Loss of Control In Flight (LOC-I) – Time to Re-define?

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Loss of Control In Flight – time to re-define?

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Loss of Control In Flight has been the primary fatal accident category for all sectors of aviation and all types of airplane, around the world for the past 55 years. Although accident rates for commercial jets have decreased from 11 fatal accidents per million departures in 1960 to less than 0.3 in 2015, Loss of Control In Flight continues to dominate the statistics. Highly publicised accidents such as Air France 447 have raised public awareness of Loss of Control In Flight. This and other high profile events, have motivated airplane manufacturers, pilot training organisations, flight simulator manufacturers, research institutions and regulators to intervene. Before intervention, a clear definition of the event is required. Current definitions are limited to non-recoverable events and the majority of previous studies have concentrated on fatal events only. This is a missed opportunity to learn lessons from near misses and recorded flight data to enhance prevention and recovery strategies. This paper presents a revised definition of Loss of Control In Flight, considering it as a recoverable event extending the it to consider prevention and recovery factors.

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I. Nomenclature

AAIB	=	UK Air Accidents Investigation Branch
AAIU	=	Irish Air Accident Investigation Unit
ATSB	=	Australian Transport Safety Bureau
AOA	=	Angle of Attack [deg]
BEA	=	French Bureau d’Enquêtes et d’Analyses pour la sécurité de l’Aviation civile
CAST	=	Commercial Aviation Safety Team
ICAO	=	International Civil Aviation Organisation
CICTT	=	CAST / ICAO Common Taxonomy Team
EASA	=	European Aviation Safety Agency
FDM	=	Flight Data Monitoring
FOQA	=	Flight Operations Quality Assurance
IATA	=	International Air Transport Association
JSAT	=	Joint Safety Analysis Team
LOC-I	=	Loss of Control – In Flight
NASA	=	National Aeronautics and Space Administration
NTSB	=	US National Transportation Safety Board
TSB	=	Canadian Transportation Safety Board
V_{min}	=	Minimum airspeed for safe flight [kts]

II. Introduction

Loss of Control In Flight (LOC-I) has been the primary fatal accident category for all sectors of aviation and all types of airplane, around the world for the past 55 years [1]. Although accident rates for commercial jets have decreased from 11 fatal accidents per million departures in 1960 to less than 0.3 in 2015, LOC-I continues to dominate the statistics. Highly publicised accidents such as Air France 447, which crashed into the Atlantic Ocean during a flight from Rio de Janeiro, Brazil, to Paris, France in 2009, have raised public awareness of LOC-I [2]. This and other tragic high-profile LOC-I events have motivated airplane manufacturers, pilot training organisations, flight simulator manufacturers, research institutions and regulators to try to identify interventions, including training and technology, to prevent LOC-I events or to enable recovery from them.

In LOC-I accident statistics, turbo-propeller aircraft are often overlooked [3] and these types of aircraft have a significantly higher average rate of LOC-I (0.68 per million flights) when compared to commercial jets (0.09) by IATA over a continuous 5 year period (**Error! Reference source not found.**). This is probably due to the different inherent stability and control characteristics of these airplane and the environment in which they operate. Turbo-propeller aircraft typically operate at lower heights above ground level and at slower airspeeds relative to commercial jets. They are also more susceptible to environmental factors such as icing and wind gusts and turbulence due to lower wing loading.

