Preliminary Analysis of Aircraft Loss of Control Accidents: Worst Case Precursor Combinations and Temporal Sequencing

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Aircraft loss of control (LOC) is a leading cause of fatal accidents across all transport airplane and operational classes, and can result from a wide spectrum of hazards, often occurring in combination. Technologies developed for LOC prevention and recovery must therefore be effective under a wide variety of conditions and uncertainties, including multiple hazards, and their validation must provide a means of assessing system effectiveness and coverage of these hazards. This requires the definition of a comprehensive set of LOC test scenarios based on accident and incident data as well as future risks. This paper defines a comprehensive set of accidents and incidents over a recent 15 year period, and presents preliminary analysis results to identify worst-case combinations of causal and contributing factors (i.e., accident precursors) and how they sequence in time. Such analyses can provide insight in developing effective solutions for LOC, and form the basis for developing test scenarios that can be used in evaluating them. Preliminary findings based on the results of this paper indicate that system failures or malfunctions, crew actions or inactions, vehicle impairment conditions, and vehicle upsets contributed the most to accidents and fatalities, followed by inclement weather or atmospheric disturbances and poor visibility. Follow-on research will include finalizing the analysis through a team consensus process, defining future risks, and developing a comprehensive set of test scenarios with correlation to the accidents, incidents, and future risks. Since enhanced engineering simulations are required for batch and piloted evaluations under realistic LOC precursor conditions, these test scenarios can also serve as a high-level requirement for defining the engineering simulation enhancements needed for generating them.

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Nomenclature

CAST	=	Commercial Aviation Safety Team
EASA	=	European Aviation Safety Agency
FAA	=	Federal Aviation Administration
ICAO	=	International Civil Aviation Organization
LOC	=	Loss of Control (in-flight)
NASA	=	National Aeronautics and Space Administration
NTSB	=	National Transportation Safety Board

I. Introduction

Aircraft loss of control (LOC) is a leading cause of fatal accidents across all transport airplane and operational classes.[1, 2, 3] LOC can be described as motion that is:

- outside the normal operating flight envelopes; not predictably altered by routine pilot control inputs;
- characterized by nonlinear effects, such as kinematic/inertial coupling;
- disproportionately large responses to small state variable changes, or oscillatory/divergent behavior;
- likely to result in high angular rates and displacements; and
- characterized by the inability to maintain heading, altitude, and wings-level flight.[4]

LOC is therefore fundamentally a dynamics and control problem, but there are many causal and contributing factors (or precursors) that can lead to LOC.[5, 6, 7] The primary causes include: entry into a vehicle upset condition; reduction or loss of control effectiveness; changes to the vehicle dynamic response in relation to handling/flying qualities; and combinations of these. There are numerous factors that have historically led or contributed to LOC. These can be grouped into three major categories: adverse onboard conditions, external hazards and disturbances, and abnormal vehicle dynamics and upset conditions. LOC causal and contributing factors within these categories are summarized in Fig. 1. Adverse onboard conditions include vehicle problems (i.e., vehicle impairment, vehicle damage, or system failures) and inappropriate crew actions or inaction. External hazards and disturbances consist of inclement weather conditions, atmospheric disturbances, poor visibility, and obstacles (fixed and moving) that require abrupt maneuvering for avoidance. Examples of abnormal vehicle dynamics include oscillatory response, uncommanded motions, and non-intuitive control response. Upset conditions include a variety of off-nominal or extreme flight conditions and abnormal trajectories (e.g., abnormal attitude, uncontrolled descent, and stall / departure). The complexity of LOC is clearly illustrated in Fig. 1, particularly considering that many LOC accidents involve combinations of the causal and contributing factors that are listed.

Solutions for LOC must therefore be developed to provide prevention and recovery capabilities under a wide variety of hazards (and their combinations) that can lead to LOC.[8,9] One onboard system concept for accomplishing this is illustrated in Fig. 2. The colors depicted in Fig. 2 are representative of the following functions: vehicle health state detection capabilities are indicated by green, vehicle flight safety state assessment and resilient guidance and control capabilities are shown in blue, crew-system interface information and support capabilities are shown in yellow, and onboard modeling capabilities are shaded in purple. The signals depicted in Fig. 2 represent vector quantities and are defined as follows: "x" is the vehicle state, "y" represents measurable outputs, "z" represents controlled variables (which can be mode-dependent), "u" represents control inputs (with subscript "p" denoting pilot input commands, and subscript "c" denoting control system commands), "n" represents noise signals, "f" represents failures (and in the case of jammed actuators, for example, can represent persistent asymmetric forces acting on the aircraft), and "d" represents external disturbances. These technologies may also be aimed at specific precursors that are shown to cause a significant proportion of accidents.

The validation of technologies developed for LOC prevention and recovery, such as those illustrated in Fig. 2, poses significant challenges. All LOC hazards and their combinations cannot be fully replicated in piloted simulation or flight test evaluations. However, the validation process must provide some measure of assurance that the new vehicle safety technologies are effective and that they do no harm – i.e., that they themselves do not introduce new safety risks. Moreover, a means of assessing hazards coverage must also be included in the validation framework.

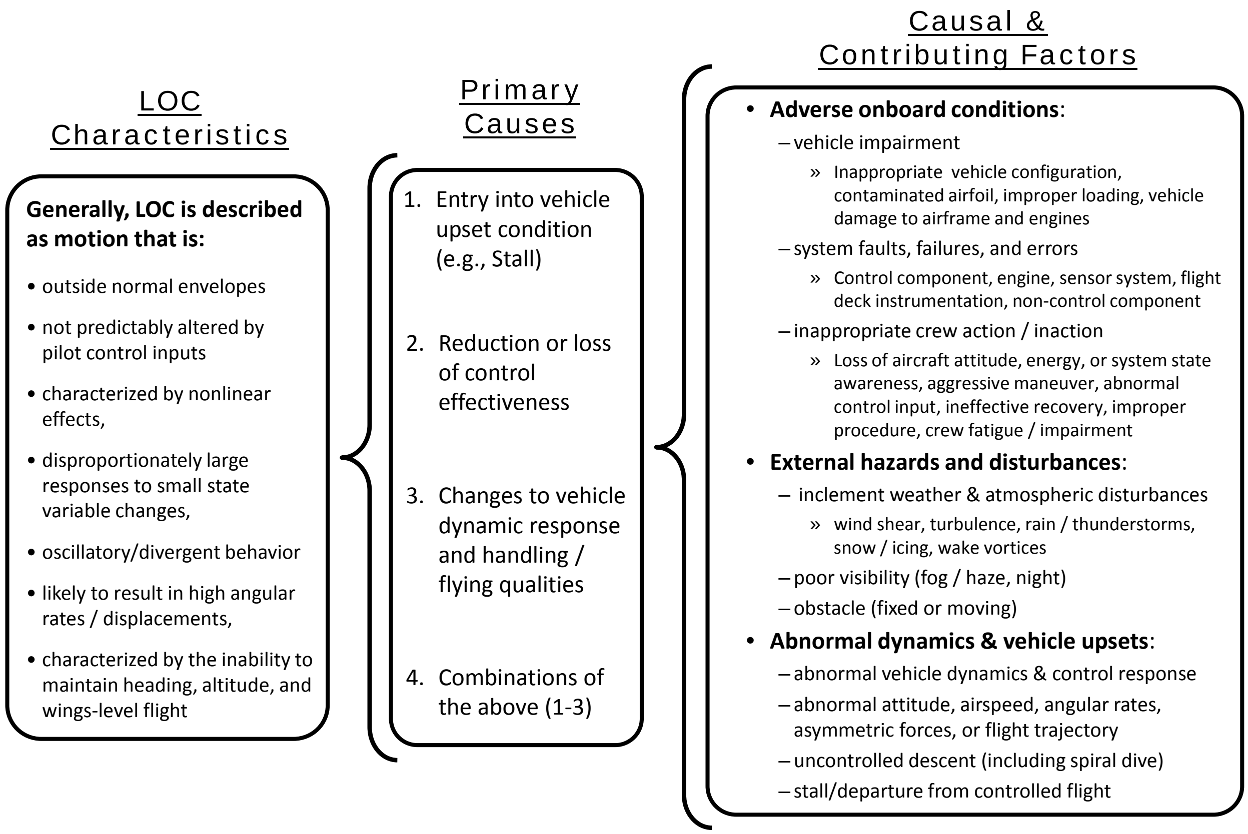

Figure 1. LOC key characteristics, primary causes, and causal & contributing factors.

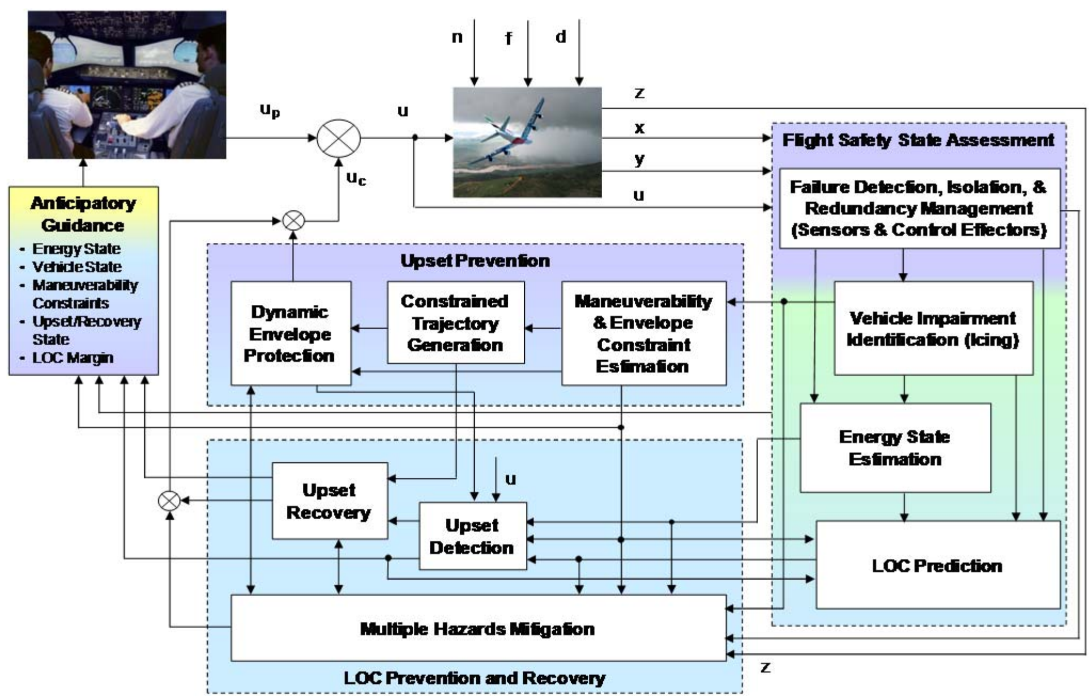

Figure 2. Onboard system concept for LOC prevention and recovery.

A validation framework involving analysis, simulation, and experimental testing was previously developed for safety-critical integrated systems operating under hazardous conditions that can lead to LOC, [10, 11] and a preliminary set of LOC test scenarios[12] was developed based on a limited accident set defined over a thirty year time period. The objectives of the current research are to define an extensive accident (and incident) set over a recent fifteen year time period, perform a thorough analysis of this accident / incident set based on a team consensus process, and develop a comprehensive set of test scenarios based on this analysis and an identified set of potential future risks. This paper presents preliminary results of this research. Specifically, this paper presents a set of 275 LOC accidents and incidents from 1996-2010, and preliminary analysis results to identify worst-case combinations of causal and contributing factors and how they sequence in time. Final analysis results and the set of LOC test scenarios, both based on a team consensus process, will be published separately. The test scenarios will be based on the analysis of accidents, incidents, and future risks, and will be developed for use in the validation of onboard systems technologies for LOC prevention and recovery. Since enhanced engineering simulations are required for batch and piloted evaluations under realistic LOC precursor conditions, these test scenarios can also serve as a high-level requirement for defining the simulation enhancements needed for generating realistic LOC test scenarios.

Section II defines the accident / incident set used in the analysis, and presents preliminary analysis results in terms of worst-case hazards combinations and how they sequence in time. Section III discusses a preliminary set of future potential risks that are relevant to LOC. Section IV discusses follow-on work, which includes finalizing the accident analysis results, finalizing the set of future risks, and developing a comprehensive set of LOC test scenarios based on the final accident / incident analysis and future risks. Section V provides a summary of the results of this paper and some concluding remarks. Appendix A provides the full set of accidents and incidents used in the analysis of Section II, and Appendix B presents LOC sequence diagrams resulting from the analysis.

II. Aircraft Loss-of-Control Accident / Incident Set and Preliminary Analysis

This section presents a detailed analysis of aircraft accidents and incidents (to be equivalently referred to as “events” in this paper). The primary accident / incident set will be categorized as LOC, but LOC-related accidents (e.g., resulting from control component failures and/or vehicle damage sufficient to alter vehicle dynamics and control characteristics) were also evaluated.

A. Accident / Incident Set Definition

Transport airplane loss-of-control events were reviewed for the fifteen year period 1996 through 2010. Only airplanes certified under Transport Category[*] or Commuter Category[†] were included. Only normal commercial or non-revenue flights were included, such as scheduled or non-scheduled passenger or cargo flights, positioning flights, or executive flights. Events that occurred during demonstration, military, training, or test flights were not considered, nor were owner-flown business jet operations.

Accident databases were searched using the terms: “loss-of-control,” “upset,” “unusual attitude,” “stall,” and “uncontrolled.” [‡] The following databases were searched:

- Aircraft Accident Report DVD[13]
- Australian Transport Safety Bureau (ATSB)
- Aviation Safety Network (ASN)

[*]Transport Category airplanes are certified under the provisions of Federal Aviation Regulations Part 25 or EASA Certification Standards Part 25 or predecessor regulations.

[†] Commuter Category airplanes are certified under the provisions of Federal Aviation Regulations Part 23 or EASA Certification Standards Part 23 or predecessor regulations. Commuter Category airplanes are limited to propeller airplanes with maximum capacity of 19 passengers and maximum approved takeoff weights of 19,000 lb.

[‡] The selection criteria used in this analysis resulted in a broader range of events than classification schemes like the CAST / ICAO Common Taxonomy Team occurrence category LOC-I (see: http://intlaviationstandards.org/CommonTaxonomies.html) and included accidents and incidents in which the flight crew failed to maintain aircraft control, as well as events involving abrupt maneuvers, weather encounters, and reduced control capability due to equipment malfunction or failure.

- Canadian Transportation Safety Board (TSB)
- Flightglobal (Ascend Database)
- French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA)
- German Bundesstelle für Flugunfalluntersuchung (BFU)
- International Civil Aviation Organization (ICAO)
- Irish Air Accident Investigation Unit (AAIU)
- National Transportation Safety Board (NTSB)

Following identification from the databases, the accident / incident reports were reviewed using all available data. Where possible, the national investigative agency report was reviewed, even if that agency's database was not available for searching.

Each accident and incident is identified by ICAO (or FAA) operator code and flight number. If the flight number is not available, the last two characters of the aircraft registration will replace the flight number. If no operator code is available (i. e. non-airline flights), the full aircraft registration is used for identification.

A total of 275 accidents and incidents were identified resulting in 7185 onboard fatalities with an additional 235 ground fatalities. Forty-one percent happened at night and forty-three percent occurred during instrument meteorological conditions (IMC). Table 1a shows a decreasing trend over the period. Table 1b shows the distribution by aircraft class and Table 1c shows the distribution to type of operation. Table 1d shows the distribution of events over phases of flight.

The set of accidents and incidents is provided in Appendix A.

Table 1a. Loss of Control Events Grouped by Five Year Interval

Region	Events	On-Board Fatalities
1996 to 2000	102	2938
2001 to 2005	99	2143
2006 to 2010	74	2104
Total	275	7185

Table 1b. Loss of Control Events Grouped by Aircraft Classification

Aircraft Classification	Events	On-Board Fatalities
Wide-body Turbojets	38	2224
Narrow-body Turbojets	96	3858
Business Jets	42	115
Turboprop Transports	44	615
Piston Transports	5	34
Commuter Airplanes	50	339
Total	275	7185

Table 1c. Loss of Control Events Grouped by Type of Operation

Operation	Events	On-Board Fatalities
Scheduled Airlines	143	5803
Non-Scheduled	87	1234
Non-Revenue Operations	28	78
Executive Transportation	17	70
Total	275	7185

Table 1d. Loss of Control Events Grouped by Phase of Flight

Region	Events	On-Board Fatalities
Takeoff	6	270
Initial Climb	79	1241
Climb	43	1697
Cruise	41	2008
Descent	17	156
Holding	22	0
Approach	34	1087
VFR Pattern	8	69
Circling	3	152
Final Approach	9	77
Landing	18	37
Go-around	8	15
Missed Approach	5	374
Maneuvering	2	2
Total	275	7185

B. Accident / Incident Statistics by Causal and Contributing Factors

A preliminary analysis was performed for the 275 accident / incident set defined above by dividing the set into subsets and allocating the subsets to the analysis team members. The initial step in the analysis consisted of a review of each event in the set. The level of detail in analyzing each accident and incident was therefore dependent on the level of detail provided in the accident and incident reports. Information from each report was transcribed into a categorized set of causal and contributing factors, using the categories and sub-categories defined in Fig. 1. A basic statistical summary of the accident / incident set in terms of individual LOC precursors (i.e., causal and contributing factors) is provided in Table 2. Table 2a summarizes the number of events and fatalities by precursor category and sub-category, and Tables 2b – 2d provide these statistics for each individual precursor within each category and sub-category. It should be noted in Table 2 that the precursors are not mutually exclusive. For example, 240 LOC events involved one or more adverse onboard conditions, and the frequency of each sub-category within this category is listed. These numbers do not add up to 240, however, because there were many events involving more than one sub-category. Similarly, adding the number of accidents listed for the three categories exceeds the 275 total because many events involved multiple categories. The same is true for Tables 2b-2d for individual precursors.

