Safety Enhancement SE 203.7 ASA – Design – Features for Current Production/In-Development Fly-by-Wire Airplane Designs	
Safety Enhancement Action:	Manufacturers study the feasibility of incorporating, into current production and in-development fly-by-wire (FBW) transport category airplane (TCA) type designs, certain recommended design features that address the risks identified by the airplane state awareness (ASA) Joint Safety Analysis Team (JSAT) and Joint Safety Implementation Team (JSIT).
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:	A CAST study of 18 loss-of-control accidents and incidents resulting from flight crew loss of ASA determined that several design features, working separately or in conjunction, could have significantly reduced the likelihood of these accidents or incidents occurring. Manufacturers should study the potential for implementation of the following features in current production and in-development FBW TCA type designs: 1. Bank angle protection. 2. Bank angle alerting and recovery guidance display systems. 3. Virtual day-visual meteorological conditions (VMC) display systems, such as synthetic vision or equivalent systems, which permit flight crews to operate in a day-VMC-like environment, regardless of external visibility. 4. Energy state cues, such as flight path, acceleration, and speed deviation, in a manner similar to modern head-up displays for two scenarios: a) As part of a virtual-VMC display, and b) As a standalone implementation on the primary flight displays (PFD). Aerospace Industries Association (AIA) and JIMDAT will review the results of the studies with manufacturers and propose follow-on CAST safety enhancements (SE) for development and implementation of forward-fit production line changes and retrofit service bulletins for those combinations of models and features determined by the studies to be feasible.

Total Financial Resources:	**<u>Total: $3.1M</u>** Output 1: $0.1M Output 2: $0.3M Output 3: $1.1M Output 4: $1.6M
Relation to Current Aviation Community Initiatives:	• CAST SE 40, *LOC – Design – Flight Envelope Protection* • CAST SE 200, *ASA – Design – Virtual Day-VMC Displays* • CAST SE 201, *ASA – Design – Bank Angle Alerting and Recovery Guidance Systems* • CAST SE 202, *ASA – Design – Bank Angle Protection* • RTCA SC–213 "Enhanced Flight Vision Systems and Synthetic Vision Systems" • 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" • Federal Aviation Administration (FAA) Title 14 of the Code of Federal Regulations (14 CFR) § 25.1322, Amendment 25–131, *Flight Crew Alerting* • FAA Advisory Circular (AC) 25.1322–1, *Flight Crew Alerting*
Performance Goal Indicators:	<u>Risk Reduction Potential</u> The ASA JSIT performed a general assessment of the potential risk reduction that could be attained by the year 2025 through implementation of the recommended features in all applicable FBW airplanes.

Feature *FBW airplanes*	**Change Type†**	**Airplanes Modified**	**%2025 Fleet Modified**	**2025 Event Risk Reduction**
Bank Angle Protection (Output 2)	P	~350	4%	1%
	P+R	~750	7%	1.8%
Bank Angle Alerting & Recovery Guidance (Output 3)	P	~1000	10%	1.4%
	P+R	~3500	33%	4.6%
Energy State Cues on PFD (Output 4)	P	~700	6%	1.4%
	P+R	~2700	26%	6.0%
Virtual Day-VMC Displays with Energy State Cues (Output 4)	P	~1000	10%	4.6%
	P+R	~3500	33%	15.3%
All Features Combined	**P**	**~1000**	**5%**	**9.0%**
	P+R	**~3500**	**33%**	**26.1%**

† P = production change only; R = retrofit change only ; P+R = production & retrofit change