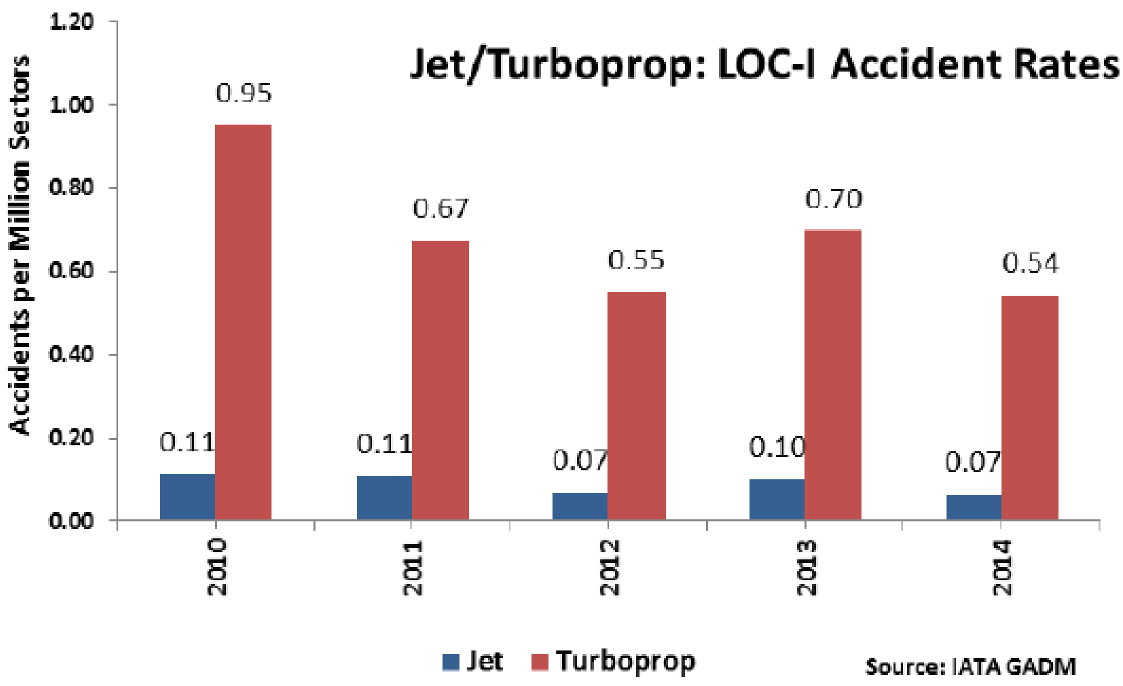

Figure 1, Commercial Jet/Turboprop LOC-I Accident Rates [3]

Current definitions of LOC-I [3,4,5,6] are insufficiently detailed to enable researchers or practitioners to identify proper safety interventions (Table 1). Most definitions consider LOC-I events as fatal, and non-recoverable and exclude events where control was regained excluding potentially valuable information to inform safety interventions or recovery procedures. From a review of previous work and evidenced-based reports, several key insights can be gleaned that may lead to a framework that can guide researchers and practitioners toward possible interventions, before and after the event. A clear and comprehensive definition is fundamental to the development of intervention strategies for prevention, recognition and recovery. LOC-I is highly complex, as evidenced by the diverse range of causal and contributory factors.

Table 1, Comparison of Definitions of Loss of Control In Flight

Organisation	**Definition**
IATA [3]	"LOC-I refers to accidents in which the flight crew was unable to maintain control of the airplane in flight, resulting in an unrecoverable deviation from the intended flight path."
JSAT [4]	"Loss of control to includes significant, unintended departure of the airplane from controlled flight, the operational envelope, or usual flight attitudes, including ground events."
CICTT [5]	"Loss of Airplane control while, or deviation from intended flight path, in flight. Loss of control in flight is an extreme manifestation of a deviation from intended flight path."
EASA [6]	"Loss of control in flight is loss of airplane control while, or deviation from intended flight path, in flight. Loss of control in flight is an extreme manifestation of a deviation from intended flight path."

Many of the definitions include common terms including – "unable to maintain control," "loss of control," "unintended departure from controlled flightpath/operational envelope," "Extreme manifestation of deviation from intended flightpath" etc.