Table 2a. Contributions to LOC Accidents and Fatalities - Category & Sub-Category Totals

Precursor	Accidents / Incidents	%	Fatalities	%
Adverse Onboard Conditions	**240**	**87.27**	**6750**	**93.95**
Vehicle Impairment	86	31.6427	2576	35.85
System & Component Failures / Malfunctions	117	42.55	3150	43.84
Inappropriate Crew Action / Inaction	160	58.18	4444	61.85

External Hazards & Disturbances	**101**	**36.73**	**3036**	**42.25**
Inclement Weather & Atmospheric Disturbances	65	23.64	1741	24.23
Poor Visibility	30	10.91	1324	18.43
Obstacle	16	5.82	601	8.36
Abnormal Dynamics & Vehicle Upset Conditions	**220**	**80.00**	**5416**	**75.38**
Abnormal Vehicle Dynamics	47	17.09	312	4.34
Vehicle Upset Conditions	188	68.36	5315	73.97

Table 2b. Contributions to LOC Accidents and Fatalities - Adverse Onboard Conditions

Precursor	Accidents / Incidents	%	Fatalities	%
Adverse Onboard Conditions	**240**	**87.27**	**6750**	**93.95**
Vehicle Impairment	**86**	**31.27**	**2576**	**35.85**
Inappropriate Vehicle Configuration	22	8.00	468	6.51
Contaminated Airfoil	22	8.00	230	3.20
Improper Loading: Weight / Balance / CG Issues	12	4.36	95	1.32
Improper Loading: Cargo Problems / Hazards	1	0.36	110	1.53
Airframe Structural Damage	33	12.00	1882	26.19
Engine Damage (FOD)	1	0.36	2	0.03
System & Component Failures / Malfunctions	**117**	**42.55**	**3150**	**43.84**
System Operational Error (Design Flaw / Validation Error)	15	5.45	497	6.92
System Operational Error (Software / Verification Error)	4	1.45	9	0.13
Control Component Failure / Malfunction	41	14.91	426	5.93
Engine Failure / Malfunction	37	13.45	989	13.76
Sensor / Sensor System Failure / Malfunction	16	5.82	671	9.34
Flight Deck Instrumentation Failure / Malfunction	11	4.00	323	4.50
System / Subsystem Failure / Malfunction (Non-control component)	12	4.36	641	8.92
Inappropriate Crew Action / Inaction	**160**	**58.18**	**4444**	**61.85**
Loss of Attitude State Awareness / Spatial Disorientation	28	10.18	1513	21.06
Loss of Energy State Awareness / Inadequate Energy Management	51	18.55	1402	19.51
Lack of Aircraft / System State Awareness / Mode Confusion	5	1.82	11	0.15
Aggressive Maneuver	14	5.09	313	4.36
Abnormal / Inadvertent Control Input / Maneuver	12	4.36	605	8.42
Improper / Ineffective Recovery	26	9.45	1164	16.20

Inadequate Crew Resource Monitoring / Management (PF, PNF, & Systems)	36	13.09	1508	20.99
Improper Procedure	53	19.27	750	10.44
Fatigue / Impairment (Includes Hypoxia)	9	3.27	376	5.23

Table 2c. Contributions to LOC Accidents and Fatalities - External Hazards & Disturbances

Precursor	Accidents / Incidents	%	Fatalities	%
External Hazards & Disturbances	**101**	**36.73**	**3036**	**42.25**
Inclement Weather & Atmospheric Disturbances	**65**	**23.64**	**1741**	**24.23**
Thunderstorms / Rain	9	3.27	611	8.50
Wind Shear	9	3.27	249	3.47
Turbulence	10	3.64	486	6.76
Wake Vortex	7	2.55	284	3.95
Snow / Icing	33	12.00	426	5.93
Poor Visibility	**30**	**10.91**	**1324**	**18.43**
Fog / Haze	16	5.82	502	6.99
Night	18	6.55	915	12.73
Obstacle	**16**	**5.82**	**601**	**8.36**
Fixed	4	1.45	8	0.11
Moving	12	4.36	593	8.25

Table 2d. Contributions to LOC Accidents and Fatalities - Abnormal Dynamics & Vehicle Upset Conditions

Precursor	Accidents / Incidents	%	Fatalities	%
Abnormal Dynamics & Vehicle Upset Conditions	**220**	**80.00**	**5416**	**75.38**
Abnormal Vehicle Dynamics	**47**	**17.09**	**312**	**4.34**
Uncommanded Motions	24	8.73	89	1.24
Oscillatory Vehicle Response (Includes PIO)	14	5.09	9	0.13
Abnormal Control for Trim / Flight	8	2.91	14	0.19
Abnormal / Counterintuitive Control Responses	4	1.45	200	2.78
Vehicle Upset Conditions	**188**	**68.36**	**5315**	**73.97**
Abnormal Attitude	29	10.55	856	11.91
Abnormal Airspeed (Includes Low Energy)	24	8.73	750	10.44
Abnormal Angular Rates	1	0.36	10	0.14
Undesired Abrupt Dynamic Response	18	6.55	218	3.03
Abnormal Flight Trajectory	26	9.45	1055	14.68
Uncontrolled Descent (Includes Spiral Dive)	47	17.09	1534	21.35
Stall / Departure (Includes Falling Leaf, Spin)	74	26.91	1796	25.00

Table 2 is useful for determining the number of events and fatalities associated with individual causal and contributing factors, but it does not provide any information on combinations or sequencing of these factors. Nonetheless, this table identifies System & Component Failures and Malfunctions, Inappropriate Crew Action and Inaction, and Vehicle Upsets as the largest sub-category contributors to the number of events and fatalities within the accident / incident set evaluated. Other key contributors included Vehicle Impairment, Inclement Weather and Atmospheric Disturbances, and Abnormal Vehicle Dynamics. The following subsections C and D address combinations and sequencing of LOC causal and contributing factors, respectively.

C. Worst-Case Precursor Combinations

A preliminary analysis of the accident / incident set in terms of worst-case combinations of causal and contributing factors (as defined by number of accidents and resulting fatalities), was determined using three-dimensional scatter plots. The three dimensions are aligned with the three categories identified in Table 2. Sphere size is directly proportional to the number of accidents, and sphere color depicts the number of fatalities as indicated by the legend. Figure 3 shows scatter plots by category and sub-category with and without within-category overlap. Fig. 3a shows worst-case precursor sub-category combinations and includes within-category overlap. For example, combinations involving system failures / malfunctions do not exclude cases that also involved inappropriate crew actions / inactions. Fig. 3b excludes within-category overlap. The team felt that excluding cases of multiple within-category precursors resulted in unacceptable loss of information, so it was determined that the analysis should include this overlap. All remaining figures in this paper therefore include within-category overlap. As indicated by Fig. 3a, precursor combinations involving system failure / malfunction, inappropriate crew action / inaction, and vehicle upset conditions led to the highest number of fatalities both with and without involvement by inclement weather / atmospheric disturbance and poor visibility. Vehicle impairment with and without vehicle upsets also led to a high level of fatalities. These worst-case sub-category combinations can be further explored by generating scatter plots within these sub-categories. For example, Figure 4 shows a precursor level scatter plot to investigate the specific precursors that contributed to the "Inappropriate Crew Action / Inaction" – "Poor Visibility" – "Vehicle Upset" combination of Figure 3a. As indicated in Figure 4b, the precursors that contributed to this sub-category combination were entirely "Loss of Attitude State Awareness" and "Loss of Energy State Awareness", predominantly at night, and leading primarily to abnormal trajectories, uncontrolled descent, and stall/departure. Additional worst-case precursor-level evaluations will be performed for the final analysis.

Figures 5a and 5b present scatter plots that separate non-fly-by-wire (non-FBW) and fly-by-wire (FBW) aircraft, respectively. Although there were only 24 accidents / incidents in the data set involving FBW aircraft, it is interesting to investigate as a separate group. The results for non-FBW aircraft are very similar to the full set. The FBW aircraft analysis identifies system failure / malfunction and vehicle impairment combined with vehicle upset as the worst-case sub-category combinations.

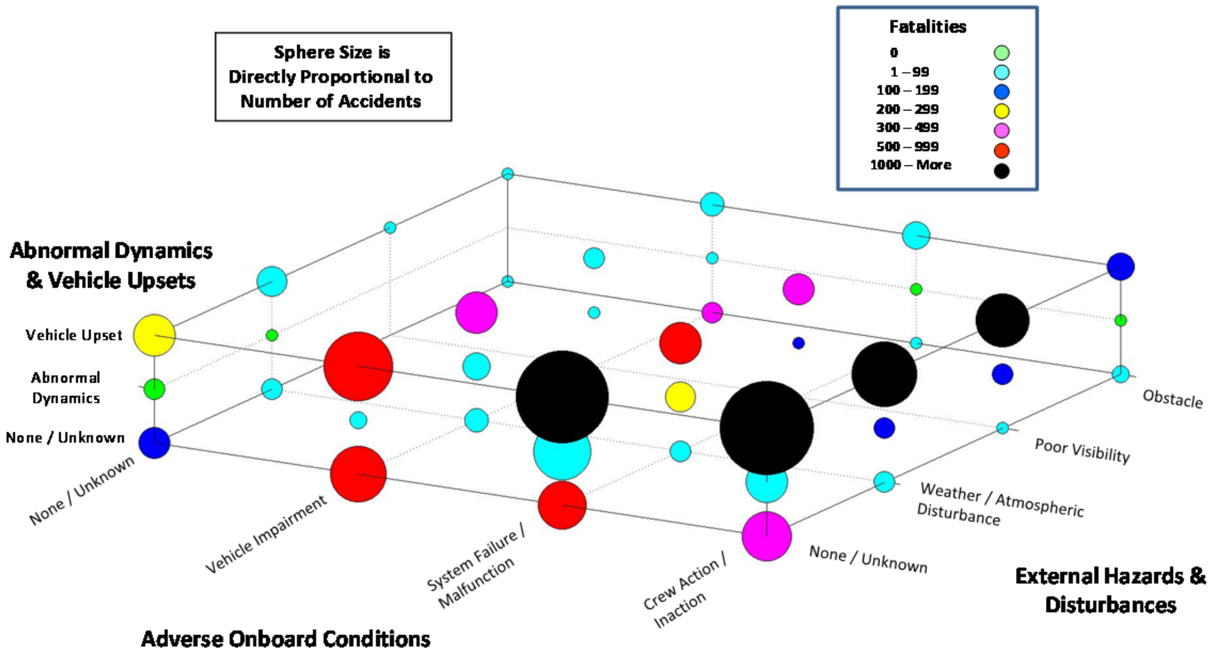

Figure 3a. Worst-Case Combinations of LOC Precursor Sub-Categories, with Within-Category Overlap.

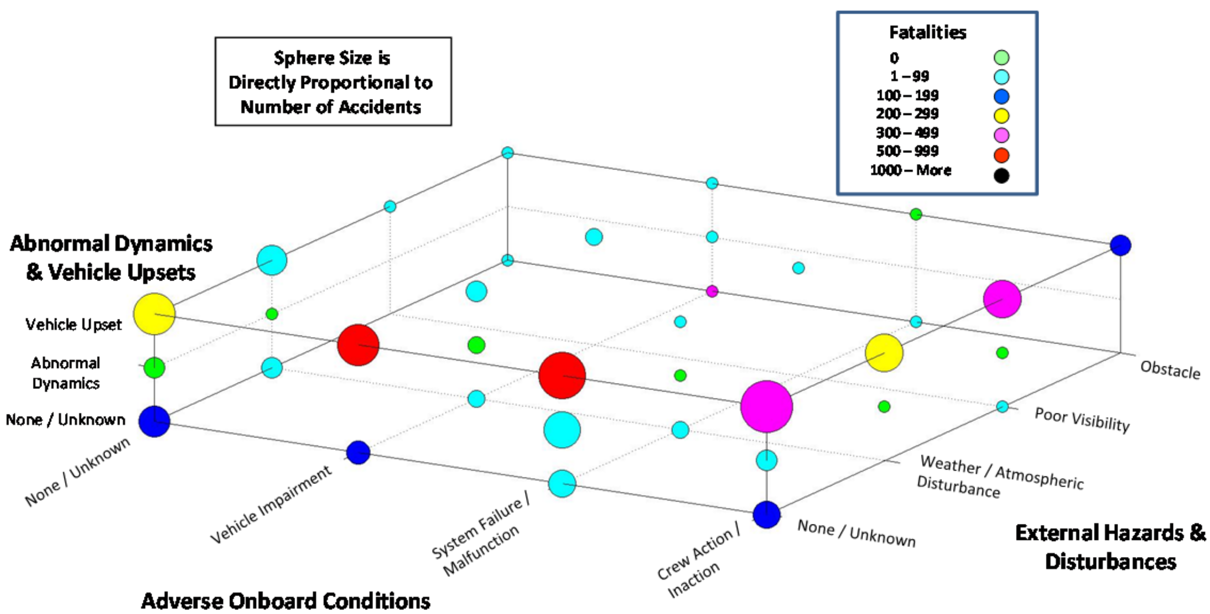

Figure 3b. Worst-Case Combinations of LOC Precursor Sub-Categories, without Within-Category Overlap.

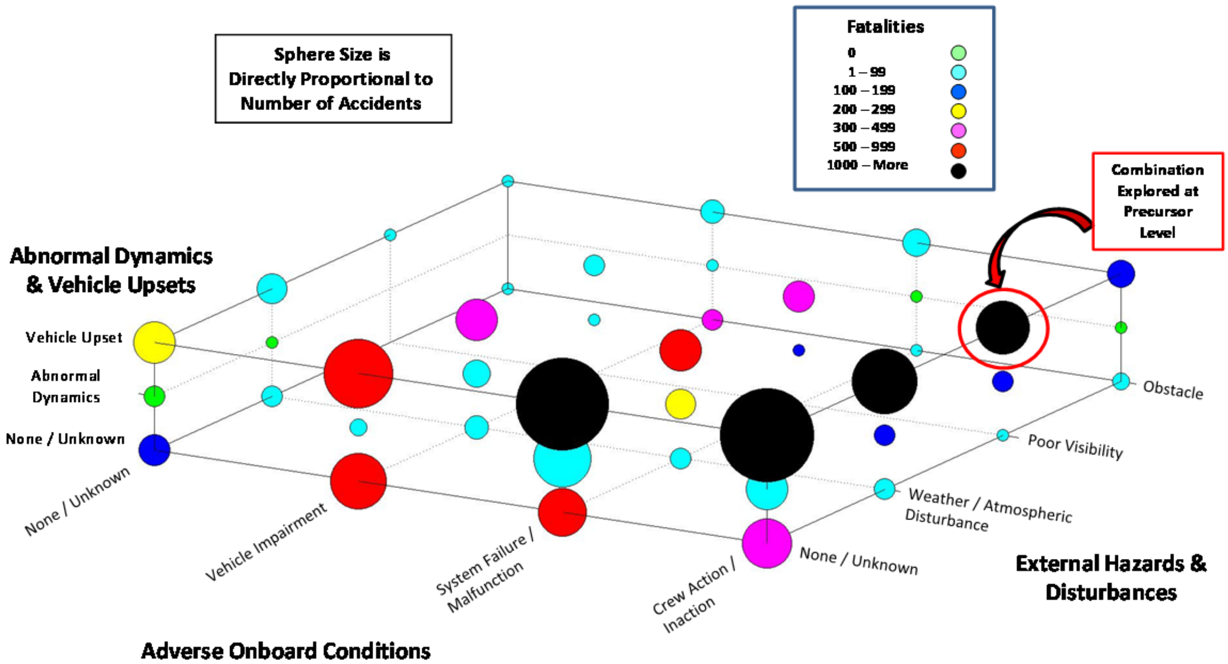

Figure 4a. Example Sub-Category Combination Explored at Precursor Level in Figure 4b.

