Commercial Aviation Safety Team (CAST)

Controlled Flight Into Terrain (CFIT)

Joint Safety Analysis Team (JSAT)

Results and Analysis

Process for Conducting Joint Safety Analysis Teams (JSAT's) - Rev. A

Master Collector Document

November 20, 1998

Commercial Aviation Safety Team (CAST)

Controlled Flight Into Terrain (CFIT)

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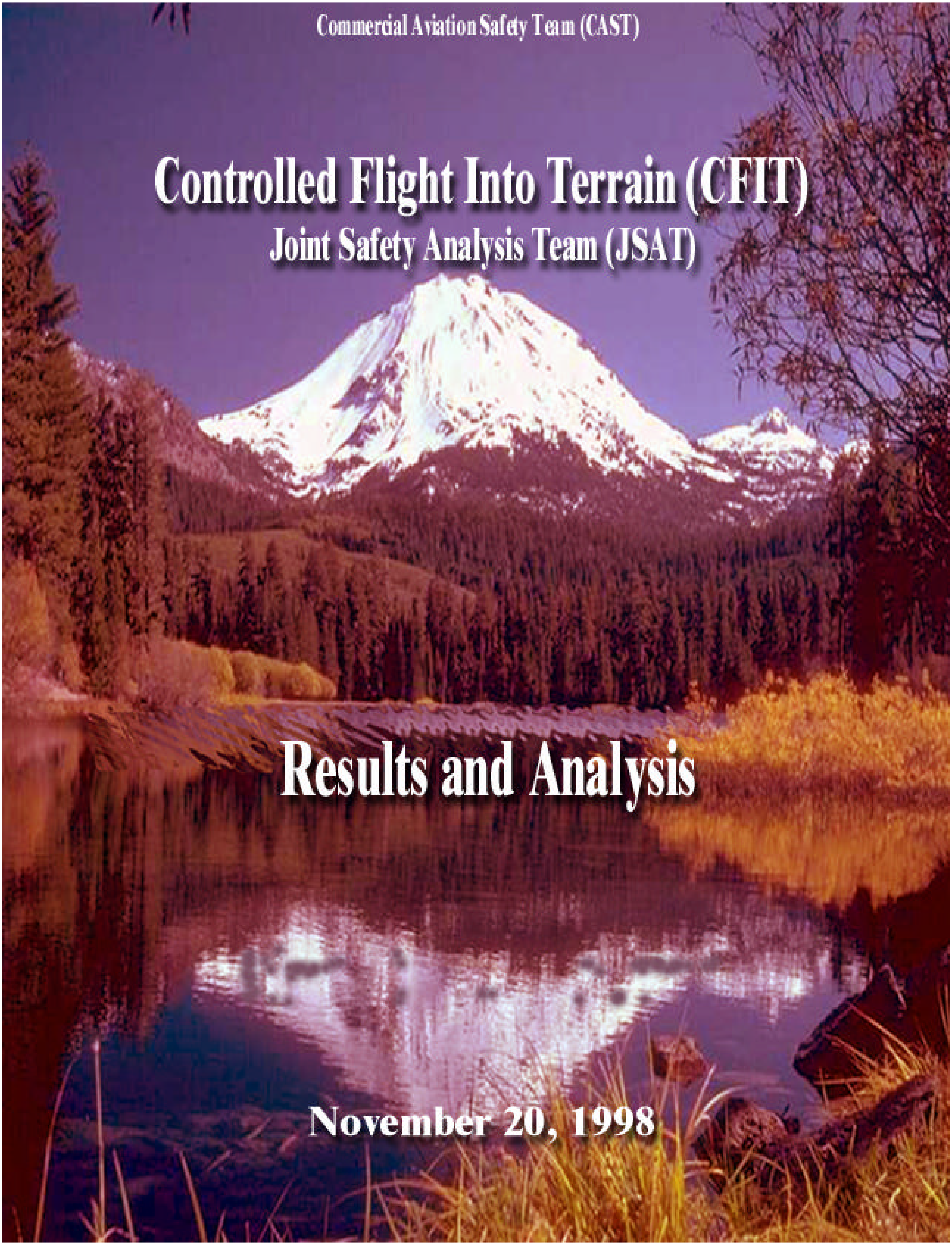

Results and Analysis

November 20, 1998

CONTROLLED FLIGHT INTO TERRAIN (CFIT)

JOINT SAFETY ANALYSIS TEAM (JSAT)

Results and Analysis

September 1, 1998

Revision A, November 20, 1998

REVISIONS

Revision A: November 20, 1998

Modified report for clarification and simplification. Clarified document purpose and recommendations. Revised prioritization category definitions and method description.

CONDUCTED BY THE

CONTROLLED FLIGHT INTO TERRAIN JOINT SAFETY ANALYSIS TEAM (CFIT JSAT)

THE SUBJECT JSAT WAS COMPOSED OF REPRESENTATIVES OF THE FOLLOWING ORGANIZATIONS:

1. Federal Aviation Administration:
   * Engine & Propeller Directorate, Aircraft Certification Service (ANE)
   * Transport Airplane Directorate, Aircraft Certification Service (ANM)
   * Flight Standards Service (AFS)
   * Office of Accident Investigation (AAI)
   * Air Traffic Service (AAT)
   * Aviation Systems Standards (AVN)
2. The Boeing Company
3. Air Line Pilots Association (ALPA)
4. National Aeronautics and Space Administration (NASA)
5. Airbus Industrie
6. Air Transport Association (ATA)

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I. EXECUTIVE SUMMARY

During the fall of 1997, the Commercial Aviation Safety Team (CAST), a combined organization of the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), Air Line Pilots Association (ALPA), Air Transport Association (ATA), and airplane and engine manufacturers dedicated to working together to improve aviation safety, chartered a Joint Safety Analysis Team (JSAT). The JSAT was tasked to develop, document, and utilize an analytical process to recommend safety intervention strategies. The team was further tasked to validate the concept of a joint industry/government task force, and to validate the developed process by review of Controlled Flight into Terrain (CFIT) data.

The JSAT reviewed 9 previously completed studies of CFIT accidents. The team also performed a detailed analysis of 10 commercial CFIT accidents utilizing the JSAT process found in the document entitled "Process for Conducting Joint Safety Analysis Teams (JSAT's)". This process develops intervention strategies and a recommended priority for implementation. The priority is based on the effectiveness of a proposed intervention in preventing the events studied and the feasibility of implementing that intervention in the United States. This document outlines the results of this JSAT activity. It is intended specifically as input to the CAST and Joint Safety Implementation Team (JSIT) and not for other purposes.

The JSAT found 21 interventions that were judged to have top overall effectiveness scores and to be no worse than moderately difficult to implement. These "recommended - highest priority" interventions can be grouped into the following general categories:

- Install TAWS-EGPWS
- Ensure CFIT prevention programs are developed, published, and implemented
- Implement flight operations quality assurance
- Expand availability and utilization of precision approach capability
- Maximize the effectiveness of MSAW
- Ensure ATC awareness/training/procedures include CFIT prevention programs

Interventions within these general categories vary in their level of specificity. Specific interventions were considered necessary in some cases to provide the detailed elements required to understand the recommendation and to aid the industry in implementation.

This report also contains other recommendations that did not fall into the "recommended - highest priority" category but may have validity within specific areas of the industry. Review of these interventions might provide beneficial guidance or support to existing programs.

The team recognized that many of these recommendations have already been implemented by various segments of the industry and government. In reviewing the interventions, organizations which have already implemented a recommendation should consider this a validation of the need for continuation of that portion of their program.

Results of this study, which used a sample of accident data, correlated closely with results of the more exhaustive studies by the Flight Safety Foundation (FSF), the CFIT task force, the Netherlands National Aerospace Laboratory (NLR), and others. This serves to validate the process and the results and complies with the direction from the CAST. It also provides validation for using the JSAT process for other areas of interest. The predominance of intervention strategies in this report which are targeted at operational issues is consistent with the results of the previous CFIT studies. This predominance is to be expected with this type of event.

This study demonstrated that a joint industry/government team can work together to develop recommended safety intervention strategies. The team recommends:

- Continuation of JSAT's.

- Review and disposition of this report by the appropriate JSIT.

II. TEAM MEMBERS

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III. ACRONYMS

AFM	Airplane Flight Manual
ALPA	Air Line Pilots Association
ASAP	Airline Safety Awareness Program
ATA	Air Transport Association
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
CAST	Commercial Aviation Safety Team
CASST	Commercial Aviation Safety Strategy Team
CFIT	Controlled Flight into Terrain
CFR	Code of Federal Regulations
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DGPS	Differential Global Positioning System
DH	Decision Height
DME	Distance Measuring Equipment
EGPWS	Enhanced Ground Proximity Warning System
ExF	Effectiveness times Feasibility score
F/O	First Officer
FAA	Federal Aviation Administration
FDR	Flight Data Recorder
FMS	Flight Management System
FOQA	Flight Operations Quality Assurance
GAIN	Global Aviation Information Network
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HUMS	Health and Usage Management System
ICAO	International Civil Aviation Organization
ISST	Industry Safety Strategy Team (former name of CAST)
JSASC	Joint Safety Analysis Steering Committee
JSAT	Joint Safety Analysis Team
JSIT	Joint Safety Implementation Team
MDA	Minimum Decision Altitude
MDA/DH	Minimum Decision Altitude/Decision Height
MSAW	Minimum Safe Altitude Warning
NASA	National Aeronautics and Space Administration
NAVAID	Navigation Aid
NOTAM	Notice to Airmen
PATI	Precision Approach and Terrain Information
PF	Pilot Flying
PNF	Pilot Not Flying
QFE	Field Level - Altimeter Setting
QNH	Mean Sea Level - Altimeter Setting
SOP	Standard Operating Procedures
SAT	Safety Analysis Team
TAWS	Terrain Awareness Warning System
TERPS	Terminal Instrument Procedures

IV. DEFINITIONS

Air Traffic Control	A service operated by the appropriate authority to promote the safe, orderly, and expeditious flow of air traffic within a country.
Airspace System	The common network of airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures; technical information; and human resources and material. Included are system components shared jointly with the military.
Datalink	Transmission of information between ground and aircraft via computer link as opposed to voice communications.
Effectiveness	Prioritization of the intervention strategies based on the breadth and depth of their relative potential for preventing accidents.
Events	Describe, relative to a time mark, the actions taken or omitted by the crew, the conversations of the crew and between the crew and ATC, and the airplane maneuvers prior to the accident.
Feasibility	Current potential for implementation of the intervention strategies on a widespread basis.
Implementation	How to incorporate a given intervention strategy.
Intervention Strategies	Proposed activity intended to prevent or mitigate a given safety-significant problem associated with the cause of an accident.
Problem Statements	Describe what went wrong, define a deficiency, or describe a potential reason some action occurred or did not occur.
Procedures	For JSAT purposes, the use of the term “procedures” refers to procedures that were followed at the time of the event.
Retrofit	Modifications made to aircraft already in service.
Synthetic Vision	Computer-generated image of local terrain and obstacle information which is presented to the crew in a clear manner to improve external situation awareness during low-visibility conditions.