III. Method

Previous work in the field was reviewed [7,8,9,10,11] in conjunction with selected evidenced-based reports [12] to identify the principal categories of causal/contributing factors or 'triggers.' Jacobson[13] reviewed information relating to LOC-I accidents: from statistical data; individual accident reports, meta-analyses and industry stakeholders. Using this information, major causal factors were highlighted resulting in the highest number of loss of control accidents. Three major groups of causal factors were identified human induced, systems induced and externally induced (Figure 2). Jacobson concluded that LOC-I accidents are usually a combination of causal contributory factors and rarely a single factor in isolation. Human induced LOC-I is dominant, and emphasis should be placed on prevention rather that recovery. That said Jacobson promotes an holistic approach encompassing both prevention (by means of improved training, technology and information) and recovery (by means of training).

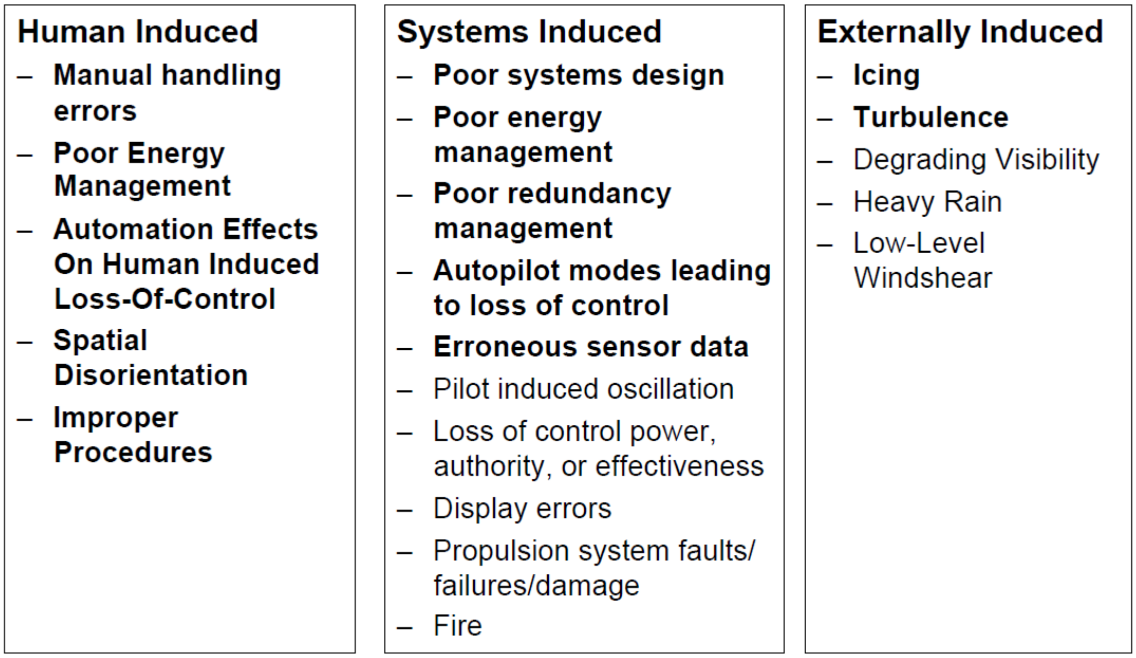

Figure 2, Major Causal/Contributory Factors to LoC-I[13]

Wilburn & Foster[14] attempted to define LOC-I using quantitative measures. Quantitative metrics to assess whether or not LOC-I was a factor in an event was used to determine the onset of LOC-I and the severity. They considered the airplane operating flight dynamics, aerodynamics, structural integrity and flight control inputs. The suggest that the excursion of three or more operational envelopes (e.g. alpha, beta, airspeed) is confirmation that a LOC-I event took place. These metrics are all output parameters and of little use to guide appropriate safety interventions.

Belcastro[9] identified LOC-I hazards and extended these to include vehicle impairment conditions, external disturbances; vehicle upset conditions and inappropriate human (crew) actions or responses. The emphasis was on guidance and navigation systems but also considers recovery factors. Key human factor related contributory factors were poor situation awareness/distraction, spatial disorientation (poor visibility) and automation mode confusion (system complexity).