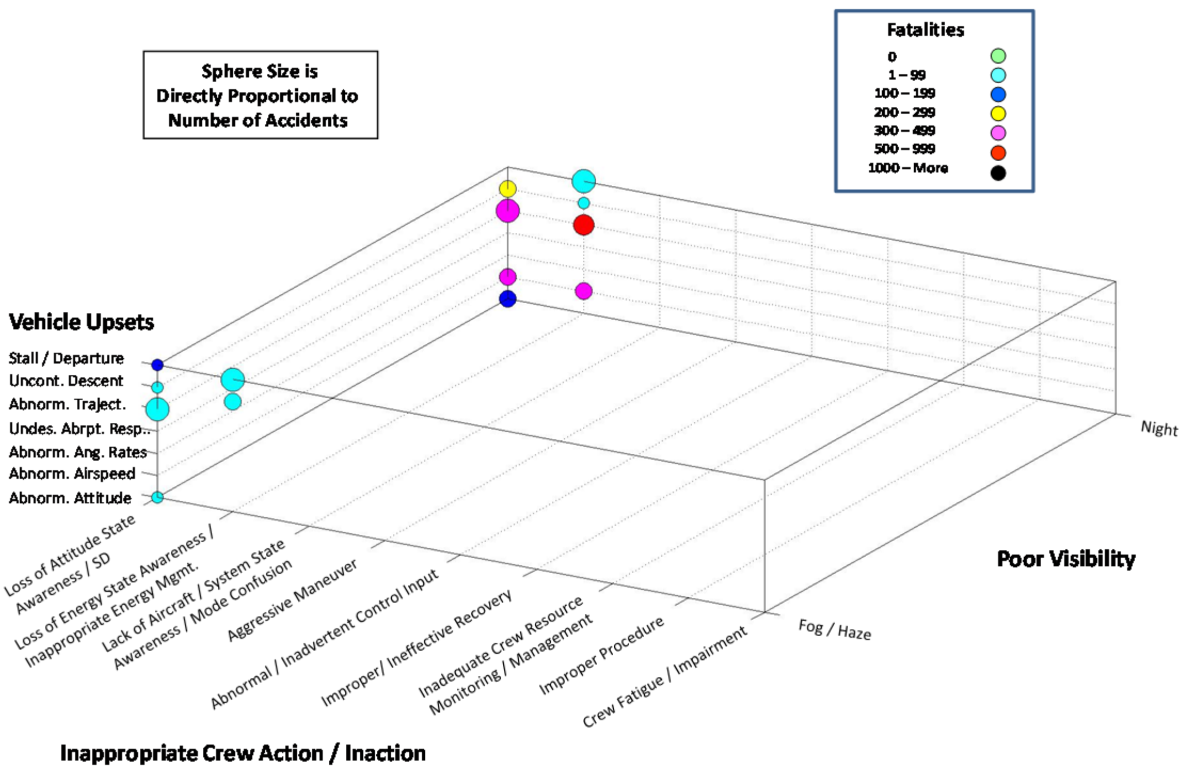

Figure 4b. Precursor Combinations within Sub-Category Combination of Figure 4b.

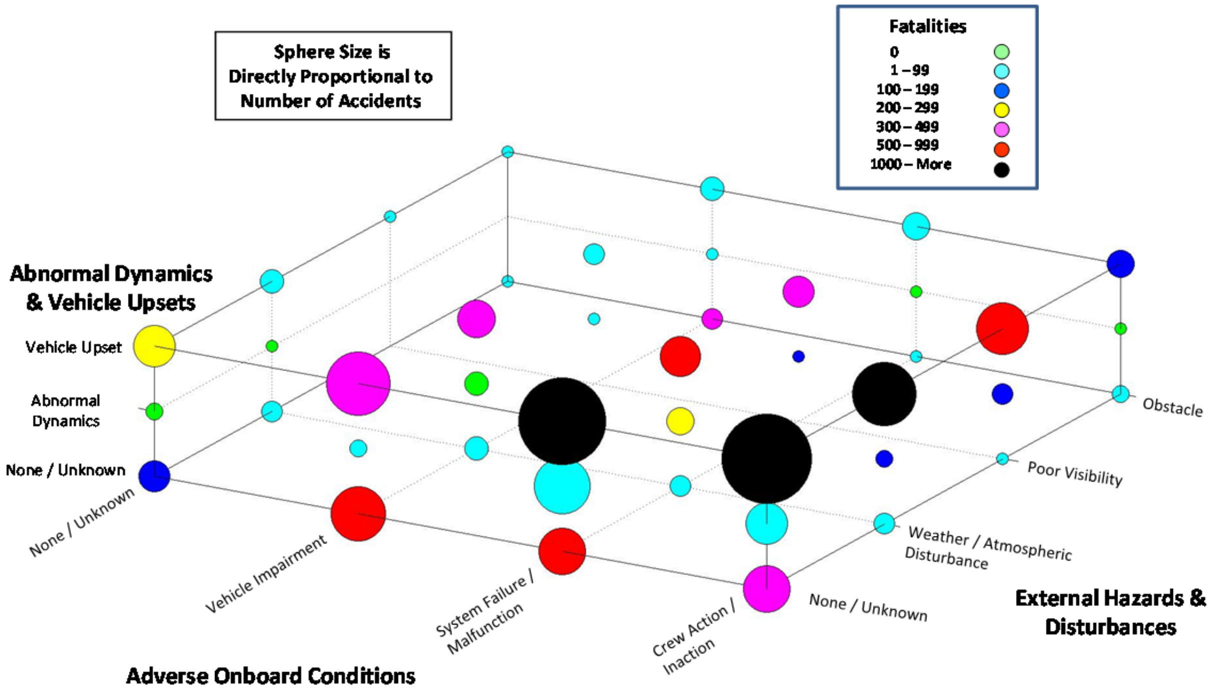

Figure 5a. Worst-Case Combinations of LOC Precursor Sub-Categories for Non-FBW Aircraft.

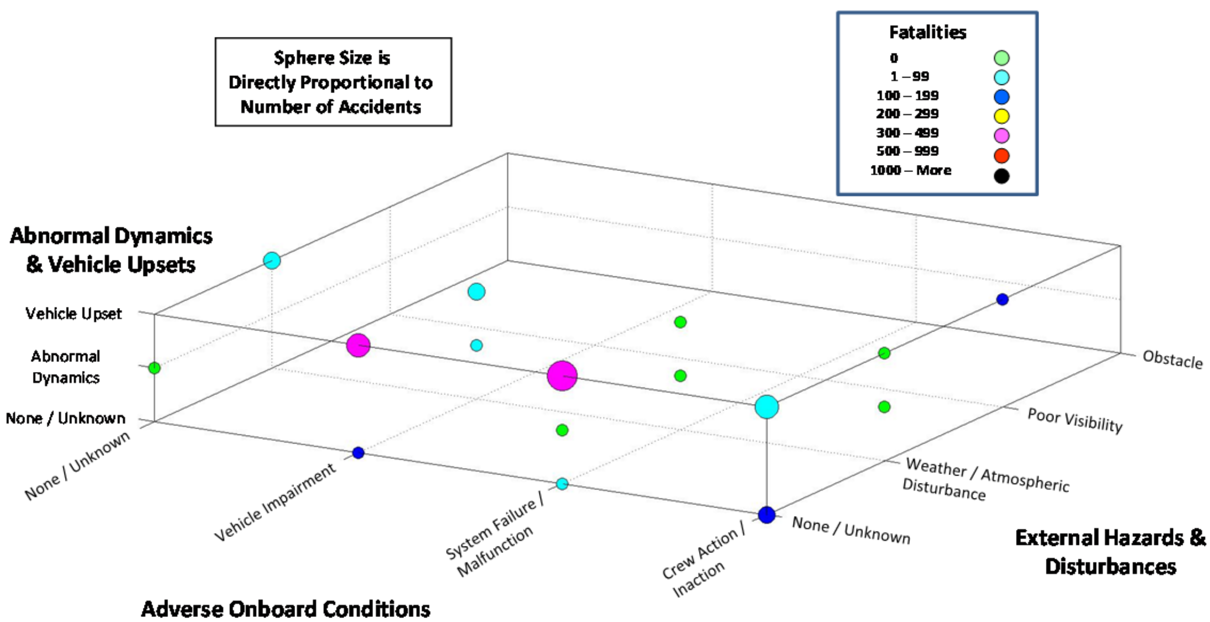

Figure 5b. Worst-Case Combinations of LOC Precursor Sub-Categories for FBW Aircraft.

D. Precursor Sequences

A preliminary analysis of precursor temporal ordering was completed to identify dominant precursors and worst case sequences for the accidents and incidents of Appendix A. Table 3a shows a summary of the sequential occurrences for each precursor category and sub-category, and Tables 3b – 3d show sequence summaries for each precursor in each sub-category. As shown, up to seven precursors were identified on several events but most of the accidents and incidents had no more than five.

Table 3a. Sequencing of LOC Accident Precursors – Category & Sub-Category Totals

Precursor	1st	2nd	3rd	4th	5th	6th	7th
Adverse Onboard Conditions	**167**	**153**	**88**	**39**	**10**	**3**	**0**
Vehicle Impairment	41	32	11	4	3	0	0
System & Component Failures / Malfunctions	84	35	10	5	1	0	0
Inappropriate Crew Action / Inaction	42	86	67	30	6	3	0
External Hazards & Disturbances	**86**	**16**	**4**	**2**	**0**	**1**	**0**
Inclement Weather & Atmospheric Disturbances	58	6	1	1	0	0	0
Poor Visibility	19	6	2	0	0	0	0
Obstacle	9	4	1	1	0	1	0
Abnormal Dynamics & Vehicle Upset Conditions	**0**	**89**	**78**	**55**	**33**	**11**	**3**
Abnormal Vehicle Dynamics	0	23	14	8	4	1	0
Vehicle Upset Conditions	0	66	64	47	29	10	3
Unknown Precipitating Events	**22**	**-**	**-**	**-**	**-**	**-**	**-**
TOTALS	**275**	**258**	**170**	**119**	**43**	**15**	**3**

Table 3b. Sequencing of LOC Accident Precursors – Adverse Onboard Conditions

Precursor	1st	2nd	3rd	4th	5th	6th	7th
Adverse Onboard Conditions	**167**	**153**	**88**	**39**	**10**	**3**	**0**
Vehicle Impairment	**41**	**32**	**11**	**4**	**3**	**0**	**0**
Inappropriate Vehicle Configuration	13	6	2	1	0	0	0
Contaminated Airfoil	2	18	1	0	1	0	0
Improper Loading: Weight / Balance / CG Issues	10	2	0	0	0	0	0
Improper Loading: Cargo Problems / Hazards	1	0	0	0	0	0	0
Airframe Structural Damage	14	6	8	3	2	0	0
Engine Damage (FOD)	1	0	0	0	0	0	0
System & Component Failures / Malfunctions	**84**	**35**	**10**	**5**	**1**	**0**	**0**
System Operational Error (Design Flaw / Validation Error)	12	1	2	0	0	0	0
System Operational Error (Software / Verification Error)	2	1	1	0	0	0	0

Control Component Failure / Malfunction	26	10	3	2	0	0	0
Engine Failure / Malfunction	27	7	0	2	1	0	0
Sensor / Sensor System Failure / Malfunction	6	10	0	0	0	0	0
Flight Deck Instrumentation Failure / Malfunction	4	3	2	1	0	0	0
System / Subsystem Failure / Malfunction (Non-control component)	7	3	2	0	0	0	0
Inappropriate Crew Action / Inaction	**42**	**86**	**67**	**30**	**6**	**3**	**0**
Loss of Attitude State Awareness / Spatial Disorientation	3	8	11	3	1	2	0
Loss of Energy State Awareness / Inadequate Energy Management	9	16	18	8	0	0	0
Lack of Aircraft / System State Awareness / Mode Confusion	1	3	1	0	0	0	0
Aggressive Maneuver	2	7	2	3	0	0	0
Abnormal / Inadvertent Control Input / Maneuver	4	3	3	2	0	0	0
Improper / Ineffective Recovery	0	7	10	5	3	1	0
Inadequate Crew Resource Monitoring / Management (PF, PNF, & Systems)	4	16	11	3	2	0	0
Improper Procedure	17	22	10	4	0	0	0
Fatigue / Impairment (Includes Hypoxia)	2	4	1	2	0	0	0

Table 3c. Sequencing of LOC Accident Precursors – External Hazards & Disturbances

Precursor	1st	2nd	3rd	4th	5th	6th	7th
External Hazards & Disturbances	**86**	**16**	**4**	**2**	**0**	**1**	**0**
Inclement Weather & Atmospheric Disturbances	**58**	**6**	**1**	**1**	**0**	**0**	**0**
Thunderstorms / Rain	8	1	0	0	0	0	0
Wind Shear	6	1	1	0	0	0	0
Turbulence	5	4	0	0	0	0	0
Wake Vortex	7	0	0	0	0	0	0
Snow / Icing	32	0	0	1	0	0	0
Poor Visibility	**19**	**6**	**2**	**0**	**0**	**0**	**0**
Fog / Haze	8	4	1	0	0	0	0
Night	11	2	1	0	0	0	0
Obstacle	**9**	**4**	**1**	**1**	**0**	**1**	**0**
Fixed	2	0	0	1	0	1	0
Moving	7	4	1	0	0	0	0

Table 3d. Sequencing of LOC Accidents –
Abnormal Dynamics & Vehicle Upset Conditions

Precursor	1st	2nd	3rd	4th	5th	6th	7th
Abnormal Dynamics & Vehicle Upset Conditions	**0**	**89**	**78**	**55**	**33**	**11**	**3**
Abnormal Vehicle Dynamics	**0**	**23**	**14**	**8**	**4**	**1**	**0**
Uncommanded Motions	0	15	6	3	0	0	0
Oscillatory Vehicle Response (Includes PIO)	0	4	2	4	3	1	0
Abnormal Control for Trim / Flight	0	2	5	0	1	0	0
Abnormal / Counterintuitive Control Responses	0	2	1	1	0	0	0
Vehicle Upset Conditions	**0**	**66**	**64**	**47**	**29**	**10**	**3**
Abnormal Attitude	0	8	12	5	3	0	1
Abnormal Airspeed (Includes Low Energy)	0	8	6	6	2	2	0
Abnormal Angular Rates	0	1	0	0	0	0	0
Undesired Abrupt Dynamic Response	0	8	6	2	1	1	0
Abnormal Flight Trajectory	0	9	3	5	6	1	2
Uncontrolled Descent (Includes Spiral Dive)	0	18	11	12	3	3	0
Stall / Departure (Includes Falling Leaf, Spin)	0	14	26	17	14	3	0

Tables 3a-d indicate that LOC events were usually first precipitated by an adverse onboard condition and most often by a system or component failure or malfunction. The second precipitating factor occurring most often was an external hazard or disturbance and in that case usually related to weather or reduced visibility. Moreover, external hazards and disturbances rarely occurred further downstream than 2nd in LOC sequences. Vehicle upsets were rarely the initial factor but rather an outcome of an external hazard/disturbance or adverse onboard condition.

Within "Adverse Onboard Conditions", inappropriate crew action / inaction and vehicle impairment were equally likely to be a precipitating factor but inappropriate crew action / inaction occurred as the second or third event in response to a precipitating factor. Adverse onboard conditions were also the most likely factor to occur second in temporal sequencing leading to aircraft LOC. Within this category inappropriate crew action / inaction was the most likely secondary factor to occur indicating crew response to some precipitating event. Vehicle impairment or system and component failure were equally likely to be the second factor where contaminated airfoil was the leading cause of impairment.

Within "External Hazards and Disturbances", the leading initial factor was snow / icing, followed by nearly equal occurrences of wind shear, turbulence, wake vortex, and thunderstorms. It is also noteworthy that external hazards or disturbances were most often a precipitating event. Vehicle upsets most often occurred as the second, third, or fourth factor in the LOC sequence indicating that multiple precursors can lead to an upset.

Tables 4a-c summarize the number of accidents and fatalities associated with each initiating precursor.

