project is to perform the research necessary to establish data-driven estimates of likelihood credits for commonly proposed risk mitigations in the UAS domain, which will ultimately lead to the development of a more objective methodology for performing the likelihood credit evaluation process for proposed risk mitigations for UAS operations by SRMPs.

Even in organizations that leverage SRM processes and employ formalized SRMPs for UAS operations, the use of decision-making tools often requires the application of user judgment and qualitative assignment of scores related to the severity or likelihood of negative events. An often flawed assumption underlying these processes is that all major or salient risks are identified and included in the analyses. Even if risks are correctly identified and included, the assignment of a severity or likelihood score, and subsequent consideration of mitigation strategies and their potential impact, is largely based on the knowledge, experience, and judgment of the individuals or panel members involved. Therefore, there is a potential for error and non-standardization. Furthermore, the variety of SRM tools and approaches used in different organizations, or even within the same organization, can create additional confusion.

PROJECT HIGHLIGHT

THE GOAL OF THIS PROJECT IS TO PERFORM THE RESEARCH NECESSARY TO ESTABLISH DATA-DRIVEN ESTIMATES OF LIKELIHOOD CREDITS FOR COMMONLY PROPOSED RISK MITIGATIONS IN THE UAS DOMAIN, WHICH WILL ULTIMATELY LEAD TO THE DEVELOPMENT OF A MORE OBJECTIVE METHODOLOGY FOR PERFORMING THE LIKELIHOOD CREDIT EVALUATION PROCESS FOR PROPOSED RISK MITIGATIONS FOR UAS OPERATIONS BY SRMPS.

As UAS are further employed in increasingly complex operational environments, it is becoming more important to establish quantitative decision-making SRM support tools and processes for use by individual operators and SRMPs. To achieve this, an analysis of the most common and consequential risks and barriers should be completed. Wherever possible, methods to identify quantifiable inputs that can be used in likelihood calculations should be adopted that are not based on operator opinion or best judgment. This research will consider that need and address the FAA-provided knowledge gaps and research questions by completing primary technical tasks focused on background report literature review, common barrier identification and assessment, likelihood calculation formulae, and barrier safety risk credit and validation.

Approach:

The approach to this project includes the following tasks:

Task 0: Program Management

Task 1: Background Report Literature Review, Common Barrier Identification and Assessment

Task 2: Likelihood Calculation Formulae

Task 3: Barrier Safety Risk Credit and Validation

Task 4: Final Briefing and Final Report

Task 0 FY25 Activities

During FY25, the program management task included the project kickoff, establishing and maintaining the research task plan, conducting technical interchange meetings, briefings at the project management reviews, producing monthly research summaries, and coordinating between the project performers and stakeholders.

Task 1 FY25 Activities

The team conducted a thorough literature review and developed a report identifying the common barriers and associated assessments. The deliverable included cost cost-benefit analysis to inform decision-makers. At the time of this report, the Task 1 report is in final review for acceptance.

Task 2 FY25 Activities:

The team began work to define relevant general likelihood formulae used in residual risk determination. At the time of this report, work for Task 2 is ongoing.

Task 3 FY25 Activities: Barrier Safety Risk Credit and Validation

Although preliminary explorations related to barrier safety risk credit and validation have begun, primary efforts for Task 3 are scheduled to begin in FY26.

Task 4 FY25 Activities: Final Briefing and Final Report

Efforts for final briefing and reporting have not commenced and will be completed near the end of the project in FY27.

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ANALYZE DRONE TRAFFIC

A11L.UAS.112_A83

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Analyze Drone Traffic

Background:

The FAA's enduring mission is to maintain the safety of the National Airspace System (NAS). To fulfill this mandate and proactively plan for the continued, safe integration of UAS, it is essential to assess the state of UAS traffic operating within the NAS, the effectiveness of existing risk mitigation procedures, and forecast future UAS integration needs. This 36-month project is designed to provide the necessary empirical data and comprehensive analysis required to support risk-based decision-making regarding UAS traffic and associated collision hazards within the NAS. This effort is a continuation of research performed under the ASSURE A50 Project, Small UAS Traffic Analysis.

The Need for Data-Driven Risk Assessment

The drive toward robust, data-driven analysis stems from acknowledged limitations in traditional approaches of safety management in the context of unmanned systems. A report by the National Academies of Science, Engineering, and Medicine (NASEM, 2018) noted that the prevalent qualitative nature of risk management processes implemented for UAS can lead to results that are not consistently repeatable, predictable, scalable, or transparent. For successful integration into the NAS, an empirical data-driven approach is required, as "accepting risk is far easier when the risk is well quantified by relevant empirical data" (NASEM, 2018, p. 41). While acknowledging that empirical data can be expensive to collect or non-existent, this project aims to address this inherent data deficit.