	<u>Implementation</u> SE Implementation will be tracked by AIA and JIMDAT through periodic reports from the manufacturers through their JIMDAT member representatives. <u>Effectiveness</u> Effectiveness of implemented features will be assessed by monitoring the following metrics: • Flight Operational Quality Assurance (FOQA) metrics show a reduction in incidents of high-risk overbanks (bank angle greater than 45 degrees associated with subthreshold roll rates at load factor less than 1.2 g's and loss of vertical speed greater than 1,000 feet per minute). • FOQA metrics show a reduction in incidents of stall warnings associated with speed decay.
Key Milestones:	<table><tr><td></td><td><u>Flow time (mo)</u></td><td><u>Start Date</u></td><td><u>Target Completion Date</u></td></tr><tr><td>Output 1:</td><td>6</td><td>12/31/2013</td><td>6/30/2014</td></tr><tr><td>Output 2:</td><td>44</td><td>6/30/2014</td><td>2/28/2018</td></tr><tr><td>Output 3:</td><td>44</td><td>6/30/2014</td><td>2/28/2018</td></tr><tr><td>Output 4:</td><td>54</td><td>6/30/2014</td><td>12/31/2018</td></tr><tr><td>**Completion:**</td><td>**60**</td><td>**12/31/2013**</td><td>**12/31/2018**</td></tr></table>
Potential Obstacles:	• Expense and complexity of design changes for existing type designs • Variation of existing fleet hardware • Flight crew training on new features • Availability of resources to conduct feasibility studies within each company
Detailed Implementation Plan Notes:	*Bank Angle Protection* Bank angle protection, as envisioned by the ASA JSAT and JSIT, involves an active flight control law that either limits the magnitude of bank angle that can be commanded by the crew, or else provides feedback cues (such as force gradients on the control wheel) to discourage flight crew inputs that would increase bank angle beyond a prescribed envelope. Bank angle protection can be implemented most directly in an FBW flight control architecture, although it is possible to implement it through hydro-mechanical means as well. In most implementations, bank angle protection includes a provision to automatically return the airplane from an excessive bank angle (generally considered to be greater than 35–40 degrees) to an acceptable bank angle (generally 30–35 degrees) and hold the airplane at that bank angle when the flight control system senses no force inputs to the pilot lateral controller.

NOTE: CAST SE 40 was adopted on the CAST plan in 2003, encouraging manufacturers to incorporate full envelope protection (including bank angle protection) in all new TCA type designs. Since that time, all manufacturers have incorporated at least some level of flight envelope protection in new type designs, but not all latest designs include bank angle protection. This SE reaffirms the previous commitment of CAST to the implementation of flight envelope protection and specifically recommends bank angle protection for those airplanes that do not employ it.

Bank Angle Alerting and Recovery Guidance

In order to provide explicit control guidance and mitigate risks resulting from excessive bank angle, manufacturers should develop additional cues on the PFDs to indicate direction for appropriate action to recover from unusual roll attitude. Such guidance should be multisensory (e.g., visual and aural) and consistent with other flight deck warnings.

Virtual Day-VMC Displays and Energy State Cues

Manufacturers should develop and implement virtual day-VMC display systems, such as synthetic vision or equivalent systems, which permit flight crews to operate in a day-VMC-like environment, regardless of external visibility. For the purpose of this SE, "virtual day-VMC displays" describe systems with the following elements:

- Presented full time in the primary field-of-view;
- Presented to both flight crew members; and
- Include display of energy state cues, including flight path, acceleration, and speed deviation, in a manner similar to modern head-up displays.

Depending on each manufacturer's implementation plan, implementation of virtual day-VMC displays may benefit from completion of associated research as described in ASA SE 200. While not a requirement for implementation, subsequent definition of these minimum system requirements in a published standards document (e.g., Radio Technical Commission for Aeronautics (RTCA) DO–315) may reduce implementation and certification risk for some future programs.

Applicability

The ASA JSIT recommends manufacturers study these features on the following models:

Bank Angle Protection[1] *Output 2*	Bank Angle Alerting w/ Recovery Guidance *Output 3*	Energy State Cues on the PFD *Output 4*	Virtual Day-VMC Display Systems *Output 4*
Boeing 747–8 /–8F Embraer ERJ 170/190 ERJ 175–E2/ 190–E2/195 E2G2[2]	Airbus[3] A318/A319/A320/A321 A330 A380 A320 neo[2] A3502 Boeing 747–8 /–8F 777 787 Bombardier C-series[2] Embraer ERJ 170/190 ERJ 175–E2/190–E2/ 195–E2[2]	Airbus[3] A318/A319/A320/A321 A330 A380 A320 neo[2] A350[2] Boeing 747–8 /–8F 777 787 Bombardier C-series[2] Embraer ERJ 170/190 ERJ 175–E2/190–E2/ 195–E2[2]	Airbus[3] A318/A319/A320/A321 A330 A380 A320 neo[2] A350[2] Boeing 747–8 /–8F 777 787 Bombardier C-series[2] Embraer ERJ 170/190 ERJ 175–E2/ 190–E2/195 E2[2]

[1] The ASA JSIT determined that all other current production and in-development FBW type designs produced by CAST-represented manufacturers incorporate a form of bank angle protection that meets the intent and functionality of IS 445. The ASA JSIT also determined that incorporation of bank angle protection into the control systems of airplanes that do not employ FBW flight controls is not likely to be feasible, based on cost, schedule, and operational impacts.