V. INTRODUCTION

During the fall of 1997, the Industry Safety Strategy Team (ISST), predecessor of the Commercial Aviation Safety Strategy Team (CASST), organized a meeting of representatives of the Federal Aviation Administration (FAA), Airline Pilots Association (ALPA), Air Transport Association (ATA), and airplane and engine manufacturers. The purpose of the meeting was to determine if there was a basis for working together to analyze accident data and jointly develop intervention strategies to reduce commercial airplane accidents. It was decided there was merit in the concept, and the organizations joined together as the Joint Safety Analysis Steering Committee (JSASC), later renamed the Commercial Aviation Safety Team (CAST). The CAST agreed to selectively pursue the intervention strategies with the highest potential for safety benefit to the flying public. This was to be accomplished through a focused application of industry and FAA resources, and a Joint Safety Analysis Team (JSAT) was chartered to analyze safety data and recommend intervention strategies to address the problems identified in that data. The accident category of Controlled Flight into Terrain (CFIT) was chosen for the first JSAT, as CFIT is the leading cause of world-wide transport-category airplane fatalities. The presence of many other CFIT studies also allowed comparison of the team's results with those of existing analyses. This latter point is important, as this first JSAT's primary aim was to develop the JSAT process, not to accomplish the definitive CFIT study. A comparative review of the recommendations from existing CFIT studies is provided in Section VIII.

The JSAT process has been documented in a companion report, entitled "Process for Conducting Joint Safety Analysis Teams (JSAT's)." The purpose of this report is to document the results of the JSAT's technical analysis, and to recommend intervention strategies to minimize the occurrence of CFIT accidents.

A copy of the CFIT Joint Safety Analysis Team (JSAT) charter is provided in Appendix A.

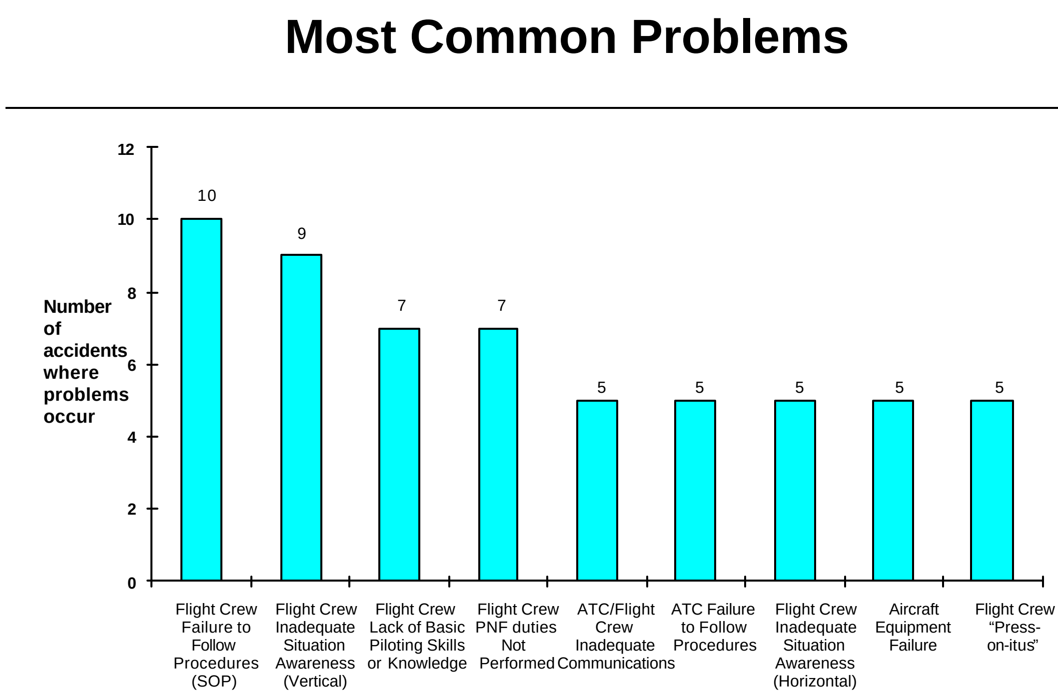
VI. CONTROLLED FLIGHT INTO TERRAIN (CFIT) ANALYSIS

Note: The analytical process outlined in this section is discussed in greater detail in the document entitled "Process for Conducting Joint Safety Analysis Teams (JSAT's)."

Twelve CFIT accidents were selected to provide the data set for analysis. Both old and new generation transport airplanes, inside and outside the United States, were included. A critical factor turned out to be finding accidents that had sufficiently detailed reports to support the analytical effort. While twelve accidents were selected, one of the reports had not been released at the time of the JSAT inception, and one did not have adequate detail. Both of these reports were thus removed from the data set. The accident data set is provided in Appendix B.

Due to scheduling constraints and team size, the decision was made to perform the initial accident review via two subteams - an East Team and a West Team (the names reflect the general split in the home locations of team members). Several individuals were members of both teams to provide continuity between the analysis process techniques used.

Figure 1



At the subteam meetings, an event sequence, consisting of time marks with corresponding events and/or problems, was developed for each accident. The event sequences were then used for assistance in identifying problems and possible interventions. Within the event sequence, there was no requirement that each problem be associated with a particular event or time mark, or that each event have a corresponding problem statement.

At the next full team meeting, the standard problem statements were developed from the individual problem lists for each accident. Appendix C contains a matrix of standard problem statements versus their occurrence within each of the reviewed accidents. Figure 1 illustrates the most common problems recorded by the JSAT evaluation of CFIT events.

Similarly, a standardized intervention strategy list was developed The team recognized that many of the intervention strategies had already been implemented by various segments of the industry and government. In reviewing the interventions, organizations which have already implemented a recommendation should consider this a validation of the need for continuation of that portion of their program.

The team used the following effectiveness scale to evaluate the effectiveness of the interventions (note that this scale is slightly different than the one recommended in the JSAT process report):

Not applicable or unknown	N/A
None (little or no potential for preventing the accident)	0
Low (some potential for preventing the accident)	1
Moderate (moderate potential for preventing the accident)	2
High (high potential to prevent the accident)	3

Team members individually rated the effectiveness of each intervention for potentially preventing each of the reviewed accidents. An average intervention rating was calculated from the individual team member assessments for each accident-intervention combination, along with an overall effectiveness score (overall average across all 10 accidents). A count was also made for each intervention to indicate the number of accidents in which the intervention had been judged to have high effect (average intervention rating for an accident of greater than or equal to 2.5).

The interventions were then assessed by the team for feasibility of implementation within the United States, using the following rating scale:

Impossible to achieve wide implementation	0
Very difficult to achieve wide implementation	1
Moderately difficult to achieve the implementation	2
Easy to achieve wide implementation	3

If an intervention was determined to be other than ‘easy to achieve wide implementation’ (other than 3 on the feasibility scale), a reason, such as cost, technology, culture, etc., was identified and included with the rating.

The CFIT overall effectiveness and feasibility ratings for each of the interventions are included in Appendix D. Note that this list contains missing identification numbers due to the elimination of duplicate interventions.

To prioritize the interventions based on effectiveness and feasibility, the team first multiplied the overall effectiveness score by the feasibility (E x F). However, the team quickly identified that the feasibility score was almost entirely responsible for the resultant E x F score. This was due to the fact that feasibility was rated only once against each intervention, while effectiveness was assessed against each of 10 accidents and then averaged across those accidents (many of which had “0” values due to nonapplicability).

The process the team settled on to group the interventions into prioritization categories began with sorting the interventions by overall effectiveness score. Next, the overall effectiveness score ordering was reviewed to identify gaps in the continuum of decreasing scores. This illustrated points of possible differentiation between categories. However, where obvious divisions did not exist in the data, the scores were grouped into “top”, “midrange” and “bottom” overall effectiveness categories based on the values of their overall effectiveness scores. The dividing lines between categories were established in a somewhat judgmental manner based on the observed range of the scores. Since the effectiveness scores were averaged across 10 accidents, many of which were not applicable to a particular intervention, the overall effectiveness scores were considerably lower than their highest individual scores had been. Thus, the overall effectiveness scores cannot be compared directly to the individual accident effectiveness scale provided above.

The overall effectiveness groups were then carried over as the starting point for three prioritization categories. The groupings were then adjusted based on the feasibility assessments. Interventions which had “top” overall effectiveness scores but had been assessed as difficult to implement were moved down to the secondary prioritization category. Interventions which had “midrange” overall effectiveness scores and were difficult to implement were likewise moved down to the third prioritization category. Finally, any intervention with a “bottom” overall effectiveness score but judged to be highly effective (2.5 or above) for at least one individual accident was moved up to the secondary prioritization category. All interventions judged as not applicable (N/A) in the U.S. were moved to the third prioritization category.

The prioritization categories are described below:

<u>Recommended</u>:	"Top" overall effectiveness scores (greater than or equal to 1.5) and no worse than moderately difficult to implement (greater than or equal to 2 on the feasibility scale)
<u>2nd choice</u>:	"Top" overall effectiveness scores (greater than or equal to 1.5) but difficult to implement (less than 2 on the feasibility scale) or: "Midrange" overall effectiveness scores (between .75 and 1.5) but no worse than moderately difficult to implement (greater than or equal to 2 on the feasibility scale) or: Interventions judged to be highly effective against at least one of the reviewed accidents (greater than or equal to 2.5) but no worse than moderately difficult to implement (greater than or equal to 2 on the feasibility scale)
<u>3rd choice</u>:	"Bottom" overall effectiveness scores (less than .75) or: "midrange" overall effectiveness scores (between .75 and 1.5) and difficult to implement (less than 2 on the feasibility scale)

It should be understood that individual differences in ratings cannot be interpreted for statistical significance. Broad categories were used for effectiveness and feasibility assessments, therefore only broad categories for prioritization can be obtained from the results.

VII. PRIORITIZED LIST OF INTERVENTIONS

TAWS-EGPWS clearly stood out on the basis of its overall effectiveness rating compared to the other interventions. Its overall effectiveness score was 2.9; the next closest overall effectiveness score was 2.3. The reason TAWS-EGPWS was judged so high in overall effectiveness is that it was seen to be a last line of defense in all of the reviewed accidents. The specifics of each CFIT accident prior to the point of impact mean that interventions aimed at addressing problems further up the chain of events may not apply in all cases. This is not to indicate that these interventions are of lesser importance; only that they are not a possible intervention in all cases.