Table 4a. Summary of LOC Accidents & Fatalities by Initiating Factors – Factor Category & Sub-Category Totals

First Precursor in LOC Sequence	Accidents / Incidents	%	Fatalities	%
Adverse Onboard Conditions	**167**	**60.73**	**4099**	**57.05**
Vehicle Impairment	41	14.91	1153	16.05
System & Component Failures / Malfunctions	84	30.55	2175	30.27
Inappropriate Crew Action / Inaction	42	15.27	771	10.73
External Hazards & Disturbances	**86**	**31.27**	**2708**	**37.69**
Inclement Weather & Atmospheric Disturbances	58	21.09	1390	19.35
Poor Visibility	19	6.91	832	11.58
Obstacle	9	3.27	486	6.76
Abnormal Dynamics & Vehicle Upset Conditions	**0**	**0**	**0**	**0**
Abnormal Vehicle Dynamics	0	0	0	0
Vehicle Upset Conditions	0	0	0	0
Unknown	**22**	**8.00**	**378**	**5.26**
TOTAL	**275**	**100**	**7185**	**100**

Table 4b. Summary of LOC Accidents & Fatalities by Initiating Factors – Adverse Onboard Conditions

First Precursor in LOC Sequence	Accidents / Incidents	%	Fatalities	%
Adverse Onboard Conditions	**167**	**60.73**	**4099**	**57.05**
Vehicle Impairment	**41**	**14.91**	**1153**	**16.05**
Inappropriate Vehicle Configuration	13	4.73	206	2.87
Contaminated Airfoil	2	0.73	55	0.76
Improper Loading: Weight / Balance / CG Issues	10	3.64	69	0.96
Improper Loading: Cargo Problems / Hazards	1	0.36	110	1.53
Airframe Structural Damage	14	5.09	711	9.89
Engine Damage (FOD)	1	0.36	2	0.03
System & Component Failures / Malfunctions	**84**	**30.55**	**2175**	**30.27**
System Operational Error (Design Flaw / Validation Error)	12	4.36	497	6.92
System Operational Error (Software / Verification Error)	2	0.73	0	0
Control Component Failure / Malfunction	26	9.45	257	3.58
Engine Failure / Malfunction	27	9.82	548	7.63
Sensor / Sensor System Failure / Malfunction	6	2.18	198	2.76
Flight Deck Instrumentation Failure / Malfunction	4	1.45	298	4.15
System / Subsystem Failure / Malfunction (Non-control component)	7	2.55	377	5.25

Inappropriate Crew Action / Inaction	**42**	**15.27**	**771**	**10.73**
Loss of Attitude State Awareness / Spatial Disorientation	3	1.09	158	2.20
Loss of Energy State Awareness / Inadequate Energy Management	9	3.27	152	2.12
Lack of Aircraft / System State Awareness / Mode Confusion	1	0.36	0	0
Aggressive Maneuver	2	0.73	4	0.06
Abnormal / Inadvertent Control Input / Maneuver	4	1.45	115	1.60
Improper / Ineffective Recovery	0	0	0	0
Inadequate Crew Resource Monitoring / Management (PF, PNF, & Systems)	4	1.45	22	0.31
Improper Procedure	17	6.18	302	4.20
Fatigue / Impairment (Includes Hypoxia)	2	0.73	18	0.25

Table 4c. Summary of LOC Accidents & Fatalities by Initiating Factors – External Hazards & Disturbances

First Precursor in LOC Sequence	Accidents / Incidents	%	Fatalities	%
External Hazards & Disturbances	**86**	**31.27**	**2708**	**37.69**
Inclement Weather & Atmospheric Disturbances	**58**	**21.09**	**1390**	**19.35**
Thunderstorms / Rain	8	2.91	415	5.78
Wind Shear	6	2.18	175	2.44
Turbulence	5	1.82	90	1.25
Wake Vortex	7	2.55	284	3.95
Snow / Icing	32	11.64	426	5.93
Poor Visibility	**19**	**6.91**	**832**	**11.58**
Fog / Haze	8	2.91	300	4.18
Night	11	4.00	532	7.40
Obstacle	**9**	**3.27**	**486**	**6.76**
Fixed	2	0.73	4	0.56
Moving	7	2.55	482	6.71

Diagrams of temporal sequences for each category are shown in Appendix B, Figures B-1 through B-6. The diagrams for sequences initiated with adverse onboard conditions are shown in Figs. B-1 through B-3. Fig. B-2 shows that a vehicle upset is the most common result of inappropriate crew action/inaction occurring in at least 71% of events (30 of 42). Furthermore, a vehicle upset is a direct result of inappropriate crew action in at least 22 of the 30 events. The highest number of fatalities occurred with a vehicle upset (53%) following inappropriate crew response (34%).

Similarly, Fig. B-1 shows that a vehicle upset occurs as a result of system and components failures in at least 64% of the events but is much less often as a direct result of the failure or malfunction but more commonly preceded by inappropriate crew action/inaction. Following system and component failures, vehicle upset is involved in 75% of fatalities. Similar results are shown by events initiated by vehicle impairment (shown in Fig. B-3) where vehicle upset occurs in at least 63% of the events, inappropriate crew action occurs in 54% of events and vehicle upset is involved in 70% of fatalities.

The diagrams for events initiated by external hazards and disturbances are shown in Fig. B-4 through B-6. Figure B-4 indicates that there is no clearly dominant factor immediately following inclement weather as the initiating precursor. However a vehicle upset occurs in 69% (40 of 58) of events and inappropriate crew action in 60% (35 of 58) of events, similar to the discussion of adverse onboard conditions.

III. Preliminary Definition of Future Potential Risks

Future potential risks relevant to LOC must be considered in developing a comprehensive set of test scenarios that enable forward-looking mitigation to emerging and future hazards. An initial set of future risks based on current trends is provided in Table 5, based on previous work (see Ref. 12).

Table 5. Potential future LOC risks list by trend.

No.	Trend / Condition	Potential LOC Risk Factors
1	Increased Automation without Improved Crew Interfaces	Increase in Inappropriate Crew Response
2	Future Vehicle Configurations without Identification of Upset Characteristics	Increased Incidents of Vehicle Upsets
3	Increased System Complexity without Comprehensive Evaluation Process	Increase in System Faults / Failures / Errors / Insufficiencies
4	High-Density Operations in Terminal Area	Increase in Wake Vortex Encounters
5	High-Density Operations in Terminal Area	Increase in Pilot Workload
6	Increase in Flight Deck Automation	Decrease in Manual Piloting Skills
7	All-Weather Operations	Increase in Snow/Icing Encounters
8	All-Weather Operations in Terminal Area	Increase in Wind Shear / Turbulence Encounters
9	High-Density Mixed-Vehicle Operations	Increased Incidence of Near-Miss and Mid-Air Collision Events
10	New Vehicle Materials with Lack of Long-Term Data on Aging and Damage Tolerance	Increase in Damage-Initiated LOC Events

IV. Future Research: Aircraft Loss-of-Control Test Scenarios

Future research will include: 1.) finalizing the accident / incident set; 2.) performing an analysis of the accident / incident set using a team consensus process; 3.) defining future risks that utilize all available sources of information as determined by CAST, the FAA and ICAO, and others in the aviation community; and 4.) developing a comprehensive set of LOC test scenarios based on the final analysis of accidents, incidents and future potential risks. The test scenarios will include adverse vehicle conditions, inappropriate crew actions / inaction, external hazards and disturbances, and abnormal vehicle dynamics and upset conditions occurring as single precursors and combined as multiple precursor events. The test scenarios will also include recommended evaluation methods, and flight conditions. An example scenario format is given below in Table 6 based on previous work (see Ref. 12).

Table 6. Potential format for LOC test scenarios.

Scenario Number	Recommended Evaluation Methods	Scenario Description	Flight Condition	Adverse Vehicle Conditions	Inappropriate Crew Action / Inaction	External Hazards & Disturbances	Abnormal Vehicle Dynamics / Vehicle Upset Conditions
Three Precursor LOC Scenarios: Vehicle Impairment –> Vehicle Upset –> Inappropriate Crew Response							
54	Analysis, Batch Simulation, Piloted Simulation	Icing with Vehicle Impairment Followed by Vehicle Stall and Inappropriate Crew Response	Approach, Takeoff, Cruise	1. Various Degrees of Vehicle Dynamics Changes under Airframe Ice Accretion (from Mild to Destabilizing), Varying Degrees of Engine Icing Effects from None to Thrust Roll-back	3. Crew Responds Inappropriately: a. Delayed Reaction b. Incorrect Recovery	1. Simulator: Icing Conditions with and without Snow	2. Stall, Various Levels of De-Stabilizing Effects from None to Unstable in a. One b. Two c. Three Axes
Four Precursor LOC Scenarios: Vehicle Failure –> Inappropriate Crew Response –> Upset –> Vehicle Damage							
55	Analysis, Batch Simulation, Piloted Simulation	Engine Failure Followed by Crew Distraction Leading to Upset and Vehicle Damage	Cruise	1. Single Engine Failure (100% Thrust Loss); 4. Various Levels of Structural Damage with and without Loss of Control Effector	2. Crew Distraction Resulting in Delayed Response Followed by Excessive Response		3. Decreased Airspeed, Asymmetric Forces / Moments, Stall / Departure

A full set of test scenarios developed through team consensus will be published in a later paper, including a correlation of the scenarios to the accidents, incidents, and future risks defined in the final analysis results.

V. Conclusion

This paper presents preliminary analysis results for a set of 275 accidents and incidents that occurred over the period 1996-2010 and involving aircraft at and above 12,500 lbs. Statistics for this set are provided in terms of each five-year period, aircraft type, operational type, and phase of flight. The analysis was performed by subsets allocated to the team, and consisted of determining individual precursor contributions to accidents and fatalities, identifying worst-case precursor combinations, and determining the temporal sequencing of precursors leading to LOC accidents and incidents from the set. Preliminary findings based on the results of this paper indicate that system failures or malfunctions, crew actions or inactions, vehicle impairment conditions, and vehicle upsets contribute the most to accidents and fatalities, followed by inclement weather or atmospheric disturbances and poor visibility. Individual precursors that contributed most to the accidents and fatalities in the analyzed set came from the System Failures / Malfunctions, Inappropriate Crew Action / Inaction, and Vehicle Upset sub-categories. Other key contributors included Vehicle Impairment, Inclement Weather and Atmospheric Disturbances, and Abnormal Vehicle Dynamics. Worst-case precursor combinations (in terms of number of accidents and fatalities) were dominated by System & Component Failures / Malfunctions, Inappropriate Crew Action / Inaction, and Vehicle Upset Conditions, with contributions from the Weather & Atmospheric Disturbance and Poor Visibility sub-categories. The next worst-case combination involved Vehicle Impairment with and without Vehicle Upsets. Further examination of the worst-case combination of Inappropriate Crew Action / Inaction – Poor Visibility – Vehicle Upset revealed that the underlying precursors consisted entirely of Loss of Attitude and Energy State Awareness, occurred predominantly at night, and led primarily to abnormal trajectories, uncontrolled descent, and stall/departure. Additional worst-case precursor-level evaluations will be performed for the final analysis. The preliminary worst-case analysis of FBW aircraft indicated that System Failures / Malfunctions and Vehicle Impairment combined with Vehicle Upsets were the largest contributors to accidents and fatalities. Analysis of temporal sequencing indicated that LOC events were usually precipitated by an adverse onboard condition, and most often by a system failure or malfunction, or by an external hazard or disturbance, usually due to weather or poor visibility. Vehicle upsets most often occurred as the second, third, or fourth factor in the LOC sequence indicating that multiple precursors can lead to an upset. Evaluation of sequence diagrams of Appendix B indicated that vehicle upset occurred as a result of system and components failures in at least 64% of the events evaluated, but was much less often as a direct result of the failure or malfunction but more commonly preceded by inappropriate crew action/inaction. Following system and component failures, vehicle upset was involved in 75% of fatalities. Similar results were shown by events initiated by vehicle impairment. Furthermore, a vehicle upset is a direct result of inappropriate crew action in at least 22 of the 30 events. The highest number of fatalities occurred with a vehicle upset (53%) following inappropriate crew response (34%). The diagrams for events initiated by external hazards and disturbances indicate that there is no clearly dominant factor immediately following inclement weather as the initiating precursor. However a vehicle upset occurs in 69% (40 of 58) of events and inappropriate crew action in 60% (35 of 58) of events, similar to that previously discussed as a result of adverse onboard conditions.

Follow-on research will involve re-evaluating the accident / incident set using a consensus process to ensure consistency, defining a set of future LOC-related risks, and generating a comprehensive set of LOC test scenarios based on the final accident / incident analysis and future risks. The analysis results and test scenarios resulting from this research can be used in the development and evaluation of technology solutions, such as onboard systems, that provide improved LOC prevention and recovery capabilities. Wider application of this research to broader LOC solutions is also envisioned.

Appendix A: Accident / Incident Set

Date	Aircraft	Regist	Operat'n	Ident	Loc'n	Light	Weather	Fat	Grd	Dam	Phase	Result	Occurrence
1/7/1996	DC-9	N922VV	SCHED	VJA 558	KBNA	Day	VMC	0	0	S	Landing	Hard Landing	Uncomm Spoiler Ext
2/6/1996	B-757	TCGEN	NSCHD	ALW 301	MDPP	Night	N/R	189	0	D	Climb	Uncont Coll w/Terr	Instrument Failure
2/12/1996	GAF-N24	N224E	SCHED	N224E	MTPP	Day	VMC	10	0	D	Initial climb	Uncont Coll w/Terr	Loss-of-Control (Vmc)
2/19/1996	CE-550	DCASH	EXEC	PWF SH		N/R	N/R	10	0	D	Approach	Uncont Coll w/Terr	Icing Stall
2/22/1996	MD-11		SCHED	CAL 4	RCTP	N/R	N/R	0	0	N/R	Initial climb	Upset	Pilot Induced Osc (PIO)
5/11/1996	DC-9	N904VJ	SCHED	VJA 592	KMIA	Day	VMC	110	0	D	Climb	Uncont Coll w/Terr	Struct Fail - Fire/Expl
6/5/1996	MD-80	N224AA	SCHED	AAL 873	KABQ	Day	VMC	0	0	M	Landg flare	Hard Landing	Atmos Disturbance
6/9/1996	B-737	N221US	SCHED	SGR 517	KRIC	Night	VMC	0	0	N	Approach	Upset	Uncommanded Bank
6/14/1996	A-320	N347NW	SCHED	NWA 395	KBOS	Day	VMC	0	0	N	Climb	Uncomm Pitch	Flight Control System
6/21/1996	A-340	DAIBE	SCHED	DLH 436	KDFW	N/R	N/R	0	0	N/R	Climb	Cabin Injuries	Unexpected Cont Gains
7/13/1996	MD-11	N1768D	SCHED	AAL 8D		Day	VMC	0		N	Descent	Cabin Injuries	Override Autopilot
7/17/1996	B-747	N93119	SCHED	TWA 800	KJFK	Dusk	VMC	230	0	D	Climb	Uncont Coll w/Terr	Struct Fail - Fire/Expl
7/20/1996	DC-6A	N313RS	NSCHD	NAC 33	PARS	Day	VMC	4	0	D	Cruise	Uncont Coll w/Terr	Struct Fail - Fire/Expl
10/22/1996	B-707	N751MA	NSCHD	MIRA MA	SEMT	N/R	N/R	4	23	D	Climb	Coll w/Obstacle	Undetermined
10/31/1996	FO-100	PTMRK	SCHED	TAM 402	SBSP	Day	N/R	96	3	D	Initial climb	Coll w/Obstacle	Loss-of-Control (Vmc)
11/7/1996	B-727	5NBBG	SCHED	ADK 86		N/R	N/R	144	0	D	Approach	Uncont Coll w/Terr	Aggressive Maneuver
11/12/1996	Il-76TD	UN76435	NSCHD	KZA 1907		N/R	N/R	37	0	D	Descent	Uncont Coll w/Terr	Struct Fail - Midair
11/12/1996	B-747	HZAIH	SCHED	SVA 763		N/R	N/R	312	0	D	Climb	Uncont Coll w/Terr	Struct Fail - Midair
12/9/1996	DC-3C	N75142	NSCHD	D7T 42	KBOI	Night	VMC	2	0	D	Initial climb	Collision w/Terrain	Stall
12/10/1996	An-74	RA74037	NSCHD	VSA 37	UERR	Night	N/R	0	0	D	Initial climb	Collision w/Terrain	Thrust Rev-Unwanted
12/21/1996	An-32B	HK4008X	NSCHD	SDV 8X	SKRG	Night	N/R	4	0	D	Approach	Collision w/Terrain	Undetermined
1/9/1997	E-120	N265CA	SCHED	COM 3272	KDTW	Day	IMC	29	0	D	Descent	Uncont Coll w/Terr	Autopilot-Induced Stall
1/25/1997	Il-76	RA76834	NREV	VSO 34	UHMA	N/R	N/R	0	0	D	Initial climb	Collision w/Terrain	TO w/Incorrect Config
2/1/1997	HS-748	6VAEO	NSCHD	DS EO	GOTT	N/R	N/R	23	0	D	Initial climb	Collision w/Terrain	Undetermined
3/2/1997	BE-200	N117WM	EXEC	PVT WM	KSLC	Dusk	IMC	1	0	S	Final appr	Uncont Coll w/Terr	Stall
3/14/1997	F-27	D2TFP	NSCHD	DTA FP	FCBB	N/R	N/R	3	0	D	Initial climb	Collision w/Terrain	Undetermined
4/14/1997	An-24	RA46516	NSCHD	RA46516		Day	N/R	50	0	D	Cruise	Uncont Coll w/Terr	Struct Fail - Fatigue
4/19/1997	BA-ATP	PKMTX	SCHED	MNA 106	WIOD	Night	N/R	15	0	D	Approach	Uncont Coll w/Terr	Atmosph Disturbance
5/8/1997	B-737	B2925	SCHED	CSN 3456	ZGSZ	Night	IMC	35	0	D	Landing	Hard Landing	Atmosph Disturbance
5/12/1997	A-300	N90070	SCHED	AAL 903	KPBI	Day	IMC	0	0	M	Level off	Upset	Stall
5/20/1997	AC-1121	N1121F	EXEC	PVT 1F		Day	IMC	4	0	D	Cruise	Uncont Coll w/Terr	Atmosph Disturbance
6/1/1997	MD-11	JA8580	SCHED	JAL 706	RJNA	Day	N/R	0	0	M	Descent	Unknown	Override Autopilot
7/3/1997	F-27	VTSSA	NSCHD	LBE SA	VABB	Night	IMC	2	0	D	Initial climb	Uncont Coll w/Terr	Undetermined
7/12/1997	DC-9	N9138	SCHED	NWA 944	KMEM	Day	VMC	0	0	M/N	Landing	Upset	Uncommanded Bank
8/7/1997	DC-8	N27UA	NSCHD	FBF 101	KMIA	Day	VMC	4	1	D	Initial climb	Uncont Coll w/Terr	Load/c/g Out Of Range
10/10/1997	DC-9	LVWEG	SCHED	AUT 2553		Night	IMC	74	0	D	Descent	Uncont Coll w/Terr	Struct Fail - Exc Limit
12/13/1997	SA-226	CP1635	NSCHD	SAVE 35	SLVT	N/R	N/R	10	0	D	Initial climb	Collision w/Terrain	Undetermined
12/16/1997	CL-600	CFSKI	SCHED	ACA 646	CYFC	Night	IMC	0	0	D	Go-around	Collision w/Terrain	Stall
2/16/1998	A-300	B1814	SCHED	CAL 676	RCTP	Night	IMC	196	7	D	Approach	Uncont Coll w/Terr	Stall
3/18/1998	SF-340	B12255	SCHED	FOS 55	RCPO	Night	IMC	13	0	D	Climb	Uncont Coll w/Terr	Spatial Disorientation
5/21/1998	DC-10	N68043	SCHED	COA 75	KLAX	Day	VMC	0	0	M	Climb	Uncomm Pitch	Autopilot
6/18/1998	SA-226	CGQAL	SCHED	PRO 420	CYUL	Day	N/R	11	0	D	Climb	Uncont Coll w/Terr	Struct Fail - Fire/Expl
7/23/1998	An-12	RA11886	NSCHD	RA11886	ULLP	Day	N/R	0	0	D	Takeoff roll	Collision w/Terrain	Loss-of-Control (Vmc)
7/28/1998	SA-227	ECFXD	NSCHD	SWT 704	LEBL	Night	VMC	2	0	D	Approach	Uncont Coll w/Terr	Loss-of-Control (Vmc)