Previous ASSURE efforts have sought to establish quantitative risk frameworks for UAS operations. For example, ASSURE A21 introduced a statistically supported, risk-based framework intended for evaluating safety risks and subsequent implementation within the agency's Safety Risk Management Program. Complementing this, ASSURE A47 extensively analyzed the probability of a small UAS (sUAS) Mid-Air Collision (MAC) with crewed aircraft, comparing resultant encounter probabilities against established aircraft bird strike statistics. The ongoing challenge for policymakers remains grounding these frameworks and risk thresholds in widespread, reliable, objective operational data.

Leveraging Remote Identification Technology

The current research is enabled by the regulatory shift toward mandatory Remote Identification (RID) for drones. RID functions as an innovative 'digital license plate' for UAS, enabling the collection of UAS traffic location and identification data. The FAA defines the requirements for RID under 14 CFR §89, which requires standard RID-equipped drones or broadcast modules to transmit location and identification information using readily available technologies like Wi-Fi or Bluetooth (Remote Identification of Unmanned Aircraft, 2025). This mechanism allows for the detection, identification, tracking, and management of UAS operating in the airspace. Data collected by RID sensors includes the UAS's unique identifier, its altitude, speed, position, and the location of the control station or take-off point. The American Society for Testing and Materials (ASTM, 2022) established the recognized performance standard for RID under ASTM F3411-22a. Data collection for this project is supported by Pierce Aerospace, Inc. and DroneSpotter, Inc.

This project is a follow-on and expansion to the foundational work performed in ASSURE A50. The previous A50 effort assessed sUAS activity in low-altitude airspace using RID sensors deployed near US airports. A50 provided initial insights into sUAS traffic trends, demonstrating activity profiles and identifying regulatory exceedances.

Approach:

Based on the outcomes of A50, the research team identified key areas requiring further investigation, which are now incorporated into the current project. These research recommendations include the need to further study RID effectiveness, particularly its range, coverage capabilities, and susceptibility to interference and shielding. Furthermore, given the exploratory nature of A50, continued expansion of sUAS detection initiatives is necessary to establish more effective sampling across the NAS.

By collecting data from 15 locations around the contiguous US, this project aims to answer critical knowledge gaps concerning traffic characteristics and safety risks:

- What is the closest point of approach distribution curve for drone traffic encountering crewed aircraft?
- What does an analysis of drone traffic indicate about current and future drone safety risks?
- What percentage of drone traffic is following Part 107 rules?
- How many aircraft are flying in No-Drone-Zones and what are their traffic attributes important for counter-drone efforts?
- What can we learn from current drone traffic?
- How is drone traffic evolving over time?
- What is the drone traffic forecast?

Task 1: Data Collection

The team set up necessary agreements and systems to collect traffic data for sUAS and manned aviation. To achieve this, agreements were developed with RID sensor vendors to facilitate large-scale data collection across 15 selected locations across the United States. Sampling locations were prioritized to collect RID data in proximity to Core 30 airports, which include the nation's largest and busiest airports. Additional sampling will be carried out at locations developing Advanced Air Mobility (AAM) or other advanced aviation operations.

Task 2: Analysis of Collected Traffic Data

Comprehensive analysis of the collected sUAS RID and manned aircraft Automatic Dependent Surveillance-Broadcast (ADS-B) data is being conducted to address key research questions related to air traffic characteristics and associated safety risks. Analysis involves leveraging RID and ADS-B data using URSA's proprietary analysis tool to determine instances where aircraft and sUAS come in close proximity. Special emphasis is placed on evaluating Near Midair Collision (NMAC) potential where UAS exceeds UAS Facility Map (UASFM) altitude limits or aircraft operate below those limits. For current and future drone safety risks, the team will holistically assess safety risks by analyzing geographic concentrations of sUAS traffic, altitude utilization, and times of traffic concentration. Findings will be contextualized relative to hazards posed to people on the ground, manned aircraft, sUAS platforms, and evolving AAM operations. The research team is also assessing exceedances with key UAS regulations, including evaluations of in-flight emergency reporting, operations from moving vehicles, altitude, speed, visibility, and other weather conditions.