In addition to its high effectiveness score, TAWS-EGPWS was judged to be moderately feasible to implement (due to retrofit issues), and so was placed in the top prioritization category ("Recommended - highest priority"). An additional 20 interventions were placed in this category due to their having the highest overall effectiveness scores in the JSAT assessments (at least 1.5 in overall effectiveness), and at least moderate feasibility (2 or greater in feasibility), giving a total of 21 in the top category.

Two interventions had top overall effectiveness scores, but low feasibility; these were placed in the second category for prioritization ("2nd choice"). An additional 31 interventions that had midrange overall effectiveness scores, and 10 interventions that had high effectiveness for at least one accident, were placed in this category. This gives a total of 43 in the secondary prioritization group.

Five interventions were determined to be either not applicable within the United States, or already widely implemented. The remaining 37 interventions, which did not meet the criteria for the first two prioritization categories, were placed in the third category for prioritization ("3rd choice").

The interventions have been arranged by topic within each of the prioritization categories. No ranking within the prioritization categories is intended, nor should any be attempted based on the data in this report.

The same method of prioritization could be performed for other regions of the world by those familiar with capabilities and infrastructure within those regions. It is expected that specific interventions would fall within different prioritization categories for different regions.

It should be noted that only slight differences in wording between certain interventions give the appearance of duplication. However, these interventions did have somewhat different intended meanings, and were therefore maintained separately through the JSAT analysis process.

Recommended - Highest priority for implementation

These interventions had "top" overall effectiveness scores and were judged no worse than moderately difficult to implement

Overall highest priority recommendation

Install TAWS-EGPWS:

Manufacturers should install TAWS-EGPWS in all new aircraft, airlines/operators should retrofit TAWS-EGPWS into the existing fleet and international regulators should require the installation of TAWS-EGPWS. (Intervention number 35)

Others

Ensure CFIT prevention programs are developed, published, and implemented:

Airlines/operators should ensure that their training/standardization programs emphasize review of approach and missed approach procedures. (7)

Airlines/operators should ensure that their training/standardization programs emphasize the importance of all flight related briefings. (17)

Airlines/operators should ensure that regularly scheduled recurrent training (e.g., LOFT) emphasizes crew cooperation and working together to maximize safe operations. (23)

Airlines/operators should establish a CRM training program. (25)

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Airlines/operators should ensure that their training/standardization programs direct the flight crews to use all available tools (charts) to establish aircraft position. (47)

Airlines/operators should ensure that their training/standardization programs direct the flight crews to regularly cross check all instrumentation. (64)

Airlines/operators should ensure that their training/standardization programs direct that flight crews use all available tools to establish aircraft position. (75)

Airlines/operators should ensure that their training/standardization programs emphasize the importance of adequate approach preparation and contingency review prior to commencing an approach. (96)

Airlines/operators should ensure that their training/standardization programs emphasize the importance of adhering to MDA/DH. (100)

Airlines/operators should ensure that their CRM training/standardization program emphasizes the importance of the team concept. (107)

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Airlines/operators and regulatory agencies should ensure that their training/standardization and monitoring programs emphasize the importance of adherence to standard operating procedures and identify the rationale behind those procedures. (110)

Airlines/operators should implement a procedure to climb to a minimum safe altitude when position uncertainty exists by at least one crew member. Flight crew must advise ATC of intentions. (19)

Airlines/operators (and manufacturers in the airplane flight manual) should implement procedures that call for an immediate execution of the escape maneuver following a GPWS warning unless there is visual confirmation of terrain. (61)

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Airlines/operators should clearly define, train and check the specific PF/PNF duties. (82)

Airlines/operators should ensure that standard operating procedures are published and enforced. (99)

Implement flight operations quality assurance (FOQA):

Airlines/operators should implement Flight Operations Quality Assurance (FOQA) programs. (54)

Airlines/operators should implement Flight Operations Quality Assurance (FOQA) programs to identify systemic procedural deviations. (56)

Expand availability and utilization of precision approach capability (glideslope or constant angle vertical guidance):

Implement precision approach capability (glideslope guidance) for all runways without established precision approach procedures (e.g., ILS, DGPS, etc.). (59)

Maximize the effectiveness of MSAW:

Review the engineering standards for the sighting of future Terminal Radar Systems to ensure the maximum effectiveness of MSAW is available. (71)

Ensure ATC awareness/training/procedures include CFIT prevention programs:

ATC should implement a Quality Assurance program to ensure adherence to established procedures. (124)

2nd choice - Secondary priority for implementation

These interventions had either: “top” overall effectiveness scores, but were difficult to implement; or “midrange” overall effectiveness scores, but were no worse than moderately difficult to implement

“Top” effectiveness scores, but difficult to implement

Datalink Aircraft Position Information:

Establish GPS datalink to relay aircraft position to ATC. (58)

Develop and Implement Synthetic Vision Capability:

The aviation industry should develop and implement synthetic vision capability (e.g., Precision Approach Terrain Information (PATI)). (85)

“Midrange” overall effectiveness scores, but no worse than moderately difficult to implement

Ensure CFIT prevention programs are developed, published, and implemented:

Airlines/operators should implement an Airline Safety Incident Reporting System (e.g., BASIS, ASAP). (1)

Airlines/operators and regulatory agencies should ensure that the frequency and effectiveness of proficiency checks for nonprecision approaches are adequate. (89)

Airlines/operators should ensure that command oversight training for captains is provided during the upgrade process and in recurrent training. (20)

Airlines/operators should ensure that CRM training is provided prior to line flying. (26)

Airlines/operators should require flight crews to perform non-FMS (raw data) approaches during proficiency/recurrent check rides. (67)

Airlines/operators should implement a reliable process to communicate information to the flight crew that may effect flight or aircraft operations. (79)

Airlines/operators should train flight crews on how flight delays (weather, maintenance, ATC, etc.) can effect their subsequent decision making relative to the safe conduct of the flight. (105)

Airlines/operators should ensure that their training/standardization programs emphasize basic airmanship skills and knowledge during initial and recurrent training. (111)

Airlines/operators and regulators should ensure that the frequency and effectiveness of proficiency checks for simulated instrument failures (partial panel) are adequate. (112)

Airlines/operators should ensure that their training/standardization programs emphasize the importance of adequate preflight planning. (113)

Airlines/operators should ensure that their training/standardization programs emphasize the dangers of rushed approaches. (115)

Airlines/operators should establish procedures for flight crews to review/cross check instructions, clearances, etc., to ensure consistency with expected procedures or practices. (95)

Emphasize Safety in Business/Operational Practices (Airlines/Regulatory Agencies):

Airlines/operators should encourage a culture that emphasizes safe arrivals over timely arrivals. (22)

Airlines/operators and regulatory agencies should emphasize that only published route segments should be flown in non-radar environments. (50)

Airlines/operators should encourage flight crews to use precision approaches (glideslope guidance) when available and appropriate. (125)

ATC should prioritize the use of precision approaches (glideslope guidance) when available and appropriate. (126)

Implement flight operations quality assurance (FOQA):

Airlines/operators should implement a Flight Operations Quality Assurance (FOQA) program to identify flight crew failure to respond to GPWS warnings. (55)

Enhance Approach Plate Procedures/Standards:

Regulatory agencies should mandate that approach plates show color contours for terrain. (5)

Regulatory agencies should establish standardized approach plate depiction/information requirements for approach plate publishers. (6)

The aviation industry should establish worldwide standards for the presentation format of instrument approach procedures. (8)

Enhance Communication:

Establish/enhance quality assurance checks/training to ensure that timely and accurate communication between controllers and flight crews is occurring. (21)

Airlines/operators and air traffic service providers should implement a monitoring program to ensure the consistent use of the ICAO phraseology. (42)

Develop additional ICAO phraseology for flight crew/air traffic service to address communication regarding aircraft position, equipment status, and communication which is not consistent with the situation or with expected responses. (83)

Airlines/operators and air traffic service providers should ensure fluency/proficiency in the use of basic English language. (40)

Airlines/operators and air traffic service providers should train flight crews and controllers to ICAO standards to ensure fluency/proficiency in the use of the ICAO phraseology. (41)

Airlines/operators should train and monitor flight crew compliance with established communication phraseology guidelines. (88)

Train and monitor ATC adherence to established communications procedures. (106)

Ensure ATC awareness/training/procedures include CFIT prevention programs:

Air Traffic service providers should train Air Traffic Controllers to use all available tools to establish aircraft position (example: don't fixate on just DME). (10)

Air Traffic service providers should emphasize in ATC training the controllers' potential in assisting the flight crew in improving their situation awareness. (12)

Air Traffic service providers should enhance ATC training to emphasize the dangers of rushed approaches and performance characteristics of modern jet transports. (13)

Expand availability and utilization of precision approach capability (glideslope or constant angle vertical guidance):

Eliminate nonprecision approaches where possible. (77)

Others which were highly effective for at least one accident, but no worse than moderately difficult to implement

Emphasize Safety in Business/Operational Practices (Airlines/Regulatory Agencies):

Airlines/operators and regulatory agencies should strictly enforce the regulations pertaining to alcohol use/substance abuse. (2)

Airlines/operators and regulatory agencies should strictly enforce flight/duty time limitations. (48)

Airlines/operators should establish a policy that supports the reporting of substance abuse. (101)

Ensure CFIT prevention programs are developed, published, and implemented:

Airlines/operators should ensure that their training/standardization programs instruct that ground proximity escape maneuvers are to be conducted with the aircraft properly configured (e.g., speedbrakes retracted). (117)

Airlines/operators should implement procedures to avoid simultaneous maintenance on redundant flight critical systems. (66)

Enhance Approach Plate Procedures/Standards:

Regulatory agencies should review and where appropriate eliminate duplicate NAVAID identifiers within the same geographic area. (74)

Upgrade/Install Flight Deck Equipment:

Ensure that failure of the aircraft system to capture glideslope (or VNAV) is adequately annunciated to the flight crew. (3)

Manufacturers should ensure that all equipment failures that may affect the safe operation of the flight are properly annunciated to the flight crew. (45)

Airlines/operators should install FMS equipment (logic) which has the capability to depict previously entered waypoints that are between the current present position and the current "to" way point. (53)

Airlines/operators should install FMS equipment (logic) which has the capability to depict previously entered waypoints behind the aircraft's flight path. (127)

3^{rd} choice - Tertiary priority for implementation

These are interventions which did not meet the criteria for the Recommended or 2^{nd} choice categories

Upgrade/Install Flight Deck Equipment:

Ensure FMS depiction is consistent with approach plate presentation. (4)

Install aural warning devices on aircraft to alert flight crew of arrival at MDA/DH. (14)

In the absence of GPS, regulatory agencies should install DME equipment at all appropriate airports. (32)

Airlines/operators should establish and implement the use of electronic checklists or other aids to ensure completion of all checklist items. (36)

The manufacturer of the FMS should ensure that the FMS logic displays NAVAIDís with the same identifier in a progressive distance manner. (76)

