Safety Enhancement SE 200.1 ASA – Design – Virtual Day-VMC Displays	
Safety Enhancement Action:	Manufacturers develop and implement virtual day-visual meteorological conditions (VMC) display systems, such as synthetic vision or equivalent systems, which will support flight crew attitude awareness similar to a day-VMC-like environment, in applicable new transport category airplane (TCA) programs. Implementation of virtual day-VMC displays will be in accordance with each manufacturer's design philosophy and product development strategy and may be contingent (as applicable) upon internal manufacturer review and acceptance of the research findings and standards development. Applicable new TCA programs include: • New type certificate programs • Major derivative, amended type certificate programs involving redesign of flight deck avionics at the manufacturer's discretion
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) Industry standards committee
Statement of Work:	A CAST study of 18 loss-of-control events determined that lack of external visual references (i.e., darkness, instrument meteorological conditions, or both) was associated with flight crew loss of attitude awareness or energy state awareness in 17 events. To provide visual cues necessary to prevent loss of control resulting from flight crew spatial disorientation and loss of energy state awareness, manufacturers should develop and implement virtual day-VMC display systems, such as synthetic vision or equivalent systems, which support flight crew attitude awareness similar to a day-VMC-like environment. For the purpose of this safety enhancement (SE), "virtual day-VMC displays" describe systems that have the following elements: • Presented full time in the primary field-of-view • Presented to both flight crew members • Include display of energy state cues, including flight path, acceleration, and speed deviation, in a manner similar to modern head-up displays These systems should be implemented on applicable new TCA programs, pending internal manufacturer review and acceptance of ongoing research activities on such systems.

Total Financial Resources:	**<u>Total:</u>** **<u>$12.8M + program development costs</u>** Output 1: $7.0M Output 2: $5.8M Output 3: see output notes
Relation to Current Aviation Community Initiatives:	• Radio Technical Commission for Aeronautics (RTCA) Standards Committee–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 • CAST SE 113 – CFIT – Synthetic Vision Systems
Performance Goal Indicators:	<u>Estimated Risk Reduction</u> 2018 –- 0.0% 2025 – 8.0% 2035 – 16.0% The estimated risk reduction scores assume the following implementation levels in applicable new TCA programs for the U.S. commercial air carrier system, based on a JIMDAT fleet projection: • 0% by the end of 2018 • 15% by the end of 2025 • 30% by the end of 2035 <u>Implementation</u> SE Implementation will be tracked by JIMDAT through periodic reports from the manufacturers through their JIMDAT member representatives. <u>Effectiveness</u> Effectiveness 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.

<table>
<tr><td>Key Milestones:</td><td>
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<tr><th></th><th>Flow time (months)</th><th>Start Date</th><th>End Date</th></tr>
<tr><td>Output 1:</td><td>51</td><td>12/31/13</td><td>3/31/2018</td></tr>
<tr><td>Output 2:</td><td>69</td><td>12/31/13</td><td>9/30/2019</td></tr>
<tr><td>Output 3:</td><td>84</td><td>12/31/13</td><td>12/31/2020</td></tr>
<tr><td>Completion:</td><td>84</td><td>12/31/13</td><td>12/31/2020</td></tr>
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</td></tr>
<tr><td>Potential Obstacles:</td><td>Virtual day-VMC display requirements are currently not standardized. Depending on each manufacturer’s implementation plan, adoption of this SE may benefit from completion of associated research to define minimum display size, features and attributes, etc., for virtual day-VMC displays to be used to prevent spatial disorientation. While not a requirement for manufacturer implementation, subsequent definition of these minimum system requirements in a published standards document (e.g., RTCA DO 315) may reduce the implementation and certification risk for some future programs.</td></tr>
<tr><td>Detailed Implementation Plan Notes:</td><td>To provide flight deck displays capable of effectively eliminating the occurrence of spatial disorientation and to further improve flight crew awareness of energy state, manufacturers should develop full time virtual day-VMC displays as described in the SE Statement of Work. Depending on each manufacturer’s implementation plan, implementation of virtual day-VMC displays may benefit from completion of associated research as described in Output 2. 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 (see Output 3).</td></tr>
<tr><td>CICTT Code:</td><td>Loss of Control–Inflight (LOC–I)</td></tr>
<tr><td colspan="2">Output 1:</td></tr>
<tr><td>Description:</td><td>Research studies publish findings to support definition of minimum requirements for virtual day-visual meteorological conditions (VMC) displays to accomplish the intended function of improving flight crew awareness of airplane attitude.</td></tr>
<tr><td>Lead Organization:</td><td>National Aeronautics and Space Administration (NASA)</td></tr>
<tr><td>Supporting Organizations:</td><td>Airbus
Aerospace Industries Association (AIA)
AIA-represented manufacturers and avionics suppliers
Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)
FAA Flight Standards Service (AFS)
The Boeing Company</td></tr>
<tr><td>Implementers:
(Select all that apply)</td><td>☐ Air Carrier
☒ Industry Association
☒ Research Organization
☐ Labor Organization</td></tr>
</table>