Further work examines sUAS operations within restricted areas, proximity to airports, and the use of the Low Altitude Authorization and Notification Capability (LAANC). Heatmaps will be generated to visualize activity near airports and critical infrastructure. The team will also analyze seasonal and geographical variations in flight characteristics, launch locations, flight durations, and platform types to develop a comprehensive database of drone activity. Longitudinal analysis will allow for insights into drone traffic evolution, identifying platform longevity, patterns of recurrent use, and telemetry-based mission profiling. Additionally, the team will generate drone traffic forecasts by correlating registration data and population trends with FAA data sources to estimate future operational growth.

Task 3: Assessment of Remote ID Performance

To evaluate the performance of RID systems, the team will analyze key signal metrics, including effective field detection range, latency, and reliability. The study will assess the effects of environmental factors such as terrain and obstacles on RID detection performance. This task supports FAA objectives in verifying RID system effectiveness and operational dependability for future regulatory and technical development.

Task 4: Annual Briefing and Report on Traffic Data Collection and Analysis

The team will deliver an annual briefing and report summarizing the data collection activities, analytical findings, and key outcomes. This deliverable will present responsive findings to address the project's research questions, preliminary results from data analyses, and recommendations for enhancing future data collection, risk modeling, and policy development.

Task 5: Final Briefing and Report

The final task serves as the culmination of the research effort. The research team will summarize and aggregate all previous reports into a final report package. The primary goal of this comprehensive document is to address the research questions and present key findings. The final report will discuss how the project outcomes, derived from presenting data and providing meaningful analysis, aggregation, interpretation, and assessment, can be used to inform policy and regulations. Additionally, this report will provide recommendations for future research and practical policy development. A final briefing will be delivered to FAA leadership, sponsors, and other industry stakeholders, highlighting the study's conclusions and recommendations.

Project Status

The project is in its first year of performance. RID sensors have been deployed to most sampling locations, and data is currently being analyzed. The research team anticipates the release of preliminary findings in December 2025.

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DISASTER PREPAREDNESS AND EMERGENCY RESPONSE PHASE IV

A11L.UAS.68_A84

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Disaster Preparedness and Emergency Response Phase IV

Background:

The A84 effort focuses on the needs of the first responders and the procedures to coordinate with UAS operators from within federal agencies such as DOI and DHS (including the Federal Emergency Management Agency [FEMA]), as well as local and state disaster preparedness and emergency response organizations, to ensure proper coordination during those emergencies. The research results, findings, and recommendations will inform requirements, technical standards, regulations, policies, and procedures for emergency responders operating UAS in the National Airspace Systems (NAS) to respond to disasters and emergencies.

This project involves researching various topics to enhance safety, improve effectiveness, and remove barriers to UAS disaster preparedness, response, and recovery. It focuses heavily on assessing the needs of local first responders and state emergency management organizations that have either yet to adopt or are in the early stages of adopting UAS technology.

The Disaster Preparedness and Emergency Response Phase IV research team will exercise the findings found in Phases I (A28), II (A52), and III (A62) of Disaster Preparedness and Emergency Response via mock events and demonstrations. Completion of this research will shed important insights into interactions between human factors, technology, and procedures. It will further improve regulatory processes and practices that govern UAS integration into the NAS. This research will enhance UAS use in disaster and emergency response by improving the effectiveness and efficiency of UAS implementation. The development of streamlined processes will drive UAS use in an organized manner, enforcing airspace safety and the effective use of UAS in disaster and emergency response.

Approach:

Task 1: Review of Previous Phases

The research team will conduct an in-depth analysis of Phase I (A28), Phase II (A52), and Phase III (A62) of A11L.UAS.68. Results, findings, recommendations, lessons learned, needs, and gaps will be captured in this report.

Task 2: Assess UAS Operator Needs, Identify Barriers to UAS Use, and Develop Support Tools

This task will focus on multiple research areas that play an essential role in the use of UAS for disaster preparedness and emergency response. It will assess the needs of local first responders and state emergency management organizations, and identify the barriers that local communities and state agencies face when implementing UAS use during disaster and emergency responses.

Task 3: Drills, Exercises, and Outreach

Eleven events will be executed in this effort. Each university will do one outreach, drill, OR exercise event focusing on one or more research area(s). The outreach events will take place first, followed by the drill events, which will expand on the outreach events, with the exercise events used to fully apply the Task 2 deliverables. The research areas will be tested through drills, exercises, and outreach events to an extent that is possible and applicable to the type of event at the time of testing. The best practices and tools will also be evaluated based on stakeholder feedback and their performance in actual disasters and exercises. The research team will leverage the data collector and database system developed in Phase III of the disaster preparedness and emergency response effort to aid cross-governmental coordination.