With respect to the use of flight safety technologies for the prevention of LOC-I, Belcastro[10] highlighted the challenges faced with validation due to the range of hazards, often occurring in combination, which cannot be fully replicated during evaluations. Belcastro emphasised that the introduction of new technologies should not introduce new safety risks and proposed a validation framework for safety-critical systems together with an overview of validation methods and tools developed by NASA with a suggested set of test scenarios for the validation of technologies for LOC-I prevention and recovery.

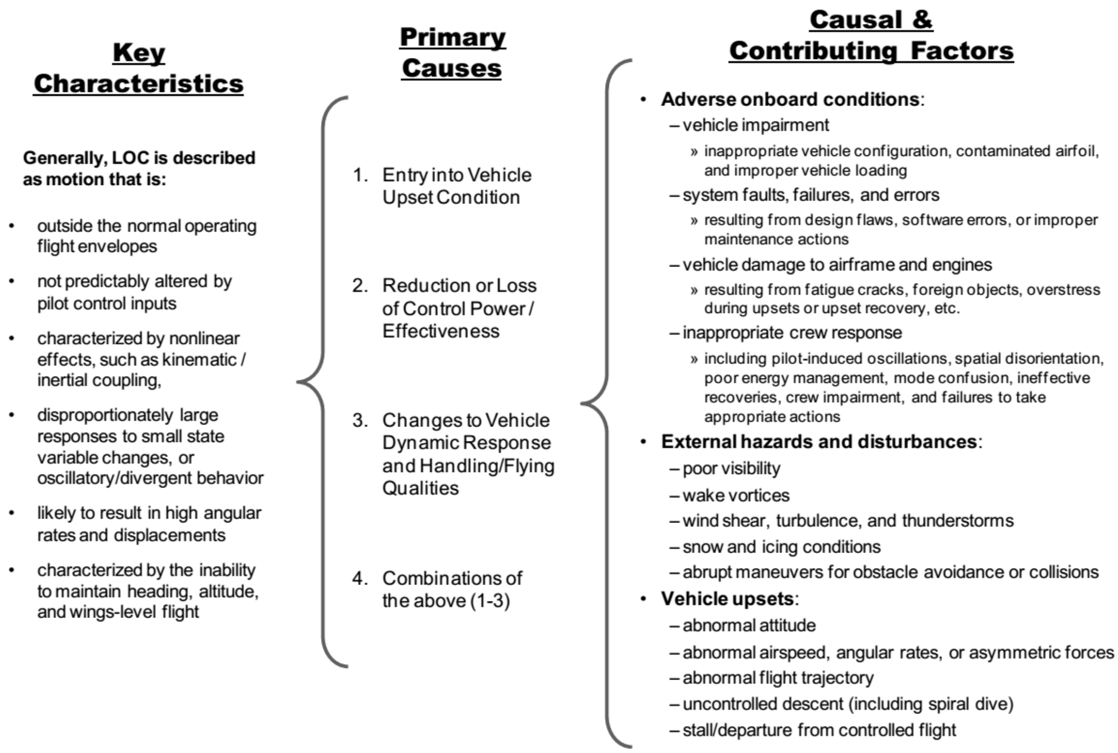

Figure 3, LOC key characteristics, primary causes, and causal & contributing factors[9]

Belcastro[9] further extended this work to link cause-effects of LOC-I. Causal and contributory factors lead to primary causes which in turn leads to key characteristics of LOC-I. This model gives insight into human factor considerations for ‘pilot in the loop’ control of the airplane, affected by control power effectiveness, vehicle dynamic response and handling/flying qualities. However, the ‘pilot in the loop’ model is not explicitly referred.

