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1. Introduction to ISIM

1.1 Safety

The mandate of the Transportation Safety Board of Canada (TSB) is to advance *transportation safety* through the identification of safety deficiencies. In transportation, safety is often viewed as the absence of accidents or freedom from the negative consequences of accidents. Such a view, however, focuses on what may only be lucky outcomes. Increasingly, transportation industries are beginning to define safety as the identification and removal of unsafe conditions that have the potential to cause or contribute to accidents. These industries have found this proactive process to be profitable in that it is almost always less expensive to manage safety than to incur the cost of an accident.

1.2 Purpose of Investigations

The TSB identifies safety deficiencies in transportation systems, primarily through the investigation of accidents and incidents. The goal is always to identify the vulnerabilities of transportation systems that might cause future accidents or contribute to their severity.

The primary purpose of investigations is therefore prevention. The best way to accomplish that purpose is to learn how the *transportation system as a whole* functioned to produce an occurrence. With this understanding, safety problems of the system become apparent.

1.3 Why ISIM?

The TSB recognizes the importance of identifying safety issues in any occurrence and making these known to the public and transportation community. *ISIM* – the *Integrated Safety Investigation Methodology* – is an important part of the *TSB 2000* initiative. Although only a part of the broader initiative, ISIM plays a major role in increasing the effectiveness and scope of the investigation process.

The goal of ISIM is to strengthen the integration of the investigation, safety deficiency analysis, and communication processes. The methodology helps investigators to identify risks in the transportation system by coordinating all aspects of the investigation process. In addition, ISIM can help to structure the written investigation report, as at each stage of ISIM, investigators produce deliverable products that can be incorporated into the final report

ISIM is new only in the sense that it is a formalization of the steps normally followed during the investigation, safety deficiency analysis, and communication processes . ISIM also emphasizes the idea of *iterative investigation*. It should not be viewed as a step-by-step process in which one starts at the beginning and proceeds through each phase one at a time to completion. Instead, ISIM is meant to be flexible so that investigators can collect data, diagram events, analyze underlying factors, and so on throughout the investigation. Collecting data must be done with an eye towards how the occurrence will be analyzed. Likewise, how events are analyzed will depend upon the data collected. Because data collection can be ongoing throughout the investigation of an occurrence, the analysis must respond as new data is uncovered.

ISIM provides a way to maintain an overall understanding of an occurrence while on-going data collection, analysis, and communication are carried out. Thus, the investigation is a kind of "living account" of the occurrence.

1.4 This Manual

As noted, ISIM is a comprehensive procedure supported by theory. This manual will have three goals:

- To convey knowledge of the theories and concepts underlying ISIM
- To convey and explain ISIM so that investigators will be able to apply it in the field
- To help investigators integrate their knowledge of ISIM theory and procedure so they will be able to apply theoretical concepts and taxonomies as part of an ISIM-based investigation.

First, the manual is designed to teach about ISIM and its underlying concepts, such as *safety significant events* and *error types*. Second, the manual demonstrates the procedures to follow when applying ISIM, such as creating an *occurrence events diagram* and performing *risk assessment*. Third, the manual will illustrate how ISIM works with the investigation techniques of the various modes. TSB investigators are already well-trained, knowledgeable and experienced in TSB accident investigation methods. Thus, the purpose of the manual is to build on that experience and knowledge to convey the new way of integrating investigation and safety analysis in the application of ISIM.

It is important to note that the manual is not a reference document of how to conduct an investigation.

1.5 Structure of This Manual

This manual is organized in two ways. First, the manual is divided into three separate modal versions, for marine, rail/pipeline, and air modes. Each modal version contains the same description of ISIM plus its own modal-specific case study. The case studies describe the application of ISIM to an actual occurrence[1] and illustrate the results of ISIM. The modal case studies follow the same format and illustrate the same concepts and procedures.

Second, each modal version of the manual is divided into two main components – an ISIM reference component and the case study component. The ISIM reference lays out the framework for performing ISIM. It defines important concepts, indicates the purpose and deliverables of each stage of ISIM, and indicates the main steps. The case study emphasizes the results of an ISIM application to an occurrence so that a practical example of ISIM is available for reference. This manual, of course, cannot cover all aspects of an investigation. The case studies are necessarily limited in scope and cover only the most important concepts and procedures of ISIM.

[1] Details of the occurrences have been changed in certain respects to better illustrate ISIM.

They also focus on only a few major events of the occurrence rather than a comprehensive look at all events.

Each modal version follows the same lesson plan, illustrated in Figure 1-1. The major components of ISIM are shown in colored boxes on the left side of the diagram. The components that make up the various analysis processes, the Integrated Investigation Process, Risk Assessment Process, Defence Analysis, and Risk Control Option Process are shown in hexagons to set them apart. Each major component is the topic of its own section describing that part of ISIM. Each section also contains the relevant part of the case study to illustrate it.

Beside each major process is a set of sub-processes or procedures that make up the major process. These are laid out on a line but are not necessarily sequential processes. The sub-processes are described for each major component and form the major steps for conducting ISIM.

Figure 1-1 lays out the components of ISIM and helps to illustrate the individual lesson segments covered in this manual. An important aspect that is not reflected in the diagram is the iterative nature of ISIM. Investigators understanding of an occurrence and its underlying factors will develop over time. Investigators may have ideas early on that are discarded and new ideas will certainly arise as more is learned about the events. Much of the analysis process is on-going as well. Event analysis proceeds by the identification of *safety-significant events* to which the integrated investigation, risk analysis, defence analysis, risk control option analysis, and safety communication processes are applied. Thus, these steps should not be viewed as a single procedure but a series of procedures which may have to be iterated as new data are uncovered.

The annexes of this manual contain additional reference material. Annex A contains the ISIM lexicon with definitions of all major concepts. Annex B provides more in-depth discussion of Occurrence Events and Underlying Factors Diagrams, which serve as a tool to integrate all aspects of ISIM. Annex C contains a more detailed description of the Integrated Process for the Investigation of Human Factors, including the steps for classifying types of human error and identifying unsafe acts and conditions and underlying factors to safety-significant events. Annex D describes the SHEL (Software, Hardware, Environment, and Liveware) and Reason models of accident causation. These models provide a framework for ISIM and the rationale for examining all aspects of a transportation system when there has been an occurrence.

Annex E contains a set of reference sheets at the back of the manual. These reference sheets provide summaries of the major ISIM stages and procedures as well as diagrams and charts that can be helpful in applying ISIM during an investigation. Annex F contains a description of the case study discussed in this manual.

Figure 1-1: ISIM Major Components and Sub-Processes

1.6 Learning Objectives

Upon completion of the manual, readers should have a good understanding of:

- What deliverables should be produced at each stage of ISIM and thus as the investigation progresses.
- How to identify significant data (in relation to ISIM analysis) from a mass of data.
- The fact that ISIM incorporates an on-going data collection (i.e., view data collection as a continuous process that overlaps with other analyses).
- How to identify safety-significant events (i.e. how to think of the analysis in terms of sets of events that combine to produce an occurrence).
- How to identify multiple safety-significant events.
- How to create an occurrence events and underlying factors diagram in a standard format.
- How to distinguish unsafe acts/decisions, unsafe conditions, and underlying factors.
- How to estimate risk – consequences and probabilities.
- How to identify and evaluate defences– use of the defences checklist.
- How to perform risk control option analysis.
- How to incorporate ISIM in safety communications and report writing.
- How to assess the performance of the ISIM process (i.e., that performance of ISIM should be measured in terms of the positive change in transportation safety and risk mitigation).

2. The Occurrence[2]

Air Canada Flight 646, C-FSKI, departed Toronto Lester B Pearson Airport, Ontario, at 21:24 eastern standard time (EST) on a scheduled flight to Fredericton, New Brunswick. On arrival, the reported ceiling was 100 feet obscured, the visibility one-eighth of a mile in fog, and the runway visual range 1,200 feet. The crew conducted a Category I instrument landing system approach to runway 15 and elected to land. On reaching about 35 feet, the captain assessed that the aircraft was not in a position to land safely and ordered the first officer, who was flying the aircraft, to go around. As the aircraft reached its go-around pitch attitude of about 10 degrees, the aircraft stalled aerodynamically, struck the runway, veered to the right and then travelled – at full power and uncontrolled – about 2100 feet from the first impact point, struck a large tree and came to rest. An evacuation was conducted; however, seven passengers were trapped in the aircraft until rescued. Of the 39 passengers and 3 crew members, 9 were seriously injured and the rest received minor or no injuries. The accident occurred at 23:48 Atlantic standard time.

[2] A comprehensive description of the occurrence is located at Annex F. Investigators are advised to read the description to gain an understanding of the occurrence prior to following the case study in ISIM. Please note that, for the sake of illustration, there may be minor discrepancies between the occurrence case description used in the Manual and the actual Board report.

3. Occurrence Assessment Process

Many accidents and incidents occur each year. Some cases will clearly proceed to an investigation due to the severity of the accident or the number of people affected. Many cases, however, will require an initial assessment to determine whether TSB should conduct an investigation and, if so, how extensive that investigation should be.

Purpose:

· To evaluate occurrences to determine which ones will be investigated.

The occurrence assessment process begins with receipt by the TSB of notification of an occurrence. The major steps of occurrence assessment are:

- TSB receipt of notification of an occurrence.
- An initial response to identify whether further fact-finding is required to facilitate TSB assessment of potential for safety pay-off of an investigation into the occurrence.
- An assessment to determine whether a field deployment is required to acquire those facts.
- An assessment of the circumstances of the occurrence to determine whether an investigation into the occurrence would likely result in an advancement to safety in the transportation system.
- An assessment of TSB resources and other obligations and commitments.

Deliverables:

· A decision to investigate or to not investigate.
· A record of essential occurrence data.

3.1 TSB Receipt of Occurrence Notification

When and how investigators respond to an incident, of course, depends on when and how TSB is notified. TSB procedures will guide your response. In particular, the following pertain to the reporting and receiving of occurrence notifications:

- TSB Regulations detail the requirements for reporting transportation occurrences to TSB. These requirements include the criteria for reporting, as well as the details that must be reported.
- The methods for reporting occurrences are also contained in other Government and organization publications (e.g., Shipping Casualties Reporting Regulations, Canada Labour Code [HRDC]).
- TSB Manual of Investigations, Volume 1, Operations General, Subsection 4.1, details the readiness state for each TSB mode.

3.2 Initial Response

The TSB Manual of Investigations, Volume 1, Operations General, Section 4.1, describes the normal alerting procedure for each TSB mode.

The TSB Manual of Investigations, Volume 2, describes in detail the initial response procedures, including the following:

- Ensuring the completeness and accuracy of all information required for the TSIS preliminary report.
- Soliciting additional information required for the decision to investigate.
- Notifying stakeholders, including appropriate agencies, companies, and governments.
- Forwarding the required information to TSB decision makers, including advice on potential safety deficiencies and risks, and on the potential for an investigation into the occurrence to advance transportation safety.

3.3 Field Deployment Decision

The TSB Manual of Investigations, Volume 2, describes in detail the criteria for deciding to deploy, including the following:

- Complete/accurate information is required and can be effectively acquired by deploying to the field.
- To avoid the loss of perishable information.
- To fulfil commitments to other organizations as contained in memoranda of understanding and letters of agreement.
- Commercial occurrences involving fatalities would normally warrant a deployment.
- Occurrences involving fatalities may warrant a field deployment to assist a coroner.
- Field deployments would require approval of the responsible manager.

Normally, a decision to deploy would be associated with occurrences for which there is the potential to advance safety. There are, however, occurrences where investigators are deployed even though an investigation is not conducted. Similarly, there are those occurrences where there is no deployment due to, for instance, an inaccessible site, yet an investigation is conducted.

3.4 Assessment of Safety Potential

The prime responsibility of the investigator is to provide the manager with information necessary to make an informed decision about whether to launch a full investigation or not. The manager will set the specific criteria for this decision but, in general, the decision will hinge on the potential for the investigation to advance safety.

The assessment as to whether an investigation would result in a safety pay-off would be based on the following factors:

- TSB professional knowledge of the transportation industry in the following areas:
  - Operations.
  - Operational standards, procedures, and practices.
  - Regulations.
  - Safety standards.
- TSB investigation knowledge in the following areas:
  - Provisions of the CTAISB Act, TSB Regulations, and TSB Occurrence Classification Policy.
  - Accident/Incident history.
  - Significant Safety Issues.
  - National and international investigation standards.
- Occurrence factors in the following areas:
  - Identified safety issues.
  - Potential safety issues.
  - Potential for advancing transportation safety.
  - Injuries, deaths, and damage to equipment and the environment.
  - Risk exposure to persons, equipment, and the environment based on a) the existence and adequacy of defences, b) probability of adverse consequences, and c) the severity of adverse consequences.

3.5 TSB Resources, Obligations, and Commitments

A decision to investigate would also include an assessment of the following:

- National and international obligations and commitments.
- Public interest and expectations.

3.6 Investigation Decision

The decision to investigate depends on whether the potential to advance transportation safety is great enough to warrant an investigation. A decision to investigate would result in the following:

- Appointment of the team leader.
- Determination of the initial scope of the investigation and composition of the investigation team.
- Estimation of resource implications, including time/work estimates.
- Communication of the decision to investigate to stakeholders.
- Deployment of the investigation team.
- Public communication of the decision to investigate, if required.
- Completion of the appropriate database entries.

A decision to not investigate would result in the following:

- Communication of the decision to not investigate to stakeholders.
- Communication of the decision to not investigate to the public, if appropriate.
- Completion of the appropriate database entries.
- Documentation and filing of pertinent data and the decision record.
- Collection of data to support the data requirements of the Board's Significant Safety Issues List.

3.7 Occurrence Assessment for the Air Canada 646 Occurrence

3.7.1 TSB Receipt of Occurrence Notification

TSB's notification of the Air Canada 646 occurrence was typical. TSB's regional office received a phone call from the Fredericton Airport Air Traffic Services alerting them to the accident. This initial call did not provide any information other than that a commercial aircraft had left the runway and was down.

3.7.2 Initial Response

Following initial response procedures, investigators at the regional office contacted head office to pass along the limited information they had received. Investigators contacted authorities at the Fredericton Airport and determined that the aircraft that crashed was Air Canada Flight 646. This information allowed investigators to determine some basic facts about the aircraft and flight:

- *Canadair CL600-2B19 Regional Jet.*
- *2 flight crew.*
- *1 flight attendant.*
- *37 passengers plus 2 infants.*

Investigators in the regional office drew up an initial list of stakeholders and alerted them to the accident. The stakeholders included:

- *Bombardier (the manufacturer).*
- *Air Canada (the operator).*
- *Transport Canada.*
- *National Transportation Safety Board (concerned foreign agency).*
- *Air Canada Pilots Association (representing the pilots).*
- *General Electric (engines).*
- *Airport Operator (ERS).*

3.7.3 Field Deployment Decision

Two investigators from the regional office deployed at 2:30 AM to the site to commence the investigation. The following were the major concerns:

- *Canada's major air carrier was involved.*
- *It was a Canadian manufactured aircraft.*
- *The number of passengers.*

3.7.4 Assessment of Safety Potential

The initial factors pointed to potential safety problems:

- *There are a large number of CL600-2B19 Regional Jet aircraft operating in Canadian and foreign carrier fleets or on order by Canadian and foreign carrier fleets; and*
- *There is potential for injury and/or death to passengers and crew.*

This assessment of safety potential was made on the basis of the investigators' professional knowledge of aircraft and the transportation system. They had no knowledge of safety issues surrounding this occurrence due to the lack of data. Instead, investigators had to rely on expectations of the kinds of problems that could have influenced the occurrence.