Task 4: Peer Review

The research team will conduct peer reviews within 30 days after receiving the drill and exercise plan, and for both the annual reports and the final report, to ensure public availability of the research.

Task 5: Final Report

The research team will summarize and aggregate the previous reports (excluding meeting notes) into a final report package for the overall project, answering the knowledge gaps and providing recommendations to counter the gaps. The report will include recommendations to the FAA and other organizations that support disaster response. The report will also discuss how project outcomes can be used to inform policy, regulations, advisory circulars, and industry consensus standards, and make recommendations for future research.

KEY FINDINGS

Task 1: Review of Previous Phases

The University of Vermont conducted an in-depth review of the previous phases of the Disaster Preparedness and Emergency Response efforts, including A28 (Phase I), A52 (Phase II), and A62 (Phase III), and delivered this report to the FAA in July of 2025. Key lessons learned from previous phases included:

- Training and Credentialing: Comprehensive training in mission planning, platform operation, and emergency protocols is essential. Scenario-based exercises build pilot confidence and operational proficiency.
- Environmental Challenges: Operations in extreme conditions (e.g., volcanic eruptions, avalanches, oil spills) require robust platforms, backup systems (e.g., PPK/RTK), and contingency planning for weather and GPS loss.

- Community Engagement: Involving local stakeholders, including medical personnel and law enforcement, enhancing mission success and fostering trust. Outreach and education are key to public acceptance and effective deployment.
- Ethical and Legal Considerations: Privacy, data retention, and airspace safety must be addressed through clear policies and responsible practices, especially in sensitive or urban environments.

Needs and gaps that were identified through this review included:

- Need for Standardized Policies and Procedures: A consistent need across all phases was the development of nationally recognized standards and guidelines for UAS operations in disasters.
- Gap in Real-world Disaster Deployment: While mock exercises provided valuable insights, there remains a significant gap in understanding UAS performance in actual disaster scenarios.
- Importance of Interoperability: Interoperability between different UAS platforms, software systems, and agencies is crucial for effective disaster response. Standardized training, data formats, and communication protocols are essential.
- Need for Scalable Data Management Solutions: The volume of data generated by UAS in disaster scenarios necessitates the development of scalable data management, processing, and sharing solutions.
- Gap in Understanding Long-Term Impacts: Limited research has been conducted on the long-term impacts of UAS integration on disaster preparedness, recovery, and community resilience.
- Value of Multi-Agency Collaboration: Effective disaster response requires seamless collaboration between different agencies and stakeholders. Pre-event planning, communication, and clearly defined roles are essential.

The recommendations that the UVM team identified for the A84 (Phase IV) effort encompass the following:

- Develop and Test Standardized Protocols: A84 should prioritize the development and real-world testing of standardized protocols for UAS operations in disasters, addressing airspace management, data security, privacy, and communication.
- Evaluate UAS Performance in Real-world Disasters: A84 should create opportunities for UAS teams to participate in real-world disaster response efforts, collecting data and evaluating performance under realistic conditions.
- Advance Technology Solutions: Continue research and development of promising technologies identified in A62, such as swarms, Remote ID, and automated air boss systems, focusing on overcoming current limitations and enhancing their capabilities for disaster response.
- Develop and Implement Scalable Data Management Solutions: Develop and implement scalable data management solutions that address storage capacity, data security, privacy, and interoperability challenges.
- Conduct Longitudinal Studies: A84 should include longitudinal studies to assess the long-term impacts of UAS integration on disaster preparedness and community resilience.

Task 2: Assess UAS Operator Needs, Identify Barriers to UAS Use, and Develop Support Tools

The Task 2 effort was accomplished by splitting the nine research focus areas/subtasks into "mini-teams." Each subtask team explored their research focus area in the context of the first responder community, identified barriers, and provided recommendations. A report for each of the nine subtasks was submitted to the FAA in September 2025 and can be referenced for extensive findings. The research focus areas included in this task and their respective descriptions are as follows:

