LOSS OF CONTROL IN FLIGHT:

A REDEFINITION BASED ON QUALITATIVE AND QUANTITATIVE APPROACHES

AEROSPACE TECHNOLOGY CONGRESS 2019

JOÃO PAULO MACEDO

PROF. JORGE HENRIQUE BIDINOTTO, PH.D.

SÃO CARLOS SCHOOL OF ENGINEERING – UNIVERSITY OF SÃO PAULO

AGENDA

1 | The Problem

2 | What is LOC-I?

3 | Motivation and Objectives

4 | Flight Test Simulations

5 | Results and Discussion

6 | Conclusion and Future Work

1 | The Problem

Why are we specifically studying LOC-I?

1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

Source: (1) ICAO. Safety Report 2017, p. 2

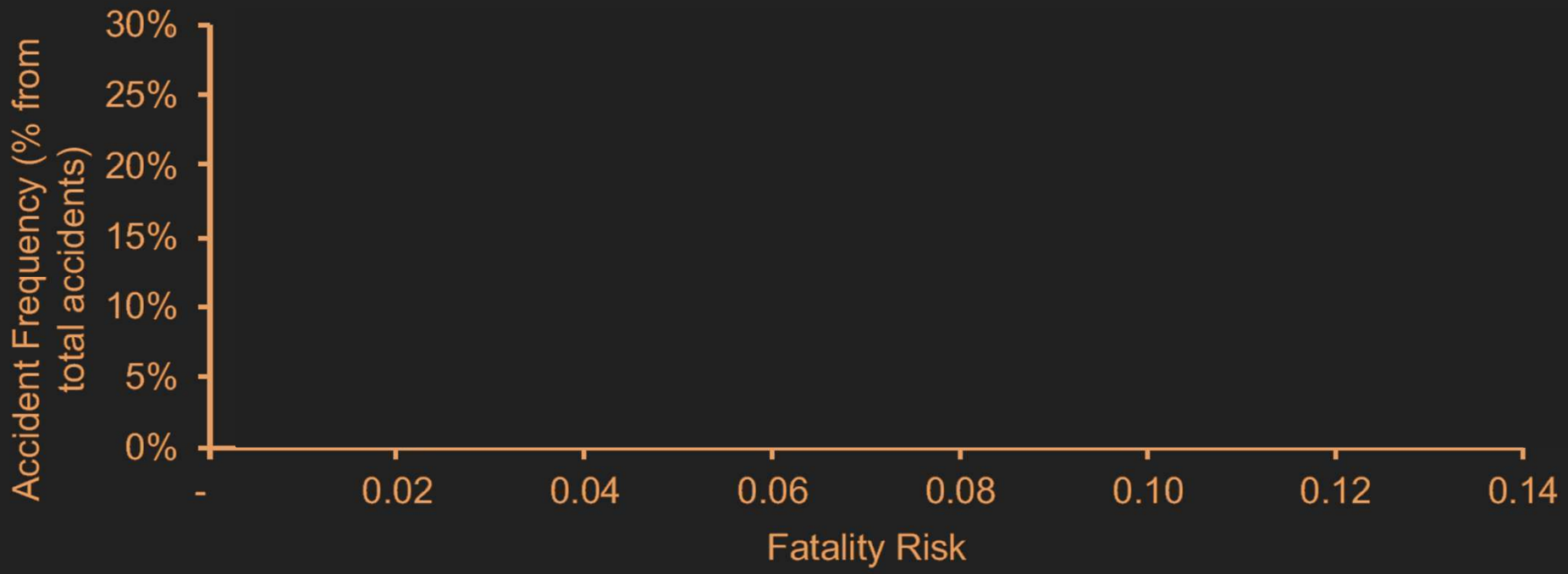
1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

Since 2006, the HRC – High-Risk Occurrences – remain the same [2]

Source: (1) ICAO. Safety Report 2017, p. 2; (2) ICAO, DOC 10004 Global Aviation Safety Plan 2017-2019