Date	Aircraft	Regist	Operat'n	Ident	Loc'n	Light	Weather	Fat	Grd	Dam	Phase	Result	Occurrence
7/30/1998	Do-228	VTEJW	SCHED	LLR JW	VOCC	Day	VMC	6	3	D	Initial climb	Uncont Coll w/Terr	Flight Control Actuator
7/30/1998	BE-1900	FGSJM	SCHED	PRB 706		Day	VMC	14	0	D	Approach	Uncont Coll w/Terr	Struct Fail - Midair
8/24/1998	DC-3	ZSNKK	NSCHD	SPZ KK	FAWB	Day	VMC	1	0	D	Initial climb	Uncont Coll w/Terr	TO w/Mis-set Trim
9/2/1998	MD-11	HBIWF	SCHED	SWR 111	CYHZ	Night	N/R	229	0	D	Cruise	Collision w/Terrain	Loss Of All Att Displ
10/17/1998	BE-99	N299GL	SCHED	AIP 5010	KMSO	Night	VMC	0	0	S	Go-around	Collision w/Terrain	Fail To Maint Airspeed
10/18/1998	A-320	EITLI	SCHED	TRZ LI	EIDW	N/R	N/R	0	0	M/N	Approach	Upset	Jammed Flight Controls
10/21/1998	E-120	PTWKH	NSCHD	PTWKH	SBFZ	Day	N/R	3	1	D	VFR pattern	Uncont Coll w/Terr	Improper Contr Oper'n
11/11/1998	SF-340	VHLPI	SCHED	KDA PI	YMML	Day	IMC	0	0	N	holding	Upset	Icing Stall
12/2/1998	CE-501	N501EZ	NREV	EXEC EZ		Day	VMC	1	0	D	Cruise	Uncont Coll w/Terr	Undetermined
12/4/1998	An-12	LZSFG	NSCHD	LXR FG	LPLA	Night	N/R	7	0	D	Initial climb	Uncont Coll w/Terr	Asymm Thrust/Drag
12/11/1998	A-310	HSTIA	SCHED	TIA 261	VSSB	Night	IMC	101	0	D	Approach	Uncont Coll w/Terr	Somatogravic Illusion
1/12/1999	F-27	GCHNL	NSCHD	EXS NL	EGJB	N/R	N/R	2	0	D	Approach	Uncont Coll w/Terr	Stall
1/28/1999	LR-35	N130F	NSCHD	USC 251	KMDW	Night	VMC	0	0	S	Landing	Hard Landing	Unstabilized Approach
2/2/1999	An-12	EYASS	NSCHD	FDN SS	FNLU	Night	N/R	11	19	D	Initial climb	Coll w/Obstacle	Undetermined
2/24/1999	Tu-154	B2622	SCHED	CSW 4509	ZSWZ	N/R	N/R	61	0	D	Approach	Uncont Coll w/Terr	Flight Cont Disconnect
4/5/1999	DHC-6	N838MA	NSCHD	DCC MA	KLNA	Day	VMC	0	0	S	Approach	Collision w/Terrain	Loss-of-Control (Vmc)
4/7/1999	B-737	TCJEP	NREV	THY 5904	LTAF	Night	IMC	6	0	D	Climb	Uncont Coll w/Terr	Instrument Failure
4/15/1999	MD-11	HL7373	SCHED	KAL 6316	ZSSS	Day	N/R	3	5	D	Climb	Uncont Coll w/Terr	Spatial Disorientation
8/26/1999	Yak-40	UK87848	SCHED	UZB 48	UTNT	Day	N/R	2	0	D	Go-around	Coll w/Obstacle	Undetermined
8/31/1999	B-737	LVWRZ	SCHED	LPR 3142	SABE	Night	N/R	63	2	D	Initial climb	Uncont Coll w/Terr	TO w/Incorrect Config
9/2/1999	B-737	N371UA	SCHED	UAL 2036		Day	VMC	0	0	M	Cruise	Atmos Disturbance	Wake Turbulence
9/14/1999	DA-900	SXECH	EXEC	OAL 3838	LROP	N/R	N/R	7	0	S	Descent	Upset	Pilot Induced Osc (PIO)
9/24/1999	A-320	CFKCO	SCHED	ACA 630	CYSJ	Night	VMC	0	0	M	Landing	Landed Short	Flt Contr Mode Change
10/9/1999	DA-900	N523AC	EXEC	PVT AC	KGRR	N/R	N/R	0	0		Descent	Aircraft Oscillat'ns	Override Autopilot
10/18/1999	SF-340	SELES	SCHED	GAO 750	ENSN	Night	IMC	0	0	M/N	Climb	Upset	Autopilot-Induced Stall
10/25/1999	LR-35	N47BA	NSCHD	SJ8 BA		N/R	N/R	6	0	D	Climb	Spiral Dive	Incapacitation: Hypoxia
11/9/1999	DC-9	XATKN	SCHED	TEJ 725	MMPN	Night	N/R	18	0	D	Climb	Collision w/Terrain	Spatial Disorientation
12/5/1999	Il-114	UK91004	NSCHD	CTB 04	UUDD	N/R	N/R	5	0	D	Initial climb	Coll w/Obstacle	Jammed Flight Controls
12/12/1999	IAI-1124	N50PL	EXEC	PVT PL		Day	VMC	3	0	D	Descent	Coll w/Obstacle	Flight Control Disconn
12/22/1999	B-747	HL7451	SCHED	KAL 8509	EGSS	Night	N/R	4	0	D	Climb	Uncont Coll w/Terr	Instrument Failure
1/5/2000	E-110	5NAXL	SCHED	EAN XL	DNAA	N/R	N/R	1	1	D	Approach	Collision w/Terrain	Stall
1/10/2000	SF-340	HBAKK	SCHED	SWR 498	LSZH	Night	IMC	10	0	D	Initial climb	Spiral Dive	Somatogravic Illusion
1/30/2000	A-310	5YBEN	SCHED	KQA 431	DIAP	Night	VMC	169	0	D	Initial climb	Collision w/Terrain	Stall
1/31/2000	MD-80	N963AS	SCHED	ASA 261		Day	VMC	88	0	D	Cruise	Uncont Coll w/Terr	Jammed Flight Controls
2/16/2000	DC-8	N8079U	NSCHD	EWW 17	KMHR	Night	VMC	3	0	D	Initial climb	Uncont Coll w/Terr	Flight Control Disconn
2/27/2000	B-747	GBDXL	SCHED	BAW 179		Night	IMC	0	0	N	Descent	Upset	Uncommanded Pitch
3/9/2000	Yak-40	RA88170	NSCHD	VGV 70	UUEE	Day	N/R	9	0	D	Initial climb	Uncont Coll w/Terr	TO w/Contam Wing
3/17/2000	DC-3	CFNTF	NSCHD	PTSN TF	CYJC	N/R	N/R	2	0	D	Go-around	Uncont Coll w/Terr	Load-c/g Out Of Rng
3/30/2000	B-767	N182DN	SCHED	DAL 106	KJFK	Night	IMC	0	0	M	Climb	Upset	Spatial Disorientation
5/2/2000	LR-35	GMURI	NSCHD	NEX RI	LFLL	N/R	N/R	2	0	D	Landing	Uncont Coll w/Terr	Loss-of-Control (Vmc)
5/21/2000	JS-3101	N16EJ	NSCHD	ORA EJ	KAVP	Day	IMC	19	0	D	Approach	Uncont Coll w/Terr	Loss-of-Control (Vmc)
6/22/2000	Y-7	B3479	SCHED	CWU 343	ZHHH	Day	IMC	42	7	D	Approach	Coll w/Obstacle	Wind Shear
6/23/2000	LR-55	N220JC	NREV	UJT JC	KBCT	Day	VMC	3	0	D	Climb	Uncont Coll w/Terr	Struct Fail - Midair
6/27/2000	A-300	N14065	SCHED	AAL 65	EGLL	N/R	N/R	0	0	N	Climb	Diversion	Wake Turbulence
7/17/2000	B-737	VTEGD	SCHED	LLR 7412	VEPT	Day	MVMC	55	5	D	Approach	Uncont Coll w/Terr	Stall
7/19/2000	G-159	CGNAK	NSCHD	AWV 9807		Night	IMC	2	0	D	Cruise	Uncont Coll w/Terr	Loss-of-Control (Vmc)
7/20/2000	DC-3	N54AA	NSCHD	N54AA	MYNN	Day	VMC	2	0	D	Initial climb	Collision w/Terrain	Undetermined
7/25/2000	AS-100	FBTSC	NSCHD	AFR 4590	LFPG	Day	VMC	109	4	D	Takeoff	Uncont Coll w/Terr	Struct Fail - Fire/Expl
8/23/2000	A-320	A4OEK	SCHED	GFA 72	OBBI	Night	VMC	143	0	D	Missed appr	Collision w/Terrain	Somatogravic Illusion

Date	Aircraft	Regist	Operat'n	Ident	Loc'n	Light	Weather	Fat	Grd	Dam	Phase	Result	Occurrence
8/31/2000	An-26	D2FDI	NSCHD	NCL DI	FNSA	N/R	N/R	44	0	D	Cruise	Uncont Coll w/Terr	Undetermined
10/2/2000	A-340	TCJDN	SCHED	THY DN		N/R	N/R	0	0	N	Cruise	Loss Of Separation	Flt Cont Mode Change
10/26/2000	CL-600	N958CA	SCHED	COM CA		Day	VMC	0	0	N	Cruise	Uncont Coll w/Terr	Wake Turbulence
11/1/2000	DHC-6	CGGAW	SCHED	YWZ 151		Day	N/R	0	0	D	Initial climb	Collision w/Terrain	Loss-of-Control (Vmc)
11/9/2000	SA-226	N731AC	NSCHD	ETA4 1000	KFWA	Night	IMC	1	0	D	Initial climb	Uncont Coll w/Terr	Instrument Failure
11/15/2000	An-24	D2FCG	NSCHD	API CG	FNLU	Day	N/R	57	0	D	Initial climb	Collision w/Terrain	Loss-of-Control (Vmc)
11/25/2000	MD-11	N582FE	SCHED	FDE 3015	KEWR	Day	VMC	0	0	N	Climb	Pilot Induced Osc	Flight Controls
12/2/2000	LR-35	CGDJH	NSCHD	CGDJH	CYVR	N/R	N/R	0	0	N	Climb	Uncomm Bank	Jammed Flight Controls
12/27/2000	E-135	N721HS	SCHED	EGF 230	KORD	Night	VMC	0	0	N	Initial climb	Upset	Jammed Flight Controls
1/25/2001	DC-3	YV224C	NSCHD	RUC 225	SVCB	Day	N/R	24	0	D	VFR pattern	Uncont Coll w/Terr	Loss-of-Control (Vmc)
1/27/2001	BE-200	N81PF	EXEC	JEK PF		Dusk	IMC	10	0	D	Cruise	Loss-of-Control	Instrument Failure
2/7/2001	A-320	ECHKJ	SCHED	IBE 1456	LEBB	Night	VMC	0	0	D	Landing	Hard Landing	Unexpect Control Gains
2/8/2001	LR-35	IMOCO	NREV	IMOCO	EDDN	Day	VMC	3	0	D	Approach	Uncont Coll w/Terr	Stall
3/17/2001	A-320	N357NW	SCHED	NWA 985	KDTW	Night	IMC	0	0	S	Rotation	Crash After Takeoff	Pilot Induced Osc (PIO)
3/19/2001	E-120	N266CA	SCHED	COM 5054	KPBA	Day	IMC	0	0	S	Descent	Upset	Icing Stall
3/20/2001	A-320	DAIPW	SCHED	DLH PW	EDFF	N/R	N/R	0	0	N	Initial climb	Uncomm Bank	Reversed Controls
3/24/2001	DHC-6	FOGES	SCHED	ISB 1501	TFFJ	Day	VMC	19	1	D	VFR pattern	Uncont Coll w/Terr	Loss-of-Control (Vmc)
4/2/2001	CE-501	N405PC	NREV	N405PC	KGRB	Day	IMC	1	0	D	Climb	Coll w/Obstacle	Spatial Disorientation
5/25/2001	A-340	FGLZC	SCHED	AFR 3682	SOCA	Day	VMC	0	0	M	Landing	Landed Short	Atmosph Disturbance
7/4/2001	Tu-154	RA85845	SCHED	VLK 352		Night	IMC	145	0	D	Approach	Uncont Coll w/Terr	Autopilot-Induced Stall
8/9/2001	BE-200	N899RW	EXEC	EXEC RW	KOKZ	Day	IMC	0	0	D	Circling appr	Collision w/Terrain	Stall
8/24/2001	LR-25	N153TW	NSCHD	AJI TW	KITH	Night	IMC	2	0	D	Initial climb	Collision w/Terrain	Somatogravic Illusion
9/12/2001	Let-410	XAACM	NSCHD	XAACM	MMCT	Day	VMC	19	0	D	Initial climb	Uncont Coll w/Terr	Fail To Maintain Cont
9/14/2001	BE-1900	CGSKC	NSCHD	SKK 621	CYYT	Night	IMC	0	0	D	Initial climb	Forced Landing	Uncommanded Pitch
9/18/2001	Let-410	TGCFE	SCHED	TGCFE	MGGT	N/R	N/R	8	0	D	Initial climb	Uncont Coll w/Terr	Stall
10/4/2001	Tu-154	RA85693	SCHED	SBI 1812		Day	N/R	78	0	D	Cruise	Uncont Coll w/Terr	Hostile Action
10/10/2001	SA-226	ECGDV	NSCHD	FTL 101		Day	IMC	10	0	D	Cruise	Uncont Coll w/Terr	Loss Of All Att Displ
10/16/2001	E-145	N825MJ	SCHED	ASH 5733	KROA	Night	VMC	0	0	S	Landing	Hard Landing	Stall
11/12/2001	A-300	N14053	SCHED	AAL 587	KJFK	Day	VMC	260	5	D	Climb	In-flight Breakup	Wake Turbulence
11/19/2001	Il-18	RA75840	NSCHD	LDF 40		N/R	N/R	27	0	D	Cruise	Uncont Coll w/Terr	Flight Control System
11/22/2001	LR-25	N5UJ	NREV	UJT UJ	KPIT	Day	VMC	2	0	D	Initial climb	Collision w/Terrain	Overcontrol
12/10/2001	LR-24	N997TD	NREV	X5CA 36		Night	VMC	2	0	D	Descent	Uncont Coll w/Terr	Undetermined
12/14/2001	DC-8	N825BX	NSCHD	RTI 8101	PANC	Night	VMC	0	0	N	Initial climb	Uncomm Bank	Flight Control Hardover
12/20/2001	CE-560	HBVLV	NREV	EGU 220	LSZH	Night	IMC	2	0	D	Initial climb	Uncont Coll w/Terr	Somatogravic Illusion
1/4/2002	CL-600	N90AG	NSCHD	PVT AG	EGBB	Day	VMC	5	0	D	Initial climb	Uncont Coll w/Terr	TO w/Contam Wing
1/22/2002	B-757	TFFIO	SCHED	ICE 315	ENGM	Day	IMC	0	0	N	Go-around	Upset	Somatogravic Illusion
4/12/2002	SA-227	ECGKR	NSCHD	TDC KR	LEPA	Night	N/R	2	0	D	Approach	Collision w/Terrain	Aggressive Maneuver
5/4/2002	BAC-111	5NESF	SCHED	EXW 4226	KNKN	Day	N/R	71	78	D	Cruise	Uncont Coll w/Terr	Stall
5/25/2002	B-747	B18255	SCHED	CAL 611		Day	N/R	225	0	D	Cruise	Uncont Coll w/Terr	Struct Fail - Fatigue
6/3/2002	MD-11	N588FE	NSCHD	FEX 5181		Night	IMC	0	0	S	Descent	Structural Failure	Overcontrol
6/4/2002	MD-80	N823NK	SCHED	NKS 970		Day	VMC	0	0	N	Cruise	Upset	Autopilot-Induced Stall
6/14/2002	A-330	CGHLM	SCHED	ACA 875	EDDF	N/R	N/R	0	0	N	Approach	Uncomm Pitch	Flight Control Logic
6/28/2002	SF-340	VHOLM	SCHED	HZL 185	YBTH	Night	N/R	0	0	N	Circling appr	Upset	Autopilot-Induced Stall
7/1/2002	B-757	A9CDHL	NSCHD	DHL 611		Night	N/R	2	0	D	Cruise	Uncont Coll w/Terr	Struct Fail - Midair
7/1/2002	Tu-154	RA85816	NSCHD	BTC 2937		Night	N/R	69	0	D	Cruise	Uncont Coll w/Terr	Struct Fail - Midair
7/28/2002	Il-86	RA86060	NREV	PLK 60	UUEE	Day	N/R	14	0	D	Initial climb	Uncont Coll w/Terr	Runaway Pitch Trim
8/14/2002	ATR-42	PTMTS	NSCHD	TTL 5561		Night	N/R	2	0	D	Cruise	Uncont Coll w/Terr	Runaway Pitch Trim
10/9/2002	B-747	N661US	SCHED	NWA 85	PANC	Night	VMC	0	0	M	Cruise	Uncomm Bank	Flight Control Hardover