Manufacturers should ensure that automated systems provide the flight crew with sufficient information (automation feedback) to prevent mode confusion. (16)

Airlines/operators should ensure the currency of the FMS database and update as appropriate. (51)

Ensure ATC awareness/training/procedures include CFIT prevention programs:

Air Traffic service providers should implement procedures that ensure that ATC trainees are always supervised. (11)

Air Traffic service providers should implement and/or review procedures to ensure ATC training does not create a hazard to flight operations. (108)

Ensure CFIT prevention programs are developed, published, and implemented:

Airlines/operators should ensure that their training/standardization programs instruct when to disengage automated systems and fly manually. (15)

Airlines/operators should ensure that their training/standardization programs establish flight crew-proficiency in the use of the FMS system. (52)

Airlines/operators should ensure that their training/standardization programs establish flight crew proficiency in all uses of the HSI display. (62)

Airlines/operators should ensure that their training/standardization programs provide an appropriate minimum amount of standard training. (114)

Airlines/operators should ensure that their training/standardization programs emphasize the dangers of high rate of descent and unstable approaches. (116)

Airlines/operators should implement procedures to ensure appropriate crew pairing. (Reference FSF corporate crew scheduling and fatigue evaluation.) (24)

Airlines/operators should implement maintenance procedures to ensure proper functioning of the CVR at all times. (Note: This intervention was recorded as a potential intervention for future accidents; it would not have prevented the subject accidents.) (27)

Airlines/operators should adopt the "delegated" approach to standard operating procedures (e.g., monitored approach procedures). (30)

Airlines/operators should ensure that crew rest considerations (cabin crew and flight crew) are calculated and administered by dispatch/crew scheduling rather than burdening crews with these considerations. (31)

Airlines/operators should implement procedures to increase flightcrew awareness of recent aircraft maintenance actions. (46)

Airlines/operators should ensure procedures do not increase pilot workload during critical phases of flight. (120)

Airlines/operators should implement a true no-fault go around policy (learning vs. blame). (123)

Enhance Communication of ATC Instructions and Weather Information through the use of Datalink:

Implement a system to automatically transmit ATC instructions/information between the ground controller and the aircraft. (28)

Implement transmission of ATC instructions (between the ground and aircraft) via a computer link that would allow downloading to the FMS. (29)

Implement real time (digital) transmission of airport and weather information to the aircraft. (94)

Implement transmission of ATC instructions/information (between the ground and aircraft) via a computer link as opposed to voice communications. (122)

Enhance Terrain Awareness and Warning System (TAWS):

Avionics manufacturers should improve GPWS capability to reduce GPWS false warnings. (60)

Install/Enhance Aircraft Maintenance & Health Monitoring Systems:

Manufacturers should develop and implement system failure annunciation capabilities to alert flight crews of pending failures (e.g., HUMS). (103)

Manufacturers should implement a system to identify the recommended implementation schedule and priority of aircraft and operational changes. (68)

Regulatory agencies should establish criteria for, and manufacturers should evaluate and improve, the reliability and failure tolerance of flight systems. (49)

Airlines/operators and regulatory agencies should review procedures to ensure that design changes (service bulletins) to flight critical systems are incorporated in a timely manner. (98)

Emphasize Safety in Business/Operational Practices (Airlines/Regulatory Agencies):

Regulatory agencies should discontinue on-time arrival tracking for airlines. (37)

Airlines/operators and regulatory agencies should strictly enforce the regulations pertaining to flight crew use of prescription and non-prescription medication. (70)

Airlines/operators and regulatory agencies should improve the availability, clarity, and prioritization of NOTAM information. (78)

Airlines/operators should ensure, and regulatory agencies should check, that operators who create their own AOM's include all procedures prescribed by original equipment manufacturers Airplane Flight Manual (AFM). (80)

Airlines/operators should implement a culture that encourages flight crew voluntary removal from flight status due to illness. (63)

Implement System Wide Information Sharing:

Airlines/operators, regulatory agencies, and manufacturers should implement a program designed for sharing of safety related information within the aviation community. (57)

Enhance Communication:

Improve the real time radio communication of critical airport and weather information. (93)

Interventions not applicable to or already widely implemented in the United States

Maximize the effectiveness of MSAW:

Install MSAW-like capabilities world-wide with emphasis on high-risk airports. (72)

Ensure ATC awareness/training/procedures include CFIT prevention programs:

Implement worldwide surveillance radar (example: ADS/B). (121)

Upgrade/Install Flight Deck Equipment:

Airlines/operators should ensure that the aircraft is equipped with all expected NAVAID frequencies. (73)

Emphasize Safety in Business/Operational Practices (Airlines/Regulatory Agencies):

Airlines/operators and regulatory agencies should prohibit engineering flight tests during revenue flights following maintenance of critical systems. (90)

Airlines/operators and regulatory agencies should standardize on usage of QNH altimeter settings. (91)

VIII. COMPARISON WITH RESULTS FROM PRIOR CFIT STUDIES

Several members of the JSAT reviewed prior CFIT studies performed by various industry and government organizations. The findings of these studies were compared, for validation purposes, to the recommendations developed by the JSAT. In general, this comparison with previous CFIT studies indicates that the problems and interventions of the JSAT have been identified by other groups. Specifics are documented in the following paragraphs.

Bateman, D., *Flight Into Terrain and the Ground Proximity Warning System, Engineering Report 070-4251*, Sundstrand Data Control, Redmond, WA, revised May, 1995 (continually updated).

The referenced report advocates the installation of EGPWS. A second conclusion notes that 40% of all CFIT losses occur during nonprecision approaches, specifically, VOR-DME/LOC-DME approaches (page 3.8). These two findings from the Bateman paper validate the JSAT top prioritization interventions recommending installation of TAWS-EGPWS and the elimination of nonprecision approaches.

FAA Human Factors Team, *The Interfaces Between Flightcrews and Modern Flight Deck Systems*, Federal Aviation Administration, June 18, 1996.

The JSAT analysis produced 36 accident problem statements and over 100 intervention strategies which were compared to the 51 Human Factors Team Report recommendations. Direct comparison is not appropriate, as the two reports had different purposes and products. The JSAT report specifically addressed CFIT accidents, whereas the Human Factors Team report addressed the overall aviation system, concentrating on modern flight decks. Despite these different approaches and purposes, there are similarities in the problem statements, intervention strategies and recommendations.

The following table shows areas of commonality between the JSAT problem statements and similar Human Factors Team Report recommendations.

JSAT Problem Statement	HF Team recommendation	Comments
1. Flightcrew lack of English language skills 4. ATC lack of English language skills		The Human Factors Team expressed concern that misunderstandings may occur when non-native English speakers use English.

JSAT Problem Statement	HF Team recommendation	Comments
2. Flightcrew failure to follow procedures (communications) 10. Flightcrew failure to follow procedures (SOP)	The FAA should initiate a review to better understand why flightcrews deviate from procedures. AutomationManagement - 4	The Human Factors Team urged the understanding of why the procedures were not followed, to determine why the flightcrew deviated.
7. ATC inadequate situation awareness (horizontal) 11. Flightcrew inadequate situation awareness (vertical) 12. Flightcrew inadequate situation awareness (horizontal) 30. ATC inadequate situation awareness (vertical)	The FAA should encourage the aviation industry to develop and implement new concepts to provide better awareness. Situation Awareness -3	This recommendation specifically addressed the vulnerabilities to controlled flight into terrain.
5. ATC/Flightcrew inadequate communications	The FAA should provide leadership to update ICAO phraseology standards and to encourage their use. Culture-3	

The following table shows areas of commonality between the CFIT intervention strategies and similar Human Factors Team Report recommendations.

JSAT Intervention Strategy	HF Team recommendation
15. Airlines/operators should ensure training/standardization programs emphasize when to disengage automated systems and fly manually.	AutomationManagement-2: The FAA should require operators' manuals and initial/recurrent qualification programs to provide clear and concise guidance on: • Examples of circumstances in which the autopilot should be engaged, disengaged, or used in a mode with greater or lesser authority; • The conditions under which the autopilot or autothrottle will or will not engage, will disengage, or will revert to another mode; and Appropriate combinations of automatic and manual flight path control (e.g., autothrottle engaged with the autopilot off).

JSAT Intervention Strategy	HF Team recommendation
16. Manufacturers should ensure the design of an automated system provides the flight crew with sufficient information (automation feedback) to prevent mode confusion.	Situation Awareness-6: The FAA should encourage standardization, as appropriate, of automation interface features, such as: • The location, shape, and direction of movement for takeoff/go-around and autothrottle quick disconnect switches; • Autoflight system mode selectors and selector panel layout; • Autoflight system modes, display symbology, and nomenclature; and Flight management system interfaces, data entry conventions, and nomenclature.
29. Transmission of ATC instructions (between the ground and aircraft) via a computer link which would allow downloading to the FMS.	Culture-4: The FAA should promote timely and clear communications between flightcrews and Air Traffic Services through: • Accelerated efforts for transmission of information via datalink, as appropriate (e.g., Automatic Terminal Information Service (ATIS), weather, pre-departure clearances (PDC)); • Assuring clear and intelligible transmission of ATIS and clearance information where datalink is unavailable or unsuitable; and Standard procedures and taxi routes.
42. Airlines/operators and air traffic service providers should implement a monitoring program to ensure the consistent use of the ICAO phraseology. 83. Develop additional ICAO phraseology for flightcrew/air traffic service to address communication regarding aircraft position and equipment status, and communication which is not consistent with expected responses..	Culture-3: The FAA should provide leadership to update ICAO phraseology standards and to encourage their use.

JSAT Intervention Strategy	HF Team recommendation
52. Airlines/operators should ensure that their training/standardization programs establish flight crew proficiency in the use of the FMS system.	Knowledge-5: The FAA should reassess the airman certification criteria to ensure that pilots are released with a satisfactory level of skills for managing and using automation. Since current training is often oriented toward preparing pilots for checkrides, the airman certification criteria should be reassessed to ensure appropriate coverage of the topics listed in Recommendation Knowledge-2.
57. Airlines/operators/regulatory agencies/manufacturers should implement a program for sharing of safety related information within the aviation community.	Measures-1: The FAA should: • Lead the aviation community to use accident precursors increasingly and consistently as an additional measure of aviation safety; • Work with industry to establish systems/processes for collecting precursor data and for tracking the influence of system changes (e.g., design changes, training changes) on safety; and Work with industry to investigate other means of assessing or communicating safety (e.g., ways of measuring errors intercepted, incidents or accidents prevented, etc.).
77. Eliminate nonprecision approaches where possible.	Situation Awareness-4: The FAA and the aviation industry should develop and implement a plan to transition to standardized instrument approaches using lateral navigation (LNAV) and vertical navigation (VNAV) path guidance for three-dimensional approaches. The use of approaches that lack vertical path guidance should be minimized and eventually eliminated.
78. Airlines/operators and regulatory agencies should implement a process to improve the availability, clarity and prioritization of NOTAM information.	Comm/Cord-5: The FAA should encourage the redesign and modernization of the information provided to the flightcrew in notices to airmen (NOTAMs), charts, approach plates, instrument procedures, meteorological data, etc. The information should be prioritized and highlighted in terms of urgency and importance, and presented in a clear, well-organized, easy-to-understand format suitable for use with current and future airplanes.