1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

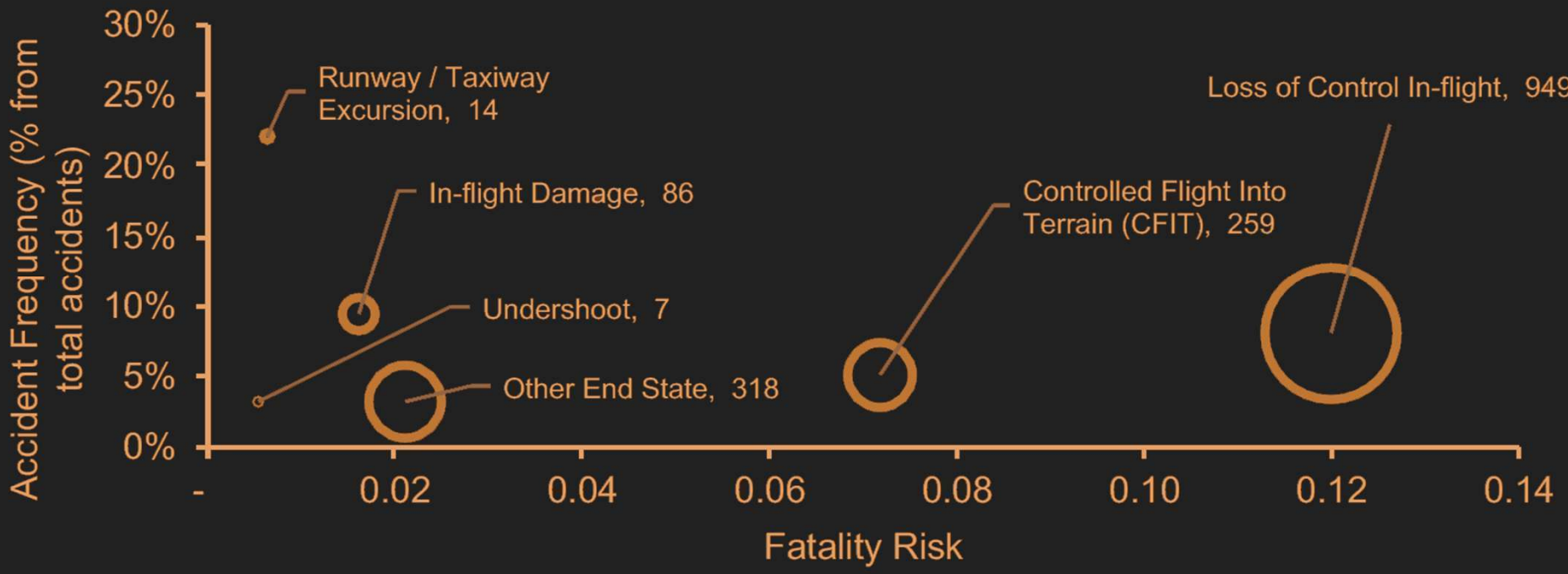
Since 2006, the HRC – High-Risk Occurrences – remain the same [2]



Source: (1) ICAO. Safety Report 2017, p. 2; (2) ICAO, DOC 10004 Global Aviation Safety Plan 2017-2019; (Graph) IATA, Safety report 2016, p. 44

