Safety Enhancement SE 207.1 (R&D)
ASA - Research – Attitude and Energy State Awareness Technologies

Safety Enhancement Action:	Aviation community (government, industry, and academia) performs research to enable development, implementation, and certification of technologies that enhance flight crew awareness of airplane energy state and conditions likely to produce spatial disorientation.
Implementers: (Select all that apply)	☐ Air Carrier ☐ Industry Association ☐ Commercial Aviation Safety Team (CAST) ☐ Joint Implementation Measurement and Data Analysis Team (JIMDAT) ☒ Research Organization ☐ Labor Organization ☒ Manufacturer ☒ Regulator ☐ Other (specify)
Statement of Work:	In a CAST study of 18 loss-of-control events, the analysis team recommended research into flight deck technologies that have potential to mitigate the problems and contributing factors that lead to flight crew loss of airplane state awareness (ASA). The aviation community (government, industry and academia) should conduct research in the following areas: 1. Assess the relative benefits associated with various methods of displaying angle-of-attack on the flight deck. 2. Develop and refine algorithms and display strategies to provide control guidance for recovery from approach-to-stall or stall. 3. Develop and refine systems that predict the future aircraft energy state and/or autoflight configuration if the current course of action is continued and provide appropriate alerting. 4. Cost-effective, user-centered flight deck alerting systems to alert flight crews to the two conditions that produced spatial disorientation in the ASA event data set, which are: a) Subthreshold rolls similar to those that have led to loss of control, and b) The somatogravic illusion. The research should focus on raising the technology readiness level (TRL) of these features to a level that enables cost-effective implementation and certification of these technologies.
Total Financial Resources:	**Total: $11.6M** Output 1: $0.6M Output 2: $4.0M Output 3: $4.0M Output 4: $3.0M

Relation to Current Aviation Community Initiatives:	• National Aeronautics and Space Administration (NASA) Aviation Safety Program – Loss of Control and Recovery Research, Spatial Disorientation/Loss of Energy State Awareness (SD/LESA) Study • Title 14, Code of Federal Regulations (14 CFR) § 25.1322, *Flight Crew Alerting*, amendment 25–131
Performance Goal Indicators:	For technology development, the research studies in this safety enhancement (SE) should be complete when they reach an acceptable Technology Readiness Level per NASA TRL definition. Output 1: N/A (technology is available; study is to ascertain benefits of different implementations) Output 2: Current TRL = 2, Target TRL = 5 Output 3: Current TRL = 2, Target TRL = 5 Output 4: Current TRL = 2, Target TRL = 5 It is assumed that the above beginning and target TRLs represent the scope of effort within NASA's leadership. Contributions by other organizations (e.g., industry) would be required to develop these outputs to end-state TRLs and implementation in revenue service. All technologies should be developed with consideration for their potential acceptability under applicable current part 25 design standards.
Key Milestones:	<u>Flow time (mo)</u> / <u>Start Date</u> / <u>End Date</u> Output 1: 66 / 1/1/2014 / 6/30/2019 Output 2: 63 / 1/1/2014 / 3/31/2019 Output 3: 72 / 1/1/2014 / 12/31/2019 Output 4: 63 / 1/1/2014 / 3/31/2019 **Completion:** **72** / 1/1/2014 / 12/31/2019
Potential Obstacles:	Availability of research funding at research organizations
Detailed Implementation Plan Notes:	None
CICTT Code:	Loss of Control–Inflight (LOC–I)
Output 1:	
Description:	Research organizations study and document the benefits, in terms of human performance, of using various forms of angle-of-attack (AOA) display to aid in upset recovery and diagnosis of air data system failures.
Lead Organization:	Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)