JSAT Intervention Strategy	HF Team recommendation
111. Airlines/operators should evaluate their training/standardization programs to ensure emphasis on basic airmanship skills and knowledge during initial and recurrent training.	Knowledge-2: The FAA should reassess the requirements that determine the content, length, and type of initial and recurrent flightcrew training. Ensure that the content appropriately includes: • Management and use of automation, including mental models of the automation, and moving between levels of automation; • Flightcrew situation awareness, including mode and automation awareness; • Basic airmanship; • Crew Resource Management; • Decision making, including unanticipated event training; • Examples of specific difficulties encountered either in service or in training; and • Workload management (task management). The FAA should work with industry to develop guiding principles and associated advisory material for training, operational procedures, and flightcrew qualification for the areas listed above.

What follows are other FAA Human Factors Team recommendations that relate to the JSAT analysis which were not specifically identified by the JSAT:

<u>Measures-2</u> In accident/incident investigations where human error is considered a potential factor, the FAA and the National Transportation Safety Board should thoroughly investigate the factors that contributed to the error, including design, training, operational procedures, the airspace system, or other factors. The FAA should encourage other organizations (both domestic and foreign) conducting accident/incident investigations to do the same. This recommendation should apply to all accident investigations involving human error, regardless of whether the error is associated with a pilot, mechanic, air traffic controller, dispatcher, or other participant in the aviation system.

<u>Situation Awareness-1</u> The FAA should require operators to increase flightcrews' understanding of and sensitivity to maintaining situation awareness, particularly:

- Mode and airplane energy awareness issues associated with autoflight systems (i.e., autopilot, autothrottle, flight management system, and fly-by-wire flight control systems);

- Position awareness with respect to the intended flight path and proximity to terrain, obstacles, or traffic; and
- Potential causes, flightcrew detection, and recovery from hazardous pitch or bank angle upsets while under autopilot control (e.g., wake vortex, subtle autopilot failures, engine failure in cruise, atmospheric turbulence).

Situation Awareness-5 The FAA should encourage the exploration, development, and testing of new ideas and approaches for providing effective feedback to the flightcrew to support error detection and improved situation awareness.

Haase, D., *ALPA Ground Proximity Warning System Survey*, November 2, 1992.

This survey was a compilation of several CFIT and GPWS papers, NTSB accident recommendations, ALPA questionnaire summaries and the ICAO *ANC Task No. OPS-9103: Review of the Provision On Ground Proximity Warning Systems in Annex 6, Parts I and II* (Haase's attachment 6).

In the ICAO review, 206 CFIT accidents were tabulated. The report states:

> "The GPWS was known to have provided a warning in 43 of the 206 accidents. However, information available shows that in 3 of these cases, there was insufficient time to react, in 17 the warning was disregarded or canceled, in 16 the response was either too little or too late."[1]

The review indicates that "CFIT accidents result from any of a number of factors, including:

- non-observance of minimum safe altitude;
- characteristics of the flight director system;
- characteristics of the autopilot;
- navigation error;
- misinterpretation of approach procedures;
- misunderstanding or misinterpretation of ATC instructions;
- ATC vectoring error;
- non-compliance with approach procedures;
- non-compliance with departure procedures;
- attempt at visual flight in non-visual conditions;
- altimeter setting error;
- temperature or pressure widely different from the standard atmosphere;
- increasing and unchecked or unappreciated bank angle;
- lack of flight crew cross-checking."[2]

Further, the ICAO paper goes on to say: "The ability of the GPWS to affect the outcome of a potential accident may itself be compromised by any of the following:

- piecemeal introduction of GPWS without proper awareness of its use, characteristics and benefits;
- no operator policy on the use of the GPWS;
- inadequate training of flight crew;
- GPWS provided but totally disabled;
- GPWS provided but partially disabled;
- GPWS disabled by the flight crew prior to approach;
- warning canceled or disregarded by the flight crew;
- too many false warning in the flight crew's previous experience;
- too many unwanted warnings in the flight crew's previous experience;
- warning too late;
- flight crew response too late and/or too little to a warning."[3]

A spreadsheet was developed to tabulate the ICAO report factors against the JAST CFIT problem statements. The ICAO review validates the recommendations for TAWS-EGPWS installation, for flightcrew training, for airline/operator policies to be implemented, standardized and monitored, and for instrument approach/departure procedures to be improved. In total, the ICAO review identified 13 factors that are contained in the JSAT analysis.

It is worth noting that the ICAO review was international in scope.

ICAO, *Safety Study, Human Factors Issues in Controlled Flight into Terrain (CFIT) Accidents, 1984-1994* (draft), September, 1994.

The referenced report dealt with human factors and organizational issues. The report cites a dual pathway to a CFIT event:

> "The analysis thus discloses a dual pathway leading to CFIT accidents: an 'active' pathway, generated by actions or inactions of front-line operational personnel (i.e., pilots, controllers, mechanics, and so forth); and a 'latent' pathway, generated by deficiencies in various aspects of the aviation system, for which managers and decision-makers are responsible."[4]

Twenty-four accidents were reviewed in the subject report. The analysis classifies the deficiencies as Organizational Process (27.8%), Active Failures (12.2%), Latent Failures (19.6%), Local Working Conditions (20.9%) and Defensces (19.6). Each of these categories includes sub-level classifications. Of the 36 standard problem statements identified in the JSAT analysis, the ICAO HF report showed strong agreement in 26 areas (72% correlation).

Khatwa, R. and Roelen, A. L. C., *An Analysis of Controlled Flight into Terrain (CFIT) Accidents of Commercial Operators 1988 Through 1994*, National Aerospace Laboratory NLR, The Netherlands, February, 1996.

The NLR report was targeted at determining if differences in air taxi, regional and major operational categories play a role in the occurrence of CFIT. The report listed several recommendations, which are tabulated below.

NLR Report: 6 Recommendations[5]	JSAT
(a) All operators should be encouraged to comply with existing and future ICAO requirements pertaining to the fitment of GPWS. Furthermore, the use of GPWS for domestic operations should be advocated as recommended by the FSF/ICAO CFIT Task Force.	Team analysis concurs with the NLR report.
(b) International support should be given to reducing the CFIT risk variances between the various ICAO regions.	International implications are beyond the scope of CFIT JSAT Charter.
(c) CFIT risk reduction efforts need to encompass not only the major air carriers, but emphasis also needs to be applied to air taxi and regional operations.	JSAT did not examine carrier category effects.
(d) Any means of reducing of flight crew procedural and tactical decision making errors is encouraged. Whether this involves training and/or improved cockpit discipline, or other measures such as error-tolerant design of check-lists and procedures is a matter of future study.	Team analysis concurs with the NLR report.
(e) Means of improving terrain situational awareness are encouraged. In this respect, the FSF/ICAO CFIT Task force is currently recommending:	Team analysis concurs with the NLR report.
· The use of colored contours to present either terrain or minimum flight altitudes on instrument approach charts;	Team analysis concurs with the NLR report..
· Technological developments that would allow a visual display of the terrain to the flight crew; and	Team analysis concurs with the NLR report.
· Radio altitude call-out facility to be employed to improve crew awareness of proximity to terrain. Where altitude call-out is not available, or where GPWS is not fitted, a radio altimeter raw data can still be used to enhance terrain awareness.	This recommendation is currently required under Part 121 procedures.

NLR Report: 6 Recommendations[5]	JSAT
(f) The international sharing of accident and incident data should be encouraged, to facilitate addressing safety problems quickly and effectively. The difficulty of obtaining high-quality information about accidents was a major problem in this study.	The JSAT strongly agrees with this recommendation and noted similar problems with acquiring high-quality information.

Phillips, R., *Investigation of Controlled Flight Into Terrain Aircraft Accidents Involving Turbine-Powered Aircraft with Six or More Passenger Seats Flying Under FAR part 91 Flight Rules and the Potential for Their Prevention by Ground Proximity Warning Systems (GPWS)*, Cambridge, MA: U. S. Department of Transportation, Volpe National Transportation System Center, Report # DOT-TSC-FA6D1-96-01, March, 1996.

The referenced Volpe report sought to determine if GPWS would have prevented CFIT accidents for aircraft operating under 14 CFR Part 91. The problem statements developed by the JSAT were compared to the NTSB accident factors and causes cited in the referenced report. There were obvious differences in accomplishing a direct validation, since this Volpe report studied Part 91 accidents, while the JSAT reviewed accidents under Part 121 operations. However, common areas were identified.

The referenced report listed fifteen Probable Causes and fifteen Contributing Factors. With the exception of items specific to Part 91 operation, all causes and factors were identified as problems in the JSAT analysis. The specific Part 91 issues highlight the conclusion that operations under reduced regulatory oversight will lead to problems related to that lack of oversight.

Phillips, R., *Investigation of Controlled Flight Into Terrain For Selected Aircraft Accidents Involving Aircraft Flying Under FAR Part 121 and 135 Flight Rules and the Potential for Their Prevention by Enhanced Ground Proximity Warning Systems (EGPWS)*, Cambridge, MA: U. S. Department of Transportation, Volpe National Transportation System Center, Report # DOT-TSC-FA6D1-96-03, July, 1996.

The referenced Volpe report examined the effectiveness of EGPWS in preventing CFR Part 121/135 or equivalent. Nine accidents were selected for review in the referenced report based on the applicability of GPWS warning profiles and the likelihood of a GPWS warning. Five of these nine were also used in the JSAT analysis and were thus not used in the comparison.

The JSAT report identified 36 distinct standardized problem statements. The number of problems identified for each of the four new accidents in the referenced report ranged from 8 to 13. The overlap between the two sets of problem statements was roughly 33%; however, the most-commonly cited problems for each accident set displayed a higher level of agreement.

Walker, David, *FSF Controlled Flight Into Terrain Task Force*, slide presentation, FSF/IFA/IATA 48th International Air Safety Symposium, Seattle, WA, November, 1995.

Recommendations from the subject presentation were found to validate those of the JSAT:

Install GPWS in aircraft
Approach Procedures
    Nonprecision approaches (NPA) are unnecessarily hazardous
    NPA must be simplified
    Nominal descent path for every approach (3 degrees)
    One final approach segment per navigation aid/runway combination
Crew/Operator and Regulatory awareness training.

Weener, E.F., *Second Annual Report of the FSF/ICAO CFIT Accident Reduction Task Force*, meeting summary, Lisbon (no date available).

