

SECTION I: SE OVERVIEW

Study Topic Overview Summary CAST chartered the Airplane State Awareness (ASA) Joint Safety Analysis Team (JSAT) in August 2010 and the ASA Joint Safety Implementation Team (JSIT) in 2012 as a follow-on activity to the previous Loss of Control (LOC) JSAT in 2000. Historically, Loss of Control-Inflight (LOC-I) has been, and continues to be, one of the largest categories of commercial aviation fatal accidents. Loss of ASA is a subset of LOC-I accidents and incidents, defined as events in which the flightcrew lost awareness of the airplane’s attitude or energy state. Between 2001 and 2010, half of all LOC-I accidents involved loss of ASA. The ASA JSIT recommended, and CAST adopted, 19 ASA SEs, 7 of which focus on airplane design.

The ASA JSAT study of 18 LOC events determined that lack of external visual references (such as darkness, instrument meteorological conditions, or both) was associated with flightcrew loss of attitude awareness or energy state awareness in 17 events.

SE Objective CAST recommends manufacturers develop and implement virtual day-visual meteorological conditions (VMC) display systems,¹ such as synthetic vision or equivalent systems, which will support flightcrew attitude awareness similar to a day-VMC-like environment, in applicable new transport category aircraft (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, and
- Major derivative, amended type certificate programs involving redesign of flightdeck avionics at the manufacturer’s discretion.

Primary Risks Mitigated Loss of Control-Inflight (LOC-I)

Action	Organization(s)	Strategy	Description	Due Date
Action 1	NASA	Research	Publish research findings to support definition of minimum requirements for virtual day-VMC displays to improve flightcrew awareness of aircraft attitude.	09/30/2018
<i>Comments: CAST closed this action based on completed NASA research. JIMDAT will review reports and recommend appropriate follow-on actions.</i>				
Action 2	FAA AIR	Standards	Publish standards and regulatory guidance material to support definition of minimum requirements for virtual day-VMC displays to improve flightcrew awareness of aircraft attitude.	06/30/2021

¹ For the purpose of this SE, “virtual day-VMC displays” describe systems that have the following elements:

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



SECTION I: SE OVERVIEW

Action	Organization(s)	Strategy	Description	Due Date
Action 3	Aircraft Manufacturers	Equipment	Establish implementation plans to incorporate virtual day-VMC displays in applicable new TCA programs.	12/31/2020
<p><i>Comments: CAST closed this action based on Airbus and Boeing reporting they have programs in place to install Day-VMC displays in new type designs and retrofits into in-production and out-of-production models as feasible.</i></p>				

See section II of this SE for detailed action descriptions.

References: The detailed analysis in the ASA JSAT Final Report (June 5, 2015) and the ASA JSIT Final Report (December 31, 2014) is available through CAST.



TABLE OF CONTENTS

SECTION II: DETAILED ACTION INFORMATION

PAGE 4

SE 200 consists of three actions, which this section lays out in detail.

- **Action 1 (NASA)**PAGE 4
Conduct research to support definition of minimum requirements for virtual day-VMC displays
- **Action 2 (FAA AIR)**PAGE 5
Update standards/guidance to support definition of virtual day-VMC display requirements
- **Action 3 (Aircraft Manufacturers, AIA)**PAGE 6
Establish virtual day-VMC display implementation plans for applicable TCA programs

SECTION III: SUPPLEMENTAL INFORMATION

PAGE 7

This section contains the following additional information that may be of interest to implementers:

- Source Study
- Related Initiatives
- Total Cost / Resource Overview

SECTION IV: REVISION LOG

PAGE 10

This section provides a history of revisions to this SE.



SECTION II: DETAILED ACTION INFORMATION

Action 1: Conduct research to support definition of minimum requirements for virtual day-VMC displays

Primary Implementer

National Aeronautics and Space Administration (NASA)

Action Objective

NASA should conduct research studies to support definition of minimum requirements for virtual day-visual meteorological conditions (VMC) displays to accomplish the intended function of improving flightcrew awareness of aircraft attitude.

