

**Turbulence
 Joint Safety Implementation Team
 Detailed Implementation Plan
 For
 Enhanced Airborne Turbulence Warnings**

DRAFT

Statement of Work: Provide improved, real-time turbulence information to aircrew of ownship, aircrew of nearby aircraft, ground operations personnel, and forecasters for turbulence avoidance decisions and for input to turbulence forecasts. Accomplish the improvement through automated, airborne, aircraft turbulence measurements, new flight deck displays of turbulence information, improved or new on-board look-ahead turbulence detection capabilities, and upgraded flight crew procedures for use of improved information to avoid turbulence. Use best industry practices and computer-human interface (CHI) standards to develop flight deck displays and aircrew procedures in order to make best use of enhanced turbulence information.

Lead Organization for Overall Project Coordination (LOOPC): NASA-Aviation Safety Program (AvSP)

SAFETY ENHANCEMENT 71: Graphical Displays-Carry On.

Score (InjryRdx %): 2007: 0.05 2020: 0.06 Full: 0.06 '07 Imp: 75%

Total Resource Requirements:

	Government		Manufacturers		Operators		Total
	FTE	\$	FTE	\$	FTE	\$	FTE/\$M
2007		2.25					0/2.25
2020							
Totals		2.25					0/2.25

Completion Date: 54 months after CAST approval of Safety Enhancement.

Note: This enhancement assumes the US fleet will become equipped with electronic flight bag or other carry on displays. The enhancement provides first generation products for those displays.

Output 1: Evaluate/demonstrate integration of uplinked information on existing carry-on displays.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 54 months after CAST approval of Safety Enhancement.

Actions:

- **FAA/NASA/ATA, RAA/AIA, Manufacturers** -- Evaluate alternative architectures for integrating uplinked data, in industry standard format, using existing communication data links.

Output 2: Set standards and CHI best practices for real time graphical flight deck display systems. Develop and implement algorithms.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 54 months after CAST approval of Safety Enhancement.

Actions:

- **NASA/FAA/Manufacturers** -- Set standards for alternate display systems (such as PC based options) incorporating CHI best practices and standards for real-time graphical flight deck display systems.
- **NASA/FAA/ Boeing/Airbus** -- Develop and implement algorithms to display turbulence on a carry on display.

Output 3: Develop/implement avoidance procedures.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 54 months after CAST approval of Safety Enhancement.

Actions:

- **Manufacturers/Airlines/Employee Organizations** -- Develop improved weather avoidance operating procedures enabled by improved turbulence information in the flight deck using industry best practices and standards as well as CHI design.
- **Airlines** -- Implement new procedures.

Output 4: Review FAA Order 8400.10 to modify/eliminate inconsistencies between the new procedures and the Order.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

3/12/03

Timeline: Completed 54 months after CAST approval of Safety Enhancement.

Actions:

- **FAA** -- Review and revise FAA Order 8400.10 as necessary to ensure uniform industry implementation of new procedures.

Performance Goals & Indicators for Safety Enhancements/Outputs:

- **Goal:** Real Time Integrated Multiple Source Weather/Turbulence Display
 - **Indicator: Short Term:** First generation turbulence products are ready for implementation into the fleet by 2007
 - **Indicator: Long Term:** 80% of fleet contains some form of integrated graphical weather/turbulence display by 2010.

SAFETY ENHANCEMENT 72: Graphical Displays-Panel Mounted-New Production

Score (InjryRdx%): 2007: 0.008 2020: 0.06 Full: 0.06 '07 Imp: 14%

Total Resources Required:

	Government		Manufacturers		Operators		Total
	FTE	\$	FTE	\$	FTE	\$	FTE/\$M
2007		4.25					0/4.25
2020				7.0			0/7.0
Totals		4.25		7.0			0/11.25

Completion Date: Completed 60 months after CAST approval of Safety Enhancement.

Output 1: Evaluate/demonstrate integration of uplinked/onboard information on existing displays.

Resources: NASA-AvSP (LOOC), FAA, NCAR, Manufacturers, and Airlines

Timeline: Completed 60 months after CAST approval of Safety Enhancement.