	☐ Commercial Aviation Safety Team (CAST) ☐ Joint Implementation Measurement and Data Analysis Team (JIMDAT)	☒ Manufacturer ☒ Regulator ☐ Other (specify) _____
Actions:	1. NASA, supported by various industry and regulatory research programs, will review, sponsor and coordinate projects studying the effectiveness of virtual day-VMC displays in improving flight crew awareness of airplane attitude as a function of various system characteristics, including but not limited to— a) Field of view; b) Presentation/removal of virtual day-VMC displays in unusual attitudes/ c) Image minification; d) Optical flow cues— i. Display elements over water or featureless terrain and ii. Use of color and texture; and e) Potential unintended consequences (e.g., attentional issues, crew resource management (CRM) impacts). 2. NASA will coordinate a review of existing literature and contracted research to determine if additional studies are required to meet the objectives listed in action 1. If additional studies are required, NASA will coordinate with the appropriate research organizations, amend existing research programs, or develop new requests for proposal (RFPs), as applicable. 3. When complete, NASA will publish reviews and findings in open publications and report completion to JIMDAT and CAST.	
Financial Resources:	Total: $7.0M (NASA contracts and manufacturer support)	
Itemized Resources:	NASA: $5.0M (contract awards, NASA labor, simulation, and flight test cost) Manufacturers: $2.0M (contract support) Notes: • For labor, 1 Full Time Equivalent (FTE) = $250K • 4 manufacturers of Title 14, Code of Federal Regulations (14 CFR) part 25 airplanes operated in U.S. 14 CFR part 121 operations are represented at CAST – Airbus (CAST member) – Boeing (CAST member) – Bombardier (represented by Aerospace Industries Association) – Embraer (represented by Aerospace Industries Association)	
Output Notes:	This output ties to research currently underway in NASA's Spatial Disorientation/Loss of Energy State Awareness (SD/LESA) Study, which is already funded. The additional itemized costs are estimates of	

	potential additional research funding required to study remaining elements, if necessary. It is not expected that NASA will fund and/or perform all required research, but should act as a central coordinator, collector, and reviewer of applicable studies and findings.
Time Line:	• 51 months to review existing research and identify additional tasking, if needed; modify existing contracts or issue requests for proposal, as applicable; and complete all research and publish findings.
Target Completion Date:	3/31/2018
Output 2:	
Description:	Standards and regulatory guidance material to support definition of minimum requirements for virtual day-visual meteorological conditions (VMC) displays to accomplish the intended function of improving flight crew awareness of airplane attitude. .
Lead Organization:	Federal Aviation Administration (FAA) Aircraft Certification Service (AIR)
Supporting Organizations:	Aerospace Industries Association (AIA) AIA-represented manufacturers and avionics suppliers Air Line Pilots Association (ALPA) Airbus European Aviation Safety Agency (EASA) Transport Canada Civil Aviation 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) _Industry standards committee
Actions:	1. FAA AIR will formally task the appropriate industry standards activity (e.g., Radio Technical Commission for Aeronautics Standards Committee (RTCA)–213 or SAE) to incorporate the research from Output 1 into an appropriate document standards document (e.g., RTCA DO-–315). The standards should define the tradeoffs between effectiveness of virtual day-VMC displays in improving flight crew awareness of airplane attitude with system design variables and specifying minimum requirements for these parameters, including but not limited to— a) Field of view; b) Presentation/removal of virtual day-VMC displays in unusual attitudes; c) Image minification; d) Optical flow cues— i. Display elements over water or featureless terrain and

	ii. Use of color and texture; and e) Potential unintended consequences (e.g., attentional issues, crew resources management (CRM) impacts). 2. FAA AIR will review the standards and publish appropriate guidance material or Technical Standard Orders (TSO), as applicable. 3. FAA AIR will track implementation and report progress to JIMDAT and CAST.
Financial Resources:	Total: $5.8M (21.0 Full Time Equivalent (FTE), $0.5M travel and administrative support)
Itemized Resources:	Manufacturers: 10.0 FTE / $250K travel to support standards committee work ALPA: 1.0 FTE / $25K travel to support standards committee work Air Carriers: 1.0 FTE / $25K travel to support standards committee work FAA AIR: 2.0 FTE / $50K travel to support standards committee work FAA AFS: 2.0 FTE / $50K travel to support standards committee work EASA: 1.0 FTE / $25K travel to support standards committee work MITRE: 1.0 FTE / $25K travel to support standards committee work NASA: 2.0 FTE / $50K travel to support standards committee work FAA AIR 1.0 FTE to develop and publish guidance material or TSO, as applicable. <u>Standards committee cost estimate per member:</u> • Assume 20 committee members working for 2 years • Assume each member works 0.25 FTE per year − 4 meetings per year, for 1 week each − 1 week per non-meeting month for support of committee work • Assume additional 0.25 FTE per organization for additional support within organization • Total labor per member organization = 1.0 FTE (0.5 FTE per year for 2 years) • Assume half domestic and half foreign travel for meetings − 4 domestic trips @ $1,500 per member = $6K − 4 foreign trips @ $4,000 per member = $16K − Total travel budget of $25K per member • Assume additional ~$25K in administrative support Notes: • For labor, 1 FTE = $250K