1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

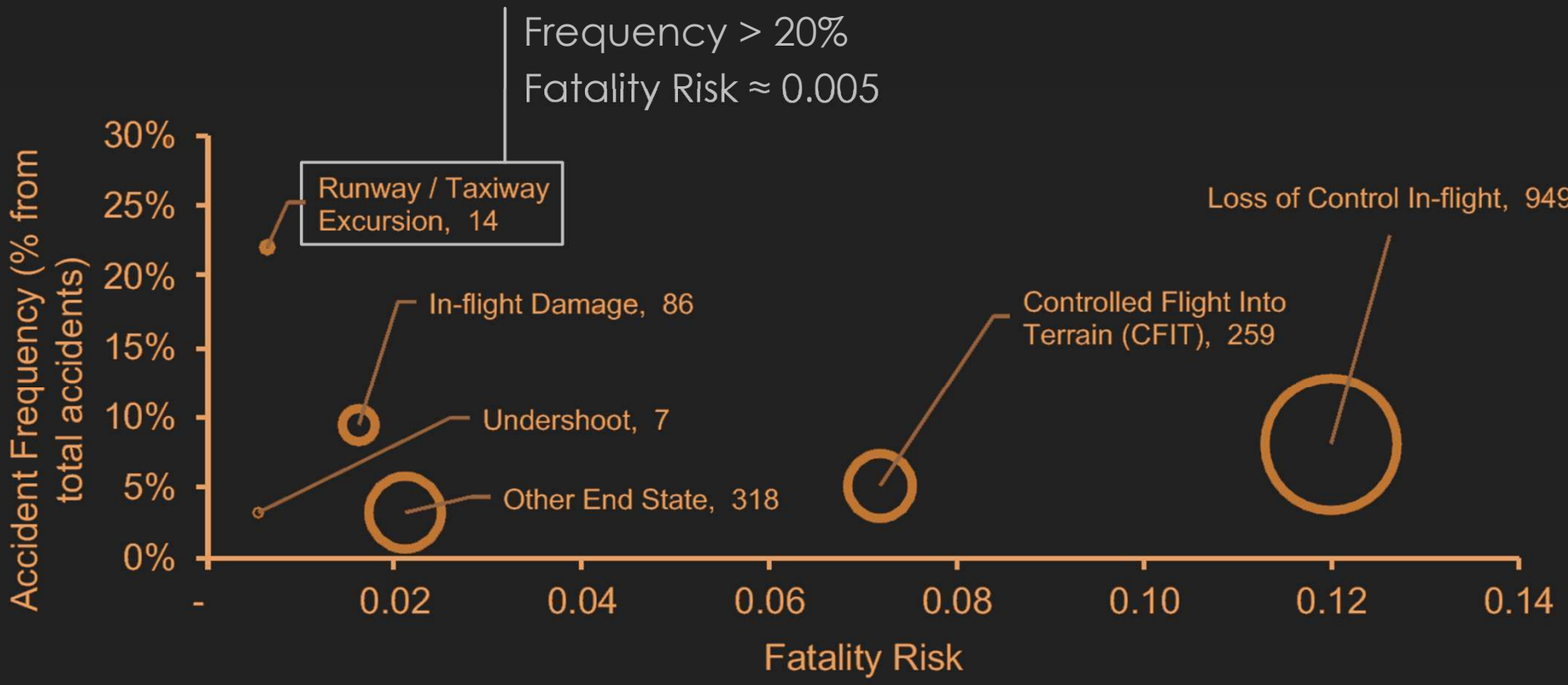
Since 2006, the HRC – High-Risk Occurrences – remain the same [2]



Source: (1) ICAO. Safety Report 2017, p. 2; (2) ICAO, DOC 10004 Global Aviation Safety Plan 2017-2019; (Graph) IATA, Safety report 2016, p. 44

1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

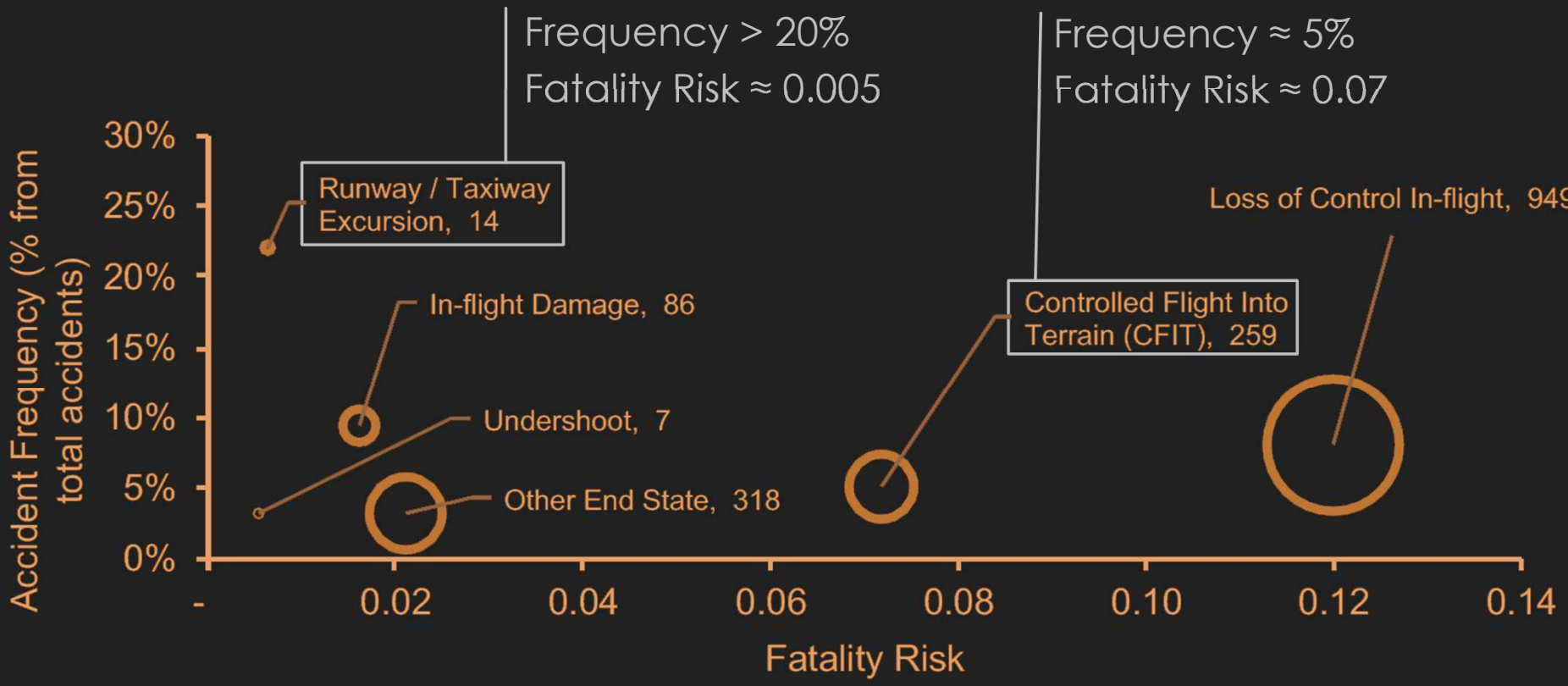
Since 2006, the HRC – High-Risk Occurrences – remain the same [2]