Actions:

- **NASA/FAA/ATA, RAA/AIA, Manufacturers** -- Evaluate alternative architectures for integrating uplinked and onboard data, in industry standard format, making maximum utilization of existing communication data links.

Output 2: Set standards and CHI best practices for display systems. Develop and implement algorithms.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 60 months after CAST approval of Safety Enhancement.

Actions:

- **NASA/FAA/Manufacturers** -- Set standards for alternate display systems (such as PC based options) incorporating CHI best practices and standards for real-time graphical flight deck display systems design to enhance and support integration of weather and turbulence data sources.
- **NASA-AvSP/FAA-AFS (HF)/Manufacturers** -- Develop algorithms for display of turbulence on existing panel-mounted displays.
- **Manufacturers** -- Implement algorithms in existing panel mounted displays in 7 aircraft type designs to display turbulence on integrated displays in new production aircraft produced in CY04 and beyond.

Output 3: Develop/implement avoidance procedures.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 60 months after CAST approval of Safety Enhancement.

Actions:

- **Manufacturers/Airlines** -- Develop improved weather avoidance operating procedures enabled by improved turbulence information on the flight deck using industry best practices and standards as well as CHI design.
- **Employee Organizations** -- Assist in development of improved avoidance procedures with experienced-based inputs to best practices.

Output 4: Review FAA Order 8400.10 to modify/eliminate inconsistencies between the new procedures and the Order.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 60 months after CAST approval of Safety Enhancement.

Actions:

- **FAA** -- Review and revise FAA Order 8400.10 as necessary to ensure uniform industry implementation of new procedures.
- **Airlines** -- Implement new procedures.

SAFETY ENHANCEMENT 73: Airborne-Detection-Enhanced Radar-New Production

Score (InjryRdx%): 2007: 0.03 2020: 0.20 Full: 0.20 '07 Imp: 14%

Total Resources Required:

	Government		Manufacturers		Operators		Total
	FTE	\$	FTE	\$	FTE	\$	FTE/\$M
2007		4.75		3.0		2.1	0/9.85
2020						4.2	0/4.20
Totals		4.75		3.0		6.3	0/14.05

Note: This project is ongoing with government and manufacturers as partners and at a significant level of government funding.

Completion Date: R&D and type design completed 36 months after CAST approval of Safety Enhancement and installation in new aircraft production begins within the following year.

Output 1: Develop/validate algorithms to estimate RMSg.

Resources: NASA-AvSP (LOOC), FAA, NASA, NCAR, AIA, Boeing, Airbus

Timeline: Completed 30 months after CAST approval of Safety Enhancement.

Actions:

- **NASA/NCAR** -- Develop aircraft response algorithms to be applied to the aircraft hazard metric (RMS normal acceleration) to serve as a basis of **new radar** turbulence development and certification.
- **NASA** -- Validate models and hazard metric.

Output 2: Upgrade, flight test, certify radar.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 36 months after CAST approval of Safety Enhancement.

Actions:

- **Manufacturers/AIA** -- Develop **new Radar** with output suitable for providing warning to ownship flight deck and for data linking to other users.
- **ATA/RAA** -- Conduct in-service flight trials to determine the effectiveness of the turbulence detection algorithms and deployment feasibility.

- **NASA** -- Assist with the flight trials, post-flight data analysis and confirm turbulence warning performance.

Output 3: Develop/implement procedures and training.

Resources: NASA/AvSP (LOOC), Manufacturers, Airlines, FAA (AFS/Human Factors), ATC

Timeline: Completed 30 months after CAST approval of Safety Enhancement.

Actions:

- **Employee Organizations** -- Assist in development of improved avoidance procedures with experienced-based inputs to best practices.
- **NASA AvSP Turbulence Team** -- Develop performance criteria and flight deck interfaces (CHI design) for the **new** radar.

Performance Goals & Indicators for Safety Enhancement/Outputs:

- **Goal:** Real Time Alerting Sensor for Clear Air Turbulence
 - **Indicator:** 20% of the fleet contains next generation CAT sensor

SAFETY ENHANCEMENT 74: Airborne Detection – Enhanced Radar – Retrofit Windshear Equipped Aircraft

Note: This is based on Safety Enhancement 73.