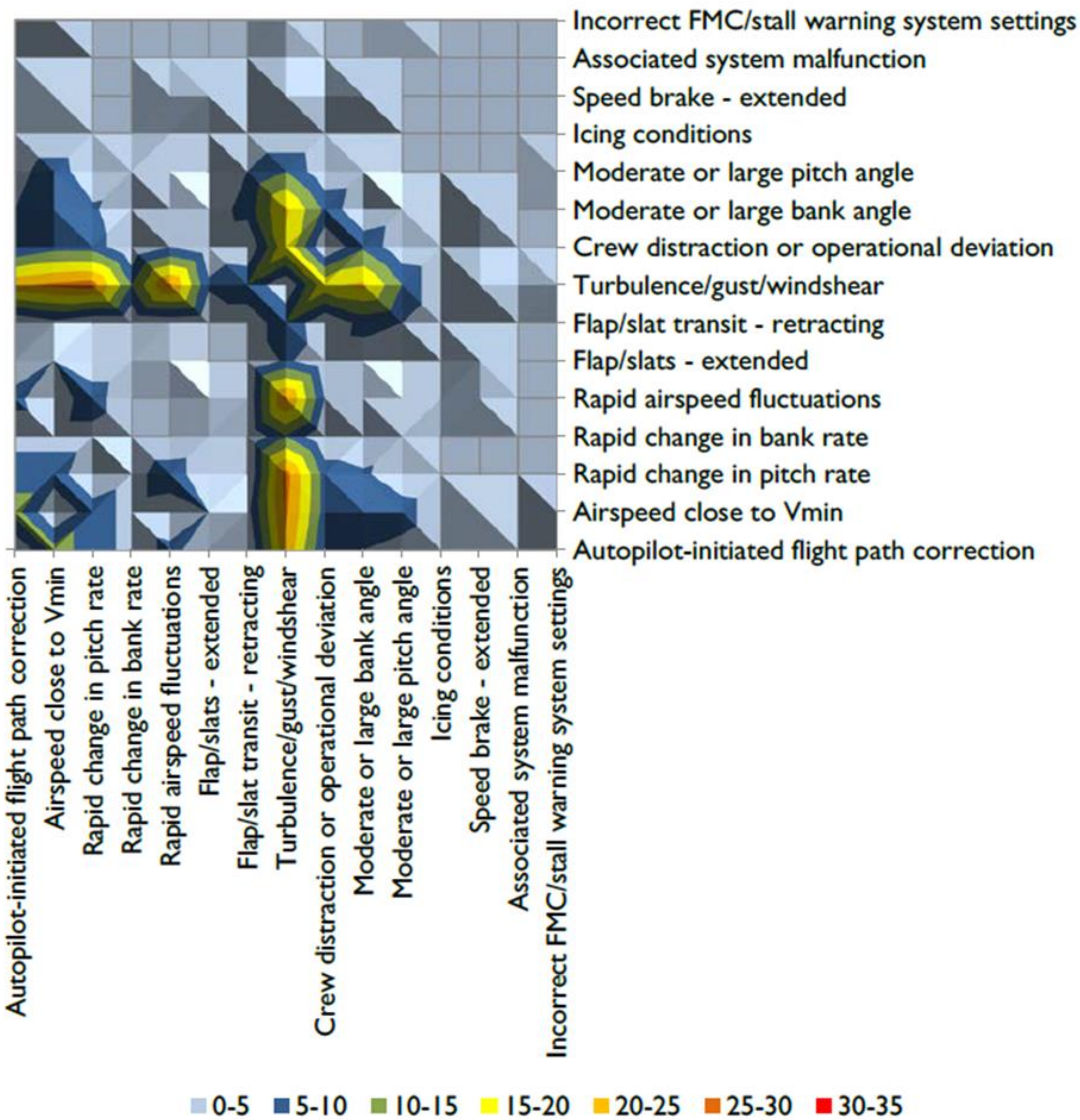

Figure 4, Cross-plot of pre-cursors to stall warning events reported to ATSB, 2008 to 2012[12]

