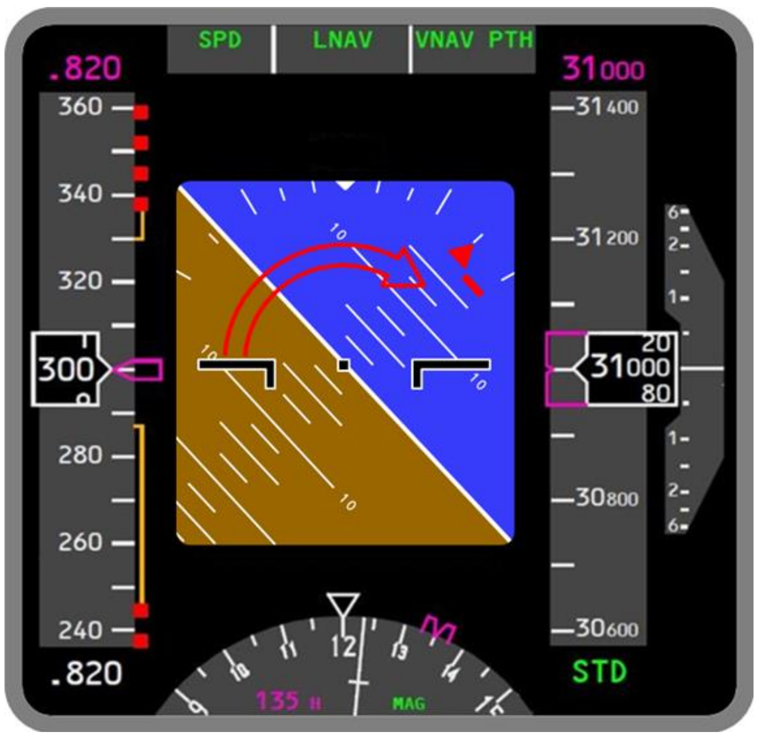
Airplane State Awareness
Joint Safety Implementation Team



Final Report
Analysis and Recommendations

June 17, 2014

Airplane State Awareness
Joint Safety Implementation Team
Final Report

Provided to the Commercial Aviation Safety Team

from

The Airplane State Awareness Joint Safety Implementation Team

June 17, 2014

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OVERVIEW

In October 2011, the Airplane State Awareness (ASA) Joint Safety Analysis Team (JSAT) completed its analysis of several transport airplane accidents and incidents associated with flightcrew loss of attitude or energy state awareness. The results and recommendations of that study were presented to the Commercial Aviation Safety Team (CAST) in December 2011. In response, CAST chartered the ASA Joint Safety Implementation Team (JSIT) to review all ASA JSAT intervention strategies (IS), assess them for feasibility, and develop new safety enhancements (SE) for the CAST Safety Plan.

The ASA JSIT launched in March 2012 and completed its work in June 2013, proposing 11 new Training, Operations, and Design CAST SEs. These SEs are predicted to reduce the risk of future ASA accidents in the United States by approximately 70 percent by 2018 and 80 percent by 2025. The ASA JSIT Safety Portfolio also includes five research and development (R&D) proposals and three design feasibility studies to provide additional information that may form the basis of future SEs.

FEASIBILITY ASSESSMENT

All ISs were rated for feasibility using the CAST JSIT process[1] on the basis of technical, financial, operational, schedule, regulatory, and social feasibility. Feasibility scores were established by consensus within each of three subteams (Design, Training, and Airline Operations) and averaged into an overall feasibility (F) score for each IS. F scores were multiplied with the ASA JSAT overall effectiveness (OE) scores for each IS to calculate a final "OExF" overall score. The ISs were then ranked by OExF for a final prioritized ranking, color-coding the scores for OE and F in accordance with the JSIT Process Handbook guidance and using past JSITs to develop breakpoints for the color boundaries.

The ASA JSIT then reviewed the color-coded ranking to determine a suitable cutoff value for advancing the highest value ISs for further evaluation. A cutoff value of 4.7 OExF was selected based on the following factors:

- A "natural" break in the ranking based on combinations of medium effectiveness and low feasibility or low effectiveness with medium feasibility;
- A reasonable balance of ISs from Design, Training, and Operations categories remaining above the cutoff;
- Consistency of percentage of ISs to advance to SEs, compared to past JSITs; and
- A "sanity check" that all ISs above the proposed cutoff were well understood by the team and that the scoring was appropriate.

Eighty-one unique ISs ranked above the cutoff and were used to develop new SEs. ISs with an OExF score below the cutoff were not used to develop new CAST SEs by the ASA JSIT; however, they were retained for review during final SE development and were included in SEs if by doing so they would strengthen the SE without contributing to its cost.

[1] See CAST JSIT Process Handbook, Revision B, July 2, 2007, for details on the JSIT process.