Score (InjryRdx%): 2007: 0.02 2020: 0.20 Full: 0.20 '07 Imp: 9%

Total Resource Requirements:

	Government		Manufacturers		Operators		Total
	FTE	\$	FTE	\$	FTE	\$	FTE/\$M
2007				0.1		7.0	0/7.1
2020				0.2		14.0	0/14.2
Totals				0.3		21.0	0/21.3

Completion Date: Completed 10 years after CAST approval of Safety Enhancement.

Output 1: Design, develop fleet retrofit - Service Bulletins.

Resources: Manufacturers

Timeline: Coincident with turbulence product introductions

Actions:

- **Manufacturers** -- Develop Service Bulletin to upgrade PWS capable equipment to include enhanced turbulence.
- **Manufacturers** -- Develop Service Bulletins for installation of weather radar equipment with enhanced turbulence capability.

Output 2: Certify retrofit configuration through Service Bulletins and Supplemental Type Certificates (STC)s.

Resources: Manufacturers, Airlines, FAA ATC

Timeline: Completed 54 months after CAST approval of Safety Enhancement.

Actions:

- **Manufacturers** -- Apply for regulatory certification of Service Bulletins and equipment modifications.
- **FAA** -- Facilitate and provide certification.
- **Airlines** -- Support certification effort as required. May require providing aircraft for flight test demonstration if an STC.

Output 3: Upgrade weather radar equipment and install Service Bulletins in aircraft.

Resources: Manufacturers, Airlines, FAA

Timeline: Completed 17 years after CAST approval of Safety Enhancement.

Actions:

- **Airlines** -- Upgrade equipment and install Service Bulletins.
- **Manufacturers** -- Provide support as required.
- **FAA** -- Provide regulatory approval of aircraft modifications.

SAFETY ENHANCEMENT 75: Airborne Detection – Enhanced Radar – Retrofit Non-Windshear-Equipped aircraft

[ELIMINATED FROM CONSIDERATION BY JSIT ON GROUNDS OF COST]

Relationship to Current Aviation Community Initiatives

Safety Enhancements 71 and 72

The current aviation community initiatives for a graphical weather display include the following:

- **AWIN:** Aviation Weather INformation is a broad based government/industry initiative to provide advanced weather products into the flight deck.
- **WINNCOMM:** Weather INformation Network COMMunication - NASA program that is investigating communication alternatives of weather products to the flight deck. This program will support flight deck initiatives such as AWIN.
- **WINN:** Weather INformation Network - Public/Private partnership focused on bringing to market a means of providing ground-based weather information to the flight deck and AOC of an airliner (anywhere in the world) or dispatch. Motivated by a government/industry desire to improve current and projected aviation weather hazard performance. Either server based using integrated display or external display with GPS link. Has been demonstrated in 777 simulator and NASA 757.
- **EWXR:** Enhanced Weather Radar is a program funded and in flight test to develop advanced processes for utilization of on-board weather radar information. Features under development include storm motion tracking, weather hazard analysis, storm top determination, and combination of airborne and ground based weather products to create a composite strategic and tactical weather display.
- **ADDS:** Aviation Digital Data Service is a web-based tool that provides graphical weather products to aviation end users. It also is used to demonstrate experimental weather products on a common grid. Also provides National Weather Service products.
- **NOWCAST:** Weather diagnosis and forecast from 0 to 2 hours.
- **EDR:** Eddy Dissipation Rate is a derived atmospheric parameter for defining atmospheric turbulence. An ICAO standard is presently in the approval stage from member states.
- **RTCA Special Committee SC-195:** This committee is developing the standards for data link of graphical weather to the flight deck.
- **ASAP:** Comprehensive FAA guidance has recently been issued recommending each air carrier's voluntary participation in an Aviation Safety Action Program (ASAP) and specifying the terms of its operation. Under ASAP a participating air carrier would encourage its employees to come forth with observations bearing on safety. Under all but certain specific conditions those observations would not incur FAA penalties, but would encourage a collaboration of managers, employees, and the FAA to address and correct safety hazards before an accident might occur. (existing since April, 2000)