Date	Aircraft	Regist	Operat'n	Ident	Loc'n	Light	Weather	Fat	Grd	Dam	Phase	Result	Occurrence
10/20/2002	B-757	TFFII	SCHED	ICE 662	KBWI	Night	N/R	0	0	N	Climb	Upset	Spatial Disorientation
11/8/2002	IAI-1124	N61RS	NREV	BQVA RS	KSKX	Day	VMC	2	0	D	Approach	Uncont Coll w/Terr	Atmosph Disturbance
12/3/2002	A-300	Unknown	SCHED	Unknown	EDDM	Day	N/R	0	0	N	Climb	Exceeded Vne/Vmo	Controls (Trim)
12/7/2002	A-320	CGIUF	SCHED	ACA 1130	CYYZ	N/R	N/R	0	0	N	Final appr	Go Around	Pilot Induced Osc (PIO)
12/7/2002	A-320	CGJVX	SCHED	ACA 457	CYYZ	N/R	N/R	0	0	N	Final appr	Hard Landing	Pilot Induced Osc (PIO)
12/21/2002	ATR-72	B22708	NSCHD	TNA 791		Night	IMC	2	0	D	Descent	Uncont Coll w/Terr	Autopilot-Induced Stall
12/27/2002	Let-410	9XRRB	SCHED	9XRRB	FMCV	Day	IMC	1	0	D	Missed appr	Uncont Coll w/Terr	Instrument Failure
1/8/2003	BE-1900	N233YV	SCHED	AMW 5481	KCLT	Day	VMC	21	0	D	Initial climb	Uncont Coll w/Terr	Flt Cont Integrity Lost
2/10/2003	An-28	ESNOY	SCHED	ENI 827	EETN	Night	IMC	2	0	D	Initial climb	Coll w/Obstacle	TO w/Contam Wing
3/6/2003	B-737	7TVEZ	SCHED	DAH 6289	DAAT	Day	N/R	102	0	D	Initial climb	Uncont Coll w/Terr	Stall
4/23/2003	BE-99	CFDYF	SCHED	ABS YF	CYPA	Day	N/R	0	0	D	Approach	Uncont Coll w/Terr	Flight Control Actuator
5/1/2003	LR-45	IERJC	NREV	IERJC	ASN	N/R	N/R	2	0	D	Initial climb	Uncont Coll w/Terr	Struct Fail - Birdstrike
6/16/2003	A-320	CGTDK	NSCHD	SSV DK	EGGD	N/R	N/R	0	0	S	Landg flare	Hard Landing	Unexpect Contr Gains
7/8/2003	B-737	STAFK	SCHED	SUD 139	HSSP	Night	N/R	116	0	D	Missed appr	Uncont Coll w/Terr	Fail To Maintain Cont
8/4/2003	LR-35	N135PT	NREV	RM6A PT	KGON	Day	VMC	2	0	D	Approach	Coll w/Obstacle	Inadvert Control Input
8/24/2003	Let-410	HHPRV	SCHED	HHPRV	MTCH	Night	N/R	21	0	D	VFR pattern	Uncont Coll w/Terr	Fail To Maintain Cont
8/26/2003	BE-1900	N240CJ	NREV	CJC 9446	KHYA	Day	VMC	2	0	D	Initial climb	Uncont Coll w/Terr	Reversed Controls
10/3/2003	CV-580	ZKKFU	SCHED	AFN 642		Night	IMC	2	0	D	Descent	In-flight Breakup	Icing Stall
10/26/2003	FH-227	LVMGV	NSCHD	CTZ 760		Night	N/R	5	0	D	Cruise	Uncont Coll w/Terr	Loss-of-Control (Vmc)
11/22/2003	A-300	OODLL	NSCHD	BCS LL	ORBS	Day	VMC	0	0	S	Climb	Runway Departure	Hostile Action
12/23/2003	LR-24	N600XJ	EXEC	PVT XJ		Day	VMC	2	0	D	Climb	Uncont Coll w/Terr	Undetermined
1/3/2004	B-737	SUZCF	NSCHD	FLS 604	HESH	Night	VMC	148	0	D	Climb	Spiral Dive	Spatial Disorientation
2/10/2004	FO-50	EPLCA	SCHED	IRK 7170	OMSI	Day	N/R	43	0	D	Final appr	Uncont Coll w/Terr	Undetermined
3/4/2004	Il-76	URZVA	NSCHD	AZV VA	UBBB	N/R	N/R	3	0	D	Initial climb	Uncont Coll w/Terr	TO w/Incorrect Config
3/19/2004	LR-35	N800AW	NSCHD	BSYA AW	KUCA	N/R	IMC	0	0	S	Go-around	Hard Landing	Stall
5/5/2004	SA-227	HK4275X	EXEC	PVT 5X	SKLC	Day	N/R	5	0	D	Final appr	Uncont Coll w/Terr	Stall
5/6/2004	Let-410	9XREF	NSCHD	9XREF		Day	N/R	6	0	D	Takeoff	Uncont Coll w/Terr	Stall
5/17/2004	DHC-6	8QTMC	SCHED	TMW MC	VRMM	Day	N/R	0	0	D	Initial climb	Coll w/Obstacle	TO w/Incorrect Config
5/18/2004	Il-76	4KAZ27	NSCHD	AHC 27	ZWWW	Day	N/R	7	0	D	Initial climb	Collision w/Terrain	Undetermined
6/18/2004	SF-340	VHKEQ	SCHED	REX EQ	YMML	Day	IMC	0	0		Descent	Upset	Autopilot-Induced Stall
7/2/2004	IAI-1124	N280AT	NSCHD	N280AT	MPTO	Day	N/R	6	0	D	Initial climb	Uncont Coll w/Terr	Undetermined
7/21/2004	DC-9	XABCS	SCHED	SER 706	MMMX	N/R	N/R	0	0	D	Initial climb	Collision w/Terrain	Wind Shear
8/11/2004	B-737	3XGCM	SCHED	GIB CM	GFLL	N/R	N/R	0	0	D	Initial climb	Collision w/Terrain	TO w/Incorrect Config
10/5/2004	An-12	STSAF	NSCHD	SRW AF		Day	N/R	4	0	D	Cruise	Uncont Coll w/Terr	Fail To Maintain Cont
10/14/2004	B-747	9GMKJ	NSCHD	MKA 1602	CYHZ	Night	N/R	7	0	D	Initial climb	Collision w/Terrain	Stall
10/14/2004	CL-600	N8396A	NREV	FLG 3701	KJEF	Night	VMC	2	0	D	Cruise	Collision w/Terrain	Autopilot-Induced Stall
11/21/2004	CL-600	B3072	SCHED	CES 5210	ZBOW	Day	N/R	53	2	D	Initial climb	Uncont Coll w/Terr	TO w/Contam Wing
11/28/2004	CL-600	N873G	NSCHD	YQCA 73	KMTJ	Day	IMC	3	0	D	Initial climb	Uncont Coll w/Terr	TO w/Contam Wing
11/30/2004	HFB-320	N604GA	NREV	GAE GA	KSUS	Night	IMC	2	0	D	Initial climb	Collision w/Terrain	Controls (Trim)
12/10/2004	BE-200	N648KA	NSCHD	YSDA KA	TS94	Day	VMC	0	0	D	Initial climb	Coll w/Obstacle	Stall
1/13/2005	E-110	N49BA	NSCHD	RLR 2352	KEEN	Night	IMC	1	0	D	Missed appr	Uncont Coll w/Terr	Loss-of-Control (Vmc)
2/16/2005	CE-560	N500AT	EXEC	N500AT	KPUB	Day	IMC	8	0	D	Final appr	Uncont Coll w/Terr	Icing Stall
2/24/2005	IAI-1124	XCCOL	EXEC	PVT OL		Day	N/R	7	0	D	Approach	Collision w/Terrain	Undetermined
3/15/2005	An-26	OB1778P	NSCHD	AMP 8P	SPIM	Day	N/R	0	0	S	Initial climb	Collision w/Terrain	TO w/Incorrect Config
3/26/2005	Let-410	HK4146	SCHED	WCW 9955	SKPV	Day	N/R	9	0	D	Initial climb	Uncont Coll w/Terr	Loss-of-Control (Vmc)
5/2/2005	SA-227	ZKPOA	SCHED	AWK 23		Night	IMC	2	0	D	Cruise	Uncont Coll w/Terr	Load-c/g Out Of Range
5/12/2005	MD-90	N910ME	SCHED	MEP 490	KIRK	Night	IMC	0	0	N	Cruise	Aircraft Oscillat'ns	Instrument Failure
5/21/2005	CL-600	N699CW	NREV	DGFA CW	KAGS	Night	VMC	0	0	N	Climb	Cabin Injuries	Aggressive Maneuver
5/27/2005	DHC-8	CGZKH	SCHED	CGZKH	CYYT	N/R	N/R	0	0	N	Climb	Upset	Autopilot-Induced Stall

Date	Aircraft	Regist	Operat'n	Ident	Loc'n	Light	Weather	Fat	Grd	Dam	Phase	Result	Occurrence
8/1/2005	B-777	9MMRG	SCHED	MAS 124	YPPH	N/R	N/R	0	0	N	Climb	Upset	Uncommanded Pitch
8/14/2005	B-737	5BDBY	SCHED	HCY 522	LGAV	N/R	N/R	121	0	D	Climb	Uncont Coll w/Terr	Incapacitation: Hypoxia
8/16/2005	MD-80	HK4374X	NSCHD	WCW 708		Night	N/R	160	0	D	Cruise	Uncont Coll w/Terr	Autopilot-Induced Stall
9/5/2005	B-737	PRBRY	SCHED	BRB 907		N/R	N/R	0	0	N/R	Cruise	Upset	Uncommanded Bank
9/5/2005	B-737	PKRIM	SCHED	MDL 91	WIMM	N/R	N/R	100	49	D	Initial climb	Coll w/Obstacle	TO w/Incorrect Config
10/3/2005	E-170	N650RW	SCHED	UHL 7621	KIAD	Day	VMC	0	0	N	VFR pattern	Cabin Injuries	Aggressive Maneuver
10/22/2005	B-737	5NBFN	SCHED	BVU 210		Night	N/R	117	0	D	Climb	Collision w/Terrain	Undetermined
11/8/2005	E-110	N7801Q	NSCHD	BQTA 352	KMHT	Day	VMC	0	0	D	Initial climb	Coll w/Obstacle	Loss-of-Control (Vmc)
12/19/2005	G-73	N2969	SCHED	CHK 101	KMPB	Day	VMC	20	0	D	Initial climb	Uncont Coll w/Terr	Struct Fail - Fatigue
12/23/2005	An-140	4KAZ48	SCHED	AHY 217		Night	IMC	23	0	D	Cruise	Uncont Coll w/Terr	Loss Of All Att Displ
12/28/2005	LR-35	N781RS	NREV	S2KA RS	KTRK	Day	IMC	2	0	D	Approach	Uncont Coll w/Terr	Stall
1/2/2006	SF-340	N390AE	SCHED	SIM 3008		Day	IMC	0	0	N	Climb	Upset	Autopilot-Induced Stall
1/5/2006	CE-560	N391QS	NSCHD	DXTA QS	KARV	Day	VMC	0		S	Landing	Coll w/Obstacle	Stall
2/8/2006	SA-226	N629EK	NSCHD	GAE EK		Day	VMC	1	0	D	Cruise	Uncont Coll w/Terr	Undetermined
2/9/2006	CL-600	N900LG	EXEC	PVT LG	KASE	Day	VMC	0	0	S	Approach	Hard Landing	Wake Turbulence
5/3/2006	A-320	EK32009	SCHED	RNV 967	URSS	Night	IMC	113	0	D	Missed appr	Uncont Coll w/Terr	Spatial Disorientation
6/21/2006	DHC-6	9NAEQ	NSCHD	NYT EQ	VNJL	N/R	N/R	9	0	D	Go-around	Collision w/Terrain	Aggressive Maneuver
7/10/2006	F-27	APBAL	SCHED	PIA 688	OPMT	Day	N/R	45	0	D	Initial climb	Collision w/Terrain	Stall
8/13/2006	L-387	7TVHG	NSCHD	DAH 2208		N/R	N/R	3	0	D	Cruise	Uncont Coll w/Terr	Undetermined
8/22/2006	Tu-154	RA85185	SCHED	PLK 612		Day	IMC	170	0	D	Cruise	Uncont Coll w/Terr	Turbulence
9/29/2006	B-737	PRGTD	SCHED	GLO 1907		Day	VMC	154	0	D	Cruise	Uncont Coll w/Terr	Struct Fail - Midair
9/29/2006	E-135	N600XL	NREV	N600XL	SBCC	Day	VMC	0	0	S	Cruise	Forced Landing	Struct Fail - Midair
10/23/2006	A-320	N924FR	SCHED	FFT 539	KDEN	Day	VMC	0	0	N	Landg flare	Uncomm Pitch	Inadvertent Cont Input
10/29/2006	B-737	5NBFK	SCHED	ADK 53	DNAA	Day	IMC	96		D	Initial climb	Uncont Coll w/Terr	Wind Shear
10/31/2006	CL-600	N322FX	NREV	N322FX	KTEB	N/R	VMC	0		N	Approach	Cabin Injuries	Aggressive Maneuver
11/30/2006	NA-265	XATNP	NSCHD	FCS NP	MMCL	N/R	N/R	2	0	D	Maneuvering	Coll w/Obstacle	Undetermined
1/1/2007	B-737	PKKKW	SCHED	DHI 574		Day	N/R	102	0	D	Cruise	Spiral Dive	Spatial Disorientation
1/10/2007	LR-35	N40AN	NSCHD	N40AN	KCMH	Night	VMC	0	0	S	Maneuvering	Overstress	Fail To Maintain Cont
1/12/2007	CE-525	N77215	NREV	SQ6R 15	KVNY	Day	VMC	2	0	D	Initial climb	Uncont Coll w/Terr	Stall
1/25/2007	FO-100	FGMPG	SCHED	RAE 7775	LFBP	Day	VMC	0	1	S	Initial climb	Coll w/Obstacle	TO w/Contam Wing
2/13/2007	CL-600	N168CK	NREV	N168CK	UUWW	N/R	IMC	0	0	D	Initial climb	Uncont Coll w/Terr	Undetermined
3/17/2007	CE-500	N511AT	NSCHD	N511AT	KBVY	Day	IMC	0	0	S	Landg flare	Collision w/Terrain	Contam Airfoil
3/27/2007	E-170	HZAEN	SCHED	SVA 1866	OERK	N/R	N/R	0	0	N/R	Descent	Uncomm Pitch	Undetermined
5/5/2007	B-737	5YKYA	SCHED	KQA 507	FKKD	Night	N/R	114	0	D	Initial climb	Spiral Dive	Spatial Disorientation
5/17/2007	Let-410	TNAHE	NSCHD	SAFE HE		N/R	N/R	3	0	D	Initial climb	Coll w/Obstacle	Undetermined
6/4/2007	CE-550	N500BP	NSCHD	DJQ BP	KMKE	Day	VMC	6	0	D	Climb	Spiral Dive	Spatial Disorientation
7/29/2007	An-12	RA93912	NSCHD	VAS 9655	UUDD	Night	N/R	7	0	D	Initial climb	Uncont Coll w/Terr	Loss-of-Control (Vmc)
8/9/2007	DHC-6	FOIQI	SCHED	TAH 1121	NTTM	Day	VMC	20	0	D	Initial climb	Uncont Coll w/Terr	Flt Cont Integrity Lost
9/23/2007	B-737	GTHOF	SCHED	TOM OF		Night	IMC	0	0	N	Landing	Upset	Stall
10/17/2007	LR-35	N31MC	EXEC	PVT MC	KGLD	Day	IMC	0		S	Landing	Collision w/Terrain	Aircraft Pitch/Roll Osc
11/4/2007	LR-35	PTOVC	NREV	PTOVC	SBMT	N/R	N/R	2	6	D	Initial climb	Uncont Coll w/Terr	Undetermined
12/10/2007	BE-200	N925TT	EXEC	PVT TT	KSMN	Dawn	IMC	2		D	Initial climb	Coll w/Obstacle	TO w/Contam Wing
12/16/2007	CL-600	N470ZW	SCHED	AWI 3758	KPVD	Day	IMC	0	0	S	Landing	Hard Landing	Stall
1/10/2008	A-320	CGBHZ	SCHED	ACA 190	KOMK	Night	N/R	0	0	M	Climb	Upset	Wake Turbulence
2/14/2008	CL-600	EW101PJ	SCHED	BRU 1834	UDYZ	N/R	N/R	0	0	D	Initial climb	Collision w/Terrain	TO w/Contam Wing
3/4/2008	CE-500	N113SH	NSCHD	N113SH	KPWA	Day	N/R	5	0	D	Climb	Collision w/Terrain	Struct Fail - Birdstrike
4/9/2008	SA-227	VHOZA	NSCHD	VHOZA	YSSY	Night	VMC	1	0	D	Climb	Spiral Dive	Spatial Disorientation
5/23/2008	BE-1900	N195GA	NSCHD	TIM 5008	KBIL	Night	IMC	1	0	D	Initial climb	Uncont Coll w/Terr	Undetermined
5/26/2008	An-12	RA12957	NREV	GAI 2063	USCC	N/R	N/R	9	0	D	Climb	Uncont Coll w/Terr	Flt Cont Integrity Lost