SAFETY ENHANCEMENTS

Interventions scoring above the cutoff value were grouped by affinity into SE concepts. In addition, high-leverage R&D interventions were identified based on the scores of the problem statements they addressed and their synergy with the SE concepts. These were presented to CAST in August 2012 and received initial approval in October 2012.

The ASA JSIT then developed Detailed Implementation Plans (DIP) based on the approved SE concepts. For the Training and Airline Operations concepts, the subteams developed some concepts directly into final SEs and combined other concepts into final SEs where synergy existed to do so. The team also delegated one concept related to air traffic control issues to the CAST Runway Excursion Joint Safety Analysis and Implementation Team, and dropped one concept related to maintenance procedures after the team determined that all recommended actions are already required by regulation in the United States. The proposed Training and Operations SEs focus primarily on the following:

- Revisions and improvements to existing flightcrew training in upset prevention and recovery, including revised approach-to-stall training;
- Revisions to go-around training;
- Policies and training for prioritizing controlled flight in non-normal situations;
- Training verification and validation;
- Enhancement of crew resource management (CRM) training to further define the duties of the pilot monitoring as a CRM practice;
- Monitoring and understanding of habitual noncompliance to standard operating procedures (SOP) and improvements to SOPs; and
- Policies for conducting non-standard, non-revenue flights.

For the Design concepts, the Design Subteam assessed the risk reduction of those features already implemented in new airplane designs, and determined which features would further reduce the risk to *new airplane* designs from ASA issues. As a result, the ASA JSIT developed three DIPs for final SEs related to *new airplane* design features:

- Bank angle protection in fly-by-wire (FBW) designs only, if not already part of the FBW control system;
- Bank angle alerting with recovery guidance; and
- Virtual day-visual meteorological condition (VMC) displays (such as synthetic vision or an equivalent system) with energy state symbology cues.

The team also identified features that, if implemented in existing designs and/or future production of current designs, could significantly reduce risk of future ASA-type events. The team then recommended manufacturers further assess the model-specific feasibility and risk reduction that would result from incorporation of these features in existing designs. The features for study in *existing airplane* designs are—

- Bank angle protection (in existing FBW designs only), if not already part of the FBW control system;
- Bank angle alerting with recovery guidance;
- Virtual day-VMC displays (such as synthetic vision or an equivalent system) with energy state symbology cues; and
- Low airspeed alerting (existing non-FBW designs only).

In developing DIPs for each SE, the team identified tangible outputs to accomplish the intent of the SE, the specific actions required to complete each output, and the parties that should undertake the actions. The team then estimated costs to accomplish the actions and a flow time for each output. Lastly, the team estimated the event risk reduction of future ASA-type events based on accomplishment of all SE outputs at full expected implementation. A summary of the SEs is presented in figure 1, and a summary of the manufacturer feasibility studies is presented in figure 2.

SE	Title	% Risk Reduction	Implementers / Costs ($M)								Flow (mos.)
			Air Carriers	Manufacturers	Regulators	Associations	Labor Orgs	Researchers	Others	Total	
192	Low Airspeed Alerting	9.6%	$0.3							$0.3	16
193	Non-standard Operations	3.9%	$4.1		$0.5	$0.1				$4.7	36
194	SOP Adherence	21.4%	$18.5			$0.2				$18.7	42
195	Training Verification & Validation	10.1%	$4.0			$0.1				$4.1	42
196	Upset Prevention and Recovery Training, Including Stall	17.1%	$3.1	$4.4	$0.3	$0.3	$0.1			$8.2	42
197	Policy and Training for Non-normal situations	10.9%	$1.1			$0.1				$1.2	36
198	Scenario-Based Training for Go-Arounds	12.7%	$0.8	$0.2	$0.3	$0.1	$0.1			$1.5	42
199	Enhanced CRM Training	28.2%	$10.8		$0.3	$0.2	$0.1			$11.4	60
200	Virtual Day-VMC Displays	16.0%†	$0.3	$17.9[1]	$1.6		$0.3	$5.5	$0.3	$25.9	84
201	Bank Alerting with Recovery Guidance	6.2%†		$6.1[2]						$6.1	84
202	Bank Angle Protection	5.0%†		$2.1[3]						$2.1	84
	Totals	**72.6%**	**$43.0**	**$30.7**	**$3.0**	**$1.6**	**$0.6**	**$5.5**	**$0.3**	**$84.2**	**84**

† for 2035 fleet implementation
[1] for 2 programs [2] for 2 programs [3] for 1 program

Figure 1. Summary of ASA Safety Enhancements

SE	Title	Implementers / Costs ($M)				Flow Time (mos.)
		Manufacturers	Industry Associations	JIMDAT	Total	
203	Study of recommended features in current and in-development FBW airplanes	$2.9	$0.1	$0.1	**$3.1**	24
204	Study of recommended features in current and in-development non-FBW airplanes	$1.6	$0.1	$0.1	**$1.8**	24
205	Study of recommended features in out-of-production airplanes	$3.5	$0.2	$0.2	**$3.9**	90
Total		**$8.0**	**$0.4**	**$0.4**	**$8.8**	**90**

Figure 2. Summary of ASA Manufacturer Feasibility Studies

As an independent check, the final SE portfolio was reviewed against the 12 ASA themes identified by the ASA JSAT from the most significant problems and contributing factors observed in the ASA event set. Figure 3 presents a high-level summary indicating themes present in each event, with yellow boxes marked with an "X." Figure 4 indicates, with green boxes, those themes addressed by actions in the ASA SE portfolio.