- **FOQA:** Public Law, FAA regulations, and comprehensive FAA guidance to enable implementation of Flight Operational Quality Assurance programs (FOQA). Under FOQA participation by an air carrier would be voluntary. Copious data from flight data recorders would be de-identified and used for analysis and identification of accident precursors. An air carrier would take corrective actions before an accident might occur, based on its analyses. At some later time, de-identified FOQA data and analysis might be shared among air carriers in order to share the safety benefits of FOQA among all air carriers. (was expected in 2000)

The current effort to improve weather avoidance operating procedures is being done on an ad-hoc basis by individual airlines. There is currently no cohesive industry wide initiative to develop improved procedures.

Safety Enhancements 73 and 74:

The following aviation community initiatives are on going for radar and next generation sensors:

- **Turbulence Prediction and Warning systems (TPAWS):** Currently NASA and FAA are leading a multi-disciplined Government/industry team for the development of enhanced turbulence systems. This includes both radar based and next generation systems. The team consists of NASA, FAA, avionics manufacturers and research organizations directed at developing the scientific basis, algorithms and performance requirements for the detection of convective and non-convective related turbulence.
 - **NASA and NCAR** are developing turbulence and thunderstorm models and corresponding radar simulations for development of turbulence detection algorithms.
 - **NASA** is conducting flight test of demonstration systems incorporating the hardware and algorithms developed by the team.
 - **Radar Manufacturers** are developing enhanced turbulence radar systems.
 - **NASA and FAA** are jointly conducting workshops for developing performance and certification criteria for development of turbulence sensors.

Programmatic approach

Organizational strategy

At the present time, several Government/industry initiatives are in progress that directly address the turbulence issues contained in these safety enhancements. These initiatives consist of industry partners developing systems and concept demonstrations with NASA providing scientific support. While NASA currently provides critical support by funding the concept development, evaluation and scientific basis, the industry partners are funding the development of products for commercial service. Current aviation community initiatives are a blend of existing technologies and new and future research.

NASA is the critical enabling body that allows industry partners to continue technology growth. CAST support of these projects also provides priority and emphasis within the FAA to support development of performance and certification criteria for these initiatives.

Our organizational strategy is to ensure NASA continues to be funded at present or greater levels to provide enabling scientific research and development in support of industry initiatives that will advance turbulence safety issues. This research will include the scientific background for turbulence detection, aircraft response and crew procedures. Demonstrations will be required that include human factors evaluation, data standard evaluation, flight testing and full evaluation of completed composite image for graphical displays and numerous other possibilities. Principle stakeholders (regulators, airframes, airlines, and manufacturers) must be involved in developing the requirements, performance and certification criteria, and defining and evaluating the human factors and display concepts against accepted best practices. The program priorities must be consistent with the dates laid out in this plan, and performed in a timely manner to support and meet aviation safety goals.

Implementation Activities

The flow of this program is to develop the science behind turbulence, demonstrate a prototype system, complete system requirements, develop a system, implement and install into the airline fleet. Actions to complete these activities are found in the **Key Products and Milestones** section.

The critical pieces are the funding of the science as well as demonstration and requirements phases of the above actions. Based on NASA progress, industry can proceed to development and implementation of the turbulence sensors and graphical displays.

Key Products and Milestones:

<u>Safety Enhancement 71: Graphical Displays – Carry on.</u>		
<u>Output 1:</u> Evaluate/demonstrate integration of uplinked information on existing carry-on displays.		
Action	Responsible Party	Completion Date