<table>
<tr><td>Supporting Organizations:</td><td colspan="2">Air Carriers
Manufacturer research organizations
National Aeronautics and Space Administration (NASA)</td></tr>
<tr><td>Implementers:
(Select all that apply)</td><td>☒ Air Carrier
☐ Industry Association
☐ Commercial Aviation Safety Team (CAST)
☐ Joint Implementation Measurement and Data Analysis Team (JIMDAT)</td><td>☒ Research Organization
☐ Labor Organization
☒ Manufacturer
☒ Regulator
☐ Other (specify) ______________________</td></tr>
<tr><td>Actions:</td><td colspan="2">1. FAA AIR will coordinate with NASA, manufacturer research organizations, and air carriers to develop and perform studies assessing the benefits, in terms of human performance, of using various forms of AOA display to aid in upset recovery and diagnosis of air data system failures. The study should include the following:
a) Literature review of previous studies on the subject of AOA indicator effectiveness and the types of indicators available for display of AOA,
b) Identification of quantitative standards to assess pilot recovery performance,
c) Training and proficiency requirements for various indicators,
d) Development of specific upsets and air data scenarios to assess,
e) Performance of tests, and
f) Documentation of results in publicly available reports.
2. Research organizations will provide final reports to JIMDAT and CAST for review and reference.
3. JIMDAT will track research results against the risk reduction performance of airplane state awareness (ASA) safety enhancements (SE) and make recommendations to CAST for future technology implementations.</td></tr>
<tr><td>Financial Resources:</td><td colspan="2">Total: $0.6M (2.0 Full Time Equivalent (FTE), $0.1M simulator time)</td></tr>
<tr><td>Itemized Resources:</td><td colspan="2">R&D Org: 2.0 FTE to perform study
$0.1M simulator time (for development and testing)

NOTES
• For labor, 1 FTE was assumed to = $250K
• Rough Order of Magnitude (ROM) estimates provided for CAST prioritization and assessment—actual resources to be informed by historical research and development (R&D) cost data from similar programs through each organization’s normal research planning process.
• “R&D Org” resources indicate general labor support required to perform the research. Specific organization support will be determined through normal organizational R&D planning efforts using</td></tr>
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	guidance from a CAST R&D forum to discuss development of and execution of R&D plans by member organizations.
Output Notes:	This is a research detailed implementation plan (DIP).
Time Line:	• 6 months from CAST approval for NASA to convene a CAST R&D forum. • 12 months from CAST approval for organizations to submit R&D proposals in their program. • 36 months from submission of proposal in R&D programs to commence R&D. • 18 months to complete R&D studies and document reports.
Target Completion Date:	6/30/2019
Output 2:	
Description:	Research organizations publish findings from study of algorithms and display scenarios to provide control guidance for recovery from approach-to-stall or stall.
Lead Organization:	National Aeronautics and Space Administration (NASA)
Supporting Organizations:	Manufacturer research organizations Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)
Implementers: (Select all that apply)	☐ Air Carrier ☐ Industry Association ☐ Commercial Aviation Safety Team (CAST) ☐ Joint Implementation Measurement and Data Analysis Team (JIMDAT) ☒ Research Organization ☐ Labor Organization ☒ Manufacturer ☒ Regulator ☐ Other (specify)
Actions:	1. NASA will coordinate with FAA AIR and manufacturer research organizations to develop and perform studies to assess algorithms and display scenarios to provide control guidance to aid pilots in recovering from approach-to-stall and stall, consistent with Title 14, Code of Federal Regulations § 25.1322, amendment 25-131, and other time critical flight deck alerting criteria. The studies should include the following: a) Literature review of past efforts to provide control guidance for recovery from pitch axis upsets, including stall; and b) Discussion of various algorithms employed to detect upsets and determine proper recovery response, including: i. Primary pitch control only; ii. Primary pitch control and pitch trim; iii. Primary pitch control, pitch trim, and thrust; and iv. Other control strategies, as applicable; c) Human Factors study of various display scenarios employed for providing direction to