Action Timeline

Flow Time: 57 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

Due Date: 09/30/2018

Timeline/Flow for Future Adopters

TBD

CAST Lead

NASA

#	Organization(s)	Detailed Steps
1a	NASA	Supported by various industry and regulatory research programs, review, sponsor and coordinate projects studying the effectiveness of virtual day-VMC displays in improving flightcrew awareness of aircraft 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. ii. Use of color and texture. e. Potential unintended consequences (such as attentional issues, and crew resource management impacts).
<i>Complete.</i>		
1b	NASA	Coordinate a review of existing literature and contracted research to determine if additional studies are required to meet the objectives listed in Subaction 1a. If additional studies are required, coordinate with the appropriate research organizations, amend existing research programs, or develop new requests for proposal, as applicable.
<i>Complete.</i>		
1c	NASA	When complete, publish reviews and findings in open publications and report completion to JIMDAT and CAST.
<i>NASA research complete. JIMDAT will review reports and recommend appropriate follow-on actions.</i>		

Notes

SECTION II

Note: See Section III for detailed costs and resources.



SECTION II: DETAILED ACTION INFORMATION

Action 2: Update standards/guidance to support definition of virtual day-VMC display requirements

Primary Implementer

FAA Aircraft Certification Service (AIR)

Action Objective

FAA AIR should update 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 flightcrew awareness of aircraft attitude.

Action Timeline

Flow Time: 30 months

- 12 months after CAST approval for FAA to task industry standards committee
- 6 months after completion of [Action 1](#) for standards committee to complete work
- 12 months after FAA receives standards to publish guidance (18 months from completion of Action 1)

Due Date: 06/30/2021

Timeline/Flow for Future Adopters

TBD when CAST closes this action.

CAST Lead

FAA AIR

#	Organization(s)	Detailed Steps
2a	FAA AIR	Formally task the appropriate industry standards activity (for example, RTCA-213 or SAE International) to incorporate the research from Action 1 into an appropriate document standards document (for example, RTCA DO-315). The standards should define the tradeoffs between effectiveness of virtual day-VMC displays in improving flightcrew awareness of aircraft attitude with system design variables and specifying minimum requirements for these parameters, including but not limited to— <ol style="list-style-type: none"> a. Field of view. b. Presentation/removal of virtual day-VMC displays in unusual attitudes. c. Image minification. d. Optical flow cues: <ol style="list-style-type: none"> i. Display elements over water or featureless terrain. ii. Use of color and texture. e. Potential unintended consequences (such as attentional issues, and crew resource management impacts).
2b	FAA AIR	Review the standards and publish appropriate guidance material or technical standard orders, as applicable.
2c	FAA AIR	Track implementation and report progress to JIMDAT and CAST.

Notes

- Standards work will overlap and proceed in parallel with the research activity in Action 1.
- Although 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.



SECTION II: DETAILED ACTION INFORMATION

Action 3: Establish virtual day-VMC display implementation plans for applicable TCA programs

Primary Implementer

Aircraft Manufacturers

Action Objective

Aircraft manufacturers should establish implementation plans to incorporate virtual day-visual meteorological conditions (VMC) displays in applicable new transport category aircraft (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 [Action 1](#) and [Action 2](#).

Action Timeline

Flow Time: 84 months

- 84 months after CAST approves SE to launch on a new aircraft program
- 144 months after CAST approves SE to achieve 2025 risk reduction expected

Due Date: 12/31/2020

Timeline/Flow for Future Adopters

TBD

CAST Lead

Aerospace Industries Association (AIA)

#	Organization(s)	Detailed Steps
3a	Aircraft Manufacturers	Review and incorporate, as applicable, study results/recommendations from the research conducted under Action 1 and the standards produced under Action 2.
	<i>Complete.</i>	
3b	Aircraft 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 Actions 1 and 2.
	<i>Complete.</i>	
3c	AIA	Track implementation and report progress to CAST.
	<i>Complete.</i>	

Notes

This action assumes completion in conjunction with a new aircraft development effort and, therefore, specific completion timelines are dependent upon new aircraft development program schedules.