	Lack of External Visual References	Flight Crew Impairment	Training	Airplane Maintenance	Safety Culture	Invalid Source Data	Distraction	Systems Knowledge	Crew Resource Management	Automation Confusion / Awareness	Ineffective Alerting	Inappropriate Control Actions	Total
Formosa Airlines Saab 340	x	x			x		x	x	x		x		7
Korean Air 747-200F	x			x		x	x		x		x		6
Flash Airlines 737-300	x		x		x		x		x	x	x	x	8
Adam Air 737-400	x		x	x			x	x	x	x	x	x	9
Kenya Airways 737-800	x		x				x		x	x	x	x	7
Aeroflot-Nord 737-500	x	x	x	x	x		x	x	x	x	x	x	11
Gulf Air A320	x		x				x		x		x	x	6
Icelandair 757-200 (Oslo)	x						x		x	x	x	x	6
Armavia A320	x	x			x		x		x	x	x	x	8
Icelandiar 757-200 (Baltimore)	x				x	x	x	x	x	x	x	x	9
Midwest Express 717	x				x	x	x		x		x	x	7
Colgan Air DHC-8-Q400	x	x	x		x		x	x	x	x	x	x	10
Provincial Airlines DHC-8	x		x				x			x	x	x	6
Thomsonfly 737-800	x		x	x	x		x			x	x		7
West Caribbean MD-82	x	x			x		x	x	x	x	x	x	9
XL Airways A320		x	x	x	x	x	x	x	x	x	x		10
Turkish Airlines 737-800	x			x	x	x	x		x	x	x		8
Empire Air ATR-42	x	x			x		x		x	x	x		7
Overall	17	7	9	6	12	5	18	7	16	14	18	12	

Figure 3. ASA Themes from ASA JSAT

	Lack of External Visual References	Flight Crew Impairment	Training	Airplane Maintenance	Safety Culture	Invalid Source Data	Distraction	Systems Knowledge	Crew Resource Management	Automation Confusion / Awareness	Ineffective Alerting	Inappropriate Control Actions	Total
Formosa Airlines Saab 340								x					1
Korean Air 747-200F						x	x						2
Flash Airlines 737-300							x			x			2
Adam Air 737-400								x		x			2
Kenya Airways 737-800							x			x			2
Aeroflot-Nord 737-500		x					x	x		x			4
Gulf Air A320			x				x				x		3
Icelandair 757-200 (Oslo)										x	x		2
Armavia A320							x			x	x		3
Icelandair 757-200 (Baltimore)					x			x				x	3
Midwest Express 717					x							x	2
Colgan Air DHC-8-Q400							x	x					2
Provincial Airlines DHC-8							x						1
Thomsonfly 737-800													0
West Caribbean MD-82							x	x			x		3
XL Airways A320								x		x			3
Turkish Airlines 737-800					x					x			2
Empire Air ATR-42							x			x			2
Overall	0	1	1	0	3	1	10	7	0	9	4	2	

Figure 4. ASA Themes Addressed by ASA SE Portfolio

RESEARCH PROPOSALS

The team developed R&D DIPs from the R&D concepts approved in October 2012, emphasizing research in technologies that either address themes not addressed by the SE portfolio or otherwise could reduce implementation costs and/or certification risks of high-value design interventions. Six R&D concepts were approved by CAST; these were consolidated into five R&D plans, summarized in figure 5. For R&D, costs reflect estimates to move the technology or knowledge to a level required for handoff to industry; actual R&D costs are to be determined through each responsible organization's normal R&D planning process.