Recommendations from the referenced meeting were found to validate those of the JSAT:

- Colored contours should be used to present either terrain or minimum flight altitude information on instrument approach charts.

- Nonprecision approach procedures should be constructed, whenever possible, in accordance with established stabilized approach criteria. Additionally, the ICAO Procedures for Air Navigation Services (PANS-OPS) should be re-examined.

- Early GPWS equipment should be taken out of service or updated, where modifications are available. Such action would result in a decrease in the number of unwanted warnings experienced and thus increase the integrity and reliability of the GPWS.

- All aeroplanes in commercial and corporate use should be equipped with GPWS even where these aeroplanes are used only in domestic operations.

- The radio altitude call-out (automatic aural) facility should be employed to enhance situational awareness of proximity to terrain.

- All States and operators should be informed of the dangers inherent in the use of three-pointer and drum-pointer altimeters and that usage of these altimeters should be discontinued.

- All States should standardize on the use of hectopascals for altimeter settings in accordance with the established international Standards, and thus eliminate the potential hazard of the mis-setting of the altimeter.

- Enhance the situational awareness by providing terrain awareness and predictive terrain hazard warning.

- Consider the use of GPS to benefit situational awareness and accuracy of navigation.

- Head-up Display benefits should be publicized more widely, use generally encouraged and development continued to eliminate known limitations.

IX. CONCLUSION

The JSAT reviewed ten representative commercial CFIT accidents for which adequate accident data was available. The team analyzed these accidents, identified problems contributing to the accidents, and developed and prioritized 106 separate intervention strategies to address the accidents. Of those intervention strategies, 21 have been identified for highest implementation priority based on their effectiveness and feasibility, as judged by the JSAT. TAWS-EGPWS, aimed at providing flight crews with increased awareness and warning of surrounding terrain, was identified as the most-recommended intervention due to its potential to intervene in the broad spectrum of CFIT accidents.

Seventeen of the remaining 20 highest priority recommendations attempt to provide a means for airlines/operators to identify those procedures, training concepts, and other programs most likely to minimize the likelihood of future CFIT and near-CFIT accidents. The other three intervention strategies are directed towards the improvement of ATC information transfer, glideslope guidance systems, and MSAW equipment.

A total of 43 intervention strategies fell into the secondary prioritization category. This group included two interventions which had top overall effectiveness scores, but low feasibility – GPS datalink and synthetic vision. If these technologies develop to the point of improving the feasibility of their implementation, GPS datalink and synthetic vision should also receive the highest priority for implementation.

The remaining interventions in the secondary prioritization category were judged to be of lesser effectiveness across the overall category of CFIT. However, each identified intervention has either high potential against a small subset of CFIT accidents, or moderate potential across the spectrum of accidents (midrange overall effectiveness scores). Again, most (20 out of 43) of the interventions in this group were targeted at possible airline/operator improvements.

Thirty-seven intervention strategies fell into the third prioritization category. These interventions did not meet the criteria for either of the first two prioritization categories. The remaining five identified intervention strategies were determined to be either not applicable within the United States, or already widely implemented.

Results of this study, which used a sample of accident data, correlated closely with results of the more exhaustive studies by the Flight Safety Foundation (FSF) CFIT task force, the Netherlands National Aerospace Laboratory (NLR), and others. This serves to validate the process and the results and complies with the direction from the CAST. It also provides validation for using the JSAT process for other areas of interest. The predominance of operational intervention strategies in this report is consistent with the results of the previous CFIT studies and is to be expected with this type of event.

X. RECOMMENDATIONS

The JSAT's findings were achieved using a process developed by industry and government representatives working cooperatively to address Controlled Flight into Terrain. These findings were further reviewed and validated against other recent CFIT studies.

This study demonstrated that a joint industry/government team can work together to develop recommended safety intervention strategies. The team recommends:

- Continuation of joint safety analyses (JSAT's).
- Review and disposition of this report by the appropriate JSIT.

XI. FOOTNOTES

[1] Captain Dave Haase, *ALPA Ground Proximity Warning System Survey*, Attachment 6 (ANC Task No. OPS-9013: Review of the provisions on ground proximity warning systems in Annex 6, Parts I and II, ICAO, Air Navigation Commission). November 2, 1992, Attachment 6, Appendix C, p. F-6.

[2] Ibid., p. F-6.

[3] Ibid., p. F-7.

[4] *Safety Study, Human Factors Issues in Controlled Flight into Terrain (CFIT) Accidents, 1984-1994* (draft). ICAO, September, 1994, unpaginated.

[5] R. Khatwa and A. L. C. Roelen, *An Analysis of Controlled Flight into Terrain (CFIT) Accidents of Commercial Operators 1988 Through 1994*. National Aerospace Laboratory NLR, The Netherlands, February, 1996, p. 46.

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XII. APPENDICES

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Appendix A

CFIT Joint Safety Analysis Team (JSAT) Charter

I **Purpose:** To review and analyze data and make coordinated recommendations to enhance commercial aviation safety.

II **Background:** Industry (ISST) and FAA have agreed to work together to identify and implement a data driven, benefit focused, safety enhancement program designed to continuously improve our safe commercial aviation system. The FAA and ISST have further agreed that cooperatively and selectively pursuing the critical few high leveraged safety intervention strategies will maximize the safety benefit to the flying public through a focused application of industry and FAA resources. To achieve this goal, the FAA and ISST have agreed to charter a working group.

III **Task:**

A. The team shall acquire publicly available data, including prior studies and analyses. This will constitute the beginning point for review and analysis.

B. The team shall develop, document, and utilize an analytical process to develop recommended safety intervention strategies. The process developed by the team should include "appropriate levels" of causal analysis to substantiate the effectiveness of recommended data driven intervention strategies. In addition to documenting its safety analysis process, analysis results, and recommended intervention strategies, the team shall define its assumptions regarding the amount and extent of data considered (fleet size, time frame, etc.).

IV **Products:** The deliverables include reports to the FAA and industry documenting the team's process, recommended safety intervention strategies and assumptions used in the analysis.

V **Membership:** The initial team will include representatives with the appropriate technical background provided by industry and the FAA.

VI **Proof of Concept:** To validate the partnership process, the team will review Controlled Flight Into Terrain (CFIT) data and present its findings and a recommendation on continuing joint analysis at an executive meeting of the ISST and FAA. Interim briefings to the ISST and FAA may be required to facilitate business planning.

VII **Resources:** The signatories agree to provide the financial, logistic and personnel resources to carry out this charter.

Appendix B

Data Set

The following is a synopsis of the accidents that were used by the JSAT:

1. Buffalo Airways, Inc., Boeing 707-351C, April 13, 1987, Kansas City, Missouri

   Aircraft crashed approximately 3 nautical miles short of Runway 1 while conducting an Instrument Landing System (ILS) approach to that runway. All 4 occupants onboard the aircraft sustained fatal injuries.

2. Flying Tiger Line, Inc., Boeing 747-200, February 18, 1989, Kuala Lumpur

   Aircraft crashed while executing a Non-Directional Beacon (NDB) approach to Runway 33 at Subang Airport. The wreckage was located approximately 9 nautical miles southeast of Subang International Airport. All 4 occupants onboard the aircraft sustained fatal injuries.

3. Markair, Inc., Boeing 737-200, June 2, 1990, Unalakleet, Alaska

   Aircraft crashed approximately 7.5 nautical miles short of Runway 14 while executing a Localizer approach to that runway. Several minor injuries and one serious injury were sustained.

4. Alitalia AZ 404, Douglas DC-9-32, November 14, 1990, Zurich, Switzerland

   Aircraft crashed while executing an approach to Runway 14 at Zurich. The aircraft first impacted trees approximately 5.2 nautical miles from the runway threshold. The aircraft then impacted the surface of the wooded north face of the Stadlerbert. All 40 passengers and 6 crewmembers sustained fatal injuries.

5. Air Inter, Airbus A320, January 20, 1992, Strasbourg, France **(Dropped due to lack of a published report)**

   Aircraft crashed while executing a Variable Omni-range Radar (VOR) procedure approach to Runway 5 into Strasbourg. The wreckage was located approximately 0.5 nautical miles to the left of and 7 nautical miles short of the VOR in use. Eighty-two passengers and 5 crewmembers sustained fatal injuries.

6. Golden Star Trading, Inc., Boeing B707, March 24, 1992, Athens, Greece

   Aircraft crashed after executing a missed approach from Runway 33 Right at Athens Airport. The wreckage was located approximately 1700' above sea level in the Hymettus mountains. All 3 crewmembers and 4 passengers sustained fatal injuries.

7. Thai Airways, Inc., Airbus A310, July 31, 1992, Kathmandu, Nepal
   Aircraft crashed after discontinuing a VOR/DME approach to Runway 2 into Tribhuvan International Airport at Kathmandu. After several course changes, the aircraft impacted a 16,000' mountain at approximately the 11,500' level, approximately 23.3 nautical miles from the Kathmandu VOR. All 99 passengers and 14 crewmembers sustained fatal injuries.

8. Pakistan Airlines, Airbus A310, September 28, 1992, Katmandu, Nepal
   Aircraft crashed while executing a Sierra Approach to Runway 2 at Kathmandu, Nepal. The aircraft impacted a steep hillside approximately 9.8 nautical miles from the runway. The wreckage was located on the hillside at the 7,300' elevation of a 7,500' mountain. All 167 individuals (passengers and crewmembers) onboard sustained fatal injuries.

9. Asiana Airlines, Boeing 737-500, July 26, 1993, Mokpo, Korea **(Dropped due to lack of information)**
   Aircraft crashed while conducting its third approach to Runway 6 at Mokpo Airport in Korea. The aircraft impacted a hill approximately 4.5 nautical miles from the airport. At least 50 passengers sustained fatal injuries.

10. Air Algerie, Boeing 737-200, December 21, 1994, Coventry, England
    Aircraft crashed while executing a Surveillance Radar Approach (SRA) to Runway 23 at Coventry Airport. The aircraft initially contacted electricity cables, which caused damage to the left wing. The aircraft then rolled and contacted a house. All 5 individuals onboard the aircraft sustained fatal injuries.

11. American Airlines, Inc., McDonnell Douglas MD-80, November 12, 1995, Hartford, Connecticut
    Aircraft was substantially damaged when it impacted trees while on approach to Runway 15 at Bradley International Airport. The aircraft also impacted an ILS antenna as it landed short of the runway. There were no injuries to any passengers or crew.

12. American Airlines, Inc., Boeing 757, December 20, 1995, Cali, Columbia
    Aircraft crashed during a descent from cruise altitude while in Visual Meteorological Conditions (VMC). The aircraft crashed into mountainous terrain approximately 33 nautical miles northeast of the Cali VOR. The wreckage was located approximately 8,900' msl, near the summit of El Deluvio. Of the 155 passengers and 8 crewmembers, 4 passengers survived the accident.