[2] Indicates a program currently in development, but beyond configuration design freeze and development of certification basis.

[3] Airbus A340 model is out of production and does not have any U.S. operators; therefore, it is not included among the recommended models for study.

Feasibility Study Guidelines

Unless otherwise noted, each feature's feasibility study should consider the following elements:

	1. Existing production change and service bulletin information. If the feature has already been incorporated in the production line of an existing type design, the manufacturer need only consider development of a service bulletin for retrofit. If a retrofit service bulletin also exists for a given model, no further study of the feature on that model is necessary. The manufacturer should identify existing service bulletin information in its response to CAST. 2. Market analysis. This analysis should include an estimate, based on the manufacturer's marketing projection, of the following as applicable for each model: a) The year in which the change could be implemented in production; b) The number of airplanes projected to be produced between implementation and the year 2025; c) The year in which a retrofit package could be offered; and d) The minimum number of airplanes for the model the manufacturer determines would need to be modified in order to justify the cost, based on the benefits accrued by reduced risk contributed by that model in the overall fleet. 3. Rough Order of Magnitude (ROM) cost estimates. Cost estimates should be given from initial development to entry into service, broken out by airplane type, and should include at least the following: a) An estimate, in hours, of the engineering, pilot, and administrative labor required to develop design changes that would introduce these features into the production line and as a retrofit package into delivered airplanes. This estimate should include supplier labor hours as well as hours estimated for certification, both by the manufacturer and the regulatory authorities. b) An estimate, in hours, of the pilot-in-the-loop simulator hours required to develop and certify the change. c) An estimate, in hours, of flight test time required to develop and certify the system. d) An estimate, in dollars, of hardware or parts required per airplane to support the change. 4. Technical feasibility assessment. This assessment should cover installation of the technologies on the production line as well as development of service bulletins to be made available for retrofitting the technology to delivered airplanes. 5. Certification risks. Any certification barriers, such as insufficient guidance for means of compliance, inconsistency with current FAA certification policy, or impact on other certified systems or Airplane Flight Manual procedures should be identified. 6. Impact to operators. An estimate, in hours, of additional flight crew training time for new systems and of airplane downtime to install service bulletins for retrofit scenarios. If the change can be implemented in parallel to other maintenance activities, only the incremental time or cost of the installation need be considered.

CICTT Code:	Loss of Control–Inflight (LOC–I)
Output 1:	
Description:	Manufacturers' agreement to perform feasibility studies for implementing recommended features in current production and in-development fly-by-wire (FBW) transport category airplane (TCA) type designs.
Lead Organization:	Aerospace Industries Association (AIA)
Supporting Organizations:	Airbus Bombardier, Inc. Embraer 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. AIA will communicate with CAST-represented airplane manufacturers that are currently producing or are expected to produce FBW TCAs for use in U.S. 14 CFR part 121 operations, explaining the airplane state awareness (ASA) analysis and encouraging them to study the feasibility of implementing the following features in current production and in-development FBW TCA type designs: a. Bank angle protection; b. Bank angle alerting and recovery guidance display systems; c. Virtual day-visual meteorological conditions(VMC) display systems, such as synthetic vision or equivalent systems, which permit flight crews to operate in a day-VMC-like environment, regardless of external visibility; and d. Energy state cues, such as flight path, acceleration, and speed deviation, in a manner similar to modern head-up displays for two scenarios: i. As part of a virtual-VMC display, and ii. As a standalone implementation on the primary flight displays (PFD). 2. CAST-represented airplane manufacturers review the communication and its applicability to their existing and in-development FBW TCA type designs. Manufacturers should then respond as follows: a. If service bulletin information to incorporate any of the features currently exists for a model, the manufacturer should identify the service bulletin information in its response. b. If the feature is currently expected to be incorporated on an existing or in-development FBW TCA type design, the manufacturer should note this in its response and provide an estimate as