3.7.5 TSB Resources, Obligations, and Commitments

In the decision to investigate, consideration was given to the fact that:

- *The aircraft was operated by the largest Canadian carrier, who owned and operated many of this class of aircraft.*
- *Bombardier has sold many CL600-2B19 Regional Jets and had the expectation of selling many more.*
- *The public would be interested in an independent analysis following an occurrence involving Air Canada.*

3.7.6 Investigation Decision

After considering all the available information, it was decided that an investigation team would be deployed.

The investigation team was set up as follows:

Lead Investigator: *IIC (Team Leader)*

Team: *The team comprised the following groups:*

- *ATC, Airports, Emergency Response.*
- *Operations, Weather.*
- *Human Performance.*
- *Recorders.*
- *Passenger Safety.*
- *Structures.*
- *Systems.*
- *Site Survey Specialist.*
- *Photography Specialist.*

Initial Scope: *The investigation initially focused on three apparent issues:*

- *The reason for the failed landing attempt and subsequent crash*
- *The evacuation*
- *The emergency response and rescue*

This accident immediately attracted a great deal of public interest. Consequently, the investigation team quickly developed a communications plan to ensure the accurate and timely release of information to the media and public. A key concern was that the team release only factual information.

4. Data Collection Process

Purpose:

- To collect, collate, and evaluate the data associated with the occurrence in order to identify the events and underlying factors.

Data collection is not a *stage* or *phase* of the investigation but a part of all investigation activities. Data collection provides the information needed to analyse the occurrence but occurrence analysis will invariably raise questions and issues that require further data collection. Thus, the process is iterative and investigators must be prepared to seek data throughout the investigation and revisit potential safety issues.

Data collection is an on-going process that will continue throughout the investigation.

Data collection cannot be thought of apart from safety analysis, which will determine the questions you ask and the kinds of information you seek.

Data collection can be organized in terms of a few key steps:

1. Collect and evaluate the preliminary data to determine the initial scope and focus of the investigation.
2. Formulate a data collection plan based on the evaluation of the preliminary data.
3. Collect additional information and re-evaluate the scope and depth of the investigation.
4. Identify potential safety issues.
5. Develop communications plans to keep stakeholders, senior management, the Board, and the public informed.

Deliverables:

- Data Collection Plan
- Occurrence Data
- List of Potential Safety Issues
- Communications Plans

4.1 Evaluate Preliminary Data

Before beginning in earnest, the investigator should consider the goals of the investigation. How much effort should be devoted to the investigation and, in what areas, will depend on the nature of the occurrence under consideration.

The evaluation of preliminary data to determine the initial scope and focus of the investigation should include the following:

- Preliminary analysis of known events.
- Consideration of the significance of potential safety issues.

4.2 Formulation of the Data Collection Plan

Once investigators have assessed the preliminary data, a plan can be developed on how to obtain the information necessary to determine what happened and why. The data collection plan can be used to prioritize data collection and plan the order in which data will be collected. This will depend both on the perishability of the data and its perceived relevance to safety-significant events.

When developing the data collection plan, the following should be taken into consideration:

1. The occurrence events to be investigated.
2. Resources required for each area of investigation.
3. Responsibilities of investigation team members.
4. Deadlines.
5. Team's internal communications plan.

4.3 Collection of Additional Information

Data collection is an on-going process. Initially, most investigation activities will centre upon data collection but will shift over the course of the investigation to more analytical activities. Data collection is a critical set of activities that contributes to all aspects of analysis.

The collection of information to determine the events and associated unsafe acts and conditions of the occurrence would involve the following:

- Use of TSB and mode-specific methodologies.
- Use of various techniques and models (e.g., SHEL and Reason models) in the Integrated Investigation Process.
- Development of the Events and Underlying Factors diagram.
- Re-evaluation of the scope and focus of the investigation.
- Collection of data to support the TSB standard data requirements as well as those of the Board's Significant Safety Issues Lists.

4.4 Substantiation of Safety Issues

Given the assessment of the preliminary occurrence data and based on investigator experience and background, potential safety issues or "hunches" may begin to emerge. The collection of additional information aids in the validation of the safety issues.

Safety Issue:

· An issue encompassing one event or linked events that has/have the potential to lead to the identification of safety deficiencies.

The substantiation of safety issues is an iterative/repetitive process involving the following:

- Assessment of the operational factors of the occurrence.
- Assessment of the technical factors of the occurrence.
- Assessment of the human performance factors of the occurrence.
- Identification of the unsafe acts and conditions.
- Identification of the underlying factors.
- Assessment of the risks.
- Analysis of the defences.
- Analysis of the risk control options.

4.5 Communications Plans

Throughout the investigation, stakeholders, the Board, and the public will need to be informed about the investigation. It is essential that a plan is developed to ensure that these entities receive the appropriate information in a timely fashion, while safeguarding against the release of sensitive or speculative information.

4.5.1 Stakeholders Communications Plan

The following should be considered when formulating a plan for communications with stakeholders:

- Sharing safety-significant information:
  - ➢ Determining involved stakeholders.
  - ➢ Determining what types of information are required by each stakeholder.
  - ➢ Determining what mechanisms, both formal and informal, are to be used to release information.
  - ➢ Sharing information with stakeholders.
  - ➢ Maintaining an up-to-date list of releasable factual information.
- Validating factual information:
  - ➢ Verifying factual data with the stakeholders.
- Coordinating investigation efforts.
- Keeping stakeholders informed of news briefings and the information to be released to the public and the press.

4.5.2 TSB Internal Communications Plan

The following should be considered when formulating a plan for communications with TSB senior management and the Board:

- Timely updates on the status of the investigation:
  - Factual information and current analysis of the occurrence.
  - Resources (internal and external) being used for the investigation.
  - Anticipation of any external contracting requirements.
  - Official observers and stakeholders.
- Safety action being taken or contemplated by stakeholders.
- Advice on all evolving safety issues and the potential requirement for Board safety action.

4.5.3 Public Communications Plan

The following should be considered when formulating a plan for communications with the public:

- TSB Communications Policy.
- TSB Major Occurrence Communications Plan.
- IIC is the TSB focal point for all public communications for the technical aspects of the investigation.
- Anticipated involvement of Communications Division staff.
- Maintain an up-to-date list of releasable information:
  - The circumstances of the occurrence.
  - Areas of investigation interest.
  - Validated safety-significant events.
- Prepare a plan for the dissemination of factual information to the public:
  - News briefings as soon as practical after arriving at the occurrence site.
  - Media tour of the site, if possible or necessary.
  - Regular news briefings.
  - Information releases as the investigation progresses.

4.6 Data Collection and Communications Plans for the Air Canada 646 Occurrence

4.6.1 Preliminary Evaluation

The first step to the investigation was to set the scope and focus. Initially, investigators knew only a few things about the occurrence:

- *The aircraft had touched down on runway 15, veered to the right, then travelled 2100 feet from the first point of impact on the runway.*
- *Passengers and crew had been injured.*
- *Some passengers had been trapped in the aircraft.*
- *ERS personnel had difficulty locating the aircraft.*
- *The reported weather had been very low.*

Consequently, these events became the initial focus of the investigation.

The overriding question was why the landing had not been successful. As with all investigations, the operations and human performance investigators prepared to determine how the crew performed and whether their actions contributed to the occurrence. Given that crew performance would be under investigation, it also became important to determine whether the crew were provided with essential supervision, training, and information. The aircraft, including its systems, maintenance, and performance, needed to be investigated. Because passengers and crew had been injured, it was important to examine crew performance in light of the emergency evacuation, emergency training requirements, crew access to that training, and the provision of emergency equipment. Given the difficulties with respect to locating the aircraft and rescuing the passengers, it was necessary to examine the adequacy of the emergency response services. The suitability of the runway, the airport flight facilities, and the weather reporting system were also under examination.

4.6.2 Data Collection Plan for the Air Canada 646 Occurrence

Based on the initial evaluation, investigators developed a data collection plan to guide the investigation. The plan, shown below, lists the identified potential safety issues and the resources to be applied to investigating each. While these issues emerged early in the investigation, investigation into other areas, including powerplants, systems, structures, maintenance, CVR and FDR analysis, site survey, and wreckage pattern analysis continued. Recording all aspects of the wreckage on film is an important part of the data collection. To do so in an occurrence of this magnitude required that a photography specialist be a member of the team. In addition, investigators, with reference to the Manual of Investigation Operations, agreed upon the responsibilities of the team members.

As stakeholders, the Board, and the public needed to be informed about the investigation in a timely fashion, investigators drew up a communications plan, described on the next page.

CRJ Occurrence: Data Collection and Communications Plans

Potential Safety Issues and Resources

1. *Low Visibility Approaches*
   - *Operations specialist*
   - *HP specialist*
2. *Crew Performance/Crew Duty Times/Crew Experience/Training & Supervision*
   - *Operations specialist*
   - *HP specialist*
3. *ERS Requirements for Passenger Flights*
   - *ATC specialist*
4. *Early Autopilot Disconnect*
   - *Operations specialist*
   - *HP specialist*
5. *Passenger Safety and Evacuation*
   - *Passenger Safety specialist*
   - *Structures specialist*
6. *Flight Crew Knowledge and Use of Emergency Equipment*
   - *Operations specialist*
   - *Passenger safety specialist*
7. *Stick Pusher Altitude Floor*
   - *Operations specialist*
   - *Systems specialist*
8. *Command Bar Logic*
   - *Operations specialist*
   - *Systems specialist*
9. *Use of 6000-foot runways*
   - *Operations specialist*
10. *Tower Controller versus FSS Specialist*
    - *ATC specialist*
11. *No ELT in the CRJ*
    - *Operations specialist*
12. *CVR G-Shut-off Switch*
    - *Recorders specialist*
13. *Regulatory Overview*
    - *Operations specialist*
    - *HP specialist*

Responsibilities
As set by the Manual of Investigation Operations.

Deadlines
Set by team to facilitate timely investigation and in keeping with Board requirements.

Stakeholders Communications Plan
A plan for sharing information with stakeholders was developed. The stakeholders included Air Canada, Bombardier, Transport Canada, NavCanada, ACPA/pilots, and GE, the engine manufacturer.

Internal Communications Plan
Team members reported informally to one another and the Team Leader (IIC) reported to TSB management. In addition, a plan for briefing TSB senior management and the Board was formulated to include updates on the status of investigation with respect to the factual information and analysis to date; the observers and stakeholders; safety action taken or contemplated by stakeholders; and evolving safety issues.

Public Communications Plan
A plan to brief the public was formulated to include news briefings as soon as practical and then to carry out regular news briefings.

The data collection plan was developed as a guide only, so the investigation team was prepared from the outset to revise the plan as needed. When new potential safety issues were identified during the course of data collection, team members met to discuss the reallocation of resources and responsibilities and communicated these changes to TSB management.

4.6.3 Collection of Additional Data

NOTE:

Because the data collection process continues throughout an investigation, the data found during the Air Canada 646 occurrence investigation will be presented as we work through the methodology. The data presentation will be included in the identification of the sequence of events; the identification of potential safety issues; the substantiation of those issues through the identification of unsafe conditions/underlying factors and their validation as safety deficiencies.

A comprehensive description of the Air Canada 646 occurrence is provided in Annex F.

5. Occurrence Sequence of Events – Identification and Display

From the beginning of an occurrence investigation, investigators will collect data that will allow them to piece together the sequence of events that led to the occurrence. Essentially, this is the "what" of any occurrence and often represents the history of the voyage/trip/flight. In addition to identifying the sequence of events, investigators are required to display these events as part of an events and underlying factors diagram[3]. The diagram is a tool for summarizing, documenting, and communicating the results of an investigation.

Purpose:

- To construct a sequence of events that tracks an occurrence from the beginning to the end in logical progression; and
- To effectively display the sequence of events graphically.

The occurrence events and underlying factors diagram will bring together all elements of the investigation in a graphic form, indicating what happened and why it happened. More specifically, the diagram will show:

- The sequence of events.
- Unsafe acts/conditions.
- Underlying factors.
- The linkage of unsafe acts/conditions and underlying factors to safety-significant events.

There are four major steps in creating the events and underlying factors diagram:

1. Identify the occurrence events.
2. Illustrate the events in the diagram.
3. Identify the unsafe acts/conditions and underlying factors.
4. Illustrate the unsafe acts/conditions and underlying factors in the diagram.

This section discusses the first two steps in detail. Steps 3 and 4 will be covered in detail in the subsequent section.

Deliverable:

- A sequence of events that pertains to an occurrence under investigation displayed graphically.

[3] Adapted from Unger, L. and Paradies, M. (1996). *Events & causal factors charting guide*. Knoxville: System Improvements, Inc.

5.1 Identify the Occurrence Events

Determine each of the events of the occurrence from the data collected. An event is described in terms of the following :

- Each event describes a single, discrete happening or an action step in a sequence of happenings/actions that led to the occurrence.
- An event is not a condition, state, circumstance, issue, conclusion or result (i.e., pipe wall ruptured," not "pipe wall had a crack in it.").
- Events should be based on solid facts or be clearly indicated as being presumptive.
- Each event should be described by a short sentence with one subject and one active verb (i.e. "Mechanic checked front end alignment," not "Mechanic checked front end alignment and adjusted camber on both front wheels.").
- Each event should be described precisely (i.e. "Operator pulled headlight switch to the on position," not "Operator turned on the lights.").
- Each event should be quantified when possible (i.e., "Plane descended 350 feet," not "plane lost altitude.").
- Additional events will be determined as information is gathered.

Portray events in a logical flow indicating 'what' happened:

- The sequence of events should track in logical progression from the beginning to the end of the occurrence (initiation, pre-accident, accident, amelioration) and should include all pertinent happenings
- Define clearly the beginning of the accident sequence.
- Analysts frequently use the accident as the key event and proceed from it in both directions to reconstruct pre-accident and post-accident sequences.
- Identify as primary events only those actions directly related to the accident.
- Identify secondary events if applicable and integrate them with the primary event sequence.

5.2 Illustrate the Events in the Events and Underlying Factors Diagram

The events and underlying factors diagram is a working tool which allows investigators to clearly specify the events and their sequence. The diagram will be expanded and revised throughout an investigation. Thus, investigators should be prepared to be flexible in determining and portraying events. However, for diagrams to be effective, especially as a communication tool, they should be created using a consistent format. Illustrate events according to the following guidelines:

- Arrange the events chronologically left to right in rectangles.
- Each event block should contain the time and date of the event when available.
- Connect events with solid arrows.

- Depict presumptive events with dashed rectangles and arrows.
- Depict primary events in a continuous horizontal line.
- Depict secondary events in parallel, converging, or horizontal lines at different levels above or below the primary sequence.
- In reconstructing the activities of specific individuals, break out each specific individual on a separate horizontal line but re-integrate each appropriately on a summary chart.