SE	Title	Theme Addressed	Implementers / Costs ($M)						Flow (mos.)
			Manufacturers	Regulators	Researchers	Others	TBD / Conditional	Total	
SE 207	Attitude and Energy State Awareness Technologies	Alerting	$2.0	$2.6	$7.0	-		**$11.6**	36
SE 208	Airplane System Awareness	Alerting, Distraction, Automation Confusion, System Knowledge	-	-	$6.0	-		**$6.0**	48
SE 209	Simulator Fidelity	Inappropriate Control Response, Training	-	$5.5	$3.0	$0.5	$5.5	**$14.5**	72
SE 210	Flight Crew Performance Assessments	Distraction, Automation Confusion	$2.5	$1.5	$6.5	$0.5		**$11.0**	60
SE 211	Training for Human Performance Attention Issues	Distraction, Automation Confusion, Training	-	$0.5	$2.5	$0.5		**$3.5**	60
Total			**$4.5**	**$10.1**	**$25.0**	**$1.5**	**$5.5**	**$46.6**	**72**

Figure 5. ASA Research Proposals

INTEGRATED SAFETY ENHANCEMENT PORTFOLIO

The ASA SEs are integrated into a coordinated safety plan, with the goal of balancing short-term tactical mitigations provided by operational and training programs against longer term, more strategic solutions resulting from improved design. Figure 6 presents an overview of each individual SE's cost-to-benefit comparison, where benefits were assessed as the expected value of cost avoided by preventing future U.S. accidents only. Based on the past rate of loss of control–inflight (LOC–I) accidents, the severity of LOC–I accidents (nearly always fully fatal), projections of fleet growth, and the U.S. Department of Transportation Value of a Statistical Life (VSL) of $9.1 million per fatality, the ASA JSIT estimated the cost of a single, fully fatal U.S. accident to be approximately $1,008 million. The benefits estimated are the probability of avoiding the associated cost of at least one future U.S. LOC–I accident.

Figure 7 shows how the full SE portfolio works together over time to reduce risk by balancing interventions related to airline operations, training, and airplane design. The results indicate the importance of both early implementation and continued emphasis of the Operations and Training SEs, as the majority of risk reduction comes from these SEs over the next two decades. At the same time, improved designs represent a strategic investment that will continue to grow into the future, resulting in a continually increasing benefit over time. When evaluated together, the 11 ASA SEs result in an approximate 80 percent overall risk reduction probability of future ASA events by 2025. For U.S. operations, this risk reduction results in a benefit-to-cost ratio of between 6-to-1 and 10-to-1, depending on the method used and assumptions made.