Appendix C

<u>Problem Statement by Accident Summary</u>

	Accident	1	2	3	4	6	7	8	10	11	12	
Prob. #	**Problem**	Buffalo 707	Flying Tiger 747	Markair 737-200	Alitalia DC-9	Golden Star 707	Thai A310	Pakistan A300	Air Algerie 737-200	American MD-80	American 757	**Total Accidents in Which Found**
1	FLIGHTCREW - LACK OF ENGLISH LANGUAGE SKILLS						✓		✓			2
2	FLIGHTCREW - FAILURE TO FOLLOW PROCEDURES (COMMUNICATIONS)		✓			✓	✓				✓	4
3	AIR TRAFFIC SYSTEM - LACK OF STANDARDIZATION (APPROACH PLATES)			✓			✓					2
4	ATC - LACK OF ENGLISH LANGUAGE SKILLS						✓				✓	2

Prob. #	Problem (Accident)	1 Buffalo 707	2 Flying Tiger 747	3 Markair 737-200	4 Alitalia DC-9	6 Golden Star 707	7 Thai A310	8 Pakistan A300	10 Air Algerie 737-200	11 American MD-80	12 American 757	**Total Accidents in Which Found**
5	ATC / FLIGHTCREW INADEQUATE COMMUNICATIONS		✓				✓	✓	✓		✓	5
6	ATC - FAILURE TO FOLLOW PROCEDURES (COMMUNICATIONS)	✓	✓				✓			✓		4
7	ATC - INADEQUATE SITUATIONAL AWARENESS (HORIZONTAL)				✓		✓				✓	3
8	ATC - FAILURE TO FOLLOW PROCEDURES (SOP)	✓	✓				✓		✓	✓		5
9	AIRLINE OPERATIONS - PF/PNF FLYING PROCEDURES (INCREASED WORKLOAD AT A CRITICAL PHASE)	✓		✓								2

	Accident	1	2	3	4	6	7	8	10	11	12	
Prob. #	**Problem**	Buffalo 707	Flying Tiger 747	Markair 737-200	Alitalia DC-9	Golden Star 707	Thai A310	Pakistan A300	Air Algerie 737-200	American MD-80	American 757	**Total Accidents in Which Found**
10	FLIGHTCREW - FAILURE TO FOLLOW PROCEDURES (SOP)	✓	✓	✓	✓	✓	✓	✓		✓	✓	9
11	FLIGHTCREW - INADEQUATE SITUATIONAL AWARENESS (VERTICAL)	✓	✓	✓	✓		✓	✓	✓	✓	✓	9
12	FLIGHTCREW - INADEQUATE SITUATIONAL AWARENESS (HORIZONTAL)		✓	✓	✓		✓				✓	5
13	INSTRUMENTATION - FLIGHTCREW MISINTERPRETED PRESENTATION	✓			✓							2
14	AIRCRAFT EQUIPMENT - EQUIPMENT FAILURE	✓	✓		✓	✓						4

	Accident	1	2	3	4	6	7	8	10	11	12	
Prob. #	**Problem**	Buffalo 707	Flying Tiger 747	Markair 737-200	Alitalia DC-9	Golden Star 707	Thai A310	Pakistan A300	Air Algerie 737-200	American MD-80	American 757	**Total Accidents in Which Found**
15	AIRLINE OPERATIONS - CORPORATE "ON-TIME" CULTURE			✓							✓	2
16	FLIGHTCREW - CRM FAILURE		✓		✓		✓				✓	4
17	AIRLINE OPERATIONS - LACK OF STANDARDIZED PROCEDURES			✓	✓		✓					3
18	AIR TRAFFIC SYSTEM - LIMITED NAVAID AVAILABILITY		✓									1
19	FLIGHTCREW - LACK OF BASIC PILOTING SKILLS	✓	✓	✓			✓		✓	✓	✓	7
20	AIRLINE OPERATIONS - LACK OF TRAINING (FLIGHTCREW)			✓						✓	✓	3

	Accident	1	2	3	4	6	7	8	10	11	12	
Prob. #	**Problem**	Buffalo 707	Flying Tiger 747	Markair 737-200	Alitalia DC-9	Golden Star 707	Thai A310	Pakistan A300	Air Algerie 737-200	American MD-80	American 757	**Total Accidents in Which Found**
21	FLIGHTCREW - "PRESS-ON-ITUS"		✓		✓					✓	✓	4
22	FLIGHTCREW - PNF DUTIES NOT PERFORMED	✓	✓	✓			✓	✓		✓	✓	7
23	FLIGHTCREW - DISREGARD FLIGHTDECK WARNING		✓				✓					2
24	FLIGHTCREW - CREW MEDICAL / FATIGUE CONCERNS		✓			✓			✓			3
25	AIRCRAFT EQUIPMENT - DESIGN SHORTCOMINGS (AVIONICS)			✓	✓		✓		✓			4
26	AIRCRAFT EQUIPMENT - FDR, CVR INOPERATIVE (for future accident prevention)					✓		✓				2

	Accident	1	2	3	4	6	7	8	10	11	12	
Prob. #	**Problem**	Buffalo 707	Flying Tiger 747	Markair 737-200	Alitalia DC-9	Golden Star 707	Thai A310	Pakistan A300	Air Algerie 737-200	American MD-80	American 757	**Total Accidents in Which Found**
27	AIR TRAFFIC SYSTEM - INADEQUATE INFRASTRUCTURE (TRAINING/ SUPERVISION)						✓					1
28	AIR TRAFFIC SYSTEM - INADEQUATE INFRASTRUCTURE (EQUIPMENT/ DESIGN)	✓					✓			✓	✓	4
29	AIRLINE OPERATIONS - NO FAULT GO AROUND POLICY						✓					1
30	ATC - INADEQUATE SITUATIONAL AWARENESS (VERTICAL)						✓				✓	2
31	FLIGHTCREW - OVER RELIANCE ON AUTOMATION (FMS)						✓			✓	✓	3

	Accident	1	2	3	4	6	7	8	10	11	12	
Prob. #	**Problem**	Buffalo 707	Flying Tiger 747	Markair 737-200	Alitalia DC-9	Golden Star 707	Thai A310	Pakistan A300	Air Algerie 737-200	American MD-80	American 757	**Total Accidents in Which Found**
32	AIRLINE OPERATIONS - INADEQUATE INFORMATION DISSEMINATION				✓					✓		2
33	AIR TRAFFIC SYSTEM - INADEQUATE INFORMATION DISSEMINATION	✓								✓		2
34	FLIGHTCREW - FAILURE TO EXERCISE COMMAND (CAPTAIN) RESPONSIBILITY				✓						✓	2
35	AIRLINE OPERATIONS - INADEQUATE SAFETY DATA SHARING				✓						✓	2
36	AIRLINE OPERATIONS - IMPROPER MAINTENANCE OF CRITICAL SYSTEMS				✓							1

Appendix D

CFIT Intervention Effectiveness and Feasibility Ratings

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
1	Airlines/operators should implement an Airline Safety Incident Reporting System (e.g., BASIS, ASAP).	0	0.99	3	Process
2	Airlines/operators and regulatory agencies should strictly enforce the regulations pertaining to alcohol use/substance abuse.	1	0.33	3	
3	Ensure that failure of the aircraft system to capture glideslope (or VNAV) is adequately annunciated to the flight crew.	2	0.70	2	Cost
4	Ensure FMS depiction is consistent with approach plate presentation.	0	0.48	2	Cost Process
5	Regulatory agencies should mandate that approach plates show color contours for terrain.	0	1.20	3	
6	Regulatory agencies should establish standardized approach plate depiction/information requirements for approach plate publishers.	1	0.93	3	
7	Airlines/operators should ensure that their training/standardization programs emphasize review of approach and missed approach procedures.	0	1.90	3	
8	The aviation industry should establish world-wide standards for the presentation format of instrument approach procedures.	1	1.20	2	Process

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
10	Air Traffic service providers should train Air Traffic Controllers to use all available tools to establish aircraft position (example: don't fixate on just DME).	0	1.00	2.5	Process
11	Air Traffic service providers should implement procedures that ensure that ATC trainees are always supervised.	0	0.19	3	
12	Air Traffic service providers should emphasize in ATC training the controllers' potential in assisting the flight crew in improving their situation awareness.	0	1.19	3	
13	Air Traffic service providers should enhance ATC training to emphasize the dangers of rushed approaches and performance characteristics of modern jet transports.	1	0.86	2.5	Process
14	Install aural warning devices on aircraft to alert flightcrew of arrival at MDA/DH.	0	0.73	1.5	Cost
15	Airlines/operators should ensure that their training/standardization programs instruct when to disengage automated systems and fly manually.	0	0.69	3	
16	Manufacturers should ensure that automated systems provide the flight crew with sufficient information (automation feedback) to prevent mode confusion.	0	0.61	1.5	Process Cost Technology
17	Airlines/operators should ensure that their training/standardization programs emphasize the importance of all flight related briefings.	1	1.64	3	

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
19	Airlines/operators should implement a procedure to climb to a minimum safe altitude when position uncertainty exists by at least one crew member. Flight crew must advise ATC of intentions.	3	1.89	2.5	Process
20	Airlines/operators should ensure that command oversight training for captains is provided during the upgrade process and in recurrent training.	0	1.18	3	
21	Establish/enhance quality assurance checks/training to ensure that timely and accurate communication between controllers and flight crews is occurring.	0	1.32	2	Process
22	Airlines/operators should encourage a culture that emphasizes safe arrivals over timely arrivals.	0	1.06	3	
23	Airlines/operators should ensure that regularly scheduled recurrent training (e.g., LOFT) emphasizes crew cooperation and working together to maximize safe operations.	0	1.50	3	
24	Airlines/operators should implement procedures to ensure appropriate crew pairing. (reference FSF corporate crew scheduling and fatigue evaluation.)	0	0.56	2	Process Cost
25	Airlines/operators should establish a CRM training program.	0	1.65	3	
26	Airlines/operators should ensure that CRM training is provided prior to line flying.	0	0.81	3	

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
27	Airlines/operators should implement maintenance procedures to ensure proper functioning of the CVR at all times. (Note: This intervention was recorded as a potential intervention for future accidents; it would not have prevented the subject accidents.)	0	0.42	1.5	Process Cost
28	Implement a system to automatically transmit ATC instructions/information between the ground controller and the aircraft.	0	0.93	1.5	Process Cost
29	Implement transmission of ATC instructions (between the ground and aircraft) via a computer link which would allow downloading to the FMS.	0	0.87	1	Process Cost Technology
30	Airlines/operators should adopt the "delegated" approach to standard operating procedures. (e.g., monitored approach procedures)	0	0.66	1	Process Technology (HF)
31	Airlines/operators should ensure that crew rest considerations (cabin crew and flight crew) are calculated and administered by dispatch/crew scheduling rather than burdening crews with these considerations.	0	0.39	3	Process
32	In the absence of GPS, regulatory agencies should install DME equipment at all appropriate airports.	0	0.59	1	Cost
35	Manufacturers should install EGPWS in all new aircraft, airlines/operators should retrofit EGPWS into the existing fleet and international regulators should require the installation of EGPWS.	10	2.93	2	Cost