	to when the feature is expected to enter into service, including availability of service bulletins for retrofit, if applicable. c. For other models, manufacturers should respond with their agreement to conduct the requested feasibility studies, and provide a point of contact for JIMDAT and AIA and estimated completion date for each study element. 3. AIA will track implementation and report progress to JIMDAT and CAST.	
Financial Resources:	Total: $0.1M (0.4 Full Time Equivalent (FTE))	
Itemized Resources:	Manufacturers: 0.3 FTE (~0.08 FTE per manufacturer, for communication and scoping of study) AIA: 0.1 FTE, for communication and tracking Notes: • For labor, 1 FTE = $250K	
Output Notes:	<u>Applicability</u> All CAST-represented manufacturers of FBW transport category airplanes should receive and respond to the CAST communication.	
Time Line:	• 3 months after CAST approval for AIA to send request letters • 6 months after CAST approval for manufacturers to respond to letter	
Target Completion Date:	6/30/2014. Completed 12/4/2014.	
Output 2:		
Description:	Manufacturers perform feasibility studies for implementing bank angle protection in current production and in-development fly-by-wire (FBW) transport category airplane (TCA) type designs.	
Lead Organization:	Aerospace Industries Association (AIA)	
Supporting Organizations:	Airbus Bombardier, Inc. Embraer JIMDAT 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. CAST-represented airplane manufacturers will perform an internal feasibility study on implementation of bank angle protection into current production and in-development FBW TCA type designs, for both forward-fit and retrofit scenarios, as described in the safety enhancement (SE) Detailed Implementation Plan Notes section. 2. Upon completion of the feasibility studies, the manufacturers will respond to AIA with their findings. Manufacturers will consult with AIA and the JIMDAT to estimate incremental values of expected risk resulting from implementation of the feature in their specific fleets. Fleet-specific values of risk reduction will be based on the estimated proportion of the fleet affected and the ASA JSIT risk reduction estimates for the feature against the event set. 3. AIA will track completion of the feasibility studies and report progress to JIMDAT and CAST.
Financial Resources:	Total: $0.3M (1.2 Full Time Equivalent (FTE))
Itemized Resources:	Manufacturers: 1.0 FTE (0.5 FTE per manufacturer, for 2 manufacturers), to perform studies AIA: 0.1 FTE, for communication, tracking, and consultation JIMDAT: 0.1 FTE, for communication, tracking, and consultation Notes: • For labor, 1 FTE = $250K
Output Notes:	
Time Line:	• 18 months after completion of Output 1 for manufacturers to complete studies • 24 months after completion of Output 1 for manufacturers to consult AIA and JIMDAT to determine feasibility
Target Completion Date:	2/28/2018 (extended from original date of 7/31/2017). Completed and closed 2/1/2018 based on aircraft manufacturer feasibility studies.
Output 3:	
Description:	Manufacturers study the feasibility and cost of implementing bank angle alerting and recovery guidance display systems in current production and in-development fly-by-wire (FBW) transport category airplane (TCA) type designs.
Lead Organization:	Aerospace Industries Association (AIA)
Supporting Organizations:	Airbus Bombardier, Inc. Embraer JIMDAT The Boeing Company
Implementers:	☐ Air Carrier ☐ Research Organization

(Select all that apply)	☒ Industry Association ☐ Commercial Aviation Safety Team (CAST) ☒ Joint Implementation Measurement and Data Analysis Team (JIMDAT)	☐ Labor Organization ☒ Manufacturer ☐ Regulator ☐ Other (specify) ______________________
Actions:	1. CAST-represented airplane manufacturers will perform an internal feasibility study on implementation of bank angle alerting and recovery guidance in current production and in-development FBW TCA type designs, for both forward-fit and retrofit scenarios, as described in the safety enhancement (SE) Detailed Implementation Plan Notes section. 2. Upon completion of the feasibility studies, the manufacturers will respond to AIA with their findings. Manufacturers will consult with AIA and the JIMDAT to estimate incremental values of expected risk resulting from implementation of the feature in their specific fleets. Fleet-specific values of risk reduction will be based on the estimated proportion of the fleet affected and the ASA Joint Safety Implementation Team (JSIT) risk reduction estimates for the feature against the event set. 3. AIA will track completion of the feasibility studies and report progress to JIMDAT and CAST.	
Financial Resources:	Total: $1.1M (4.4 Full Time Equivalent (FTE))	
Itemized Resources:	Manufacturers: 4.0 FTE (1 FTE per manufacturer, for 4 manufacturers), to perform studies AIA: 0.2 FTE, for communication, tracking, and consultation JIMDAT: 0.2 FTE, for communication, tracking, and consultation Notes: • For labor, 1 FTE = $250K	
Output Notes:		
Time Line:	• 18 months after completion of Output 1 for manufacturers to complete studies. • 24 months after completion of Output 1 for manufacturers to consult AIA and JIMDAT to determine feasibility.	
Target Completion Date:	2/28/2018 (extended from original date of 7/31/2017). Completed and closed 2/1/2018 based on aircraft manufacturer feasibility studies.	
Output 4:		
Description:	Manufacturers study the feasibility and cost of implementing virtual day-visual meteorological conditions (VMC) displays, such as synthetic vision or equivalent systems, and the full time presentation of energy state cues (flight path, acceleration, and speed deviation) in a manner similar to modern head-up displays, in current production and in-development fly-by-wire (FBW) transport category airplane (TCA) type designs.	