5.3 Identification and Depiction of the Occurrence Events for the Air Canada 646 Occurrence

The occurrence events diagram for the Air Canada 646 occurrence is illustrated here in two stages of completeness. The diagram, like all other aspects of the investigation, is a living document that changes as more is learned.

5.3.1 Initial Diagram

The first diagram (Figure 5-1) summarizes the events that were identified. Only a few events are depicted because investigators initially knew little more than that Air Canada 646 went off the runway and crashed some distance from the runway. In fact, one event (Aircraft rolled right to about 55 degrees of bank) is shown in dashed boxes to indicate that, at this stage, it was a merely presumptive event that remained to be confirmed.

Although this initial diagram shows little about what happened, investigators began developing the diagram right away. In doing so, the framework was created for depicting the many other events that were to be uncovered during the investigation.

5.3.2 After Extensive Data Collection

The diagram for the Air Canada 646 occurrence was developed continuously throughout the investigation. All the changes made as the diagram was expanded are not illustrated. The second diagram (Figure 5-2) shows you what the diagram looked like after investigators had identified many more of the occurrence events through interviews with the survivors, authorities, and Air Canada.

This version of the diagram contains many events that depict what happened during the occurrence. This diagram concentrates on showing just the occurrence events but no unsafe conditions or underlying factors. In practice, investigators would almost never identify the occurrence events to this level of detail without also identifying one or more unsafe conditions. This diagram, however, is meant to illustrate how the occurrence diagram is created. The next section will discuss how to depict unsafe conditions and underlying factors.

6. Integrated Investigation Process

The Integrated Investigation Process (IIP) represents the integration of all investigation/analytical techniques used by investigators to uncover the unsafe conditions and underlying factors that explain an occurrence. These unsafe conditions may be indicative of systemic safety deficiencies that put the transportation system at risk. Thus, the purpose of the IIP is to uncover the unsafe conditions and underlying factors (potential safety deficiencies) associated with the safety-significant events of the occurrence.

Purpose:

· To uncover the underlying factors (potential safety deficiencies) associated with the safety-significant event under investigation.

The IIP depends on the identification of safety-significant events, which are those events that played a critical role in producing the occurrence. Analysis of the occurrence events should yield a number of safety-significant events, each of which needs to be analysed further to determine why it happened. The IIP must be applied to each safety- significant event identified for the occurrence.

Analysis: The process of organizing facts by using methods, tools, techniques to:

· Assist in deciding what additional facts are needed.
· Establish consistency, validity, and logic.
· Establish sufficient and necessary causal and contributory factors.
· Guide and support inference and judgments (conclusions).

The IIP is iterative in that it is repeated until the underlying factors have been identified. Not all the necessary data to do an analysis will be available from the start; it will take time to obtain information. Investigators should be prepared to develop an analysis of unsafe conditions over time, taking into account new data as they become available.

Key Feature:

· Analysis of unsafe conditions is an on-going process.

The IIP is conducted as follows:

- Determine whether the event is a potential safety-significant event worthy of further investigation/analysis.
- Identify whether the event is an unsafe act or has an unsafe condition associated with it.
- Analyse all unsafe acts and/or unsafe conditions using applicable analysis methods to uncover other underlying unsafe acts or conditions.
- Reapply the analysis process until the underlying factors have been identified.

- Display the unsafe acts/conditions and underlying factors graphically on the events and underlying factors diagram

Deliverable:
- The precise identification of the underlying factors and their validated linkage between the events and the factors.
- The unsafe acts/conditions and underlying factors displayed graphically on the events and underlying factors diagram.

6.1 Potential Safety Significant Events

Safety-Significant Event:
- An event that played a role or could have played a role in causing an occurrence, or a event that is deemed worthy of further analysis.

The first step is to determine which events in the occurrence sequence are potential safety-significant events worthy of further investigation/analysis. Identify safety-significant events by asking the following questions:

- Is the event undesirable (e.g., from a safety risk perspective)?
- Is the event potentially linked as an antecedent to an undesirable event?
- Is the event non-standard?
- Is the event one of alternative actions or options available?

These questions are depicted in a flowchart in Figure 6-1. A “Yes” answer to one or more of these questions indicates the need to examine the event further. Events that do not meet any of the above criteria need not be analysed further.

Antecedent event:
- An event that comes before and has a direct relationship with a subsequent event.

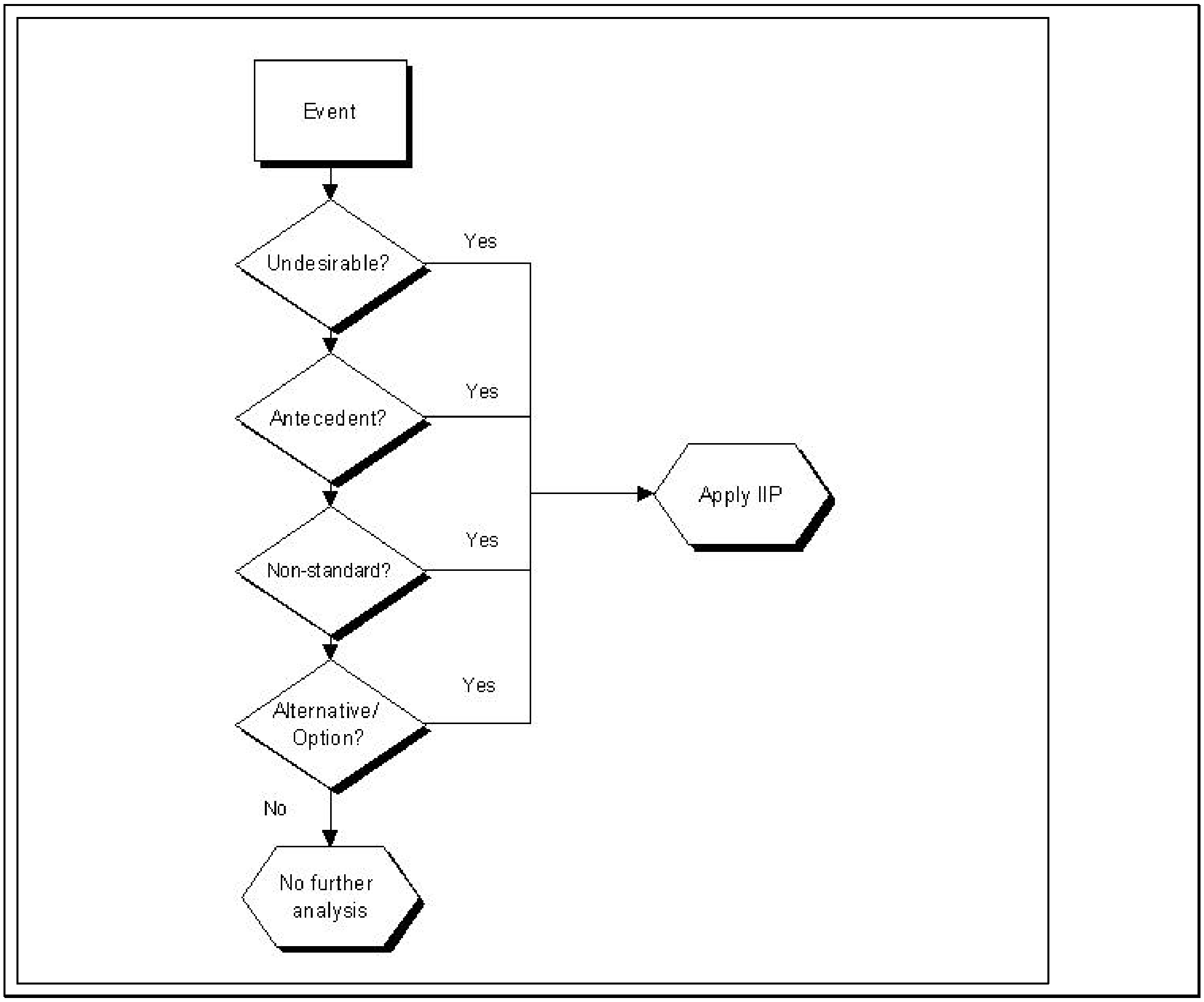


Figure 6-1: Procedure to Determine Safety-Significant Events

6.2 Identify Unsafe Acts/Conditions

Investigators begin by identifying *unsafe acts* and *unsafe conditions*. Almost always, some person or persons involved in an occurrence has engaged in some unsafe act(s) that can be linked to the outcome of the occurrence. Sometimes, persons involved in the occurrence have not committed an unsafe act but are recipients of an unsafe condition. Investigators should look beyond those persons directly involved in the occurrence and identify unsafe acts by people– management, regulators, and so on – who, although separated in time and space from the accident, nevertheless played a role in guiding how the transportation system performed. Often, these people establish the unsafe conditions that put a transportation system at risk.

Unsafe Condition:

· A situation or condition that has the potential to initiate, exacerbate, or otherwise facilitate an undesirable event, including an unsafe act.

Unsafe Act/Decision:

· An error (slip, lapse, or mistake) or deliberate deviation from prescribed operating procedures which, in the presence of a potential unsafe condition, leads to an occurrence or creates occurrence potential.

There is a straightforward process to determine whether an event is itself an unsafe act or has an unsafe condition associated with it. Simply follow these decision rules:

- If the event action is considered to be an error or a deliberate deviation from prescribed operating procedures that, in the presence of a potential unsafe condition, leads to an occurrence or creates the potential for an occurrence, then it is an unsafe act;
- If the event action has associated with it a situation or condition that has the potential to initiate, exacerbate, or otherwise facilitate an undesirable event, including an unsafe act, then the situation or condition is an unsafe condition.

Together, unsafe acts and conditions are the main links of the causal chain between the occurrence events and the underlying factors.

6.3 Uncover Other Underlying Unsafe Acts or Conditions

Analysis and further data collection will aid investigators in identifying the unsafe acts and unsafe conditions that contributed to safety-significant events. Analyse all unsafe acts and/or unsafe conditions using applicable analysis methods to uncover other underlying unsafe acts or conditions, as follows:

- Several unsafe acts or decisions may be identified when evaluating the occurrence events; however, the unsafe act (event) nearest the occurrence often provides a convenient starting point for the reconstruction of the relationship of events and their analysis.
- For unsafe acts, use the unsafe act analysis as identified in the Integrated Investigation Process illustrated in Figure 6-2.
- For unsafe conditions, use existing investigation methodologies, including unsafe act analysis.
- For each unsafe act and condition, there are likely to be several antecedent unsafe acts or conditions.
- Some unsafe conditions identified at this stage may have the potential in themselves to present an unacceptable level of risk and may be progressed immediately to a risk analysis.

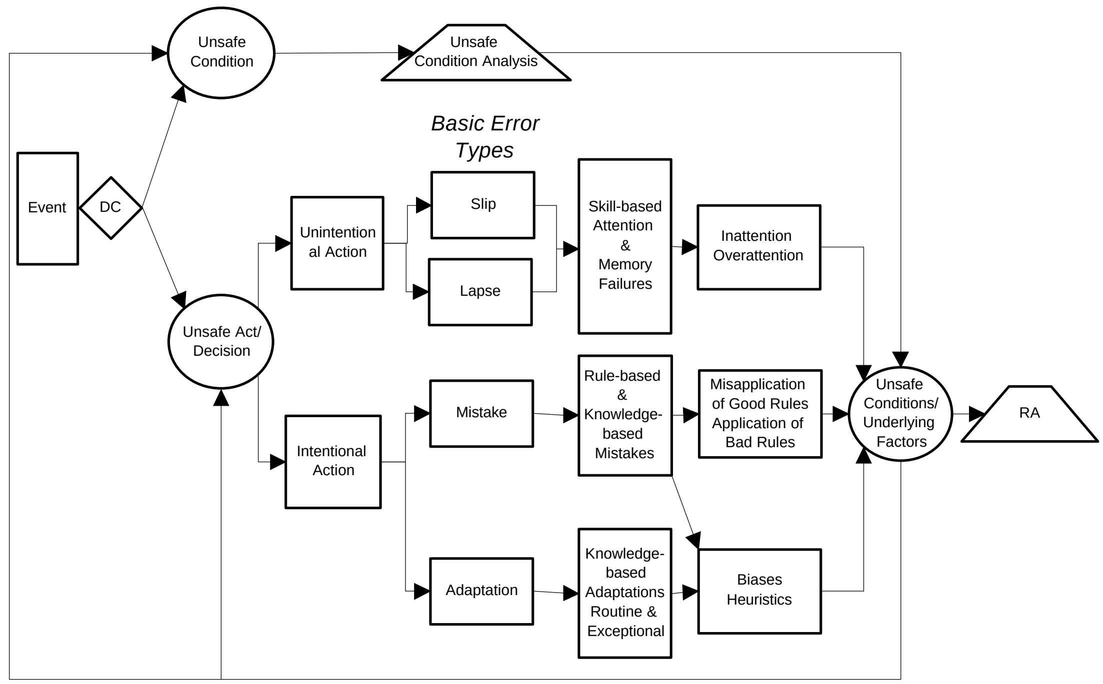


Figure 6-2: Integrated Investigation Process.

6.4 Reapply the Analysis Process

The goal of the IIP is to identify the underlying factors that caused or contributed to a safety-significant event.

Underlying Factor:

· An unsafe condition for which no further unsafe acts/conditions apply.

To identify underlying factors, investigators must reapply the analysis process several times until the point is reached where no further unsafe acts/conditions can be identified or any further conditions are beyond control within the transportation system.

Reapply the analysis process until the underlying factors suitable for progression to a risk analysis have been identified, as follows:

- The products of the previous step will be other unsafe acts and conditions. For each of these, repeat the previous step until the point has been reached where the identified unsafe conditions are worthy of progression to risk analysis or the unsafe act or condition is deemed not suitable for further investigation/analysis.
- An underlying factor represents the final level of identification of an unsafe condition, and no further unsafe acts/conditions apply.
- Normally, only underlying factors are progressed to risk analysis. However, occasionally, a stand-alone unsafe condition could be progressed to risk analysis.

(Unsafe acts analysis facilitates the determination of unsafe conditions/underlying factors. Unsafe acts themselves are not progressed through a risk analysis because, in the context if the occurrence investigation, they are viewed as individualistic behaviour. Instituting safety action on an individual's behaviour would only serve to correct or mitigate that behaviour.)

6.5 Display Unsafe Acts/Conditions and Underlying Factors in the Occurrence Events and Underlying Factors Diagram

The occurrence events and underlying factors diagram is used to indicate key events and underlying factors. Unsafe acts/conditions and underlying factors are added to the diagram to document the causal chain of conditions and acts that led to each safety-significant event,

As the analysis is developed, the unsafe acts/conditions and underlying factors are illustrated in the events diagram for the occurrence, as follows:

- Depict unsafe acts/conditions and underlying factors in solid-lined ovals and connect to events with solid arrows.
- Depict presumptive factors with dashed ovals and arrows.
- Describe factors precisely with date and time, if possible.
- Unsafe acts/conditions and underlying factors should derive directly from the events and unsafe acts/conditions immediately preceding them.
- The events diagram graphically indicates which items should be progressed to risk analysis. The documented chain of unsafe acts/conditions and underlying factors assists investigators in identifying safety deficiencies, determining if further investigation is necessary, assessing the need for immediate or ultimate safety action and preparing for justification in the final report.