Date	Aircraft	Regist	Operat'n	Ident	Loc'n	Light	Weather	Fat	Grd	Dam	Phase	Result	Occurrence
6/14/2008	MD-10	N554FE	SCHED	FDE 764		N/R	VMC	0		S	holding	Exc Design Loads	Stall
6/18/2008	DHC-6	N656WA	SCHED	WIG 6601	KHYA	Day	VMC	1	0	D	Takeoff	Uncont Coll w/Terr	TO w/Gust Locks Eng
6/30/2008	Il-76	STWTB	NSCHD	BBE 700	HSSS	Day	N/R	4	0	D	Initial climb	Collision w/Terrain	TO w/Incorrect Config
7/10/2008	BE-99	CCCFM	SCHED	CCCFM	SCPF	N/R	N/R	9	0	D	Initial climb	Uncont Coll w/Terr	Stall
7/16/2008	DHC-6	CGBEB	NSCHD	NWI EB		Day	VMC	0	0	S	VFR pattern	Coll w/Obstacle	Stall
8/20/2008	MD-80	ECHFP	SCHED	JKK 5022	LEMD	N/R	N/R	154	0	D	Takeoff	Collision w/Terrain	TO w/Incorrect Config
9/14/2008	B-737	VPBKO	SCHED	AFL KO	USPP	Night	IMC	88	0	D	Approach	Spiral Dive	Spatial Disorientation
10/7/2008	A-330	VHQPA	SCHED	QFA 72	YPLM	N/R	N/R	0	0	M	Cruise	Upset	Flight Control Logic
11/1/2008	C-212	N437RA	NSCHD	ATS RA		Dusk	VMC	0	0	S	VFR pattern	Collision w/Terrain	Asymm Thrust/Drag
11/4/2008	LR-45	XCVMC	EXEC	PVT MC	MMMX	N/R	N/R	9	7		Approach	Uncont Coll w/Terr	Wake Turbulence
12/7/2008	LR-23	XCLGD	EXEC	XCLGD		N/R	N/R	2	0	D	Go-around	Uncont Coll w/Terr	Undetermined
1/27/2009	ATR-42	N902FX	SCHED	CFS 8284	KLLB	Night	IMC	0	0	S	Final appr	Uncont Coll w/Terr	Stall
2/7/2009	E-110	PTSEA	NSCHD	PTSEA	SWKO	Day	N/R	24		D	Climb	Collision w/Terrain	Undetermined
2/7/2009	CE-650	IFEEV	NREV	AOE 301		N/R	N/R	2	0	D	Climb	Spiral Dive	Undetermined
2/12/2009	DHC-8	N200WQ	SCHED	CJC 3407	KBUF	Night	VMC	49	1	D	Approach	Uncont Coll w/Terr	Stall
2/25/2009	B-737	TCJGE	SCHED	THY 1951	EHAM	Day	N/R	9	0	D	Approach	Collision w/Terrain	Stall
5/11/2009	B-747	GBYGA	SCHED	BAW GA	FAJS	Night	VMC	0	0	N	Initial climb	Stall Buffet	Uncomm Config Chng
6/1/2009	A-330	FGZCP	SCHED	AFR 447	TASIL	Night	IMC	228	0	D	Cruise	Uncont Coll w/Terr	Spatial Disorientation
6/30/2009	A-310	300	SCHED	IYE 626	FMCH	Night	VMC	152	0	D	Circling appr	Collision w/Terrain	Fail To Maintain Airspd
7/15/2009	Tu-154	EPCPG	SCHED	CMP 7908		N/R	N/R	168	0	D	Cruise	Collision w/Terrain	Undetermined
10/21/2009	B-707	STAKW	NSCHD	SUD 2241	OMSJ	N/R	N/R	6	0	D	Initial climb	Uncont Coll w/Terr	Fail To Maintain Cont
11/1/2009	Il-76	RF76801	NREV	RF76801	UERR	N/R	N/R	11	0	D	Initial climb	Collision w/Terrain	Undetermined
11/28/2009	MD-11	ZBAV	SCHED	SMJ 324	ZSPD	N/R	N/R	3	0	D	Initial climb	Uncont Coll w/Terr	Undetermined
1/5/2010	LR-35	N720RA	NREV	RAX 988	KPWK	Day	VMC	2		D	VFR pattern	Uncont Coll w/Terr	Undetermined
1/6/2010	BE-99	N206AV	SCHED	JIKA AV	KEAR	Dawn	IMC	0	0	S	Landg flare	Hard Landing	Icing Stall
1/21/2010	BE-1900	N112AX	SCHED	AER 22	PASD	Night	VMC	2	0	D	Initial climb	Uncont Coll w/Terr	Undetermined
1/25/2010	B-737	ETANB	SCHED	ETH 409	OLBA	Night	IMC	90	0	D	Climb	Spiral Dive	Spatial Disorientation
2/13/2010	B-737	N221WN	SCHED	SWA 2534	KBUR	Day	VMC	0		N	Approach	Cabin Injuries	Aggressive Maneuver
2/14/2010	CE-550	OKACH	NREV	TIE 039C		Night	VMC	2	0	D	Cruise	Uncont Coll w/Terr	Intentional Acrobatics
5/12/2010	A-330	5AONG	SCHED	AAW 771	HLLT	Day	IMC	103	0	D	Approach	Collision w/Terrain	Somatogravic Illusion
8/25/2010	Let-410	9QCCN	SCHED	9QCCN	ZFBO	N/R	N/R	20	0	D	Final appr	Collision w/Terrain	Load - c/g Out Of Rng
9/3/2010	B-747	N571UP	SCHED	UPS UP	OMDB	Night	N/R	2	0	D	Climb	Uncont Coll w/Terr	Struct Fail - Fire/Expl
10/11/2010	A-380	FHPJA	SCHED	AFR 006	KJFK	Day	N/R		0	N	Final appr	Altitude Deviation	Flap/Slat Ext Spd Exc
11/4/2010	ATR-72	CUT1549	SCHED	CRN 883		N/R	IMC	68	0	D	Cruise	Uncont Coll w/Terr	Contaminated Airfoil
11/5/2010	BE-1900	APBJD	NSCHD	JSJ JD	OPKC	N/R	N/R	21	0	D	Initial climb	Collision w/Terrain	Loss-of-Control (Vmc)
11/28/2010	Il-76	4LGNI	NSCHD	4LGNI	OPKC	N/R	N/R	8	4	D	Initial climb	Coll w/Obstacle	Loss-of-Control (Vmc)

Appendix B: Accident Sequence Diagrams

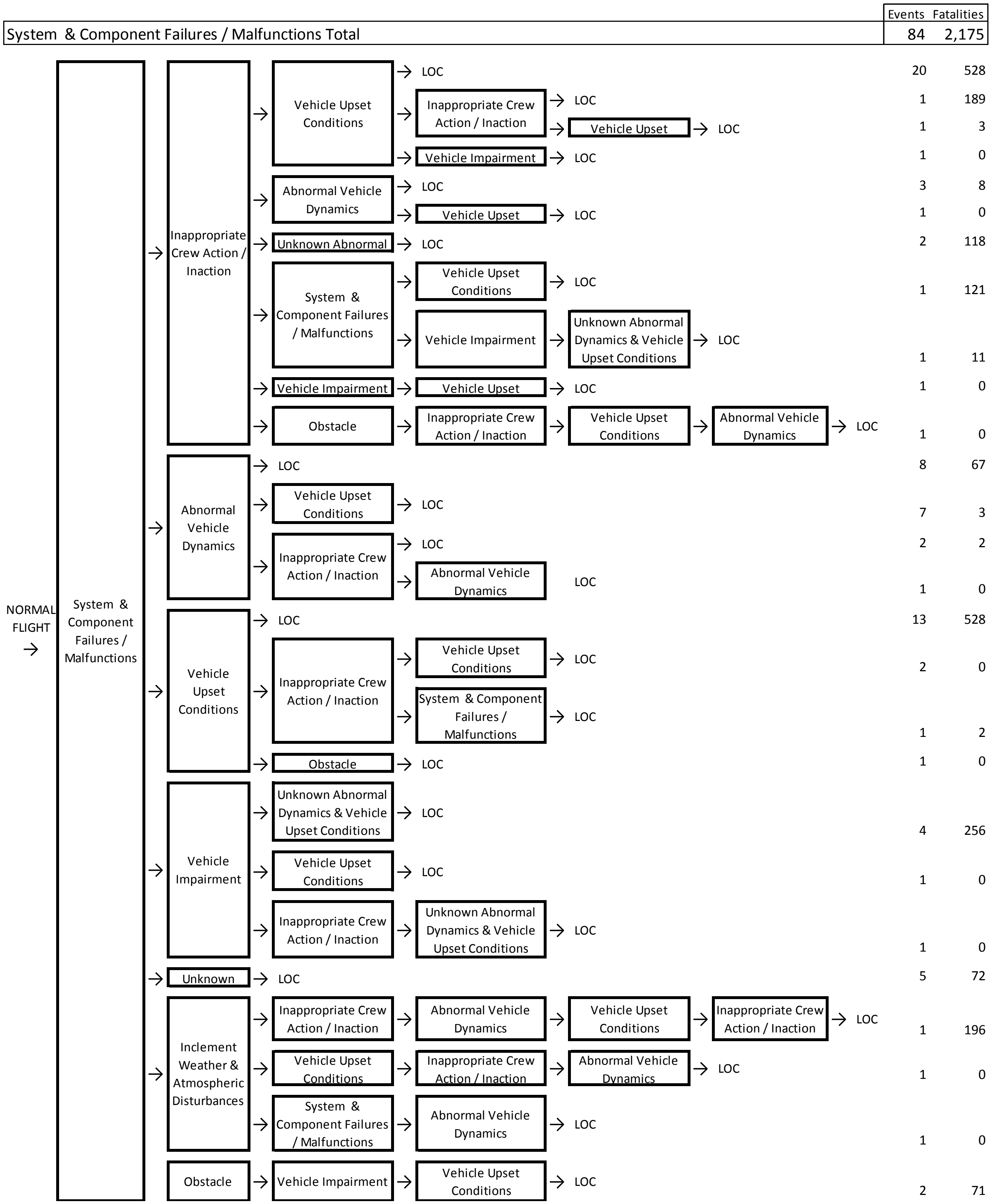

Figure B-1. LOC Sequences Initiated by System & Component Failures / Malfunctions.

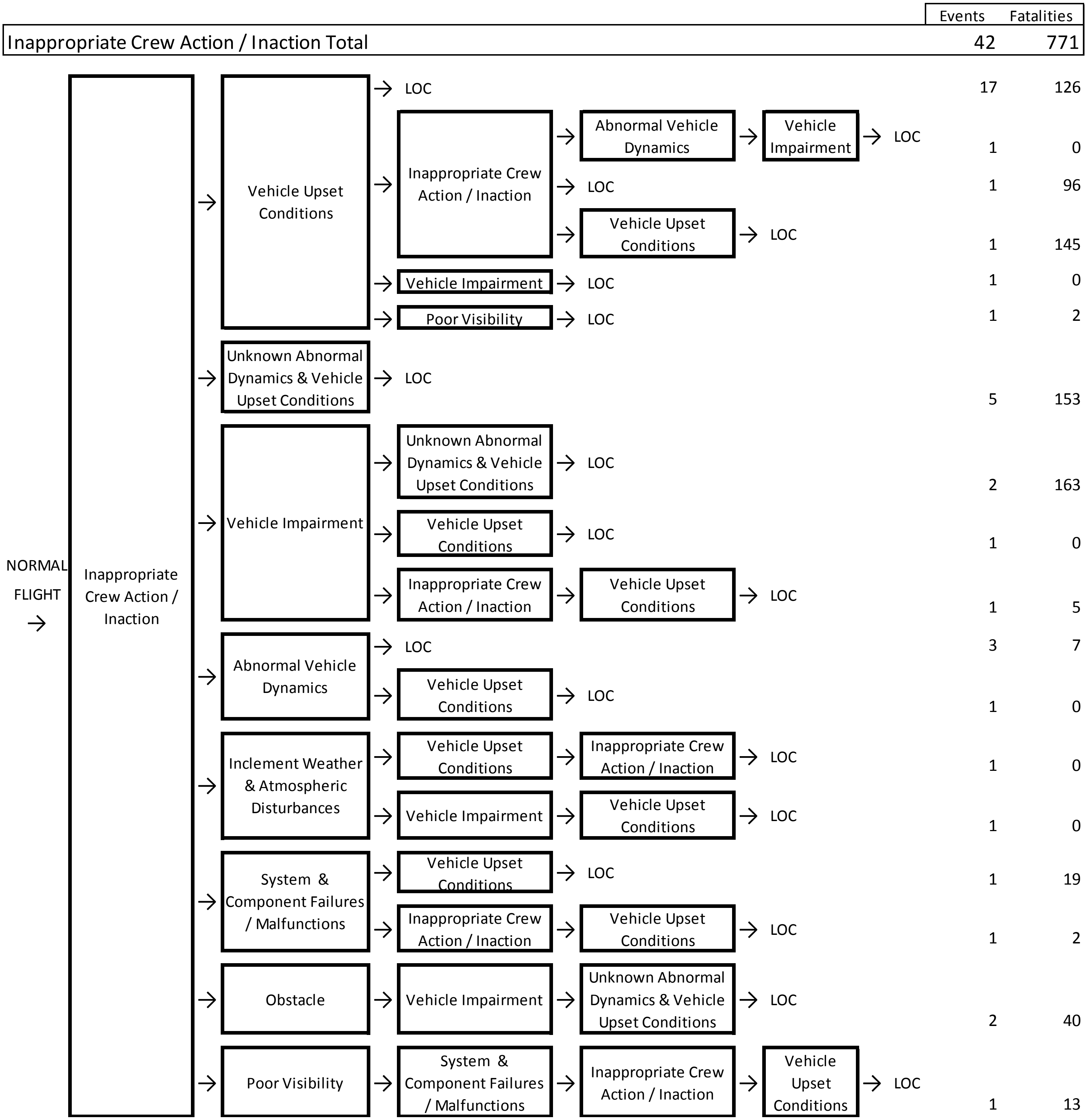

Figure B-2. LOC Sequences Initiated by Inappropriate Crew Action / Inaction.