Evaluate alternative architectures for integrating uplinked data, in industry standard format, using existing communication data links.	FAA/NASA/ ATA/RAA/AIA/ Manufacturers	54 months after CAST approval *
Output 2: Set standards and CHI good practices and standards for real time graphical flight deck display systems. Develop and implement algorithms.		
Action	Responsible Party	Completion Date
Set standards for alternate display systems (such as PC based options) incorporating CHI best practices and standards for real-time graphical flight deck display systems.	NASA/FAA/ Manufacturers	54 months after CAST approval *
Develop and implement algorithms to display turbulence on a carry on display.	NASA/FAA/ Manufacturers	54 months after CAST approval *
Output 3: Develop/implement avoidance procedures.		
Action	Responsible Party	Completion Date
Develop improved weather avoidance operating procedures enabled by improved turbulence information on the flight deck using industry best practices and standards as well as CHI design.	ATA/Airlines/ Manufacturers/ Employee Organizations	54 months after CAST approval *
Implement new procedures	Airlines	54 months after CAST approval *
Output 4: Review FAA Order 8400.10 to modify/eliminate inconsistencies between the new procedures and the Order.		
Action	Responsible Party	Completion Date
Review and revise FAA Order 8400.10 as	FAA	54 months after

necessary to ensure uniform industry implementation of new procedures.		CAST approval *
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Safety Enhancement 72: Graphical Displays – Panel Mounted-New Production		
Action	Responsible Party	Completion Date
<u>Output 1:</u> Evaluate/demonstrate integration of uplinked/onboard information on existing carry-on displays.		
Action	Responsible Party	Completion Date
Evaluate alternative architectures for integrating uplinked and onboard data, in industry standard format, making maximum utilization of existing communication data links.	NASA/FAA/ ATA/RAA/AIA/ Manufacturers	60 months after CAST approval *
<u>Output 2:</u> Set standards and CHI good practices for display systems. Develop and implement algorithms.		
Action	Responsible Party	Completion Date
Set standards for alternate display systems (such as PC based options) incorporating CHI best practices and standards for real-time graphical flight deck display systems design to enhance and support integration of weather and turbulence data sources.	NASA/FAA/ Manufacturers	60 months after CAST approval *
Develop algorithms for display of turbulence on existing panel mounted displays	NASA-AvSP/ Manufacturers/ Airlines/FAA- AFS/HF, ATC	60 months after CAST approval *
Implement algorithms in existing panel mounted displays in 7 aircraft type designs to display turbulence on integrated displays in new production aircraft produced in CY04 and beyond.	Manufacturers	60 months after CAST approval *

<u>Output 3: Develop/implement avoidance procedures.</u>		
Action	Responsible Party	Completion Date
Develop improved weather avoidance operating procedures enabled by improved turbulence information on the flight deck using industry best practices and standards as well as CHI design	Manufacturers/ Airlines	60 months after CAST approval *
Assist in development of improved avoidance procedures with experienced-based inputs to best practices	Employee Organizations	60 months after CAST approval *
<u>Output 4: Review FAA Order 8400.10 to modify/eliminate inconsistencies between the new procedures and the Order.</u>		
Action	Responsible Party	Completion Date
Review and revise FAA Order 8400.10 as necessary to ensure uniform industry implementation of new procedures.	FAA	60 months after CAST approval *
Implement new procedures.	Airlines	60 months after CAST approval *

<u>Safety Enhancement 73: Airborne-Detection-Enhanced Radar-New Production.</u>		
<u>Output 1: Develop/validate algorithms to estimate RMSg.</u>		
Action	Responsible Party	Completion Date
Develop aircraft response algorithms to be applied to the aircraft hazard metric (RMS normal acceleration) to serve as a basis of new radar turbulence development and certification.	NASA/NCAR	30 months after CAST approval
Validate models and hazard metric.	NASA	30 months after CAST approval

<u>Output 2: Upgrade, flight test, certify radar.</u>		
Action	Responsible Party	Completion Date
Develop new radar with output suitable for providing warning to ownship flight deck and for data linking to other users.	Manufacturers/ AIA	36 months after CAST approval
Conduct in-service flight trials to determine the effectiveness of the turbulence detection algorithms and deployment feasibility.	ATA/RAA/	36 months after CAST approval
Assist with flight trials, post-flight analysis and confirm turbulence warning performance	NASA	36 months after CAST approval
<u>Output 3: Develop/implement procedures and training.</u>		
Action	Responsible Party	Completion Date
Assist in development of improved avoidance procedures with experienced-based inputs to best practices.	Employee Organizations	30 months after CAST approval
Develop performance criteria and flight deck interfaces (CHI design) for the new radar.	NASA-AvSP Turbulence Team	30 months after CAST approval