6.6 IIP for the Air Canada 646 Occurrence

6.6.1 Safety Issues List

Having collected considerably more data, investigators were able to discard, combine or reaffirm potential safety issues identified early in the investigation of the Air Canada 646 occurrence. As well, other potential safety issues emerged. By organizing their investigation around safety issues and the occurrence events associated with them, investigators were able to structure their work program and ultimately the occurrence report.

There were a number of safety issues identified for the Air Canada 646 occurrence:

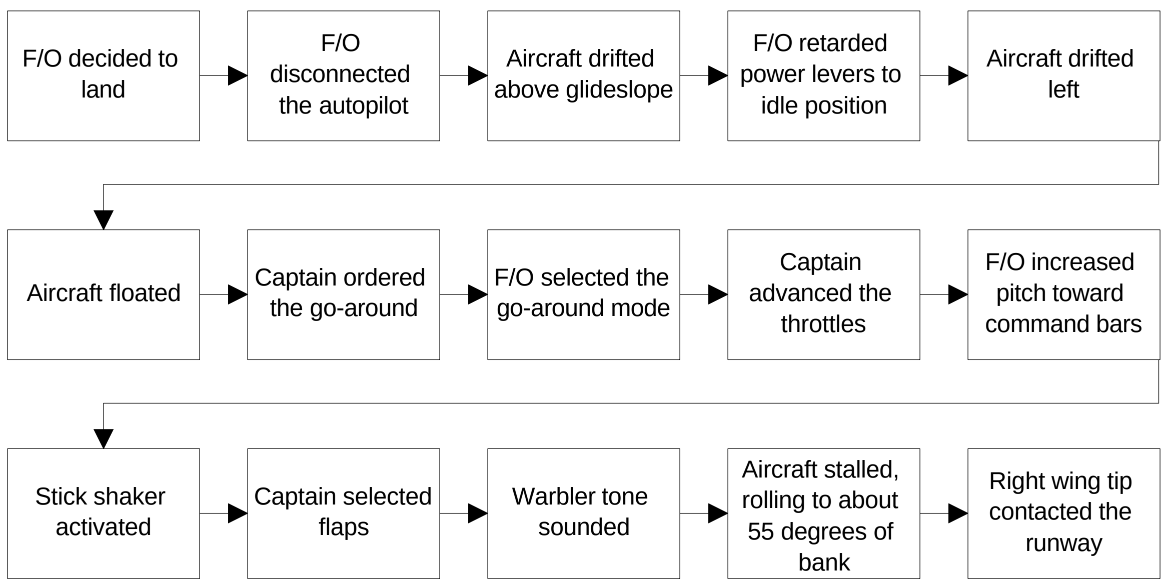
- *ERS requirements for passenger flights.*
- *Crew experience.*
- *Go-around commands by PNF.*
- *Low-energy go-arounds and aircraft performance.*
- *Aircraft icing.*
- *Low-visibility approaches.*
- *CRJ stall characteristics.*
- *CRJ stall protection system.*

- *ELT.*
- *Passenger safety and evacuation.*
- *Wing surface condition.*
- *CVR shut-off switch.*
- *Baseline for performance measurements.*

For the sake of brevity, we will limit the discussion of the ISIM to three of these:

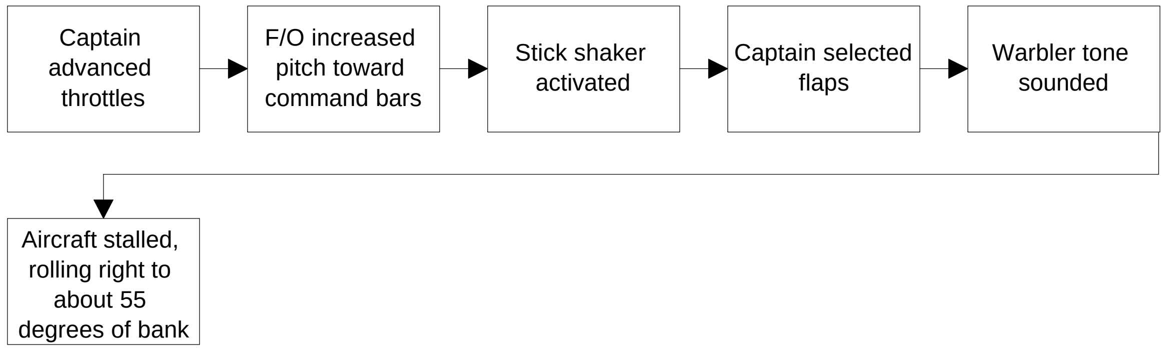
- *Low-energy go-arounds.*
- *Aircraft Icing.*
- *Passenger safety and evacuation.*

Low-energy Go-arounds



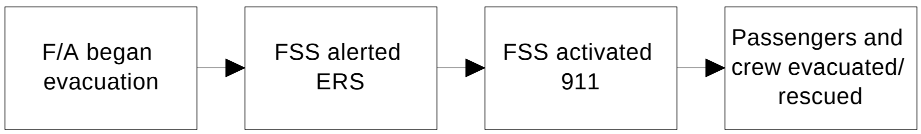
- *The go-around was attempted after the thrust levers were retarded to idle for the landing.*
- *Expectations of TC and Bombardier were that a go-around in the CL-65 would be initiated from within the demonstrated flight envelope for a go-around.*
- *It was anticipated that, once the thrust levers were reduced for landing, ground contact was likely, and any attempt to commence a climb before the engines had achieved go-around thrust could result in a stall.*
- *After the thrust levers are reduced for landing, the engines require eight seconds to spool up to go-around thrust.*
- *According to information provided by TC after the accident, a go-around or balked landing outside the demonstrated flight envelope is a high-risk manoeuvre.*
- *During certification of an aircraft, manufacturers are required to demonstrate go-arounds; however, the conditions under which the go-arounds are demonstrated do not form part of the documentation that leads to aircraft limitations or boundaries for the go-around.*
- *The only published restriction to conducting a go-around in a CL-65 is contained in a CAUTION in the AFM, which states that a go-around manoeuvre should not be attempted after the thrust reversers have been deployed.*

Aircraft Icing



- *Current procedures do not require CRJ crews to turn on the wing anti-ice in known icing conditions prior to the ice-detection system alert.*
- *Up to 0.020 inches of ice could accrete to the wings before the crew is alerted to the presence of icing by the ice detection system.*
- *The Display Control Unit inhibits the ice detection system caution ICE message below 400 feet radar-altimeter height, which could allow additional ice to build up without the pilots' being alerted.*
- *Even after the anti-ice systems are turned ON, additional ice build-up could occur prior to the wings reaching the temperature that would melt ice.*
- *The normal buffer of 4 to 5 degrees AOA between the stick pusher and the natural stall would be reduced by the presence of ice.*
- *Because the go-around procedure could result in relatively high AOAs, probably approaching the stall warning trip point, it would be prudent to take measures to ensure that ice is not adhering to the wing.*

Passenger Safety and Evacuation



- *Due to a power failure, the PA system could not be used to order the evacuation.*
- *The front galley door was inoperative.*
- *The crash axe used was unsuitable for freeing trapped passenger.*
- *All flashlights were stored in the same general forward area.*
- *No effective on-board signalling device was available to signal rescuers.*
- *The aircraft was difficult to find.*
- *The aircraft was not equipped with an ELT.*
- *The flight crew had not received hands-on training on the operation and use of emergency exits.*
- *Had an ELT been installed on-board the aircraft and had it activated, the ELT signal would have been heard by the FSS specialist; the fact that the accident had happened would have been immediately known.*
- *The FSS may have been able to use the portable ELT locating device to help locate the aircraft more quickly.*
- *Under certain specified conditions, Canadian Air Regulation (CAR) 605.38(3) exempts multi-engined turbo-jet aeroplanes, such as the Canadair CL-600, from requiring an ELT.*

To advance these issues further, it is necessary to focus on the unsafe acts/conditions and underlying factors associated with them. To do so, investigators first identified the safety-significant events worthy of further investigation and analysis.

6.6.2 Potential Safety-Significant Events

The first step in identifying the underlying factors is to determine the safety-significant events associated with each of the potential safety issues. Table 6-1 below shows the application of decision criteria to some of the occurrence events (Note: each occurrence event was subjected to the decision criteria; however, for the sake of brevity, only the events associated with the safety issues: low-energy go-arounds; aircraft icing; and passenger safety and evacuation are shown). The decision criteria used to determine whether events are safety significant (see Table 6-1) are listed across the top row. An assessment of whether further analysis is required is also included.

Potential Safety Issue	Event	Undesirable	Antecedent	Non-Standard	Options Available	Further Analysis
Low-energy go-arounds	*Captain ordered go-around*		*Yes*			*Yes*
Low-energy go-arounds	*F/O increased pitch to the command bars*	*Yes*	*Yes*			*Yes*
Aircraft Icing	*The aircraft stalled*	*Yes*	*Yes*	*Yes*		*Yes*
Passenger Safety and Evacuation	*Passengers and crew were evacuated/rescued*	*Yes*		*Yes*		*Yes*

Table 6-1: Identification of Safety-Significant Events

All of the events listed in Table 6-1 are safety-significant events.

The event, Captain ordered go-around, was antecedent to a subsequent event: F/O increased pitch to the command bars. Discussion of this event will be included in the discussion of the subsequent event as the two are linked under the safety issue low-energy go-arounds.

The event, F/O increased pitch to the command bars, was significant because the aircraft was in a low-energy state when the go-around was initiated.

The event, the aircraft stalled, met all the criteria of a safety-significant event.

The event, passengers and crew were evacuated/rescued, is safety significant because rescue personnel had difficulty finding the aircraft and several passengers were injured.

The third version of the diagram (Figure 6-3) shows the occurrence events already found, but the safety-significant events have been highlighted to make them more apparent.

6.6.3 Identifying unsafe acts/conditions and underlying factors

The goal of the IIP is to develop a complete chain of unsafe acts and unsafe conditions until the underlying factors for each event have been determined. To attain this goal it may be necessary to reapply the IIP several times. The following descriptions illustrate the use of the IIP in determining the unsafe acts/conditions and underlying factors antecedent to each identified safety-significant event and its associated safety issue. Note: the flowchart shown in Figure 6-2 is a tool used to assist in the systematic investigation of the underlying factors.

For discussion here, we will focus on three safety-significant events associated with the safety issues:

Safety Issue	*Safety-Significant Event*
Low-energy Go-arounds	*F/O increased pitch to the command bars*
Aircraft Icing	*The aircraft stalled*
Passenger Safety and Evacuation	*Passengers and crew were recovered*

*1)   **Safety Issue – Low-energy Go-arounds***

Safety-significant Event: F/O increased pitch to the command bars.

The second step in the IIP is to determine whether the safety-significant event is an unsafe act/decision or has an unsafe condition associated with it. The event was assessed to be an unsafe act because it was an intentional action carried out in the presence of an unsafe condition – the low-energy state of the aircraft. The action was analysed to determine more precisely the nature of the error and any other unsafe acts/conditions antecedent to it. The analysis is as follows:

Unsafe Act:** **The F/O increased the pitch to the command bars while the aircraft was in a low-energy state.

The fourth version of the occurrence events and underlying factors diagram (Figure 6-4) shows the unsafe acts and conditions (including those for aircraft icing and passenger safety and evacuation safety issues).

By following the human factors analysis of the IIP, investigators determined that the action was a rule-based mistake. The F/O had misapplied a good rule, that is, he did not perceive the aircraft state as being any different from an aircraft in a normal go-around situation and, as a result, applied normal procedure. It was determined that crews lacked awareness of the hazards associated with conducting a go-around in a low-energy state.

Reapply the IIP to uncover other unsafe acts/conditions or underlying factors

Underlying Factor:** **At the time of the occurrence, the information available to crews to assess whether a go-around could be carried out successfully from the existing state of the aircraft was inadequate.

Investigators found a number of inadequacies in the procedures and training with respect to go-arounds conducted in a low-energy state.

First, the published go-around procedure did not adequately reflect that once power is reduced to idle for landing, a go-around will probably not be completed without the aircraft contacting the runway. The only published restriction in the AFM regarding go-around procedures states that a go-around manoeuvre should not be attempted after thrust reversers have been deployed. Nowhere in the applicable manuals is it reflected that a safe go-around, without ground contact, will probably not be possible once power is reduced to idle for landing.

Second, the conditions under which go-arounds were performed during certification did not form a part of the go-around documentation provided to the airline operator. As these conditions were not part of the documentation, they were not taken into account when the go-around procedures were written into aircraft and training manuals, and when training was provided to flight crews. The go-around conditions for certification were not mentioned in the AFM, the FCOM, the AOM, or training manuals.

Third, the aircraft operating philosophy stressing that the flight director commands must be followed for proper flight control is valid for most anticipated flight conditions. Notwithstanding, not all commanded pitch attitudes are achievable or safe. In particular, following the command bars in go-around mode does not ensure that a safe flying speed will be maintained because, unlike in the windshear guidance mode, the positioning of the command bars does not take into consideration the airspeed, flap configuration, and the *rate of change of the AOA—all factors to consider in achieving an adequate stall margin. The high level of concentration required during a go-around and the limited time available may limit a pilot's ability to recognize and react to indications from other instruments. In this case, rotating the aircraft toward the command bars was a priority task for the first officer, and the level of concentration required to get the aircraft pitch to match the command bars probably affected his ability to adequately monitor the airspeed. The command bars, by directing the pilot to pitch the aircraft to 10 degrees nose-up without taking into account stall margin factors, probably contributed to the onset of the stall.*

Fourth, the sequential nature of steps within the go-around procedure placed some precedence and importance on achieving the pitch change over airspeed. The direction in the go-around procedure (as presented in the AFM, AOM, and training manuals) to rotate the pitch ***toward*** *rather than* ***to*** *the flight director command bars was intended to emphasize that the flight director guidance was an initial reference and to promote airspeed awareness during the go-around. However, the go-around procedure, in directing the pitch adjustment prior to noting the climb speed requirement of* V_2 *+ 10 knots, places some precedence and importance on achieving the pitch change. In addition, the sequential nature of steps within the procedure, and the high level of concentration required when initiating the go-around, can result in the passage of a critical amount of time before the airspeed is considered by the pilots. These factors would be more pronounced for pilots who have low flight-time on the aircraft and low experience with the procedure.*

Fifth, in training, go-arounds were normally initiated from a stabilized approach. Various conditions and configurations for go-around were demonstrated during training; however, practice go-arounds were normally initiated from a stabilized approach. In the stabilized approach, when go-around thrust is selected, aircraft speed increases almost immediately, and rotating the aircraft nose-up, toward the command bars, does not result in airspeed loss. In this case, immediate and frequent monitoring of the aircraft's speed is not required. When practising go-arounds from single-engine approaches, or in response to wind shear, pilots must closely monitor the airspeed. Based on their training, the occurrence pilots' interpretation of the procedure was that the aircraft was to be rotated to the command bars as the first step of the go-around procedure.

2) Safety Issue – Aircraft Icing

Safety-significant Event: The aircraft stalled.