Source: (1) ICAO. Safety Report 2017, p. 2; (2) ICAO, DOC 10004 Global Aviation Safety Plan 2017-2019; (Graph) IATA, Safety report 2016, p. 44

1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

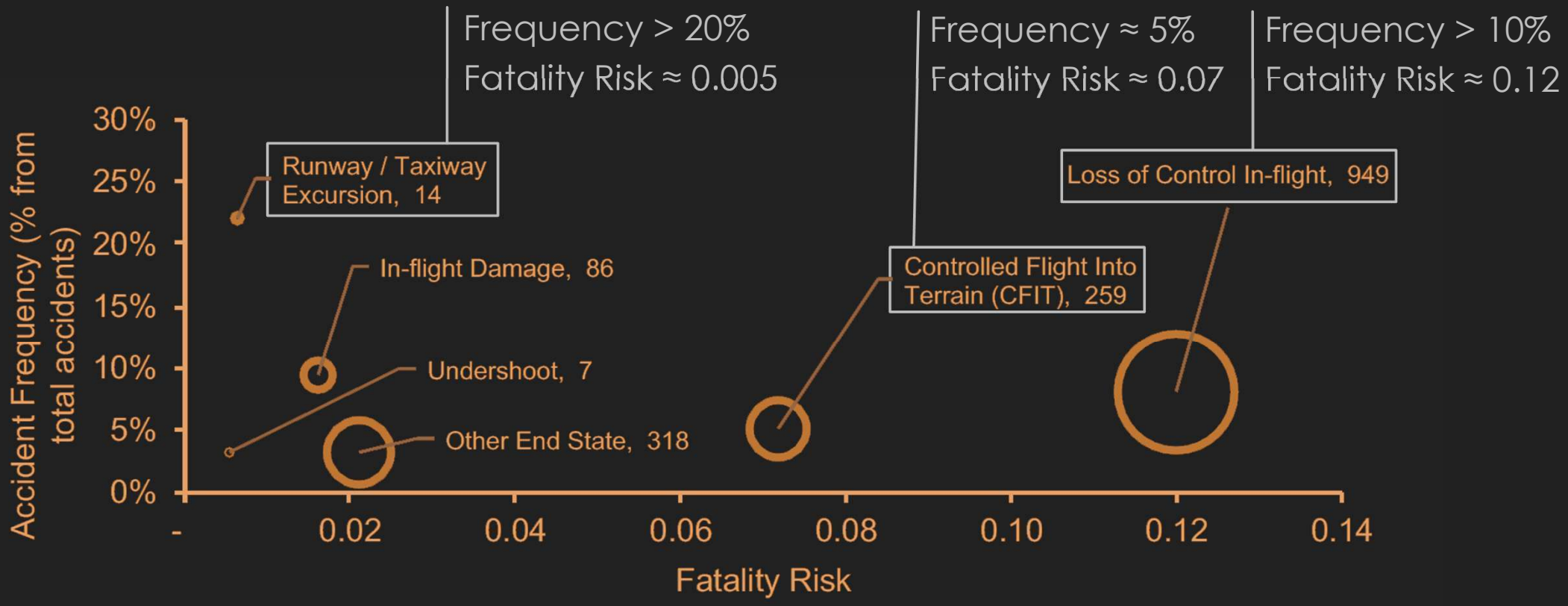
Since 2006, the HRC – High-Risk Occurrences – remain the same [2]