Selected meta analyses reports focussing on non-fatal events were reviewed to provide further insight into LOC-I causal and contributory factors. An ATSB study of accident/incident reports in Australia for stall warnings in high capacity airplanes[12] used FOQA/FDM data associated with stall warning events to identify common pre-cursors (Figure 4). The report highlighted pre-cursors associated with automation, environmental conditions, moderate or large airplane attitudes, rapid changes in pitch/roll rates (g-loading), airspeeds close to V_{min} aircraft configuration, crew distraction or operational deviation. A cross-plot of pre-cursors for stall warnings showed that turbulence, gusts and or windshear had a profound effect on the number of stall warning events recorded.

In line with the generally accepted definition of an upset – "an airplane in flight unintentionally exceeding the parameters normally experienced in line operations or training," Fucke et al[15] defined the relationship between different types of upsets. Upset situations are dynamic and conditions may change quickly with the airplane alternating between different types of upsets depending upon pilots' action/inaction and external environmental factors.

IV. Discussion of Results

A critical review of current definitions for LOC-I was conducted in combination with a review of previous analyses of causal, contributory factors and characteristics. This has resulted in a LOC-I framework to inform safety interventions pre and post-event and this has informed the re-definition of LOC-I.

A. LOC-I Framework

The review of previous work in the field and evidenced-based meta-analysis of non-fatal events stall warning events identified six principle categories of contributing factors or 'triggers.' These may be summarised as: intentional and unintentional pilot control inputs, working and non-working automation, part and full-systems or powerplant failure and environmental factors such as turbulence, gusts and windshear. These 'triggers' can be considered as pre-cursors to an upset and/or stall and mishandled recovery can result in the airplane alternating between a stall and an upset condition. If these conditions are unchecked then the consequence can be a departure from controlled flight resulting in LOC-I (Figure 5).

The general assumption, that LOC-I is an unrecoverable event fails to consider those events where successful recovery strategies were adopted and airplanes returned to controlled flight. There are five possible factors that may influence recovery to controlled flight, all of which are necessary to effect a successful outcome. These are: correct recognition of the situation and comprehension of the airplane and automation state (sensing/perception), followed by manual or automated application of an appropriate (context sensitive) recovery method (decision/action). However, for the recovery method to be successful, sufficient height above surrounding terrain is necessary in combination with sufficient control authority for recovery within the airplane's structural design limits. If all five are present/possible then the airplane will be returned to controlled flight (Figure 5).