In investigating the reasons for the stall, investigators found an unsafe condition "The aircraft was contaminated with ice." Delving further, they found an underlying factor concerning the aircraft's protection against icing:

Reapply the IIP to uncover other unsafe acts/conditions or underlying factors

Unsafe Condition: ***The aircraft was contaminated with ice.***

Underlying Factor: ***The aircraft may not be protected against ice build-up on wings and engines during critical phases of flight, despite the safeguards put in place to defend against icing.***

The aircraft is equipped with an ice detection system. However, the system is limited in that it requires an ice build-up of about 0.020 inches before it alerts the crew to the presence of ice. Further the 'amber ice caution' message which alerts the crew to icing is inhibited by the display control unit when the radio altitude is less than 400 feet with the *gear extended. Further, crew anti-ice procedures do not require that the anti-ice be selected ON in known icing conditions until the crew is alerted by the amber light.*

Post-accident analysis indicated that, even though as much as 0.020 inches of ice could have accumulated on the wings during the final stages of the approach, the presence of ice would not have been indicated due to the threshold level of ice required to trip the ice detection and the fact that ice indications would have been inhibited after the aircraft descended below 400 feet above ground level. Because even an average thickness of 0.020 inches on the leading edge of the aircraft's wing could lower the stalling angle-of-attack (AOA) by five degrees, the combination of the procedure to not select anti-ice ON until an indication of ice is annunciated and the inhibiting of indications below 400 feet could results in a detrimental amount of ice being on the wing during landing or go-around. In particular, under the circumstances that existed for the occurrence flight and the limitations of the ice-detection and annunciation systems, the procedures on the use of wing anti-ice did not ensure a clean wing during the go-around and may have negated the safety margins of the stall warning and prevention system.

Further, the 1996 certification of the ice detection system as the primary ice indicator and associated aircrew procedures did not adequately consider the implications of ice build-up below the threshold and the inhibiting of the ice advisory below 400 feet on the reduction of the available angle of attack before the stall.

3) Safety Issue – Passenger Safety and Evacuation

Safety-significant Event: Passengers and crew were evacuated/rescued.

Analysis of this event determined that there was an unsafe condition associated with it concerning the location of the down aircraft:

Reapply the IIP to uncover other unsafe acts/conditions or underlying factors

Unsafe Condition: ***The aircraft was difficult to find.***

The Fredericton FSS specialist heard the aircraft go by but did not see it due to poor visibility. It was approximately 15 minutes after the accident had occurred when, after a passenger was encountered wandering near the runway, it was ascertained that the aircraft had crashed on the airfield. Further application of the IIP revealed two underlying factors:

Reapply the IIP to uncover other unsafe acts/conditions or underlying factors

Underlying Factors: ***There was no effective signalling device on-board the aircraft.***

The aircraft was allowed to operate without an ELT.

Without an effective signalling device, the crew and passengers had no means to alert ERS to the accident and direct emergency personnel to the crash site. This caused a long delay before ERS could respond. The carriage of survival equipment that would provide the means for signalling distress is not required by the Canadian Aviation Regulations (CARs). The only equipment available to signal were the emergency flashlights. Although the flight attendant and subsequently a passenger repeatedly signalled using a flashlight, given the reduced visibility in dense fog it was not an effective signalling tool, and they were unsuccessful in attracting attention. This occurrence has shown that effective signalling equipment is required, even when an accident occurs at an airport. Any circumstance that impedes, or does not facilitate, a timely response by emergency personnel can be hazardous to the survival of passengers and crew.

The aircraft was not equipped with an ELT. The Fredericton FSS routinely monitors the ELT frequency and has access to a portable ELT locating device. Consequently, the activation of an ELT in the crash sequence would have immediately alerted the FSS that the accident had occurred and the portable ELT locating device would have assisted in more quickly locating the downed aircraft. Under certain conditions, CAR 605.38 exempts multi-engine turbo-jet aeroplanes, such as the CL-65, from requiring an ELT. Non-turbo-jet aeroplanes, like the Dash-8 and ATR-42, similar to the CL-65 in terms of passenger capacity and operational environment, are required by regulations to be equipped with an ELT. TSB information indicates that there is no significant difference in accident rates between turbo-jet and non-turbo-jet aeroplanes strictly as a function of propulsion system factors.

Analysis of the event also determined that there were a number of unsafe conditions concerning the evacuation of the passengers. They were as follows:

Unsafe Conditions: ***The flight crew had not been given hands-on training on the operation and use of emergency exits.***

The flight crew were unaware that a pry bar was available and carried as standard emergency equipment on the aircraft.

All flashlights were stored in the same general area.

In the aftermath of an aircraft accident, especially where there is only one flight attendant, flight crew may be the only crew members available to conduct an evacuation and direct passengers after the evacuation; therefore, it is imperative that they have the knowledge and skills to conduct the evacuation. Although CARs state that, during training, practical training must be completed on emergency exits, Air Canada provides practical training on doors only, and the occurrence pilots did not receive practical training on doors or any other exits.

The flight crew were unaware that there was a pry bar on the aircraft, and that it was standard emergency equipment. Although "location and use of emergency equipment" is a line indoctrination training objective, it is not included as a check item on the Pilot Line Indoctrination Checklist. Given that the pry bar was stronger than the crash axe used by the flight crew to free the trapped hand of one of the passengers, the pry bar may have been a more effective tool to use.

Although emergency flashlights were not effective in signalling the rescuers, they were useful in other ways during the evacuation. It was noted that the emergency flashlights were all stored in the same general forward area, three in the flight deck and one just outside the flight deck, in the storage area under the flight attendant's seat. Placement of the flashlights in this manner facilitates ready access by the crew, which is essential in an emergency. However, locating all units of one type of emergency equipment in the same area may be inappropriate; during an accident, damage to that one area of the aircraft could render all units inaccessible or unserviceable.

Figure 6-5 shows the final version of the occurrence events and underlying factors diagram with all underlying factors indicated. Underlying factors are indicated by ovals just as unsafe conditions because they are basically the same thing. Underlying factors are those conditions for which risk analysis will typically be conducted (although some unsafe conditions in this case were progressed to risk analysis).

Reference

Reason, J. (1990). *Human error.* New York: Cambridge University Press.

7. Risk Assessment Process

Once the analysis has revealed underlying factors related to the safety-significant events of the occurrence, it is important to know the level of risk associated with each identified factor. Risk indicates the need for some action to address a safety issue and helps investigators prioritize efforts to generate risk control options.

Purpose:

· To estimate and evaluate risk potential associated with the unsafe conditions and underlying factors identified in the IIP.

Risk:

· Assessed potential for adverse consequences resulting from an unsafe condition/underlying factor. It is the probability that, during a defined period of activity, the unsafe condition/underlying factor will result in an accident with definable consequences.

Risk can be defined in terms of two components: the probability that the unsafe condition/underlying factor will lead to an adverse consequence and the severity of that adverse consequence. Rare adverse consequences are less risky than frequent adverse consequences and consequences of negligible effect are less risky than catastrophic consequences. Therefore, risk assessment consists of two main sub-processes: analysis of the probability of adverse consequences and analysis of the severity of adverse consequences. An estimated level of risk can be assigned to an unsafe condition or underlying factor based on the results of these two analyses.

Risk is determined by:

- Identifying the adverse consequence(s) associated with the unsafe condition/underlying factor.
- Assessing the probability of the adverse consequence.
- Assessing the potential severity of the adverse consequence.
- Assigning the estimated risk level.

Deliverable:

· Estimated level of risk for each unsafe condition/underlying factor.

7.1 Identify the Adverse Consequence(s)

Identify the adverse consequence associated with the unsafe condition/underlying factor. This may be an unsafe condition consequent to the underlying factor or the sequence event itself. In identifying the adverse consequence, a rule of thumb is to select the most likely thing to happen as a result of the underlying factor.

7.2 Probability of Adverse Consequence

The purpose of the probability analysis is to determine the frequency of each undesired event and the probability of an adverse consequence pertaining to that event. Together, these components can be considered the risk exposure associated with the event.

Normally, investigators will need to rely on their expertise and experience in the transportation domain to estimate the probabilities of events and adverse consequences. As an aid, investigators can use the following kinds of questions to help refine their estimates of risk exposure:

- Is there a history of occurrences like this or is this an isolated occurrence?
- How many similar occurrences were there under similar circumstances in the past? (Take into account changes in the transportation system).
- What system defences need to fail for the adverse consequence to be realized?
- How many pieces of equipment are there that might have similar defects?
- Have deficiencies identified in past occurrences been adequately addressed?
- How many operating or maintenance personnel are following or are subject to the practices or procedures in question?
- To what extent are there organizational, management, or regulatory implications that might reflect larger systemic problems?
- What percentage of the time (hours, days, trips, etc.) is the suspect equipment or the questionable procedure or practice in use?
- How often or how long is the subject exposed to the risk?

7.3 Potential Severity of Consequences

The purpose of this analysis is to determine the severity of the adverse consequences associated with a risk. Consequence analysis involves estimating the potential impact of the accident on people (individuals, societal, etc.), property, environment, and often commercial operations.

Again, investigators will need to rely on their expertise and experience in the transportation domain to judge the potential severity of the adverse consequences. The following questions can serve as an aid to investigators to help refine their estimates of severity. The questions are divided into the major aspects of a transportation system that can be harmed by an accident:

- Life:
  - ➢ How many persons could be affected by the risk?
    - ◊ Fare-paying passengers?
    - ◊ Transportation employees?
    - ◊ Bystanders or general public?
- Property:
  - ➢ What could be the extent of property damage?
    - ◊ Direct property loss to the operator?
    - ◊ Damage to adjacent infrastructure?
    - ◊ Third-party collateral damage?

- Environmental:
  - ➢ What could be the environmental impact?
    - ◊ Dangerous commodity spill?
    - ◊ Physical disruption of natural habitat?
- Commercial:
  - ➢ What could be the impact on carriers?
    - ◊ On commercial operations?
    - ◊ Corporate viability?
    - ◊ Financial markets?
- Other:
  - ➢ What could be the public and media interpretation?
  - ➢ What might be the implications?
    - ◊ Internationally?
    - ◊ Nationally?
    - ◊ Locally?

7.4 Assign Estimated Risk Level

Once the probability and severity of an adverse consequence have been estimated, investigators can determine the estimated level of risk. Evaluation of risk is undertaken using available data, supported by judgments on the severity of potential adverse consequences and the probability of those consequences. The risk matrix below provides guidance in completing a qualitative assessment of risk.

		Probability of Adverse Consequences (Over Time)				
		Frequent	*Probable*	*Occasional*	*Unlikely*	*Most Improbable*
Severity of Consequence	*Catastrophic*	High	High	High	Medium	Medium-Low
	Major	High	High	High-Medium	Medium	Low
	Moderate	High	Medium	Medium	Medium-Low	Low
	Negligible	Low	Low	Low	Low	Low

Table 7-1: Risk Matrix

Definitions of Probabilities of Adverse Consequence:

Frequent: Likely to occur often during the life of an individual system, or occur very often in the operation of a large fleet of similar systems.

Probable: Likely to occur several times during the life of an individual system, or occur often in the operation of a large fleet of similar systems.

Occasional: Likely to occur sometime in the life of an individual item or system, or will occur several times in the life of a large fleet, similar items, components or system.

Unlikely: Unlikely but possible to occur sometime in the life of an individual item or system, or can reasonably be expected to occur in the life of a large fleet, similar items, components or system.

Most improbable: So unlikely to occur in the life of an item or system that it may be assumed not to recur, or it may be possible but extremely unlikely to occur in the life of a large fleet, similar items, components or system.

Definitions of Severity of Adverse Consequence:

Catastrophic: Death or loss of system or plant such that significant loss of production, significant public interest, or regulatory intervention occurs or reasonably could occur.

Major: Severe injury, major system damage or other event that causes some loss of production, that effects more than one department, or that could have resulted in catastrophic consequences under different circumstances.

Moderate: Minor injury, minor system damage, or other event generally confined to one department.

Negligible: Less than the above.

7.5 Risk Assessment for the Air Canada 646 Occurrence

Safety Issue	*Underlying Factors*
Low-energy Go-arounds	*1. At the time of the occurrence, the information available to crews to assess whether a go-around could be carried out successfully from the existing state of the aircraft was inadequate.*
Aircraft Icing	*1. The aircraft may not be protected against ice build-up on wings and engines during critical phases of flight, despite the safeguards put in place to defend against icing.*
Passenger Safety and Evacuation	*1. There was no effective signalling device on-board the aircraft.* *2. The aircraft was allowed to operate without an ELT.* *3. The flight crew had not been given hands-on training on the operation and use of emergency exits.* *4. The flight crew were unaware that a pry bar was available and carried as standard emergency equipment on the aircraft.* *5. All flashlights were stored in the same general area.*

All the stand-alone unsafe conditions and the underlying factors were subjected to the risk assessment process. However, for illustration purposes, a risk assessment of one stand-alone unsafe condition identified in the previous section will be discussed and an estimated level of risk assigned. The results of the risk assessment for the remaining stand-alone unsafe conditions and underlying factors are discussed at the end of this chapter.

7.5.1 Risk Assessment of an Underlying Factor

Safety Issue *– Aircraft Icing*

Underlying Factor *- The aircraft may not be protected against ice build-up on wings and engines during critical phases of flight, despite the safeguards put in place to defend against icing.*

A discussion of the risk assessment steps for the underlying factor stated above follows:

1) Identify the adverse consequence(s) of the unsafe condition/underlying factor

Icing on the wings during critical phases of flight (landing or go-around) can result in loss of control of the aircraft and a crash.

2) Assess the probability of the adverse consequence

To assess the probability of adverse consequence, the following questions were considered and the answers summarized as follows:

- *Is there a history of occurrences like this or is this an isolated occurrence?*

  This is the first known occurrence of this type.

- *How many similar occurrences were there under similar circumstances in the past?*

  None.

- *What system defences had to fail for the adverse consequence (loss of control/crash)to be realized?*

  Crew awareness of ice and aircraft speed.
  Ice detection system.
  Stall protection system.
  Company procedures.
  Certification.

- *How many operating personnel are following or are subject to the practices or procedures in question?*

  All CRJ go-arounds conducted in icing conditions without anti-icing selected ON are at risk, in particular those done from a low-energy state. More and more CRJ aircraft are being operated world-wide, although only a portion of these would be operating in icing conditions on approach.

- *How often or how long is the subject exposed to the risk?*

  Commercial aviation is an industry in which aircrews and passengers are often exposed to icing conditions during critical phases of flight such as landings and go-arounds.