<u>Safety Enhancement 74: Airborne-Detection-Enhanced Radar-Retrofit Windshear Equipped Aircraft.</u>		
<u>Output 1: Design, develop, fleet retrofit – Service Bulletins</u>		
Action	Responsible Party	Completion Date
Develop Service Bulletin to upgrade PWS capable equipment to include enhanced turbulence.	Manufacturers	10 years after CAST approval
Develop Service Bulletins for installation of weather radar equipment with enhanced turbulence capability.	Manufacturers	10 years after CAST approval
<u>Output 2: Certify retrofit configuration through Service Bulletins and Supplemental Type Certificates (STCs).</u>		
Action	Responsible Party	Completion Date
Apply for regulatory certification of Service	Manufacturers	54 months after

Bulletins and equipment modifications.	FAA	CAST approval 54 months after CAST approval
Facilitate and provide certification.		
Output 3: Upgrade weather radar equipment and install Service Bulletins in aircraft.		
Action	Responsible Party	Completion Date
Upgrade equipment and install Service Bulletins.	Airlines	17 years after CAST approval
Provide support as required	Manufacturers	17 years after CAST approval
Provide regulatory approval of aircraft modifications.	FAA	17 years after CAST approval

Note: '' - denotes currently scheduled government / industry milestones*

Risk Description and Risk Mitigation Plan:

RISK DESCRIPTION	RISK MITIGATION PLAN
R6 - Government does not maintain monetary support of turbulence effort within the responsible Government agency.	M6 – CAST and industry assist the responsible Government agency by advocating funding and prioritization for continued turbulence funding. Industry provides guidance for needs and priorities to support aviation safety.
R7 - Responsible Government organization priority shifts away from turbulence.	M7 - CAST and Industry assist the responsible Government organization by advocating funding and prioritization for continued turbulence funding. Industry provides guidance for needs and priorities to support aviation safety.
R8 - Responsible Government organization schedule not compatible with industry need.	M8 - Industry assists the responsible Government organization in aligning goals with industry needs through AvSP Turbulence Team meetings.
R9 – Inability to complete significant fleet installations in time to impact 2007 safety goals	M9 – Align the responsible Government organization/industry goals to optimize completion of required outputs, involve airlines in planning and development, ensure compatibility with airline needs.
R10 – Unfavorable airline economics and competition for funds with other needs.	M10.1 – Develop cost/benefit analysis to encourage airlines to implement in time to impact 2007 AvSP goals. M10.2 Manufacturers/OEMs provide low cost upgrades for incentive.
R11 – Lack of manufacturer/OEM incentives/commitment	M11.1 – Manufacturers/OEMs develop business case based on airline needs to show economic feasibility of system product development M11.2 – Competition between suppliers will drive development
R12 – Human Factors (CHI) display product relevance – flight deck real estate.	M12.1 – Conduct Human Factors evaluations early in system development, involving OEMs, airlines and regulators to ensure best practices and effective use of flight deck resources M12.2 – Evaluation of alternative methods of presentation.

<p>R13 – Performance of sensors falls short of minimum performance expectations for safety improvement.</p>	<p>M13.1 – Continued research for improved sensor performance.</p> <p>M13.2 – Educate the aviation community to what expectations for individual sensors should be.</p> <p>M13.3 – Restructure turbulence response procedures to utilize available sensor performance.</p>
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Impact on Non-Part 121 or International Applications

Part 129 - International

Benefits achieved by implementing these safety enhancements will benefit the international fleet in a like fashion to the U.S. fleet.

Part 135

Part 135 aircraft would benefit from these safety enhancements if the aircraft were able to equip with the sensor, e.g., have a radome large enough to handle air transport size radar antenna.

General Aviation

Sensor equipment will most likely not fit on the majority of general aviation aircraft. However, these safety enhancements would benefit general aviation if the graphical display or carry on display were used.