Output Notes:	• Standards work will overlap and proceed in parallel with the research activity in Output 1. • While not explicitly required for adoption of virtual day-VMC displays, these standards and guidance may reduce development and certification risk for some manufacturers' installations, and thus may be on their critical path for those manufacturers' implementation.
Time Line:	• 12 months after CAST approval for FAA to task industry standards committee • 6 months after completion of Output 1 for standards committee to complete work • 12 months after FAA receives standards to publish guidance (18 months from completion of Output 1)
Target Completion Date:	9/30/2019 (Cascade delay from OP1 extension. OP2 originally 6/30/2018).
Output 3:	
Description:	Manufacturers establish implementation plans to incorporate virtual day-visual meteorological conditions (VMC) displays in applicable new transport category airplane (TCA) programs, in accordance with each manufacturer's design philosophy and product development strategy. To minimize development and certification risk, implementation of virtual day-VMC displays may, at each manufacturer's discretion, be contingent upon their review and acceptance of applicable research findings and industry standards established in Outputs 1 and 2.
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. Airplane manufacturers will review and incorporate, as applicable, study results/recommendations from the research conducted under Output 1 and the standards produced under Output 2. 2. Airplane manufacturers implement virtual day-VMC displays in applicable new TCA programs, in accordance with each manufacturer's design philosophy and product development strategy and contingent (as applicable) upon internal manufacturer review and acceptance of the research findings and standards developed in Outputs 1 and 2. 3. AIA will track implementation and report progress to CAST.
Financial Resources:	See below
Itemized Resources:	Many costs associated with implementing this feature would occur as part of any new airplane program;

	therefore only incremental development costs should be considered. These incremental costs depend on many factors and the total cost to provide this functionality in the future airplane fleet depends upon the number of airplane programs that implement it, with initial development costs being higher on the first program to incorporate the feature and significantly reduced development costs for implementation in follow-on programs. Taken together, the variations of possible scenarios make it impractical to estimate a single, total cost for this output. The manufacturers on the Joint Safety Implementation Team (JSIT) instead developed a range of potential development costs which are provided here for reference. The JSIT anticipates the costs to incorporate this feature in a new airplane program, while not insignificant, will likely be small in comparison to total program cost. <u>Estimated incremental development costs per program:</u> Incremental program (per manufacturer) cost estimates for additional engineering work expected to implement this feature in a new airplane program were estimated for current technology synthetic vision systems or similar displays. Other implementations, such as synthetic vision fused with enhanced vision systems, would have higher costs. • Manufacturer engineering and pilot hours: 15,000–50,000 • Avionics supplier engineering hours: 25,000–40,000 • Simulator time: 100–300 hours, dedicated • Flight test time: 20–50 hours, dedicated • Parts: none (software only, will use same displays) Based on these estimates, the JSIT anticipates that development costs of virtual day-VMC displays (for the initial program) may run in the range of $6M to $15M for each manufacturer. Follow-on programs would have reduced costs. These estimates account for the following elements: 1. Design – airplane manufacturers: a) Definition of avionics requirements (e.g., graphics/throughput) to support functionality. b) Integration of system into manufacturer's flight deck and do initial functional validation. 2. Install/Build- avionics suppliers: a) Code creation. b) Line replaceable unit (LRU) assembly. c) Software delivery. 3. Test – airplane manufacturers and avionics supplies:

	a) Software qualification. b) Functional verification. c) Integration. d) Ground and flight tests. e) Fault testing. 4. Certification – airplane manufacturers and regulators: a) Application and project planning. b) Certification plan and basis (requirements definition), identify means of compliance. c) Component compliance findings. d) Conformity and test observation. e) Review data and final compliance finding. 5. Training/Flight Operations – airplane manufacturers: a) Engineering course/procedures development. b) Update manuals. c) Develop training materials. d) Update simulators.
Output Notes:	This output assumes completion in conjunction with a new airplane development effort and, therefore, specific completion timelines are dependent upon new airplane development program schedules.
Time Line:	• 84 months after CAST approves safety enhancement (SE) to launch on a new airplane program • 144 months after CAST approves SE to achieve 2025 risk reduction expected.
Target Completion Date:	12/31/2020

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 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 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.