*Given the nature of the risk, the exposure to the risk, the number of aircraft involved, and the past occurrence record (no previous occurrences), the probability of the adverse consequence, loss of control and crash, is considered **Occasional to Unlikely**.*

3) Assess the potential severity of the adverse consequence

- *Because recovery from an aerodynamic stall on the CRJ is not assured, a stall could result in loss of up to 50 lives.*
- *Because recovery from an aerodynamic stall on the CRJ is not assured, a stall could result in loss of the aircraft.*
- *Environmental impact would be limited to the accident site: fluid leaks, fire, impact damage.*
- *The manufacturer and its product would lose credibility, which would adversely affect industry sales of all its aircraft, nationally and internationally.*
- *Canada's reputation for quality aviation products would suffer, which would adversely affect sales, nationally and internationally.*
- *The reputation of the operators of the CRJ could be affected and result in lowering ticket sales, in particular on those routes served by CRJs.*
- *The public could lose confidence in the manufacturer's product and in the airlines that operate it.*

*As evidenced in this occurrence, injury to, and possible loss, of all or some passengers and crew members can be expected. In this occurrence, there was the potential for the loss of 39 passengers and 3 crew members. Given that the consequence is applicable to all CRJ aircraft operating in icing conditions, that death or injury can be expected, that an adverse economic impact for both manufacturer and operator could be expected, and that there would be public and media implications, the severity is considered to be **Catastrophic**.*

4) Assign the estimated level of risk

*The estimated level of risk given the subjective assessments of probability and severity of consequence is **High to Medium** as indicated in Table 7-2, Risk Matrix following:*

		Probability of Adverse Consequences (Over Time)				
		Frequent	Probable	Occasional	Unlikely	Most Improbable
Severity of Consequence	Catastrophic	High	High	High	Medium	Medium-Low
	Major	High	High	High-Medium	Medium	Low
	Moderate	High	Medium	Medium	Medium-Low	Low
	Negligible	Low	Low	Low	Low	Low

Table 7-2: Risk Matrix for the Air Canada 646 Occurrence: Aircraft Icing

The remainder of the unsafe conditions and underlying factors and their adverse consequence were estimated to have a level of risk as follows:

Low-energy Go-arounds
1. At the time of the occurrence, the information available to crews to assess whether a go-around could be carried out successfully from the existing state of the aircraft was inadequate. Consequently, a crew could attempt a go-around from an energy state where a go-around could not be successfully completed. **Estimated Level of Risk - High**
Passenger Safety and Evacuation
1. There was no effective signalling device on-board the aircraft, the adverse consequence of which is that survivors of a crash are not able to remotely signal emergency personnel for assistance. **Estimated Level of Risk - Medium**
2. The aircraft was allowed to operate without an ELT. Without an ELT, emergency personnel may be unable to locate a crashed aircraft or may not even know that a crash has occurred, thus delaying assistance. **Estimated Level of Risk - Medium**
3. The flight crew had not been given hands-on training on the operation and use of emergency exits. In the event that a flight crew would have to conduct the evacuation, without training on the operation and use of doors and emergency exits, flight crew may inadvertently delay the emergency evacuation. **Estimated Level of Risk - Medium-Low**
4. The flight crew were unaware that emergency equipment in the form of a pry bar was available and carried as standard emergency equipment on the aircraft; lack of knowledge with respect to the existence of emergency equipment could impede the success of the passenger evacuation. **Estimated Level of Risk - Medium-Low**
5. All flashlights were stored in the same general area. In the event of damage to that area during an accident, all flashlights would be rendered inaccessible. **Estimated Level of Risk - Medium-Low**

8. Defence Analysis

A major component of any transportation system is the set of defences put in place to protect people, property, and/or the environment. These defences can be used to:

- Reduce the probability of unwanted events.
- Reduce the negative consequence associated with unwanted events.

Defence:

- A physical or administrative measure to limit, reduce, or prevent an unwanted event from harming persons or objects.

Defences can, through their absence, misuse, poor design, or insufficiency contribute to an occurrence. Thus, it is crucial to analyse the defences of the transportation system involved in an occurrence to determine what role they played in causing the occurrence.

Analysis of defences leads to a better understanding of the safety issues and safety problems associated with an occurrence. In particular, this analysis is used, in conjunction with the risk assessment process, to validate safety deficiencies identified through the IIP.

Purpose:

- To examine the situation to determine the absence or status of defences and to identify those that are missing or less-than-adequate.

In this process, investigators will:

- Analyse defences.
- Validate safety deficiencies.

Deliverables:

- A list of defences that are missing or less-than-adequate.
- A list of validated safety deficiencies.

8.1 Analyse Defences

Defences, in the context of ISIM, are barriers/guards that isolate and protect persons, property, and environment (targets) from unsafe conditions. Defences can be divided into two categories, physical and administrative, as illustrated in the table below.

Physical Defences	Administrative Defences
Guards	Safety regulations, standards, codes
Walls	Policies, procedures
Survival suits	Supervision, inspection, maintenance plans
Warning signals	Operational readiness
Alarms	Personal readiness, fitness for duty, training
	Management support and services

Table 8-1: Types of Defences

Thus, defences can be aimed at limiting the likelihood of an accident and the harm that will be inflicted should an accident occur. Defences can be placed:

- On sources (of risk).
- On humans or object (targets).
- Between the sources and targets.

Less-than-adequate defences are those that are:

- Provided for but not advertised or made known to users.
- Absent or not provided.
- In place but not practical.
- Not functioning as intended.

Analyse defences as follows:

- Determine if the defences (physical and administrative) were provided to prevent this occurrence or make its consequences less severe (if not, why not?).
- Determine if the defences were used (if not, why not?).
- Determine if the defences were practical for effective use.
- Determine if the defences functioned as intended.
- Determine if the defences failed (why did they fail and how?).
- Determine if the defences succeeded in preventing or reducing the severity of consequences as they were intended to.
- Determine if defences implemented following an occurrence were adequate.
- Determine the less-than-adequate defences that are associated with the risks.

8.2 Defence Worksheet

A worksheet has been developed to help investigators with the Defence Analysis. The worksheet, shown below, serves as a reminder of the kinds of defences likely to have been present in the transportation system and provides a checklist to record the status of each.

The worksheet is simply a tool to help record and organize the investigation of defences. The same investigative techniques are applied to uncover defences as to uncover any other aspect of the occurrence. The investigation, however, can proceed more effectively by listing defences and categorizing them by type, either physical or administrative. The worksheet will help keep track of defences and ensure that all the many different types of defences that can be present in a transportation system are considered.

The worksheet may be used as a job aid in conducting Defence Analysis to achieve the following objectives:

- Increase the depth and quality of investigation.
- Reduce oversights and omissions.
- Minimize uncertainties.
- Guard against arriving at premature findings.
- Prevent informal conclusions based on perceptions.
- Help determine the findings as to cause(s) and contributing factors.

Defence Analysis Worksheet						
(1) Physical Defences						
Types	**Not provided**	**Did not use**	**Failed**	**Did not fail/Not found inadequate**	**More defences needed**	**Providers/ Remarks**
On the source (of risk)						
On the human or object (target)						
Between unsafe condition and the target						
System design & manufacturing						
Repair & overhaul						

Figure 8-1: Defence Worksheet

(2) Administrative Defences						
Types	**Not provided**	**Did not use**	**Failed**	**Did not fail/Not found inadequate**	**More defences needed**	**Providers/ Remarks**
Operational readiness (Risk assessment, system support services, fitness of organization for mission)						
Personal readiness (Qualification, knowledge, experience, fitness for duty)						
Team readiness (Qualification, knowledge, experience, fitness for duty)						
Information system (Technical information for operation, information on safe operating procedures, and practices)						
Training and awareness						
Inspection and preventative maintenance						
Supervision, performance monitoring, and corrective actions						
Company procedures						
Company manning policies						
Company management philosophy						
Regulatory policies						
Legislation						
Regulations						
Regulatory implementation						
Regulatory surveillance, inspection, and audit						
Regulatory enforcement						
Codes, standards, guidelines						
Incentives (positive incentives, negative incentives, etc.)						
Emergency preparedness						

Figure 8-1: Defence Worksheet (continued)

8.3 Safety Deficiencies

Each unsafe condition/underlying factor progressed through the risk assessment must undergo a defence analysis to determine if the unsafe condition/underlying factor is a safety deficiency. The combination of risk assessment and defence analysis validates the safety deficiency. Safety deficiencies are the unsafe conditions and underlying factors with risks for which the defences are less than adequate. They represent policies, equipment, training, practices etc. that fail to maintain adequate control of risks. Based on the depth of the investigation, those risks for which the defences are considered to be not inadequate would not be progressed further. (The underlying factors and adequacies of their defences should be documented).

Safety Deficiency:

- An unsafe condition or underlying factor with risks for which the defences are less-than-adequate.

8.4 Air Canada 646 Occurrence Defence Analysis

All the stand-alone unsafe conditions and underlying factors of the CRJ accident underwent a defence analysis. Defence worksheets, filled out for those unsafe conditions and underlying factors associated with the safety issues low-energy go-arounds, aircraft icing, and passenger safety and evacuation, follow. Note: only the defences applicable to the unsafe conditions and underlying factors are listed.

8.4.1 Low-energy Go-arounds

At the time of the occurrence, the information available to crews to assess whether a go-around could be carried out successfully from the existing state of the aircraft was inadequate. Consequently, a crew could a attempt a go-around from an energy state where a go-around could not be successfully completed.

(1) Physical Defences		
Types	***Status***	***Remarks***
On the source (of risk) *- Flight Director*	*Inadequate* *More defences needed*	*In the go-around mode, pitch guidance does not take into account aircraft configuration, airspeed, angle of attack, or other performance parameters.*
(2) Administrative Defences		
Types	***Status***	***Remarks***
Company procedures	*Inadequate* *More defences needed*	*The aircraft operating philosophy stressing that the flight director commands must be followed for proper flight control is not always valid.*
Personal readiness	*Inadequate* *More defences needed*	*Crews were unaware of the implications of conducting a go-around once the power had been reduced to idle for landing.*

Training and awareness	*Inadequate* *More defences needed*	*Practice go-arounds were normally initiated from a stabilized approach. In the stabilized approach, when go-around thrust is selected, aircraft speed increases almost immediately, and rotating the aircraft nose-up, toward the command bars, does not result in airspeed loss, and frequent monitoring of airspeed is not required.*
Information system	*Inadequate* *More defences needed*	*The conditions under which go-arounds were performed during certification did not form part of the go-around documentation provided to the airline operator*
Company procedures	*Inadequate* *More defences needed*	*The sequential nature of the go-around procedure places some precedence and importance on achieving the pitch change over airspeed.* *The published procedures do not adequately reflect that once power is reduced to idle for landing, a go-around will probably not be completed without the aircraft contacting the runway.*

8.4.2 Aircraft Icing

The aircraft may not be protected against ice build-up on wings and engines during critical phases of flight, despite the safeguards put in place to defend against icing. Icing on the wings during critical phases of flight can result in loss of control of the aircraft and a crash.

(1) Physical Defences		
Types	***Status***	***Remarks***
On the source (of risk) *- Ice detection system*	*Failed* *More defences needed*	*The ice detection system is limited in that it needs about 0.020 inches of ice accumulation on the probes before it alerts the crew. This amount of ice may be enough to lower the AOA by five degrees, bringing the aircraft closer to the stall AOA.* *The amber ice caution message which alerts cres to the presence of ice is inhibited below a radio altitude of 400 feet.*
- Stall Protection System	*Failed* *More defences needed*	*The SPS does not take into account the effect of ice accumulation on the stall AOA.*
(2) Administrative Defences		
Types	***Status***	***Remarks***
Company procedures – Wing anti-ice	*Failed* *More defences needed*	*Anti-ice procedures do not require that the anti-ice be selected ON in known icing conditions until the crew is alerted by the ice detection system.*
Regulatory surveillance, inspection and audit	*Failed* *More defences needed*	*The 1996 certification of the ice detection system as the primary ice indicator and associated aircrew procedures did not adequately consider the implications of ice build-up below the threshold and the inhibiting of the ice advisory below 400 feet on the reduction of the available angle of attack before the stall.*

8.4.3 Passenger Safety and Evacuation

1. *There was no effective signalling device on-board the aircraft, the adverse consequence of which is that survivors of a crash are not able to remotely signal emergency personnel for assistance.*

(1) Physical Defences		
Types	***Status***	***Remarks***
Between the unsafe condition and the target – On-board signalling device	*Not provided*	*Without an effective signalling device to alert rescue crews to the aircraft's location, the rescue of passengers was delayed.*
(2) Administrative Defences		
Types	***Status***	***Remarks***
Regulations	*Not provided*	*Signalling device not required by CARs.*

2. *The aircraft was allowed to operate without an ELT. Without an ELT, emergency personnel may be unable to locate a crashed aircraft or may not even know that a crash has occurred, thus delaying assistance.*

(1) Physical Defences		
Types	***Status***	***Remarks***
Between the unsafe condition and the target – ELT	*Not provided*	*The aircraft was not equipped with an ELT.*
(2) Administrative Defences		
Types	***Status***	***Remarks***
Regulations	*Not provided*	*Under certain conditions, CAR 605.38 exempts multi-engine turbo-jet aeroplanes, such as the CL-65, from requiring ELT. Non-turbo-jet aeroplanes, like the Dash-8 and ATR-42, similar to the CL-65 in terms of passenger capacity and operational environment, are required by regulations to be equipped with an ELT.*

3. *The flight crew had not been given hands-on training on the operation and use of emergency exits. In the event that a flight crew would have to conduct the evacuation, without training on the operation and use of doors and emergency exits, flight crew may inadvertently delay the emergency evacuation.*

(1) Physical Defences		
Types	***Status***	***Remarks***
None		
(2) Administrative Defences		
Types	***Status***	***Remarks***
Personal readiness	*Inadequate*	*The occurrence pilots had not received practical training on doors or any other exits despite regulations to the contrary.*
Training and awareness	*Not Provided*	*Although CARs state that, during training, practical training must be completed on emergency exits, Air Canada provides practical training on doors only.*

4. *The flight crew were unaware that a pry bar was available and carried as standard emergency equipment on the aircraft. Lack of knowledge with respect to the existence of emergency could impede the success of the passenger evacuation.*

(1) Physical Defences		
Types	***Status***	***Remarks***
None		
(2) Administrative Defences		
Types	***Status***	***Remarks***
Information system	*Inadequate*	*Although the location and use of emergency equipment is a line indoctrination training objective, it is not included as a specific check on the Pilot Line Indoctrination Checklist.*
Training and awareness	*Inadequate*	*The availability and location of the pry bar was covered during training. However, of the several CRJ pilots who were interviewed, none was aware its existence.*

8.4.4 Safety Deficiency

Those underlying factors for which an estimated level of risk was determined and for which the defences were found to be less than adequate are safety deficiencies. In other words, the combination of risk assessment and defence analysis validates the safety deficiency. The safety deficiencies for three of the safety issues low-energy go-arounds, aircraft icing, and passenger safety and evacuation are as follows:

Safety Issue	***Safety Deficiency***
Low-Energy Go-Arounds	***Because neither the training nor the procedures provided crews with information on conducting go-arounds once the power had been reduced to idle for the landing, crews may continue to attempt a go-around in a low-energy state, unaware that they may not be successful.***
Aircraft Icing	***Because of the limitations of the ice detection system and its associated aircrew procedures, icing can build-up on the wings during critical phases of flight which could result in loss of control of the aircraft and a crash.***
Passenger Safety and Evacuation	***Because the carriage of signalling device on-board the aircraft is not required, survivors of a crash may continue to be placed in situations where they cannot signal emergency personnel for assistance.***
	Because the aircraft is not required to operate with an ELT, emergency personnel may be unable to locate a crashed aircraft or may not even know that a crash has occurred, thus delaying assistance.
	Without appropriate hands-on training on the operation and use of emergency exits, flight crews may continue to inadvertently delay the emergency evacuation.
	Lack of knowledge by flight deck crew concerning the existence and location of emergency equipment, in this occurrence a pry bar, could impede the success of the passenger evacuation.
	Because the flashlights were stored in the same general area, all flashlights would be rendered inaccessible in the event of damage to that storage area during an accident.