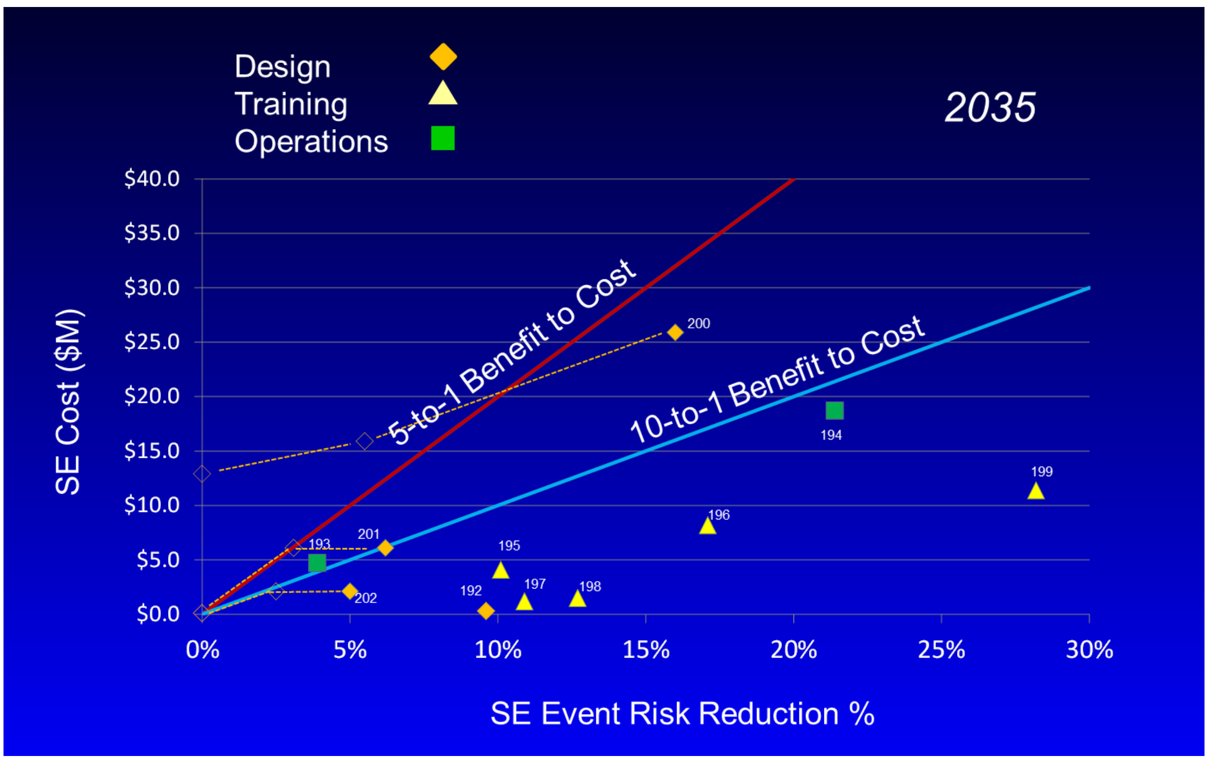

Figure 6. Individual SE Cost-Benefit Comparisons

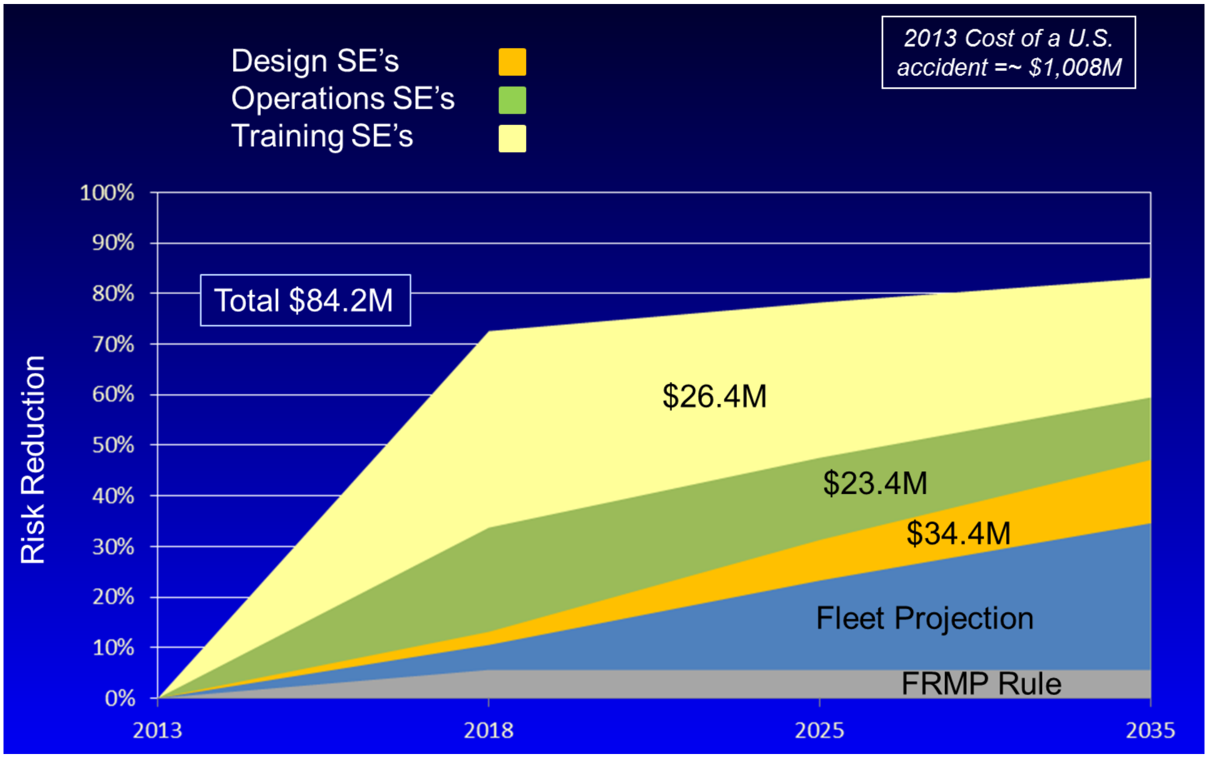

Figure 7. Risk Reduction of Full ASA SE Portfolio Over Time

CONCLUSION

The ASA SE portfolio was constructed by the ASA JSIT to provide near-term and far-term solutions that reinforce one another and provide a balanced, redundant approach to addressing the issue of ASA. The analysis estimates that implementation of the 11 Training, Operations, and Design SEs would reduce the risk of future ASA events approximately 70 percent by 2018 and 80 percent by 2025. The benefits predicted from the risk reduction probability achieved both by each individual SE and by the ASA portfolio as a whole exceed the costs by a ratio of between 6-to-1 and 10-to-1. Furthermore, the ASA JSIT used a cost estimation process that is generally conservative, relying on the highest costs provided by the parties, using a high cost value to estimate the cost of labor, and assuming that all parties enacting the SEs would incur all the associated cost (that is, no credit was given for the likely reality that some operators and manufacturers are already performing some of the actions recommended in the SEs).

The ASA JSIT recommends adoption by all U.S. CAST members of the 11 Training, Operations, and Design SEs detailed in this report, and further recommends these SEs be communicated to international aviation safety communities for their review and implementation where applicable. The ASA JSIT also recommends completion of the three recommended manufacturer feasibility studies and the five research proposals, with the goal of obtaining and using the knowledge gained to define potential future SEs.

APPENDIX A—DETAILED IMPLEMENTATION PLANS

This appendix contains a list of the 11 new ASA SEs in Table A–1 and 3 feasibility studies and 5 ASA R&D proposals as in Table A–2.

