Safety Enhancement SE 208.3 (R&D)
ASA – Research – Airplane Systems Awareness

Safety Enhancement Action:	Aviation community (government, industry, and academia) performs research to develop flight deck systems that enhance flight crew awareness of system status and the interaction of systems, particularly in non-normal situations involving failures in one or more systems.
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 accidents and incidents, 15 events involved a lack of aircraft system state awareness. The aviation community (government, industry and academia) should conduct research and development on aircraft systems that improve flight crew awareness of system status and the interaction of systems, particularly in non-normal situations involving failures in one or more systems, including: 1. Displays that present, in an intuitive manner— a. The current and future expected state of automated systems; and b. The aircraft flight-critical data systems in use by autoflight system, flight control laws, and primary flight instruments. 2. Improved alerting methodologies and algorithms that— a. Effectively prioritize alerts and messages, b. Appropriately escalate alerts the flight crew has not correctly addressed, and c. Effectively inform the flight crew of unusual and potentially problematic autoflight control inputs (including all trim and thrust changes). 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: $6.0M** Output 1: $3.0M Output 2: $3.0M
Relation to Current Aviation Community Initiatives:	• National Aeronautics and Space Administration (NASA) Aviation Safety Program – Vehicle Systems Safety Technologies (VSST) • Title 14, Code of Federal Regulations (14 CFR) 25.771(a), *Pilot compartment —Unreasonable concentration or fatigue*

	• 14 CFR 25.1302, *Installed systems and equipment for use by the flightcrew* • Advisory Circular (AC) 25.1302, *Installed systems and equipment for use by the flightcrew* • 14 CFR 25.1309 (a) and (c), *Equipment, systems and installations*, amendment 25–123 • 14 CFR 25.1322, *Flight Crew Alerting*, amendment 25–131 • 14 CFR 25.1329, *Flight guidance system – Autopilot, flight director and autothrust*
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: Current TRL = 2, Target TRL = 5 Output 2: 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 14 CFR part 25 design standards.
Key Milestones:	<table><tr><td></td><td><u>Flow time (mo)</u></td><td><u>Start Date</u></td><td><u>End Date</u></td></tr><tr><td>Output 1:</td><td>91</td><td>1/1/2014</td><td>8/05/2021</td></tr><tr><td>Output 2:</td><td>91</td><td>1/1/2014</td><td>8/05/2021</td></tr><tr><td>Completion:</td><td>91</td><td>1/1/2014</td><td>8/05/2021</td></tr></table>
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:	Develop intuitive displays that enhance flight crew awareness of the status of automated systems and understanding of the interaction of systems, particularly in non-normal situations involving failures in one or more systems.
Lead Organization:	National Aeronautics and Space Administration (NASA)

<table>
<tr><td>Supporting Organizations:</td><td colspan="2">Aerospace Industries Association (AIA)
Airbus
Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)
The Boeing Company</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. NASA will coordinate with FAA AIR and manufacturer research organizations to develop and assess displays that improve flight crew awareness of current and future aircraft system state and interaction, including—
a) Displays that present the current and future expected state of automated systems in an intuitive manner. Displays should provide information for both the mode currently selected and impending mode transitions expected per design of these systems.
b) Displays that show, in a simple, integrated manner (e.g, a synoptic), the aircraft flight-critical data systems in use by automated systems and primary flight instruments, for both the mode currently selected and any impending mode transitions expected per design of these systems.
i. Aircraft flight-critical data systems include airspeed and altitude systems, angle-of-attack sensors, inertial reference systems, and navigation systems.
ii. Automated systems include the autopilot, autothrottle, flight management and navigation, autotrim, and flight control laws.
iii. Primary flight instruments include airspeed, altimeter, attitude indicator, and heading indicator.
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>Total:</td><td>$3.0M (8.0 Full Time Equivalent (FTE); $0.8M simulator testing; $0.2M hardware)</td></tr>
<tr><td>Itemized Resources:</td><td>R&D Org:</td><td>8.0 FTE to perform study (NASA only)
$0.8M simulator time (for development and testing, ~200 hours at $4k per hour)
$0.2M hardware and materials (modified displays)</td></tr>
</table>

	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:	Completed and closed August 5, 2021, based on NASA briefings provided in 2018–2019 covering their Technologies for Aircraft State Awareness (TASA) projects, and the publication and distribution of related reports.
Output 2:	
Description:	Develop alerting methodologies and algorithms to improve flight crew recognition of aircraft system status during time-critical situations.
Lead Organization:	National Aeronautics and Space Administration (NASA)
Supporting Organizations:	Airbus Aerospace Industries Association (AIA) Federal Aviation Administration (FAA) Aircraft Certification Service (AIR) The Boeing Company
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 assess alerting methodologies that improve flight crew awareness of aircraft system state and interaction by—

	a) Effectively prioritizing alerts and messages; b) Appropriately escalating alerts the flight crew has not correctly addressed; and c) Alerting to unusual and potentially problematic autoflight control inputs, including all trim and thrust changes, including— i. The airplane flightpath deviates from what the system expects given the autoflight mode selected, ii. The autoflight control authority is saturated and autoflight system cannot achieve the commanded path, iii. The airplane nose-up trim commands in low airspeed or high angle-of-attack conditions, and iv. The autothrottle command of asymmetric thrust to achieve a desired flight path command when one throttle or engine is malfunctioning. 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: $3.0M (8.0 Full Time Equivalent (FTE); $0.8M simulator testing; $0.2M hardware)
Itemized Resources:	R&D Org: 8.0 FTE to perform study (NASA only) $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.
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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:	Completed and closed August 5, 2021, based on NASA briefings provided in 2018–2019 covering their Technologies for Aircraft State Awareness (TASA) projects, and the publication and distribution of related reports.

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 1203—To improve flightcrew understanding of airplane automated systems (flight controls, autotrim, engine controls, flight management system (FMS) and autoflight, etc.) current status and future state, manufacturers should design and implement systems to convey this information in a simple, integrated manner (e.g., crew resource management (CRM) applied to automated systems). IS 430—Research should be conducted to determine the optimal way to provide flight crews with aircraft status recognition during critical situations. IS 1207–R—To improve flight crew awareness of autoflight system control inputs, the aviation industry should perform research and development of autoflight systems that provide alerting of unusual and potentially problematic autoflight control inputs (including all trim and thrust changes), in accordance with 14 CFR 25.1322 at Amendment level 25–131, conditioned upon results of IS 1224 (See 1207). IS 1224—To improve flightcrew awareness of autoflight system control inputs, the aviation community should research and develop the ability to detect and alert to unusual and potentially problematic autoflight control inputs (including trim and thrust changes). IS 1014–R—To redirect attention to a critical event, the aviation industry should perform research and development of methods for removing non-relevant primary flight display (PFD)/navigation display (ND) information when flight crews fail to respond appropriately to a time-critical warning (See IS 1014) IS 243–R—To prevent alerting overload, the aviation industry should perform research and development of smart alerting systems such as those with prioritization schemes or cancelable nuisance alerts. (See 243) IS 1220–R—To mitigate effects of flight crew channelized attention, confirmation bias, or diverted attention, the aviation industry should perform research and development of alerting systems that highlight or repeat alerts for uncorrected conditions in high-workload or non-normal conditions (e.g., increasing PITOT HEAT alert from a CAUTION to a WARNING in icing conditions). (See IS 1220)

	IS 15–R—To warn of impending loss of control with the autoflight system fully engaged, the aviation industry should perform research and development of systems that can annunciate airplane flight conditions that significantly differ from what is being commanded by the selected autoflight system mode. (See IS 243 & IS 515)