9. Risk Control Option Analysis

Once the risks associated with underlying factors have been estimated, investigators can begin to devise safety actions to combat those problems. The culmination of the investigation is to generate means to reduce risk to the transportation system.

Purpose:

- To identify risk control options that will assist in developing convincing arguments for reducing and/or controlling safety deficiencies.

Risk control option analysis is completed by the following steps:

- Determine control strategies (reduce probability, reduce impact, segregate targets from risk, redundancy).
- Evaluate risk control options (feasibility, effectiveness, residual risks, test of reasonableness).
- Consider implementation approaches (regulatory, non-regulatory).
- Consider acceptability.

The results of this analysis can then be directly used in subsequent safety communications.

Deliverable:

- A list of risk control options defined in terms of how defences can reduce and control safety deficiencies.

9.1 Determine the Options for Controlling Risk

There are normally control options available for any risk control situation, although some will be more effective than others. One of the important aspects of risk management is to ensure that the full range of possible control measures is considered and that the optimal trade-off between measures is made. Taking a structured approach, in which a variety of risk control measures is generated, allows investigators to consider how defences can be most effectively used to control risk. A risk control option may be considered unacceptable by stakeholders if the cost of controlling the risk outweighs the benefits.

In determining the options for controlling risk, consider one or more of the following strategies:

- Reducing the probability of adverse consequences (e.g., defences, such as designing systems for minimum hazard, modifying human behavior, improving human performance, safety procedures).
- Reducing the consequence of similar occurrences (e.g., defences, such as emergency preparedness, guards, etc.).
- Segregating the risk exposures (e.g., defences, such as separation of hazards).

- Adding redundancy in safety system (e.g., defences, such as monitoring of operators' action, team work, etc.).

9.2 Evaluate Control Options

After generating a list of risk control options, they must be critically evaluated to facilitate the development of effective safety action. The options, be they regulatory or non-regulatory, are evaluated in terms of the following:

- Residual risk relative to the original condition.
- Benefits that would result from selecting a specific control option.
- Administrative feasibility (is it doable, durable, enforceable?).
- Financial feasibility.
- Treatment of residual risk after prevention and mitigation.

Although this process includes an analysis of financial feasibility, investigators are not required to conduct detailed cost/benefit analysis; this responsibility rests with action agencies, such as Transport Canada. Investigators, however, must test the reasonableness of any control option being promoted.

9.3 Consider the Feasibility of Risk Control Options

Acceptance of risk control options will depend on their feasibility. Impractical or unworkable options may affect how stakeholders perceive all other options generated by TSB. Thus, it is important to consider the feasibility of risk control options before making them part of any communication.

Take into account the following elements in considering the feasibility of the control measures:

- Acceptability to the public and stakeholders.
- Acceptability to the legal system (e.g., Human Rights, Privacy Act, etc.).
- Acceptability to the culture and values of the society.
- Impact on the market system and competitiveness.
- Impact on public perception when dealing with "perceived risks."

In addition to the estimated risk (i.e., probability and consequence), investigators must take into account the public's perception (perceived risk) in assessing the risk, developing risk control measures, and evaluating such control measures. Thus, investigators should try to assess not just the feasibility of control options but the acceptability of the risks associated with the unsafe conditions to those potentially affected by the risks. The stakeholders may find the risks preferable to the control measures. Similarly, it is equally important that investigators assess the public/stakeholders' acceptability for the action plan to address such risks. The acceptability of the risks, and therefore the reluctance to mitigate these risks, will generally be higher if the stakeholders have a voluntary association with the risks, the risks are known or no alternatives are available.

Control options must be documented. Because the Board considers responses to recommendations from action agencies and organizations, staff must have a comprehensive justification for the proposed control measures available for ready reference.

9.4 Risk Control Options for the Air Canada 646 Occurrence

This discussion will focus on the risks associated with three of the safety issues: low-energy go-arounds; aircraft icing; and passenger safety and evacuation. Safety deficiencies were identified for each of these issues. The following discussion describes risk control options for each safety deficiency and evaluates the feasibility of each one.

9.4.1 Low-energy Go-arounds

1) Safety deficiency: *Because neither the training nor the procedures provided crews with information on conducting go-arounds once the power had been reduced to idle for the landing, crews may continue to attempt a go-around in a low-energy state, unaware that they may not be successful.*

Option A: ***Replace the current flight director on the CRJ aircraft with one that uses dynamic inputs to calculate the pitch-up attitude.***

Discussion: *The current flight director does not use aircraft configuration, airspeed or AOA in calculating the pitch-up attitude. The arrangement of the current flight director is common and certification and equipment standards do not require that flight director guidance be linked to performance parameters. When Air Canada ordered the CRJ, the option for a more intelligent flight director was available; however, Air Canada opted not to buy it.*

There would be a cost to replacing the flight director, which may be prohibitive under a rigorous cost/benefit analysis.

Conclusion: *It was considered that this option was not feasible.*

Option B: ***Air Canada take whatever measures necessary to ensure that their pilots and training personnel are aware of the hazards associated with low-energy go-arounds or balked landings and verify that their training programs and procedures are appropriate for low-energy operations.***

Discussion: *Following the occurrence, Air Canada undertook a number of actions to address the safety deficiency. They are as follows:*

- *the go-around procedure in the CL-65 AOM has been amended to amplify the importance of airspeed during a go-around;*
- *a NOTE has been added to the CL-65 AOM stating that when a go-around is executed in close proximity to the ground, landing gear ground contact may occur;*

- *the CL-65 pilot training program has been amended to include information on low-energy go-arounds*

These actions are pertinent to the safety deficiency and should help to reduce the risk.

Conclusion: *Given the actions taken by Air Canada, this option will not be pursued through further safety action requirements. However, the safety action taken should be included in Section 4 of the Board's public report.*

Option C: ***Transport Canada ensure that pilots operating turbo-jet aircraft receive training in, and maintain their awareness of, the risks of low-energy conditions, particularly low-energy go-arounds.***

Discussion: *Following the occurrence, Transport Canada issued a Commercial and Business Aviation Advisory Circular to notify pilots and operators of the potential hazards associated with conducting a go-around once an aircraft has entered the low-energy regime. The circular advised that air operators should immediately ensure that their pilots and training personnel are aware of the hazards associated with low-energy go-arounds and verify that their training programs address these hazards and provide procedures for dealing with them. Dissemination of the advisory circular should reduce the risk of accidents involving low-energy go-arounds in the short term.*

Advisory circulars are intended to provide information and guidance regarding operational matters; they do not become a formal part of the safety requirements established by Transport Canada. In the absence of formal entrenchment in the aviation system, these advisory circulars tend to lose their information value as newer circulars on other topics appear. Since the importance of knowledge of low-energy go-arounds will not decrease over time, some process is required to ensure that new pilots are informed of, and experienced pilots maintain their awareness of, the risks involved.

Conclusion: *This option was considered to be feasible and appropriate.*

9.4.2 Aircraft Icing

1) Safety deficiency: *Because of the limitations of the ice detection system and its associated aircrew procedures, icing can build-up on the wings during critical phases of flight which could result in loss of control of the aircraft and a crash.*

Option A: ***Modify the Ice Detection System***

Discussion: *This option may not be technically possible and, if possible, would likely be expensive. A retroactive application would entail effort and expense on the part of the manufacturer and operating airlines.*

Conclusion: *It was considered that this option was not feasible.*

Option B: ***The manufacturer change the stall protection parameters to better protect against the adverse affects of ice.***

Discussion: *This option may not be technically possible and, if possible, would likely be expensive. A retroactive application would entail effort and expense on the part of the manufacturer and operating airlines.*

Conclusion: *It was considered that this option was not feasible.*

Option C: ***TC modify its certification of the aircraft to better evaluate the effects of wing icing on the stall characteristics and stall angle.***

Discussion: *This option would be difficult and time-consuming but would enhance the certification of many future aircraft. Changes to certification, however, would probably not be applied retroactively and many existing aircraft would not be covered.*

Conclusion: *It was considered that this option was not feasible.*

Option D: ***Air Canada change its CRJ procedures to require the use of wing anti-ice for approaches in known icing conditions.***

Discussion: *On 11 March 1998, to address the issue of the "ICE" caution being inhibited below the radio altitude of 400 feet agl, Air Canada issued Aircraft Technical Bulletin No. 158 amending the procedures in its AOM (Volume 2/02.00- .02/ .30- .43) as follows:*

During flight, the engine cowl and wing anti-ice system must be ON when:

- *i) icing conditions are indicated by the ice detection system, or*
- *ii) there is visual detection of ice formation on the airplane surfaces (windshield wipers, window frames, etc.), or*
- *iii) operating below 400 agl and icing conditions exist as defined by the AOM, Vol. 2, 02.17.01, or*
- *iv) an ice detector has failed and icing conditions exist as defined by the AOM, Vol. 2, 02.17.01.*

These actions are pertinent to the safety deficiency and should help to reduce the risk.

Conclusion: *Given the actions taken by Air Canada, this option will not be pursued through further safety action requirements. However, the* *safety action taken should be included in Section 4 of the Board's public report.*

Option E: ***TC, Air Canada, or Bombardier issue safety material regarding the risks of ice build-up prior to detection system indications and the lowering of stall protection in icing conditions.***

Discussion: *In March of 1998, Bombardier Regional Aircraft Division, with Transport Canada approval, issued All Operator Message No. 234 referring to Temporary Revision CRJ/61 which was sent to all CL-65 operators. The temporary revision consolidated and clarified icing definitions and procedures for operation in icing conditions, as defined in the Airplane Flight Manual, CSP A-012, to ensure that the ice protection systems are activated whenever the aircraft is operating in conditions that could lead to ice accumulating on the wing and engine cowl leading edges.*

These actions are pertinent to the safety deficiency and should help to reduce the risk.

Conclusion: *Given the initiative undertaken by Bombardier and TC in this regard, this option will not be pursued through further safety action requirements. However, the safety action taken should be included in Section 4 of the Board's public report.*

Option F: ***TC consider taking action to remove the inhibition of the amber ICE light below 400 feet on existing and future CL-65 aircraft.***

Discussion: *The TSB reviewed the actions taken by Air Canada and Bombardier and recognized that those actions will reduce the the possibility of ice accumulation on the CL-65 aircraft. Nevertheless, there is still a risk that while an aircraft is operating below 400 feet agl, ice could accumulate to an extent that aircraft performance would be materially affected without the pilots being aware that they had entered icing conditions or that ice had accumulated. If the amber ICE light were not inhibited below 400 feet, however, an extra safeguard would be in place to alert pilots to the presence of ice.*

The Federal Aviation Administration (USA) considers illumination of the amber ICE light to be a warning light, not a caution light. Consequently illumination of the amber light is not inhibited on CL-65 aircraft registered in the USA.

It is acknowledged that illumination of the amber ICE light at low altitude could introduce some risk by distracting the crew; however, this risk must be compared to the risk associated with the increased potential for ice accumulating during a critical stage of flight if illumination of the amber ICE light is inhibited.

Conclusion: *This option was considered to be feasible and appropriate.*

9.4.3 Passenger Safety and Evacuation

1) Safety deficiency: *Because the carriage of a signalling device on-board the aircraft is not required, survivors of a crash may continue to be placed in situations where they cannot signal emergency personnel for assistance.*

Option A: ***TC review CAR 602.61(2) with a view to requiring aircraft operating under the CAR to carry an on-board signalling device.***

Discussion: *Any circumstance or situation that impedes, or does not facilitate, a timely response by emergency rescue personnel is unsafe in that it creates a risk to passenger and crew survivability.*

Conclusion: *This was considered to be a feasible and appropriate option.*

2) Safety deficiency: *Because the aircraft is not required to operate with an ELT, emergency personnel may be unable to locate a crashed aircraft or may not even know that a crash has occurred, thus delaying assistance.*

Option A : ***TC review CAR 605.38(3) with a view to eliminating the ELT carriage exemption for turbo-jet aircraft.***

Discussion: *While aircraft like the CRJ are not required to carry an ELT, turbo-prop aircraft similar to the CRJ in the number of passengers they carry and the environment in which they operate are not exempt from carrying an ELT. The TSB has no information to indicate that there is a significant difference in accident rates between turbo-prop and turbo-jet aircraft. Any risk mitigation with respect to post-crash survivability that is gained by being equipped with an ELT could equally apply to all aircraft of similar size and operation, regardless of the type of propulsion system.*

Conclusion: *This was considered to be a feasible and appropriate option.*

3) Safety deficiency: *Without appropriate hands-on training on the operation and use of emergency exits, flight crews may continue to inadvertently delay the emergency evacuation.*

Option A: ***TC take whatever measures necessary to ensure that flight crew practical training is in accordance with CAR 705.124 and CASS 725.124(14)(c).***

Discussion: *Despite Air Canada's intent to provide pilots with practical training on the aircraft doors during initial training, neither flight deck crew member involved in the occurrence had received such training. While the operation of emergency exits by flight crew was not* *called for in this occurrence, there is a risk that, in other circumstances, a lack of practical training could adversely affect their ability to open emergency exits in a timely and effective manner, and thereby delay the evacuation of the aircraft.*

Conclusion: *This was considered to be a feasible and appropriate option.*

4) *Safety deficiency:* *Lack of knowledge by flight deck crew concerning the existence and location of emergency equipment, in this occurrence a pry bar, could impede the success of the passenger evacuation.*

Option A: ***TC take whatever measures necessary to ensure that flight crew training is in accordance with CAR 705.124 with respect to emergency equipment.***

Discussion: *Neither crew member was aware that there was a pry bar on the aircraft. In discussions with Air Canada, it became evident that some flight training personnel were also unaware that a pry bar is standard emergency equipment. Lack of knowledge by flight deck crew concerning the existence and location of emergency equipment could impede the success of the evacuation.*

Conclusion: *This is considered to be a feasible and appropriate option.*

5) *Safety deficiency:* *Because the flashlights were stored in the same general area, all flashlights would be rendered inaccessible in the event of damage to that storage area during an accident.*

Option A: ***TC review the practice of locating flashlights in only one location on those aircraft where the cabin crew is comprised of one flight attendant.***

Discussion: *Locating all of the emergency flashlights in close proximity within an aircraft increases the risk that all of them may be destroyed or inaccessible if that portion of the aircraft is damaged during an accident. Flashlights are a necessary piece of emergency equipment particularly if an accident occurs at night, if the fixed emergency lighting system is not operable, if there is smoke inside the aircraft and for survival following an evacuation. Lack of flashlights could hamper the flight and cabin crew's ability to carry out their emergency/survival duties. To mitigate this risk, one of the flashlights, or an additional flashlight, could be located elsewhere in the aircraft.*

Conclusion: *This is considered to be a feasible and appropriate option.*

10. Safety Communication Process

One of the most important roles of the TSB is to communicate the findings of investigations to stakeholders and the public. The effectiveness of communication will ultimately determine the effectiveness of risk control options to enhance safety of transportation systems.

Purpose:

- To ensure that identified risks are communicated effectively.