Table A–1. ASA Safety Enhancements

SE	Title
192	Low Airspeed Alerting
193	Non-standard Operations
194	SOP Adherence
195	Training Verification & Validation
196	Upset Prevention and Recovery Training, Including Stall
197	Policy and Training for Non-normal situations
198	Scenario-Based Training for Go-Arounds
199	Enhanced CRM Training
200	Virtual Day-VMC Displays
201	Bank Alerting with Recovery Guidance
202	Bank Angle Protection

Table A–2. ASA Feasibility Studies

SE	Title
203	Study of recommended features in current and in-development FBW airplanes
204	Study of recommended features in current and in-development non-FBW airplanes
205	Study of recommended features in out-of-production airplanes
207	Attitude and Energy State Awareness Technologies
208	Airplane System Awareness
209	Simulator Fidelity
210	Flight Crew Performance Assessments
211	Training for Human Performance Attention Issues

Brief descriptions of the SEs and links to the full detailed implementation plans are below.

Safety Enhancement SE 192 ASA – Design – Low Airspeed Alerting

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having Air Carriers implement low airspeed alerting on existing transport category airplane (TCA) type designs as practical and feasible.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents determined that low energy state and stall, resulting from flight crew loss of airplane state awareness (ASA), played a role in 8 events. To further improve early flight crew awareness of a decreasing energy state throughout the U.S. fleet, air carriers should implement existing manufacturer service bulletins to provide low airspeed alerting on existing transport category type designs as applicable.

Safety Enhancement SE 193 ASA – Operations - Non-Standard, Non−Revenue Flights:

Status: Underway

Background

The purpose of this Safety Enhancement is to improve the safety of non-standard flight, non-revenue operations (functional check flights, ferry flights, demonstration flights, etc.) To reduce accidents and incidents due to loss of airplane state awareness during high risk maneuvers in functional check flights, as well as in other non-standard, non-revenue flight operations:

1. Regulators should specify types of non-standard, non-revenue flights an air carrier is authorized to perform.

2. Air Carriers should perform an operational risk assessment for non-standard, non-revenue flight operations and develop related operational and training guidelines.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control events identified one accident in which flight crew members were not adequately prepared for a high risk test maneuver performed during a functional check flight.

Safety Enhancement SE 194 ASA – Operations – Standard Operating Procedures Effectiveness and Adherence

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having Air Carriers develop and implement improved Standard Operating Procedures (SOPs) to reduce flight crew member loss of airplane state awareness.

In a Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents, insufficient adherence to SOPs was a factor in 15 events. To improve flight crew adherence to SOPs and reduce the risk of lost awareness of airplane state, air carriers should:

1. Review, and update as needed, current SOPs for consistency with the CAST Plan, manufacturer recommendations, and air traffic control (ATC) procedures;

2. Assess level of adherence to current SOPs, identifying possible reasons for insufficient adherence to certain procedures; and

3. Develop training programs to provide pilots with rationale for SOPs, focusing on those with lower adherence rates.

Safety Enhancement SE 195 ASA – Training – Flight Crew Training Verification and Validation

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having Air Carriers verify and validate the quality of training provided to aircrews, with emphasis on externally provided training.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents concluded that, in several of the events, the flight crew did not respond to situations in accordance with how they had been trained. In some of these events, a review of the accident report indicated proficiency issues with pilot even after checking and qualification, particularly when training had been provided by an external training organization. To improve flight crew proficiency in handling issues that can lead to loss of airplane state awareness, air carriers should verify and validate the quality and consistency of training, with emphasis on externally-provided training. This should include examining both the content and conduct of training. Training verification and validation should include improving surveillance of and communication with third-party training providers.

Safety Enhancement SE 196 ASA – Training - Effective Upset Prevention and Recovery Training, Including Approach-to-Stall

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having Air Carriers conduct effective upset prevention and recovery training, including approach-to-stall, in realistic scenarios, using qualified flight simulator training devices. Air carriers should review, incorporate, and adopt the best practices recognized by the aeronautical community with regards to upset prevention and recovery training, including the following:

1. Airplane and simulator manufacturers ensure that training devices satisfactorily represent aircraft characteristics for proposed scenarios,
2. Approach-to-stall training in realistic scenarios, and
3. Upset prevention and recovery training in realistic scenarios.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents showed that, in many situations, the flight crew failed to properly respond to and recover from an unexpected upset, approach to stall, or stall situation resulting from flight crew loss of airplane state awareness (ASA).

Safety Enhancement SE 197 ASA – Training - Policy and Training for Non-normal Situations

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having each Air Carrier clearly state a policy, reinforced in training, that emphasizes establishing controlled and stabilized flight as the primary consideration during non-normal situations. To improve flight crew proficiency during upsets or non-normal situations, air carriers should emphasize through training and standard operating procedures (SOPs) the importance of controlling and stabilizing the airplane before evaluating non-normal situations.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents showed that in many situations the flight crew did not make controlling the airplane their primary objective during non-normal situations. In many of these events, the flight crew did not apply workload management or crew coordination skills and did not initiate or complete the appropriate non-normal checklist after the airplane entered an upset.

