Safety Enhancement SE 204.5 ASA – Design – Features for Existing Non-Fly-by-Wire Airplane Designs	
Safety Enhancement Action:	Manufacturers study the feasibility of incorporating, into current production and in-development non-fly-by-wire (non-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 non-FBW type designs: 1. Low airspeed caution alerting; 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; and 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.

<table>
<tr><td>Total Financial Resources:</td><td><u>Total:</u> <u>$1.8M</u>
Output 1: $0.1M
Output 2: $0.3M
Output 3: $0.6M
Output 4: $0.8M</td></tr>
<tr><td>Relation to Current Aviation Community Initiatives:</td><td>• Radio Technical Commission for Aeronautics (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
• Aviation Rulemaking Advisory Committee (ARAC) Avionics Systems Harmonization Working Group Report, Low Speed Alerting Recommendations Report – Phase II, published March 11, 2013
• CAST SE 192, ASA – Design – Low Airspeed Alerting
• CAST SE 200, ASA – Design – Virtual Day-VMC Displays
• CAST SE 201, ASA – Design – Bank Angle Alerting and Recovery Guidance Systems</td></tr>
<tr><td>Performance Goal Indicators:</td><td><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 non-FBW production airplanes:
<table>
<tr><th>Feature
Non-FBW airplanes</th><th>Change Type†</th><th>Airplanes Modified</th><th>%2025 Fleet Modified</th><th>2025 Event Risk Reduction</th></tr>
<tr><td rowspan="2">Low Airspeed Caution Alert (Output 2)</td><td>P</td><td>~300</td><td>3%</td><td>0.7%</td></tr>
<tr><td>P+R</td><td>~800</td><td>11%</td><td>2.6%</td></tr>
<tr><td rowspan="2">Bank Angle Alerting & Recovery Guidance (Output 3)</td><td>P</td><td>~500</td><td>5%</td><td>1%</td></tr>
<tr><td>P+R</td><td>~2900</td><td>32%</td><td>6.6%</td></tr>
<tr><td rowspan="2">Energy State Cues on PFD (Output 4)</td><td>P</td><td>~500</td><td>5%</td><td>1.2%</td></tr>
<tr><td>P+R</td><td>~2900</td><td>32%</td><td>7.6%</td></tr>
<tr><td rowspan="2">Virtual day-VMC displays with Energy State Cues (Output 4)</td><td>P</td><td>~500</td><td>5%</td><td>2.7%</td></tr>
<tr><td>P+R</td><td>~2900</td><td>32%</td><td>17.1%</td></tr>
<tr><td>All features combined</td><td>R</td><td>~500</td><td>5%</td><td>5.9%</td></tr>
</table></td></tr>
</table>

		P+R	**~2900**	**32%**	**34.0%**

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

Implementation

SE Implementation will be tracked by JIMDAT through periodic reports from the manufacturers through their JIMDAT member representatives.

Effectiveness

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:

	Flow time (mo)	Start Date	Target Completion Date
Output 1:	6	12/31/2013	6/30/2014
Output 2:	37	6/30/2014	7/31/2017
Output 3:	37	6/30/2014	7/31/2017
Output 4:	54	6/30/2014	12/31/2018
Completion:	**60**	**12/31/2013**	**12/31/2018**

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:

Low Airspeed Caution Alerting

In order to improve early flight crew awareness of a decreasing energy state, manufacturers should develop and implement multisensory low airspeed alerting at the caution level (see 14 CFR 25.1322, amdt 25–131) in existing and in-development airplanes, as practical and feasible. The focus of this SE is on low cost, low technology solutions with ease of retrofit and production incorporation. For example, when airspeed decreases below the minimum maneuver speed by a specified margin (but is still above the stall warning speed), an aural alert (e.g., "Airspeed Low") would sound accompanied by an amber visual cue on the airspeed indicator.