Safety communication involves the following:

- Identify stakeholders and decision makers.
- Develop safety communication plan.
- Develop safety deficiency communication.
- Follow-up to Board Safety Communications.
- Integration with the Investigation Communications Plan.

Deliverables:

- Safety communications in an appropriate form.
- Communication to stakeholders and decision makers.

10.1 Identify Stakeholders

Identify those organizations or persons who can best effect changes in the transportation system, such as the regulator of the activity and corporate decision makers and management at all levels – local, sectorial, regional, national, and international.

10.2 Develop a Safety Communications Plan

It is crucial to plan safety communications ahead to ensure timely and accurate communications. The objective of the safety communications plan is to communicate safety deficiencies in the most effective way to convince stakeholders and decision makers to take remedial action.

The following should be considered when developing this plan:

- Communications should be timely.
- The urgency of communications should be based on the estimated level of risk.
- The method of communication (formal, informal, etc.) should be guided by:
    - ➢ The estimated level of risk (probability and consequence).
    - ➢ The scope of the problem.
    - ➢ The type of stakeholder and decision maker.
- Communicating at an informal team level would not preclude subsequent communications at a higher level

- Consultations with stakeholders to facilitate validation of safety deficiencies and risk control options would be a prerequisite for issuing safety communications at a formal level

Methods for communicating safety deficiencies include:

- Informal by the Investigation Team.
    - ➢ Direct verbal communication.
        - ◊ Individual and group discussions.
        - ◊ Investigation process briefings.
        - ◊ Safety issues under consideration.
- Formal by the Investigation Team in conjunction with TSB management.
    - ➢ Direct written communication.
        - ◊ Occurrence Bulletin.
        - ◊ Information Letter.
        - ◊ Advisory Letter.
- Formal by the Board.
    - ➢ Interim recommendations for safety deficiencies requiring urgent action.
    - ➢ Report findings as to causes and contributing factors.
    - ➢ Actions taken.
    - ➢ Safety issues under consideration.
    - ➢ Recommendations.
    - ➢ Safety concerns.

Method of communication would be based on risk potential, as follows:

- Low risk:
    - ➢ Team (informal).
    - ➢ Board Report Factual section and, if required, the Analysis section.
- Medium risk:
    - ➢ Team (informal), if appropriate.
    - ➢ Team (formal).
    - ➢ Board Report Factual section, and Analysis section.
    - ➢ Board Report Findings and Safety Action, if required.
- High risk:
    - ➢ Team (informal), if appropriate.
    - ➢ Team (formal), if appropriate.
    - ➢ Board Interim Recommendations.
    - ➢ Board Report Factual section and Analysis section.
    - ➢ Board Report Findings, Action Taken, Recommendation, Concern.

Communication of safety issues, safety action taken by stakeholders and decision makers, and safety action proposed by the Board would be guided by the TSB Communication Policy.

10.3 Develop the Safety Deficiency Communication

When developing safety communications, there are a number of key procedures to follow.

First, in the introduction to the safety communication, describe the problem in terms of the following:

- The underlying unsafe condition
- The assessed risk
- Inadequate defences
- Past TSB safety actions, remedial action taken as a result of such action, and any residual risk.

Second, present a compelling argument to those who can best influence the necessary change:

- Ensure that data (e.g., historical statistics, previous safety action, risk exposure trend, etc.) used in the analysis and the arguments presented are accurate and adequate.
- State any assumptions and uncertainties associated with the analysis used for the argument.
- Support the argument by including the relevant outcomes of the risk analysis process (risk assessment, defence analysis, and safety deficiency identification).
- Evaluate changes to the safety issues that took place during the investigation and point out residual risks.
- Clearly state the safety deficiency.

Third, discuss the safety communication with key decision makers and stakeholders prior to formal dissemination. It is important to offer due consideration to stakeholders' input and analyses.

During the process, bear in mind the probable reaction of the public, stakeholders, and decision makers to the proposed safety action. By anticipating criticism, counter-arguments, and objections, these concerns can be addressed before they are ever raised. This strengthens the arguments for the safety action and presents a greater image of fairness.

10.4 Board Safety Communications Follow-up

The following would be integral to determining the effectiveness of Board safety communications:

- Monitoring of actions taken in response to determine the extent to which the underlying safety deficiency has been, or is currently being, addressed.
- Assessing replies to Recommendations (and Advisories) as follows:
  - ➢ Analysing the substance of the response/comments to determine the extent to which any planned action will reduce or eliminate the risks to persons, property, or the environment.
  - ➢ Reassessing the risks associated with the safety deficiency at issue.
  - ➢ Categorizing the degree of risk mitigation (taken or proposed) as follows:

    - ◊ Fully satisfactory.
    - ◊ Satisfactory intent.
    - ◊ Satisfactory in part.
    - ◊ Unsatisfactory.
  - ➢ Recommending if and what TSB follow-up action should be taken
- Preparing a response to the comments received, if required
  - ➢ If a reply to a TSB recommendation is deemed to be unsatisfactory, in that significant risks to persons, property, or the environment will persist, a letter of concern may be required to express the Board's dissatisfaction over the action.

10.5 Communications in the Air Canada 646 Occurrence

Communication of the deficiencies took place at both the informal and formal levels. Informally, the team held regular investigation progress meetings. As well, the investigation team consulted with stakeholders throughout the investigation and provided briefings as new potential safety issues emerged. As a result of these meetings, Bombardier, Air Canada and TC undertook a number of initiatives that essentially reduced the need for the Board to issue formal recommendations for some of the deficiencies. Those deficiencies that were estimated to be of a medium to low risk were communicated to the appropriate regulatory or corporate officials through either safety advisory or information letters by the investigation team in conjunction with TSB management. All safety deficiencies were communicated formally by the Board report. The communication strategy for each of the safety issues and their safety deficiencies is discussed below:

10.5.1 Low-energy Go-arounds

Safety deficiency: ***Because neither the training nor the procedures provided crews with information on conducting go-arounds once the power had been reduced to idle for the landing, crews may continue to attempt a go-around in a low-energy state, unaware that they may not be successful.***

Informal communication

Investigators discussed the safety issue during briefings to stakeholders, including Transport Canada, Air Canada, and Bombardier. Discussion and consultation of past and current status of this safety issue facilitated the validation of the safety deficiency and led to the following actions being taken by Transport Canada.

On 13 May 1998 Transport Canada issued a Commercial and Business Aviation Advisory Circular to notify pilots and air operators of the potential hazards associated with a balked landing or go-around. The circular advised that air operators should immediately ensure that their pilots and training personnel are aware of the hazards associated with low-energy go-arounds or balked landings and verify that their training programs address the hazards inherent in, and procedures for dealing with, low-energy operations.

Formal communication

> *As the level of risk was estimated to be High, the deficiency was reported in all major sections of the formal Board report. The safety action taken by TC with regards to the advisory circular was included in Part 4 Safety Action as Action Taken.*
>
> *The TSB recognized that dissemination of the advisory circular should reduce the risk of accidents involving low-energy go-arounds in the short term. However, it also recognized that advisory circulars are intended to provide information and guidance regarding operational matters and they do not become a formal part of the safety requirements established by Transport Canada. In the absence of formal entrenchment in the aviation system, these advisory circulars tend to lose their information value as newer circulars on other topics appear. Since the importance of knowledge of low-energy go-arounds will not decrease over time, some process is required to ensure that new pilots are informed of, and experienced pilots maintain their awareness of, the risks involved. It was decided that a formal Board recommendation would be issued (Reference – Risk Control Option Analysis, Low-energy Go-arounds, Safety Deficiency #1, Option C). The Board's recommendation was as follows:*
>
>> *The Department of Transport ensure that pilots operating turbo-jet aircraft receive training in, and maintain their awareness of, the risks of low-energy conditions, particularly low-energy go-arounds.*

10.5.2 Aircraft Icing

Safety Deficiency: ***Because of the limitations of the ice detection system and its associated aircrew procedures, icing can build-up on the wings during critical phases of flight which could result in loss of control of the aircraft and a crash.***

Informal communication

> *Investigators discussed the safety deficiency associated with this safety issue during briefings to stakeholders, including Transport Canada, Air Canada, and Bombardier. Discussion of past and current status of this safety issue facilitated the validation of the safety deficiency and led to the following actions being taken by Transport Canada, Air Canada, and Bombardier.*
>
> *Air Canada issued Aircraft Technical Bulletin No. 158 amending the procedures in its AOM to address the issue of the ICE caution being inhibited below the radio altitude of 400 feet. Bombardier also issued an All Operator Message No. 234 referring to a temporary revision which consolidated and clarified icing definitions and procedures for operating in icing conditions.*

Formal communication

> *As the level of risk was estimated to be High-Medium, the deficiency was reported in all major sections of the formal Board report. The actions undertaken by TC, Bombardier and Air Canada were included in Part 4 Safety Action as Action Taken.*
>
> *The Board recognized that, while the procedures outlined in these two documents will reduce the possibility of ice accumulation on the aircraft, it also recognized that a risk still existed with ice accumulation below 400 feet. This ice accretion could*

materially affect the performance of the aircraft without the crew being aware that they had entered icing conditions or that ice had accumulated. Because of this, it was determined that an additional safeguard to alert pilots to the presence of ice was needed (Reference – Risk Control Option Analysis, Aircraft Icing, Option F). To that end, a Safety Advisory was issued by the TSB suggesting that TC consider taking action to remove the inhibition of the amber ICE light below 400 feet agl on existing and future CL-65 aircraft.

10.5.3 Passenger Safety and Evacuation

Safety Deficiency: ***Because the carriage of a signalling device on-board the aircraft is not required, survivors of a crash may continue to be placed in situations where they cannot signal emergency personnel for assistance.***

Informal Communication

Investigators discussed the safety issue during briefings to stakeholders, including Transport Canada and Air Canada. Discussion of this safety issue facilitated the validation of the safety deficiency.

Formal communication

A Safety Information Letter documenting the risks of this deficiency was sent by the investigation team in conjunction with TSB management to TC for their action (Reference – Risk Control Option Analysis, Passenger Safety and Evacuation, SD#1, Option A). TC responded to the letter advising that they would be establishing a working group to review the current survival equipment regulation and all associated issues and concerns, including 'a means for signalling distress.'

As the level of risk for this deficiency was Medium, it was reported in the Factual, Analysis, and Findings sections of the formal Board report. The response to the Safety Information Letter was included in Part 4 Safety Action, Action Taken.

Safety deficiency: ***Because the aircraft is not required to operate with an ELT, emergency personnel may be unable to locate a crashed aircraft or may not even know that a crash has occurred, thus delaying assistance.***

Informal communication

Investigators discussed the safety issue during briefings to stakeholders, including Transport Canada and Air Canada. Discussion of this safety issue facilitated the validation of the safety deficiency.

Formal communication

A Safety Advisory documenting the risks of this deficiency was sent by the investigation team in conjunction with TSB management to TC for their action (Reference – Risk Control Option Analysis, Passenger Safety and Evacuation, SD#2, Option A). TC responded to this advisory indicating that the CARs Regulatory Committee had decided to initiate amendments to remove the exemption from CAR 605.38.

As the level of risk for this deficiency was Medium, it was reported in the Factual, Analysis, and Findings sections of the formal Board report. The response to the Safety Advisory was included in Part 4 Safety Action, Action Taken.

Safety Deficiencies: ***Without appropriate hands-on training on the operation and use of emergency exits, flight crews may continue to inadvertently delay the emergency evacuation.***

Lack of knowledge by flight deck crew concerning the existence and location of emergency equipment, in this occurrence a pry bar, could impede the success of the passenger evacuation.

Informal communication

Investigators discussed the safety issue during briefings to stakeholders, including Transport Canada and Air Canada. Discussion of this safety issue facilitated the validation of these safety deficiencies.

Formal communication

Safety Information Letters documenting the risks of both deficiencies were sent by the investigation team in conjunction with TSB management to TC for their action (Reference – Risk Control Option Analysis, Passenger Safety and Evacuation, SD#3, Option A & SD#4, Option A). TC responded to the letters advising that they will develop Commercial and Business Aviation Advisory Circulars for air operators, and Policy Letters for Commercial and Business Aviation Inspectors responsible for the approval of flight crew member training programs. These documents are being developed to clarify the intent of the "emergency exits" training requirement, as well as the training requirements for the location and use of emergency equipment, including practical training. Appropriate amendments to the Commercial Air Service Standards will be proposed by Transport Canada.

As the level of risk for these deficiencies was Medium-Low, they were reported in the Factual, Analysis, and Findings sections of the formal Board report. The response to the Safety Information Letter was included in Part 4 Safety Action, Action Taken.

Safety Deficiency: ***Because the flashlights were stored in the same general area, all flashlights would be rendered inaccessible in the event of damage to that storage area during an accident.***

Informal communication

Investigators discussed the safety issue during briefings to stakeholders, including Transport Canada and Air Canada. Discussion of this safety issue facilitated the validation of the safety deficiency.

Formal communication

A Safety Advisory documenting the risks of this deficiency was prepared by the investigation team and sent by the DOI to TC for their action (Reference – Risk Control Option Analysis, Passenger Safety and Evacuation, SD#5, Option A). TC responded to this advisory indicating that they will develop a Commercial and Business Aviation Advisory Circular, for air operators, to recommend that, on aircraft types where only one flight attendant is carried and the flight attendant seat is located forward, an additional flashlight be carried on that aircraft and that it be located in the rear of the aircraft.

Air Canada responded, indicating that they have published Insert No. 72 to their Flight Attendant Manual (Publication 356), regarding the carriage of an additional flashlight in the aft of the CL-65 aircraft.

As the level of risk for this deficiency was Medium-Low, it was reported in the Factual, Analysis, and Findings sections of the formal Board report. The response to the Safety Advisory was included in Part 4 Safety Action, Action Taken.

10.5.4 Board Safety Communication Follow-up

Investigators monitored the actions taken in response to the safety communications and assessed the replies as follows:

The response to the recommendation requiring TC to ensure that pilots operating turbo-jet aircraft receive training in, and maintain their awareness of, the risks of low-energy conditions, was assessed as Fully Satisfactory. TC indicated that low-energy conditions would be incorporated into the flight crew training program.

The response to the safety advisory concerning removing the exemption for the ELT was assessed as Fully Satisfactory. TC indicated that the exemption would be removed and that the time for maintenance would be reduced from 90 days to 30 days.

The response to the safety advisory suggesting that TC consider taking action to remove the inhibition of the amber ICE light below 400 feet agl on existing and future CL-65 aircraft was assessed as Fully Satisfactory. TC indicated that Bombardier and TC reached an agreement that the inhibition of the caution message below 400 feet agl on approach was not acceptable and that Bombardier is preparing to make the appropriate change. The deletion of the ICE caution message will be mandated by TC.

The responses to the safety information letters were assessed as Fully Satisfactory. In addition to the safety action taken over the course of the investigation, TC also indicated that Policy Letter 130 – Emergency Procedures Training for Pilots was in the final revision stage and that issuance of it would follow shortly. The purpose of the policy letter was to clarify the requirement for and the intent of practical training during emergency procedures training. A proposed amendment to the Commercial Air Service Standard 725.124(14) to clarify the meaning of and requirement for practical training was also anticipated.