SECTION III: SUPPLEMENTAL INFORMATION

Source Study ASA Joint Safety Analysis Team (JSAT) Final Report (June 5, 2014)
ASA Joint Safety Implementation Team (JSIT) Final Report (December 31, 2014)

- Related Initiatives**
- RTCA Standards Committee–213: Enhanced Flight Vision Systems and Synthetic Vision Systems
 - 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

Total Cost	\$12,750,000	<i>Note: For labor, 1 Full Time Equivalent (FTE) = \$250,000</i>
<u>Action 1</u>	\$7,000,000	NASA contracts and manufacturer support. ²
<u>Action 2</u>	\$5,750,000	21 FTE Plus \$500,000 travel and administrative support.
<u>Action 3</u>	See below	

	Organization	Resources Needed
<i>Direct Resource Overview – Government</i>	FAA AFS	<ul style="list-style-type: none"> • Action 2: 2.0 FTE/\$50,000 travel to support standards committee work.³
	FAA AIR	<ul style="list-style-type: none"> • Action 2: 2.0 FTE/\$50,000 travel to support standards committee work; 1.0 FTE to develop and publish guidance material or TSO, as applicable.³
	NASA	<ul style="list-style-type: none"> • Action 1: \$5,000,000 (contract awards, NASA labor, simulation, and flight test cost). • Action 2: 2.0 FTE/\$50,000 travel to support standards committee work.³

² This action 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.

³ Standards committee cost estimate per member:

- 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 = \$6,000
 - 4 foreign trips @ \$4,000 per member = \$16,000
 - Total travel budget of \$25,000 per member
- Assume additional ~\$25,000 in administrative support



SECTION III: SUPPLEMENTAL INFORMATION

	Organization	Resources Needed
<i>Direct Resource Overview – Industry</i>	Air Carriers	<ul style="list-style-type: none"> Action 2: 1.0 FTE/\$25,000 travel to support standards committee work.⁴
	Aircraft Manufacturers	<ul style="list-style-type: none"> Action 1: \$2,000,000 (contract support). Action 2: 10.0 FTE/\$250,000 travel to support standards committee work.⁴ <p><i>Note: Four manufacturers of Title 14, Code of Federal Regulations (14 CFR) part 25 aircraft operated in U.S. 14 CFR part 121 operations are represented at CAST:</i></p> <ul style="list-style-type: none"> o Airbus (CAST member), o Boeing (CAST member), o Bombardier (represented by AIA), and o Embraer (represented by AIA).
	ALPA	<ul style="list-style-type: none"> Action 2: 1.0 FTE/\$25,000 travel to support standards committee work.⁴
	EASA	<ul style="list-style-type: none"> Action 2: 1.0 FTE/\$25,000 travel to support standards committee work.⁴
	MITRE	<ul style="list-style-type: none"> Action 2: 1.0 FTE/\$25,000 travel to support standards committee work.⁴

⁴ Standards committee cost estimate per member:

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Assume additional ~\$25,000 in administrative support



SECTION III: SUPPLEMENTAL INFORMATION

*Action 3
Resource
Overview*

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 action. The manufacturers on the ASA 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.

Estimated incremental development costs per program:

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: 15,000–25,000.
- 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 \$6 million to \$15 million 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.



SECTION III: SUPPLEMENTAL INFORMATION

- b) Update manuals.
- c) Develop training materials.
- d) Update simulators.

*Indirect
Resource
Overview*

The organizations identified in this section are not expected to incur direct costs associated with implementing this SE, but they may incur indirect costs within their normal line of work.

Organization	Description
N/A	N/A



SECTION IV: REVISION LOG

Major revisions (whole numbers) represent CAST-approved changes to SE language. Minor revisions (decimals) represent minor changes to target dates or completion notes that do not affect implementer actions.

Revision	Date	Description
1.5	11/02/2020	Action 2 due date extended from 12/31/2020 to 06/30/2021.
1.4	08/06/2020	Action 3 closed.
1.3	12/05/2019	Action 2 due date extended from 12/31/2019 to 12/31/2020.
1.2	10/03/2019	Action 2 due date extended from 09/30/2019 to 12/31/2019.
1.1	10/04/2018	Action 1 closed.
1.0	09/17/2018	New SE format. Content reorganized and terminology updated. No substantive changes.
0.2	02/01/2018	Action 1 due date extended from 03/31/2018 to 09/30/2018.
0.1	10/06/2016	Action 1 due date extended from 12/31/2016 to 03/31/2018. Action 2 due date extended from 06/30/2018 to 09/30/2019.
Original	12/04/2013	CAST adopted SE 200.