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
36	Airlines/operators should establish and implement the use of electronic checklists or other aids to ensure completion of all checklist items.	0	0.42	2	Process
37	Regulatory agencies should discontinue on-time arrival tracking for airlines.	0	0.34	2.5	Process
40	Airlines/operators and air traffic service providers should ensure fluency/proficiency in the use of basic English language.	1	1.08	2.5	Process
41	Airlines/operators and air traffic service providers should train flight crews and controllers to ICAO standards to ensure fluency/proficiency in the use of the ICAO phraseology.	2	1.46	2	Process
42	Airlines/operators and air traffic service providers should implement a monitoring program to ensure the consistent use of the ICAO phraseology.	1	1.45	2	Process
45	Manufacturers should ensure that all equipment failures that may affect the safe operation of the flight are properly annunciated to the flight crew.	1	0.52	1	Process Cost Technology
46	Airlines/operators should implement procedures to increase flightcrew awareness of recent aircraft maintenance actions.	0	0.19	2.5	Process
47	Airlines/operators should ensure that their training/standardization programs direct the flight crews to use all available tools (charts) to establish aircraft position.	4	2.18	3	Process

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
48	Airlines/operators and regulatory agencies should strictly enforce flight/duty time limitations.	1	0.42	3	
49	Regulatory agencies should establish criteria for, and manufacturers should evaluate and improve, the reliability and failure tolerance of flight systems.	0	0.48	1	Process Cost Technology
50	Airlines/operators and regulatory agencies should emphasize that only published route segments should be flown in non radar environments.	0	1.03	3	Process
51	Airlines/operators should ensure the currency of the FMS database and update as appropriate.	0	0.28	3	
52	Airlines/operators should ensure that their training/standardization programs establish flight crew proficiency in the use of the FMS system.	0	0.60	3	
53	Airlines/operators should install FMS equipment (logic) which has the capability to depict previously entered way points that are between the current present position and the current "to" way point.	1	0.61	3	
54	Airlines/operators should implement Flight Operations Quality Assurance (FOQA) programs.	0	1.68	2	Process Cost
55	Airlines/operators should implement a Flight Operations Quality Assurance (FOQA) program to identify flight crew failure to respond to GPWS warnings.	1	1.26	2	Process Cost

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
56	Airlines/operators should implement Flight Operations Quality Assurance (FOQA) programs to identify systemic procedural deviations.	0	1.81	2	Process Cost
57	Airlines/operators, regulatory agencies, and manufacturers should implement a program designed for sharing of safety related information within the aviation community.	0	0.79	1	Process
58	Establish GPS datalink to relay aircraft position to ATC.	5	2.22	1	Cost Process
59	Implement precision approach capability (glideslope guidance) for all runways without established precision approach procedures (e.g., ILS, DGPS, etc.).	4	2.20	2	Cost Process Technology
60	Avionics manufacturers should improve GPWS capability to reduce GPWS false warnings.	0	0.56	3	
61	Airlines/operators (and manufacturers in the airplane flight manual) should implement procedures that call for an immediate execution of the escape maneuver following a GPWS warning unless there is visual confirmation of terrain.	2	1.50	3	
62	Airlines/operators should ensure that their training/standardization programs establish flight crew proficiency in all uses of the HSI display.	0	0.66	3	
63	Airlines/operators should implement a culture which encourages flight crew voluntary removal from flight status due to illness.	0	0.19	2	Process

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
64	Airlines/operators should ensure that their training/standardization programs direct the flight crews to regularly cross check all instrumentation.	2	1.99	3	
66	Airlines/operators should implement procedures to avoid simultaneous maintenance on redundant flight critical systems.	1	0.28	2	Process
67	Airlines/operators should require flight crews to perform non-FMS (raw data) approaches during proficiency/recurrent check rides.	0	0.78	3	Cost
68	Manufacturers should implement a system to identify the recommended implementation schedule and priority of aircraft and operational changes.	0	0.18	2.5	Process
70	Airlines/operators and regulatory agencies should strictly enforce the regulations pertaining to flight crew use of prescription and non-prescription medication.	0	0.15	3	
71	Review the engineering standards for the siting of future Terminal Radar Systems to ensure the maximum effectiveness of MSAW is available.	1	1.98	3	
72	Install MSAW-like capabilities world-wide with emphasis on high-risk airports.	6	2.33	N/A	
73	Airlines/operators should ensure that the aircraft is equipped with all expected NAVAID frequencies.	1	0.31	N/A	

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
74	Regulatory agencies should review, and where appropriate, eliminate duplicate NAVAID identifiers within the same geographic area.	1	0.31	2	Process Cost
75	Airlines/operators should ensure that their training/standardization programs direct that flight crews use all available tools to establish aircraft position.	3	1.95	3	
76	The manufacturer of the FMS should ensure that the FMS logic displays NAVAIDs with the same identifier in a progressive distance manner.	0	0.00	2	Cost
77	Eliminate nonprecision approaches where possible.	2	1.39	2	Cost
78	Airlines/operators and regulatory agencies should improve the availability, clarity, and prioritization of NOTAM information.	0	0.35	1.5	Cost Process Technology
79	Airlines/operators should implement a reliable process to communicate information to the flight crew that may effect flight or aircraft operations.	2	0.89	2	Process
80	Airlines/operators should ensure, and regulatory agencies should check, that operators who create their own AOM's include all procedures prescribed by original equipment manufacturers Airplane Flight Manual (AFM).	0	0.39	2.5	Process
82	Airlines/operators should clearly define, train and check the specific PF/PNF duties.	1	1.63	3	

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
83	Develop additional ICAO phraseology for flight crew/air traffic service to address communication regarding aircraft position and equipment status, and communication which is not consistent with the situation or with expected responses.	2	1.33	1.5	Process
85	The aviation industry should develop and implement synthetic vision capability (e.g., Precision Approach Terrain Information(PATI)).	3	2.22	1	Technology Cost Process
88	Airlines/operators should train and monitor flight crew compliance with established communication phraseology guidelines.	0	1.02	2	Process
89	Airlines/operators and regulatory agencies should ensure that the frequency and effectiveness of proficiency checks for nonprecision approaches are adequate.	0	1.33	2	Process
90	Airlines/operators and regulatory agencies should prohibit engineering flight tests during revenue flights following maintenance of critical systems .	1	0.28	N/A	
91	Airlines/operators and regulatory agencies should standardize usage of QNH altimeter settings.	0	0.37	N/A	
93	Improve the real time radio communication of critical airport and weather information.	0	0.53	2	Process
94	Implement real time (digital) transmission of airport and weather information to the aircraft.	0	0.53	1.5	Cost

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
95	Airlines/operators should establish procedures for flight crews to review/cross check instructions, clearances, etc. to ensure consistency with expected procedures or practices.	0	1.40	2	Process
96	Airlines/operators should ensure that their training/standardization programs emphasize the importance of adequate approach preparation and contingency review prior to commencing an approach.	2	1.73	3	
98	Airlines/operators and regulatory agencies should review procedures to ensure that design changes (service bulletins) to flight critical systems are incorporated in a timely manner.	0	0.26	2	Cost Process
99	Airlines/operators should ensure that standard operating procedures are published and enforced.	0	1.51	2	Process
100	Airlines/operators should ensure that their training/standardization programs emphasize the importance of adhering to MDA/DH.	1	1.73	3	
101	Airlines/operators should establish a policy which supports the reporting of substance abuse.	1	0.40	3	
103	Manufacturers should develop and implement system failure annunciation capabilities to alert flight crews of pending failures (e.g., HUMS).	0	0.49	0.5	Cost Technology Process

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
105	Airlines/operators should train flight crews on how flight delays (weather, maintenance, ATC, etc.) can effect their subsequent decision making relative to the safe conduct of the flight.	0	0.85	3	
106	Train and monitor ATC adherence to established communications procedures.	0	1.39	2	Process
107	Airlines/operators should ensure that their CRM training/standardization program emphasizes the importance of the team concept.	0	1.73	3	
108	Air Traffic service providers should implement and/or review procedures to ensure ATC-training does not create a hazard to flight operations.	0	0.40	3	
110	Airlines/operators and regulatory agencies should ensure that their training/standardization and monitoring programs emphasize the importance of adherence to standard operating procedures and identify the rationale behind those procedures.	1	1.67	3	
111	Airlines/operators should ensure that their training/standardization programs emphasize basic airmanship skills and knowledge during initial and recurrent training.	0	1.38	3	
112	Airlines/operators and regulators should ensure that the frequency and effectiveness of proficiency checks for simulated instrument failures (partial panel) are adequate.	1	0.90	2.5	Process

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
113	Airlines/operators should ensure that their training/standardization programs emphasize the importance of adequate preflight planning.	0	0.84	3	
114	Airlines/operators should ensure that their training/standardization programs provide an appropriate minimum amount of standard training.	0	0.55	3	
115	Airlines/operators should ensure that their training/standardization programs emphasize the dangers of rushed approaches.	2	1.33	3	
116	Airlines/operators should ensure that their training/standardization programs emphasize the dangers of high rate of descent and unstable approaches.	0	0.68	3	
117	Airlines/operators should ensure that their training/standardization programs instruct that ground proximity escape maneuvers are to be conducted with the aircraft properly configured (e.g., speedbrakes retracted).	1	0.53	3	
120	Airlines/operators should ensure procedures do not increase pilot workload during critical phases of flight.	0	0.58	1.5	Process
121	Implement worldwide surveillance radar (example: ADS/B)	0	1.17	N/A	

#	Intervention	Number of accidents in which highly effective	Overall Effectiveness	U.S. Feasibility	Issues
122	Implement transmission of ATC instructions/information (between the ground and aircraft) via a computer link as opposed to voice communications.	0	1.41	1	Technology Cost Process
123	Airlines/operators should implement a true no-fault go around policy (learning vs. blame).	0	1.20	1.5	Process
124	ATC should implement a Quality Assurance program to ensure adherence to established procedures.	0	2.09	3	
125	Airlines/operators should encourage flight crews to use precision approaches (glideslope guidance) when available and appropriate.	1	0.92	3	
126	ATC should prioritize the use of precision approaches (glideslope guidance) when available and appropriate.	1	0.95	2.5	Process Cost
127	Airlines/operators should install FMS equipment (logic) which has the capability to depict previously entered way points behind the aircraft's flightpath.	1	0.51	3	