Safety Enhancement SE 198 ASA – Training – Scenario-Based Training for Go-Around Maneuvers

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having Air Carriers conduct effective, scenario-based go-around training that matches realistic situations.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents showed that go-arounds, in some situations, contributed to flight crew loss of airplane state awareness (ASA). Air carriers should incorporate scenario-based go-around training (both initial and recurrent) that matches realistic situations. In addition, air carriers should perform an assessment to identify additional improvements to go-around procedures and training. This assessment would include a review of ongoing go-around initiatives, research planning, review of Aviation Safety Information Analysis and Sharing (ASIAS) metrics and data, and review of air traffic control go–around procedures.

Safety Enhancement SE 199 ASA – Training - Enhanced Crew Resource Management Training

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having Air Carriers and other training providers, as well as regulators, enhance acceptance, utilization, and effectiveness of Crew Resource Management (CRM) principles on the flight deck by revising curriculum content and delivery. These principles should provide clear, unambiguous roles for the pilot flying (PF) and pilot monitoring (PM) in normal and non-normal operations.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents showed that in many situations CRM was not effective when it was needed most. Additionally, the PM was often unable to clearly communicate the seriousness of the situation to effect a change in the behavior of the PF.

To reduce accidents and incidents due to loss of airplane state awareness (ASA), air carriers should integrate, and regulators should encourage, formal CRM training in initial and recurrent classroom and simulator sessions in accordance with the latest version of Federal Aviation Administration (FAA) guidance material. This enhanced CRM Training should include, but not be limited to:

1. The importance of the team concept and recognition and impact of flight deck authority gradient,
2. The responsibility of both pilots to effectively communicate information relating to the current or future state of the aircraft and any required corrective actions,
3. Situation awareness and decision making skills, and task prioritization,
4. Active PM roles with emphasis on detecting, challenging and correcting errors committed by the PF, and
5. Employing "progressive intervention strategies" from communication to direct intervention.

Safety Enhancement SE 200 ASA – Design – Virtual Day-VMC Displays

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having manufacturers develop and implement virtual day-Visual Meteorological Conditions (VMC) display systems (such as Synthetic Vision Systems or equivalent) that 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 and
- Major derivative, amended Type Certificate programs involving redesign of flight deck avionics at the manufacturer's discretion.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents determined that lack of external visual references (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. For the purpose of this safety enhancement, “virtual day-VMC displays” describe systems that have the following elements:

- Are presented full time in the primary field-of-view.
- Are 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 transport category airplane programs, pending internal manufacturer review and acceptance of ongoing research activities on such systems.

Safety Enhancement SE 201 ASA – Design – Bank Angle Alerting and Recovery Guidance Systems

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having manufacturers implement bank angle alerting and recovery guidance display systems on applicable new transport category airplane (TCA) programs. Applicable new TCA programs include:

1. New type certificate programs and
2. Major derivative, amended type certificate programs involving redesign of flight deck avionics.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents determined that excessive bank, resulting from flight crew loss of airplane state awareness (ASA), played a role in 6 accidents. To provide assistance during recovery from unusual bank angles, and reduce fatal accidents due to spatial disorientation, manufacturers should develop and implement bank angle alerting and recovery guidance display systems in accordance with Title 14, Code of Federal Regulations (14 CFR) 25.1322, amendment 25-131 on applicable new TCA programs launched after January 1, 2015.

Safety Enhancement SE 202 ASA – Design - Bank Angle Protection

Status: Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having manufacturers implement include bank angle protection on applicable new fly-by-wire (FBW) transport category airplane (TCA) programs. Applicable new fly‒by-wire (FBW) TCA programs include:

1. New type certificate programs and
2. Major derivative, amended type certificate programs involving redesign of the FBW flight control system, or conversion from a conventional control system to a FBW control system

In a Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents, excessive bank resulting from flight crew loss of airplane state awareness (ASA) played a role in 6 accidents. To reduce fatal accidents due to loss of airplane state awareness, manufacturers should develop and implement bank angle protection on applicable new FBW TCA programs launched after January 1, 2015.

Safety Enhancement SE 203 ASA – Design – Features for Current Production/In-Development Fly- by-Wire Airplane Designs

Status: Research and Development Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having manufacturers study the feasibility of incorporating certain recommended design features into current production and in-development Fly-By-Wire (FBW) transport category airplane (TCA) type designs. Features for study should include:

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 Systems or equivalent, 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).

Commercial Aviation Safety Team (CAST) and the Aerospace Industries Association (AIA) will review the results of the studies with manufacturers and propose follow-on CAST safety enhancements 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.

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.