- 2.1 – Best Practices Multimedia Content (NCSU, NMSU, UVM): Research the best practices for developing and delivering multimedia content to reduce barriers to the safe and effective use of UAS technology for disaster response and recovery.
- 2.2 – Tools (MSU, KSU, NCSU): Evaluate tools that can enhance the use of UAS for disaster response and recovery, including tools developed as part of A62 and those emerging in the UAS disaster response community that are either open-source or commercial.
- 2.3 – Automated Airboss (UAH, ERAU, UND): Research the role of Automated Air Boss during multi-UAS operations within a disaster response area, assessing the needs of local first responders and state emergency management organizations for an Automated Airboss application.
- 2.4 – UAS Traffic Management in Disasters (UND, ERAU, UAF): Research the role of UAS Traffic Management (UTM) in enhancing the use of UAS in disaster response and recovery.
- 2.5 – Use of Counter UAS for Disaster Response (NMSU, UND, UAH, UAF): Leverage existing Counter UAS systems data to research and analyze the potential effects of using Counter UAS systems that may be utilized for disaster response.
- 2.6 – Cyber Protection (UND, NMSU, OSU): Research cyber protection issues surrounding the effective and safe use of UAS for disaster response and recovery efforts.
- 2.7 – Drone as a First Responder (UAH, KSU, UAF): Research the limitations and improvements to the DFR program and the Fire Department and Emergency Service Agency's use of UAS through the DFR program.
- 2.8 – Legislation, Policies, Procedures, and Standards (KSU, UM, UND): Research the impact of new legislation, policies, and standards on UAS disaster and emergency preparedness, response, and recovery operations.
- 2.9 – Additional Use Cases and Operational Characteristics (NMSU, ERAU, KSU, NCSU, MSU, OSU, UAF): Research additional UAS use cases and operational characteristics supporting disaster, emergency response, and recovery missions.

Task 3: Drills, Exercises, and Outreach

The A84 research team is actively collaborating on and compiling information for the Master Event Plan. The Master Event Plan is a high-level draft document detailing the 11 events to occur. This includes logistics for each event, such as event overviews (tentative date, location, partners, etc.), the research areas to be incorporated into the event, and the expected outcomes of the event. The Master Event Plan is expected to be solidified by November 2025. Event designation across the 11 universities is as follows:

Outreach Events (coordinated efforts between the university and the first responder community): ERAU, NCSU, UM

Drill Events (single agency/organization supervised activities to validate specific functions/capabilities): NMSU, OSU, UND, UVM

Exercise Events (multi-agency coordinated efforts to execute scenario-based operations): KSU, MSU, UAF, UAH

Task 4: Peer Review

This task has not started. Findings and deliverables related to this task are expected by November 2025.

Task 5: Final Report

This task has not started. Findings and deliverables related to this task are expected by September 2028.