	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 primary flight displays (PFD) to indicate direction for appropriate action to recover from unusual roll attitude. For example, at an excessive right bank angle, a bank angle aural alert would sound accompanied by an amber visual cue on the attitude indicator. If the bank angle continued to increase in the direction of the upset, the alert could transition to a warning. The aural could change to "bank angle, roll left," and the display could provide a red arrow cue to indicate the direction to roll towards wings-level. Such guidance should be integrated with either aural or tactile alerting schemes. *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., 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:

Low Airspeed Caution Alerting[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 Boeing 767	Boeing Boeing 737–NG Boeing 767 737 MAX[2]	Boeing Boeing 737NG Boeing 767 737 MAX[2]	Boeing Boeing 737NG Boeing 767 737 MAX[2]
Bombardier CRJ 700/900 Q400	Bombardier CRJ 700/900 Q400	Bombardier CRJ 700/900 Q400	Bombardier CRJ 700/900 Q400

[1] This functionality has been incorporated into the 737NG and 737 MAX airplane programs as a stand-alone feature.

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

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 and 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 in current production and in-development non-fly-by-wire (non-FBW) transport category airplane (TCA) type designs.
Lead Organization:	Aerospace Industries Association (AIA)
Supporting Organizations:	Bombardier, Inc. 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 non-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 in current production and in-development non-FBW TCA type designs: a. Low airspeed caution alerting; b. Bank angle alerting and recovery guidance display systems; c. 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; 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 (PFDs). 2. CAST-represented airplane manufacturers review the communication and its applicability to their in current production and in-development non-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 their response. b. If the feature is currently expected to be incorporated on an in current production and in-development non-FBW TCA type design, the manufacturers should note this in their 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 non-FBW TCA 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 low airspeed caution alerting in current production and in-development non-fly-by-wire (non-FBW) transport category airplane (TCA) type designs.
Lead Organization:	Aerospace Industries Association (AIA)
Supporting Organizations:	Bombardier, Inc. 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 low airspeed caution alerting in current production and in-development non-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 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.
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:	Output extended from original date of 6/30/2016 to 7/31/2017.
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:	8/3/2017 output closed 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 non-fly-by-wire (non-FBW) transport category airplane (TCA) type designs.
Lead Organization:	Aerospace Industries Association (AIA)
Supporting Organizations:	Bombardier, Inc. 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 alerting and recovery guidance in current production and in-development non-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 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.
Financial Resources:	Total: $0.6M (2.2 Full Time Equivalent (FTE))
Itemized Resources:	Manufacturers: 2.0 FTE (1.0 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:	Output extended from original date of 6/30/2016 to 7/31/2017.
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:	8/3/2017 output closed 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 (flightpath, acceleration, and speed deviation) in a manner similar to modern head-up displays, in current production and in-development non-fly-by-wire (non-FBW) transport category aircraft (TCA) type designs.
Lead Organization:	Aerospace Industries Association (AIA)
Supporting Organizations:	Bombardier, Inc. 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 virtual day-VMC displays, such as synthetic vision or equivalent systems, and the full-time presentation of energy state cues (flightpath, acceleration, and speed deviation) in a manner similar to modern head-up displays, in current production and in-development non-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.
Financial Resources:	Total: $0.8M (3.2 Full Time Equivalent (FTE))
Itemized Resources:	Manufacturers: 3.0 FTE (1.5 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:	• 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 is complete for manufacturers to complete studies • 24 months after research is complete 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. SE 192 being revised to recommend after-market implementation of low airspeed alerting on targeted fleets.

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 1233—To improve flight crew awareness of low airspeed, manufacturers should develop and regulators should ensure implementation of systems that alert flight crews when the airplane reaches its minimum maneuvering speed (i.e., "top of amber band") on airplanes with no (or with overrideable) flight envelope protection, iaw 25.1322 at amdt 25–131. 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). *Virtual Day-VMC Displays and Energy State Cues* 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—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 Display (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.