	flight crew for recovery; d) Preliminary assessment of possible failure modes and potential system safety and certification issues that need to be addressed. 2. Research organizations will provide final reports to JIMDAT and CAST for review and reference. 3. JIMDAT will track research results against the risk reduction performance of airplane state awareness (ASA) safety enhancements (SE) and make recommendations to CAST for future technology implementations.
Financial Resources:	Total: $4.0M (12.0 Full Time Equivalent (FTE), $0.8M simulator time, $0.2 hardware and materials)
Itemized Resources:	R&D Org: 12.0 FTE to perform study $0.8M simulator time (for development and testing, ~200 hours at $4k per hour) $0.2M hardware and materials (modified displays) NOTES: • For labor, 1 FTE was assumed to = $250K • Simulator hourly rate includes labor for development and testing of software in addition to direct cost of operation. • Rough order of Magnitude (ROM) estimates provided for CAST prioritization and assessment—actual resources to be informed by historical research and development (R&D) cost data from similar programs through each organization's normal research planning process. • "R&D Org" resources indicate general labor support required to perform the research. Specific organization support will be determined through normal organizational R&D planning efforts using guidance from a CAST R&D forum to discuss development of and execution of R&D plans by member organizations.
Output Notes:	This is a research detailed implementation plan (DIP).
Time Line:	• 6 months from CAST approval for NASA to convene a CAST R&D forum. • 12 months from CAST approval for organizations to submit R&D proposals in their program. • 12 months from submission of proposal in R&D programs to commence R&D. • 39 months after R&D forum for research organizations to complete studies and document reports.
Target Completion Date:	3/31/2019 (Extended from original date of 12/31/2018).
Output 3:	
Description:	Research organizations publish findings from studies to develop and assess systems that predict the future aircraft energy state and/or autoflight configuration if the current course of action is continued and provide appropriate alerting.

Lead Organization:	Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)	
Supporting Organizations:	Manufacturer research organizations National Aeronautics and Space Administration (NASA)	
Implementers: (Select all that apply)	☐ Air Carrier ☐ Industry Association ☐ Commercial Aviation Safety Team (CAST) ☐ Joint Implementation Measurement and Data Analysis Team (JIMDAT)	☒ Research Organization ☐ Labor Organization ☒ Manufacturer ☒ Regulator ☐ Other (specify)
Actions:	1. FAA AIR will coordinate with NASA and manufacturer research organizations to develop and perform studies to assess systems that predict the future aircraft energy state and/or autoflight configuration if the current course of action is continued and provide appropriate alerting, with emphasis on: a) Effectiveness; b) Low cost; c) Alignment with current and expected future certification requirements (i.e., Title 14, Code of Federal Regulations §§ 25.1302, 25.1309, 25.1322, and 25.1329); and d) Potential for retrofit. *2.* Research organizations will provide final reports to JIMDAT and CAST for review and reference. 3. JIMDAT will track research results against the risk reduction performance of airplane state awareness (ASA) safety enhancements (SE) and make recommendations to CAST for future technology implementations.	
Financial Resources:	Total: $4.0M (12.0 Full Time Equivalent (FTE), $0.4M simulator time, $0.2 hardware and materials)	
Itemized Resources:	R&D Org: 12.0 FTE to perform study $0.8M simulator time (for development and testing; ~200 hours at $4k per hour) $0.2M hardware and materials (modified displays) NOTES: • For labor, 1 FTE was assumed to = $250K. • Simulator hourly rate includes labor for development and testing of software in addition to direct cost of operation. • Rough Order of Magnitude (ROM) estimates provided for CAST prioritization and assessment – actual resources to be informed by historical research and development (R&D) cost data from similar programs through each organization's normal research planning process. • "R&D Org" resources indicate general labor support required to perform the research. Specific	

	organization support will be determined through normal organizational R&D planning efforts using guidance from a CAST R&D forum to discuss development of and execution of R&D plans by member organizations.
Output Notes:	This is a research detailed implementation plan (DIP).
Time Line:	• 6 months from CAST approval for NASA to convene a CAST R&D forum. • 12 months from CAST approval for organizations to submit R&D proposals in their program. • 36 months from submission of proposal in R&D programs to commence R&D. • 36 months after R&D forum for research organizations to complete studies and document reports.
Target Completion Date:	12/31/2019
Output 4:	
Description:	Conduct research into the feasibility of cost-effective and user-centered flight deck alerting systems to alert flight crews to the spatial disorientation-inducing conditions of subthreshold rolls that have led to loss of control and the somatogravic illusion.
Lead Organization:	National Aeronautics and Space Administration (NASA)
Supporting Organizations:	Manufacturer research organizations Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)
Implementers: (Select all that apply)	☐ Air Carrier ☐ Industry Association ☐ Commercial Aviation Safety Team (CAST) ☐ Joint Implementation Measurement and Data Analysis Team (JIMDAT) ☒ Research Organization ☐ Labor Organization ☒ Manufacturer ☒ Regulator
Actions:	1. NASA will coordinate with FAA AIR and manufacturer research organizations to develop and perform studies to assess algorithms and displays that promote cost-effective and user-centered flight deck alerting systems that alert flight crews to the spatial disorientation-inducing conditions of subthreshold roll and the somatogravic illusion. These systems should be consistent with Title 14, Code of Federal Regulations part 25 requirements in general and in particular § 25.1322, amendment 25–131 and other time critical flight deck alerting criteria. The studies should— a) Establish and execute an research and development (R&D) plan to determine technologies and/or training required, including assessment of various forms of attitude indicators for ease of interpretation in high workload situations; b) Consider whether inputs to automation may be beneficial; c) Include establishment of acceptable false alarm rate and plan to meet or exceed this rate; and d) Focus on lower cost solutions more amenable to retrofit. 2. Research organizations will provide final reports of these studies to JIMDAT and CAST for review