<table>
<tr><td>Lead Organization:</td><td colspan="2">Aerospace Industries Association (AIA)</td></tr>
<tr><td>Supporting Organizations:</td><td colspan="2">Airbus
Bombardier, Inc.
Embraer
JIMDAT
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. CAST-represented airplane manufacturers will perform an internal feasibility study on implementation of virtual day-VMC displays and full time presentation of energy state cues (flight path, acceleration, and speed deviation) in a manner similar to modern head-up displays, into current production and in-development FBW TCA type designs, for both forward-fit and retrofit scenarios, as described in the safety enhancement (SE) Detailed Implementation Plan Notes section. The study should consider two options:
a) Virtual day-VMC displays that incorporate energy state cues as part of the display, and
b) Energy state cues presented on the primary flight displays (PFD) without virtual day-VMC displays.
2. Upon completion of the feasibility studies, the manufacturers will respond to AIA with their findings. Manufacturers will consult with AIA and the JIMDAT to estimate incremental values of expected risk resulting from implementation of the feature in their specific fleets. Fleet-specific values of risk reduction will be based on the estimated proportion of the fleet affected and the airplane state awareness (ASA) Joint Safety Implementation Team (JSIT) risk reduction estimates for the feature against the event set.
3. AIA will track completion of the feasibility studies and report progress to JIMDAT and CAST.</td></tr>
<tr><td>Financial Resources:</td><td colspan="2">Total: $1.6M (6.4 Full Time Equivalent (FTE))</td></tr>
<tr><td>Itemized Resources:</td><td colspan="2">Manufacturers: 6.0 FTE (1.5 FTE per manufacturer, for 4 manufacturers), to perform studies
AIA: 0.2 FTE, for communication, tracking, and consultation
JIMDAT: 0.2 FTE, for communication, tracking, and consultation

Notes:
• For labor, 1 FTE = $250K</td></tr>
<tr><td>Output Notes:</td><td colspan="2"></td></tr>
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Time Line:	• 36 months after CAST approval for research activities to report results for informing virtual day-VMC system minimum requirements to be effective mitigation against spatial disorientation (see CAST SE 200, *ASA – Design – Virtual Day-VMC Displays*) • 18 months after research activities conclude to complete studies • 24 months after research activities conclude for manufacturers to consult AIA and JIMDAT and determine feasibility
Target Completion Date:	12/31/2018. Completed and closed 10/04/2018 based on manufacturers reporting requested technologies are already implemented where feasible and will be considered in future designs.
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 445—To help avoid loss of control, manufacturers should develop and implement flight envelope protection (e.g., bank/pitch angle limits, overspeed, angle of attack, load factor). IS 1002—To prevent unusual attitudes and enhance recovery from them, manufacturers should design and implement attitude alerting systems that provide caution and warning level alerts, including multisensory flight crew guidance, as appropriate and in accordance with 14 CFR § 25.1322 at Amendment level 25–131 (e.g., "roll left" combined with arrows to indicate direction for recovery). IS 1003—To prevent the occurrence of spatial disorientation, manufacturers should develop and regulators should ensure implementation of synthetic vision systems on the primary flight display (PFD)—using standardized formats—to support continuous attitude, altitude and terrain awareness. IS 1039—To improve flight crew awareness of energy state, manufacturers should provide flight path marker, acceleration, speed deviation, and runway symbol on the PFD and/or head-up displays (HUD). IS 1010—To prevent the occurrence of spatial disorientation, the aviation industry should conduct research to establish minimum requirements (e.g., field of view, field of regard, display minification, display elements) necessary for a synthetic vision system to prevent spatial disorientation.