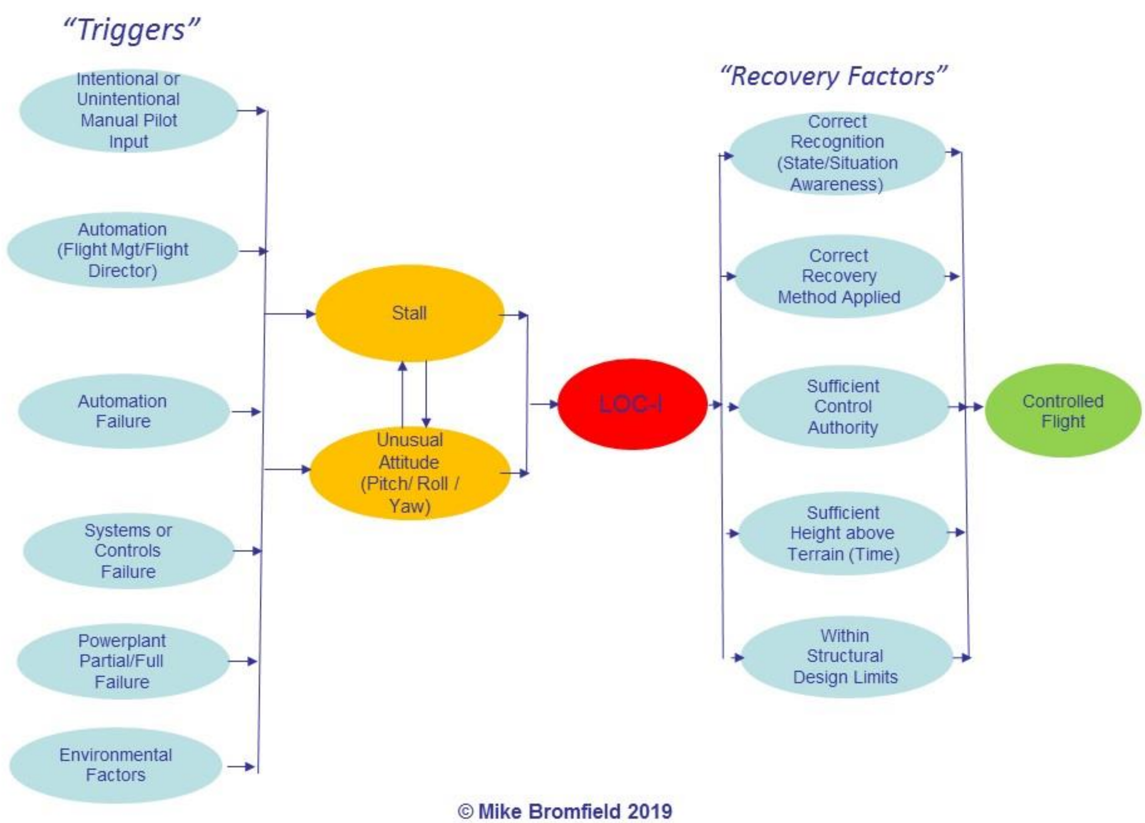

Figure 5, LOC-I Framework - Triggers & Recovery Factors[16]

B. Re-definition of LOC-I

Most current definitions of LOC-I also consider it to be an unrecoverable event, however, valuable lessons can be learned from non-fatal events where aircrew are able to supplement flight data with qualitative data. Some non-fatal events have resulted in exceeding the airplanes' structural design limits making them in some cases beyond economic repair, however crews were able to effect a successful outcome. FDM/FOQA programmes may also provide useful data in relation to pre-cursors to LOC-I[12]. LOC-I is a fundamental control problem involving human in the loop and human-systems integration challenges requiring an understanding of human sensing, perception, decision and action is required.

In summary, based upon the newly developed LOC-I framework, the proposed re-definition of Loss of Control In flight is:-

"A deviation from intended flight path such that the safety of crew, passengers & airplane is significantly threatened. This may be triggered by:

– intentional or unintentional manual pilot control input;
– automation (Flight Mgt. or Flight Director);
– automation and/or system(s) failure;
– environmental factor(s); or
– any combination of the above,

resulting in:-

– unusual attitude in pitch, roll, yaw or any combination or
– full aerodynamic stall, asymmetric stall or tail stall.

that may be recoverable if recognized by the crew (situation awareness), given:

– sufficient height above terrain and
– sufficient pitch, roll & yaw control authority (controllability) for recovery within the airplane's structural design limits."

V. Conclusions

A clear and comprehensive re-definition of LOC-I encompassing event pre-cursors and recovery factors to improve understanding and reduce ambiguity has been proposed. Using this definition, current and past intervention strategies can be evaluated and future intervention strategies designed for improved levels of mitigation. The definition also includes reference to recovery factors, not previously presented. Factors have been gleaned from a review of past research as well as incident/accident reports involving LOC-I. An enhanced framework has been developed consisting of six principle categories of "triggers," that may result in in LOC-I and four principle "recovery factors," which are those factors that effect a successful recovery. This re-definition of LOC-I and its associated framework will be used to inform future work with respect to the development of intervention and recovery strategies.

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