Safety Enhancement SE 204 ASA – Design – Features for Existing non-Fly- by-Wire Airplane Designs

Status: Research and Development Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having manufacturers study the feasibility of incorporating certain recommended design features into current production and in-development non-Fly-By-Wire (non-FBW) transport category airplane (TCA) type designs. Features for study should include:

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 Systems or equivalent, 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).

Commercial Aviation Safety Team (CAST) and the Aerospace Industries Association (AIA) will review the results of the studies with manufacturers and propose follow-on CAST safety enhancements 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.

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.

Safety Enhancement SE 205 ASA – Design – Features for Out-of-Production Airplane Designs

Status: Research and Development Underway

Background

The purpose of this Safety Enhancement is to reduce the risk of loss-of-control accidents by having manufacturers study the feasibility of incorporating certain recommended design features into existing out-of-production transport category airplane (TCA) type designs. Features for study should include:

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 Systems or equivalent, 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).

Commercial Aviation Safety Team (CAST) and the Aerospace Industries Association (AIA) will review the results of the studies with manufacturers and propose follow-on CAST safety enhancements 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.

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.

Safety Enhancement SE 207 ASA - Research – Attitude and Energy State Awareness Technologies

Status: Research and Development Underway

Background

The purpose of this Safety Enhancement is to outline research to be conducted by the aviation community (government, industry, and academia) to enable the development, implementation, and certification of technologies that enhance flight crew awareness of airplane energy state and conditions likely to produce Spatial Disorientation.

Based on the problems uncovered in a Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents, the analysis team recommended research into flight deck technologies that have the potential to mitigate the problems and contributing factors that lead to flight crew loss of airplane state awareness (ASA). The research should cover the following areas:

1. Assess the relative benefits associated with various methods of displaying angle-of-attack on the flight deck;
2. Develop and refine algorithms and display strategies to provide control guidance for recovery from approach-to-stall or Stall;
3. Develop and refine systems that predict the future aircraft energy state and/or autoflight configuration if the current course of action is continued and provide appropriate alerting; and
4. Cost-effective, user-centered flight deck alerting systems to alert flight crews to the two conditions that produced Spatial Disorientation in the airplane state awareness (ASA) event data set, which are:
    a. Subthreshold rolls similar to those that have led to loss of control and
    b. The somatogravic illusion.

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.

Safety Enhancement Concept SE 209 ASA – Research - Simulator Fidelity

Status: Research and Development Underway

Background

To improve pilot performance during recovery from a full Stall, the aviation industry should perform research to determine the benefits of using various levels of prototype advanced aerodynamic modeling of full stall characteristics to perform full stall recovery training. The research should determine:

1. The upset and stall recognition and recovery learning objectives (i.e., metrics for satisfactorily completing the training);
2. The ability to satisfactorily model full stall characteristics across a variety of aircraft types;
3. Whether the various model characteristics make a difference in full stall recovery training;
4. How to insert aircraft response characteristics into the simulator to ensure the skills learned in simulator training are directly usable in real flight.

Safety Enhancement SE 210 ASA - Research – Flight Crew Performance Data

Status: Research and Development Underway

Background

The purpose of this Safety Enhancement is to outline research to be conducted by the aviation community (government, industry and academia) to enhance tools and methods for collecting and analyzing flight crew performance data in situations associated with loss of energy and/or attitude state awareness. The tools and methods should be suitable for use in the design process.

In a Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents, 9 events involved flight crew performance limitations. The aviation community should conduct research and development to enhance tools and methods for analyzing flight crew performance for use in design practices and processes. The research should focus on flight crew responses to situations associated with loss of energy and/or attitude state awareness, and should:

1. Develop a database of historical flight crew performance responses situations associated with loss of energy and/or attitude state awareness.
2. Enhance methods and guidelines used in the design process to assess flight crew performance in these situations.
3. Develop and validate prototype technologies for detection and mitigation of attention issues for use in design evaluation.

Safety Enhancement SE 211 ASA - Research – Training for Attention Management

Status: Research and Development Underway

Background

The purpose of this Safety Enhancement is to outline research to be conducted by the aviation community (government, industry and academia) to develop and assess training methods and realistic scenarios that can address the attention-related human performance limitations observed in the airplane state awareness (ASA) event data, including channelized attention, confirmation bias, and startle/surprise, with accompanying performance measures.

A Commercial Aviation Safety Team (CAST) study of 18 loss-of-control accidents and incidents showed that issues with flight crew attention were involved in 16 of the 18 events. The aviation community should conduct research on methods for understanding the phenomena of flight crew channelized attention, confirmation bias, startle/surprise, and diverted attention.

1. Research and training organizations develop methods to detect and measure attention-related human performance limitations.
2. Research organizations should work with industry partners (air carriers, manufacturers, and commercial training providers) to develop methods and guidelines for creating training scenarios that induce attention-related human performance limitations and develop and assess potential mitigations to these issues in the training environ.