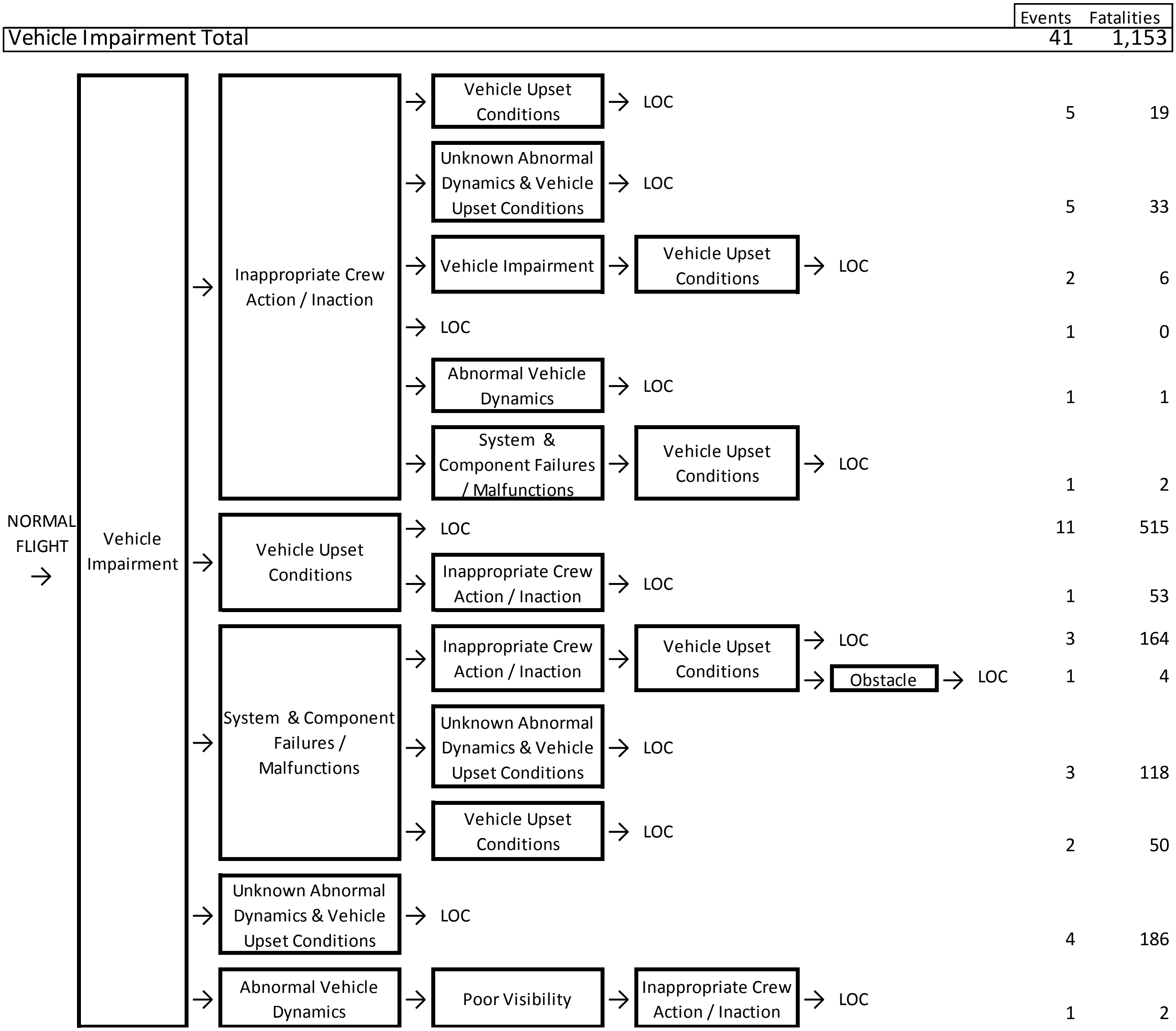

Figure B-3. LOC Sequences Initiated by Vehicle Impairment.

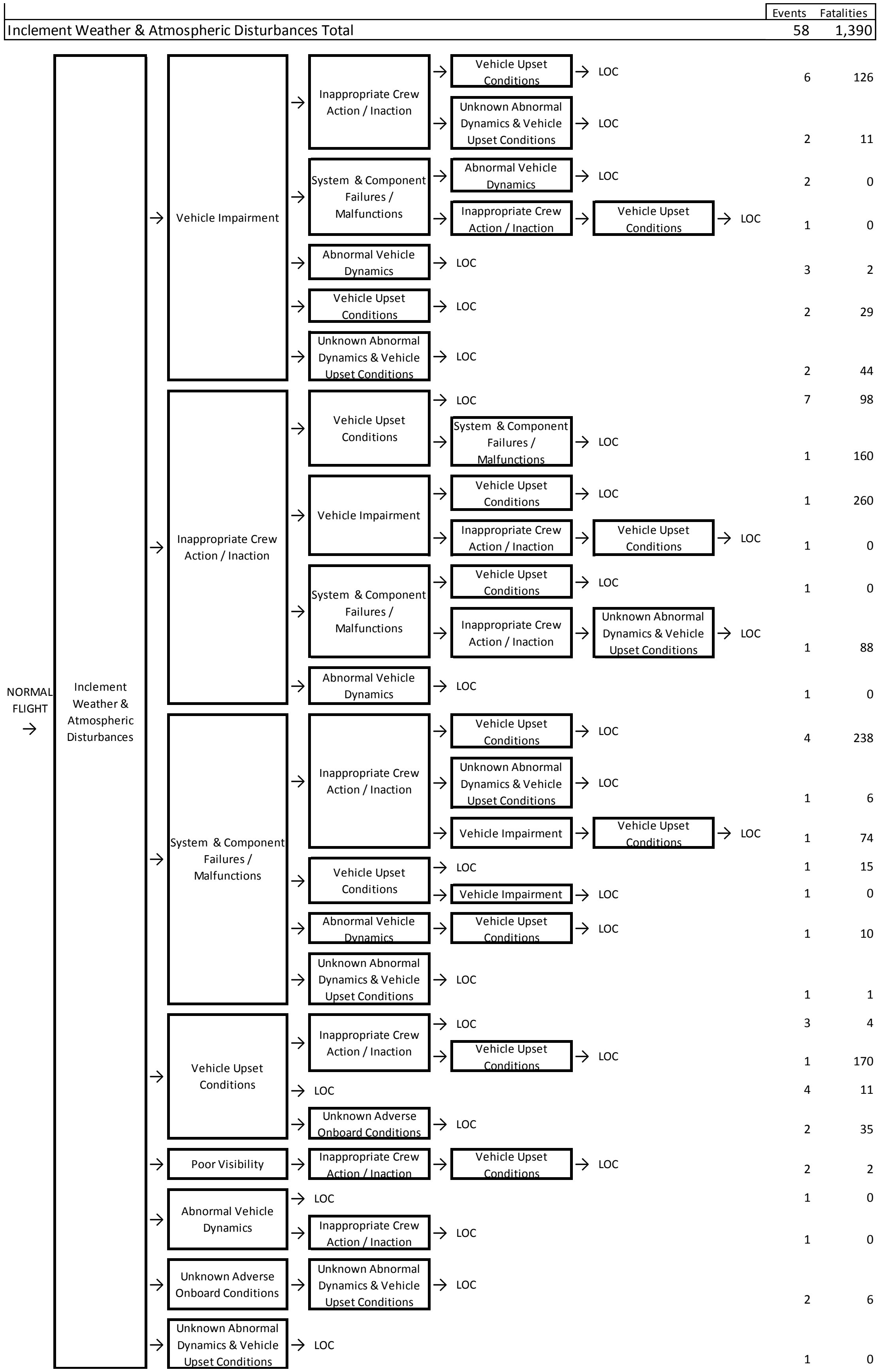

Figure B-4. LOC Sequences Initiated by Inclement Weather & Atmospheric Disturbances.

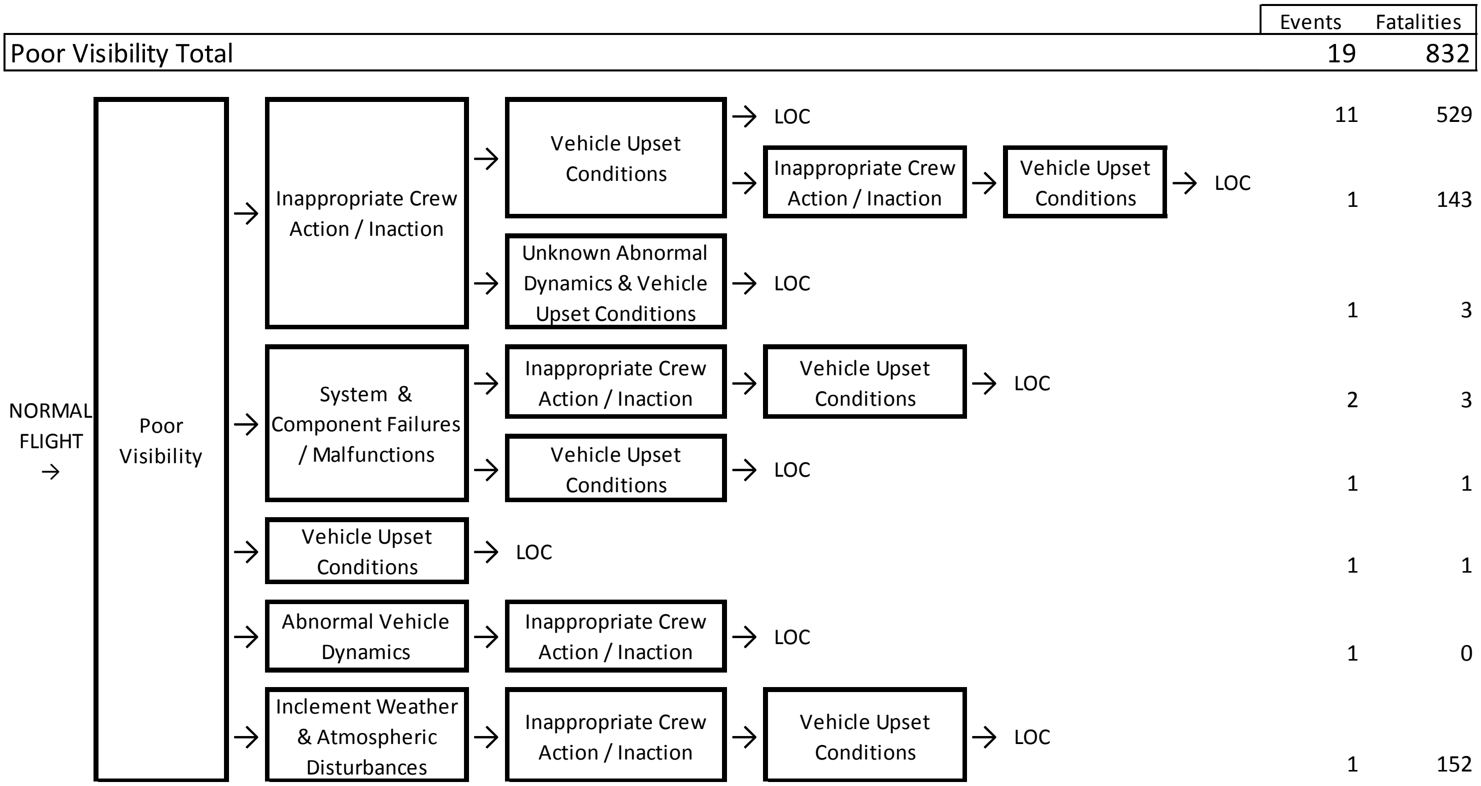

Figure B-5. LOC Sequences Initiated by Poor Visibility.

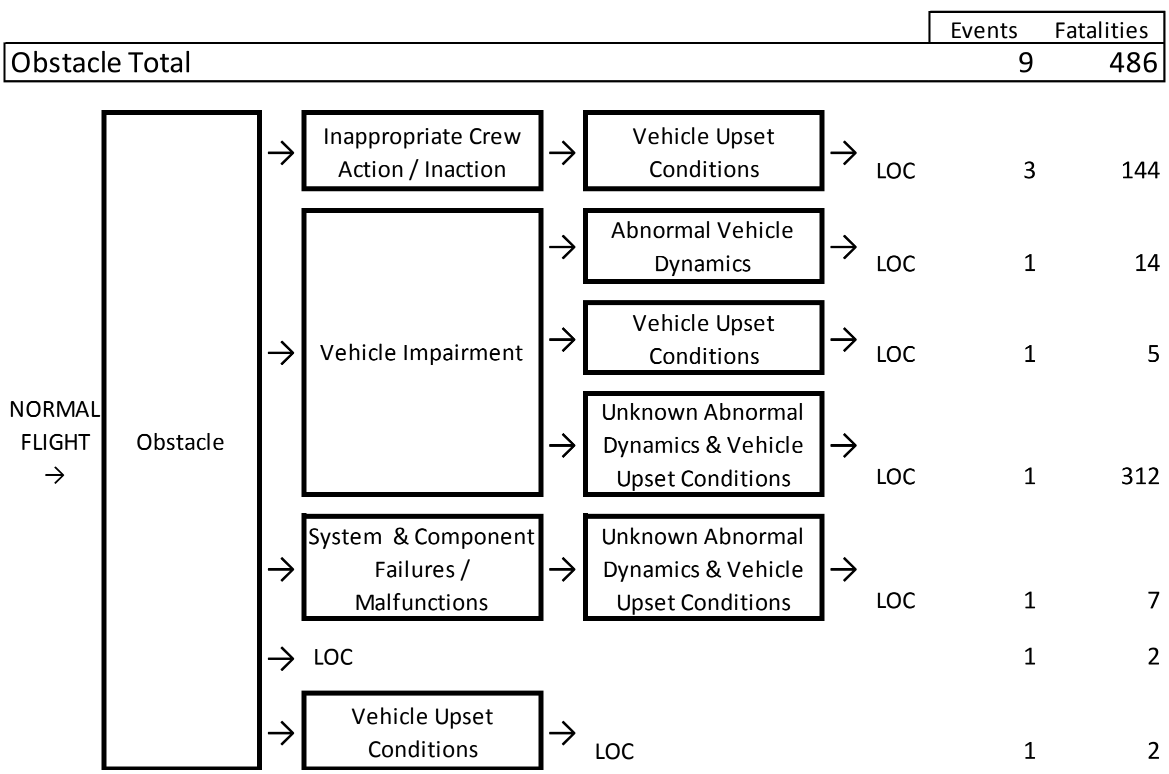

Figure B-6. LOC Sequences Initiated by an Obstacle.

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Dedication

The research presented in this paper is dedicated to the memory and research contributions of Dr. Celeste M. Belcastro of NASA Langley Research Center, who lost her courageous and selfless battle with cancer and passed from this life on August 22, 2008. She dedicated her life and career to aviation safety research, and made numerous technical and leadership contributions in the areas of vehicle health management and safety-critical avionics systems. Just prior to her illness, she had embarked on a research collaboration with her identical twin, Dr. Christine M. Belcastro, to address aircraft loss of control. Her absence from this work will forever be a significant and irreparable loss to the aerospace research community.

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