	and reference. 3. JIMDAT will track research results against the risk reduction performance of airplane state awareness (ASA) safety enhancements (SE) and make recommendations to CAST for future technology implementations.
Financial Resources:	Total: $3.0M (8.0 Full Time Equivalent (FTE), $0.8M simulator time, $0.2 hardware and materials)
Itemized Resources:	R&D Orgs: 8.0 FTE to perform study (4 FTE per year for 2 years) $0.8M simulator time (for development and testing) $0.2M hardware and materials (modified displays) NOTES: • For labor, 1 FTE was assumed to = $250K. • Simulator hourly rate includes labor for development and testing of software in addition to direct cost of operation. • Rough Order of Magnitude (ROM) estimates provided for CAST prioritization and assessment—actual resources to be informed by historical R&D development cost data from similar programs through each organization's normal research planning process • "R&D Org" resources indicate general labor support required to perform the research. Specific organization support will be determined through normal organizational R&D planning efforts using guidance from a CAST R&D forum to discuss development of and execution of R&D plans by member organizations.
Time Line:	• 6 months from CAST approval for NASA to convene a CAST R&D forum. • 12 months from CAST approval for organizations to submit R&D proposals in their program. • 12 months from submission of proposal in R&D programs to commence R&D. • 39 months after R&D forum for research organizations to complete studies and document reports.
Target Completion Date:	3/31/2019 (Extended from original date of 12/31/2018.

Reference Material	
Supporting CAST Intervention Strategies	NOTE: *This section lists applicable CAST Intervention Strategies (IS) used to develop the actions in this detailed implementation plan (DIP). These ISs are listed to provide traceability and supporting rationale for the recommended actions. IS recommendations may be wholly or only partly represented in the DIP, based on a final determination of feasible actions during DIP development.* IS 381R—To provide improved pilot awareness of the airplane's energy state, the aviation industry should perform research and development of more effective energy management monitoring and alerting systems. IS 416R—To provide improved flight crew situational awareness, the aviation industry should perform research and development of systems that can predict and indicate the future aircraft energy state and/or autoflight configuration if the current course of action is continued (i.e., analogous to Enhanced Ground Proximity Warning System (EGPWS) mode that analyzes the airplane's descent rate vs. its terrain map, and tells the crew that a conflict will occur if they continue at that descent rate. The system would warn the crew that, if they continue at the current roll rate (for example), the plane will exceed the envelope, or the autopilot will reach the limits of its authority, etc.) IS 1018—To enhance airplane attitude awareness, the aviation industry should conduct research to explore other potentially more intuitive displays of attitude information to flightcrews (e.g., frequency-separated attitude display that combines western attitude director indicator (ADI) horizon geometry with eastern ADI style of dynamics for the aircraft symbol and other as-yet unidentified ideas). IS 1206R—To improve flightcrew awareness and understanding of how to properly respond to stall warning or recover from a stalled condition, the aviation industry should perform research and development of stall warning systems that provide guidance to the flightcrew for proper recovery, in accordance with 14 CFR § 25.1322 at Amendment level 25–131. IS 1213—To prevent spatial disorientation accidents, the aviation industry should conduct research and development of feasible flight crew alerting systems to alert crew to flight conditions that can lead to common spatial disorientation (SD) situations (e.g., subthreshold roll that does not match flight plan, somatogravic accelerations). IS 1232R—To improve flightcrew awareness of energy state, the aviation industry should perform research and development of systems that alert flight crews to low energy state (i.e., the combination of airspeed, altitude, descent/climb rate, thrust setting, airplane configuration, etc.), in accordance with § 25.1322 at amdt 25–131.