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FUTURE RESEARCH

UPCOMING RESEARCH

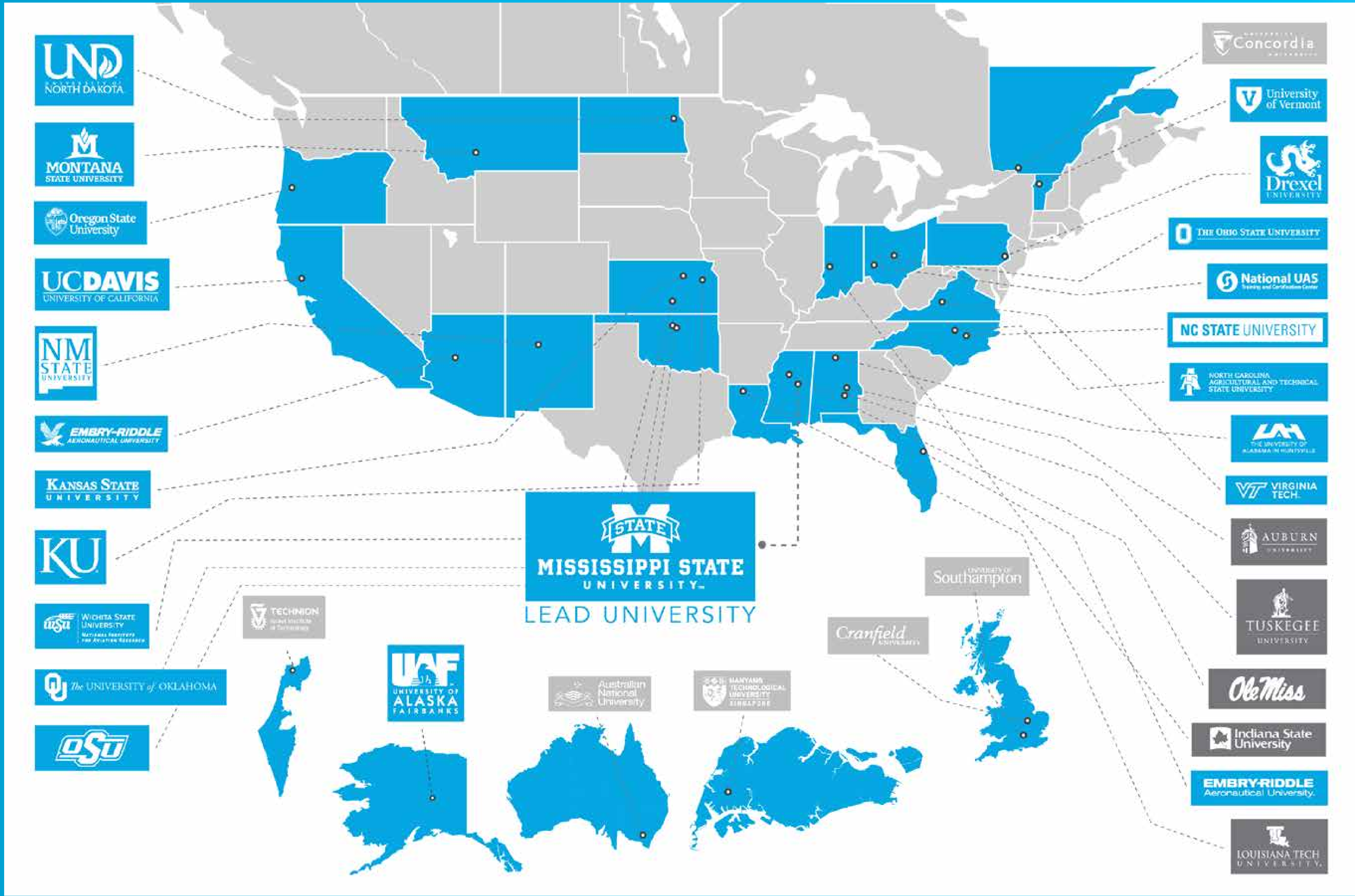
- A11L.UAS.102_A78: Evaluate the Applicability of Crashworthiness Standards for Urban Air Mobility
- A11L.UAS.137_A89: Multi Rotor Safety
- A11L.UAS.141_A90: Development of UAS Remote Identification Compliance Testing Capability
- A11L.UAS.142_A91: Develop Models to Inform Composite Power Lift Vehicles (CPLV) Mid-Air Collision Severity Assessment

SIGNIFICANT EVENTS

UAS Center of Excellence (COE) Selection announced by FAA Administrator Huerta	**May 2015**
UAS COE Kick-Off Meeting	**June 2015**
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

SIGNIFICANT EVENTS

Program Management Review - Columbus, OH	September 2023
Commercial Drone Exhibition - Las Vegas, NV	September 2023
Unmanned Systems, West - San Diego, CA	September 2023
ICAO Drone Enable – Montreal, Canada	December 2023
Jarlath O'Neil-Dunne Memorial – Burlington, VT	January 2024
NIST Public Safety Communications Research (PSCR) UAS Workshop – Gaithersburg, MD	February 2024
Program Management Review – Arlington, VA	April 2024
XPONETIAL – San Diego, CA	May 2024
Western Regional Partnership Principles Meeting – Beaver Creek, CO	May 2024
Future Proof UAS – Huntsville, AL	May 2024
FAA Drone & Advanced Air Mobility Symposium – Baltimore, MD	July 2024
Global Autonomous Systems Conference – Anchorage, AK	August 2024
Commercial Drone Expo – Las Vegas, NV	September 2024
ICAO AAM Symposium – Montreal, Canada	September 2024
NATO Innovation Conference – Setubal, Portugal	September 2024
Program Management Review – Burlington, VT	October 2024
ICAO Conference – Montreal, Canada	October 2024
ASTM International conference – Philadelphia, PA	October 2024
North Carolina Advanced Mobility Symposium – Durham, NC	November 2024
SAE Counter UAS Homeland Security Conference – Arlington, VA	February 2025
Counter UAS Symposium – Oklahoma City, OK	March 2025
ASTM Standards Committee – Detroit, MI	May 2025
AUVSI XPONENTIAL – Houston, TX	May 2025
Drone and AAM Policy Symposium – Washington, DC	July 2025
Program Management Review – Grand Forks, ND	September 2025



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Alliance for System Safety of UAS through Research Excellence