Source: (1) ICAO. Safety Report 2017, p. 2; (2) ICAO, DOC 10004 Global Aviation Safety Plan 2017-2019; (Graph) IATA, Safety report 2016, p. 44

1 "Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective" [1]

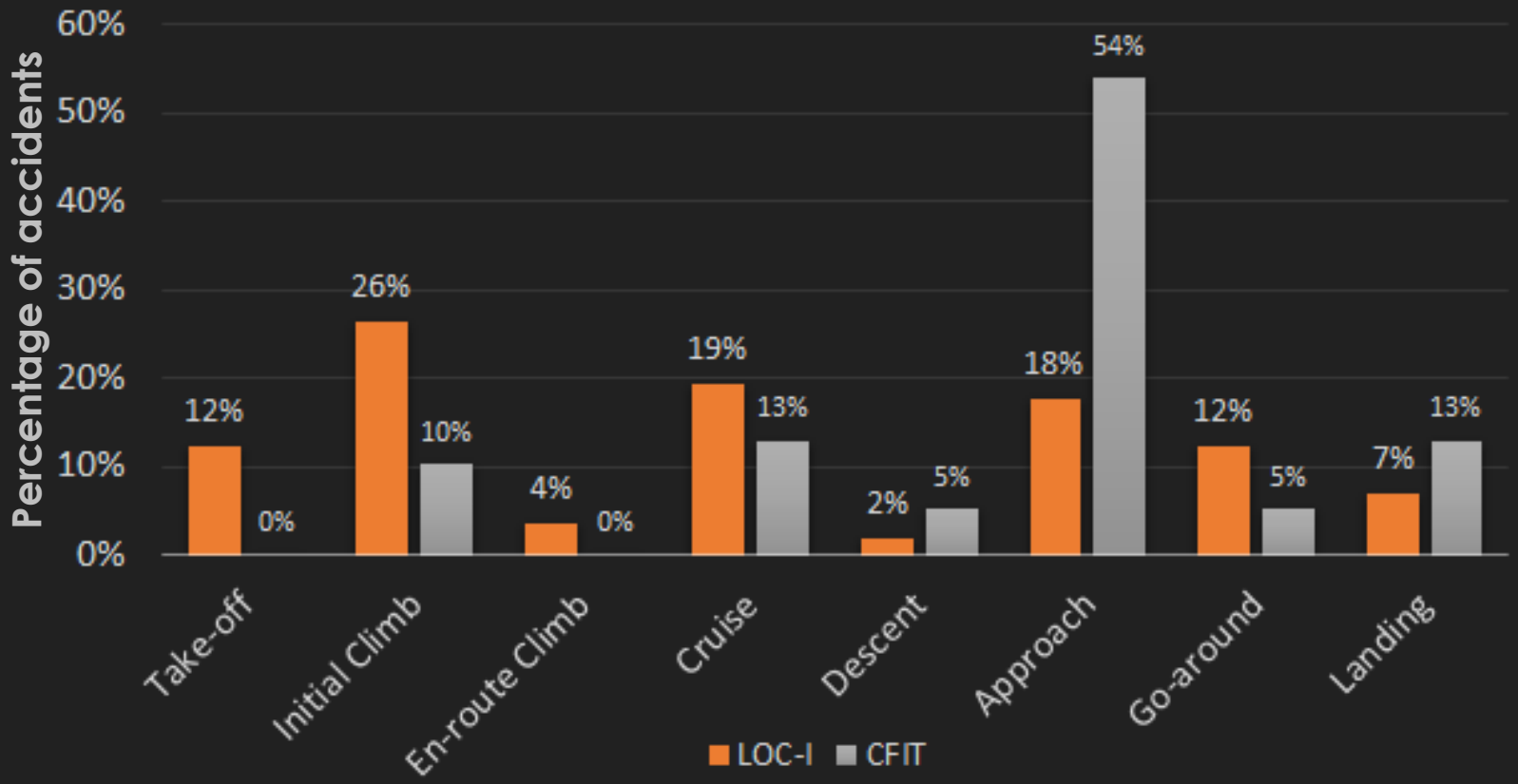
Since 2006, the HRC – High-Risk Occurrences – remain the same [2]



Source: (1) ICAO. Safety Report 2017, p. 2; (2) ICAO, DOC 10004 Global Aviation Safety Plan 2017-2019; (Graph) IATA, Safety report 2016, p. 44

1 **CFIT** accidents are typically associated with the **approach phase**, whereas **LOC-I** permeates **all phases of flight**

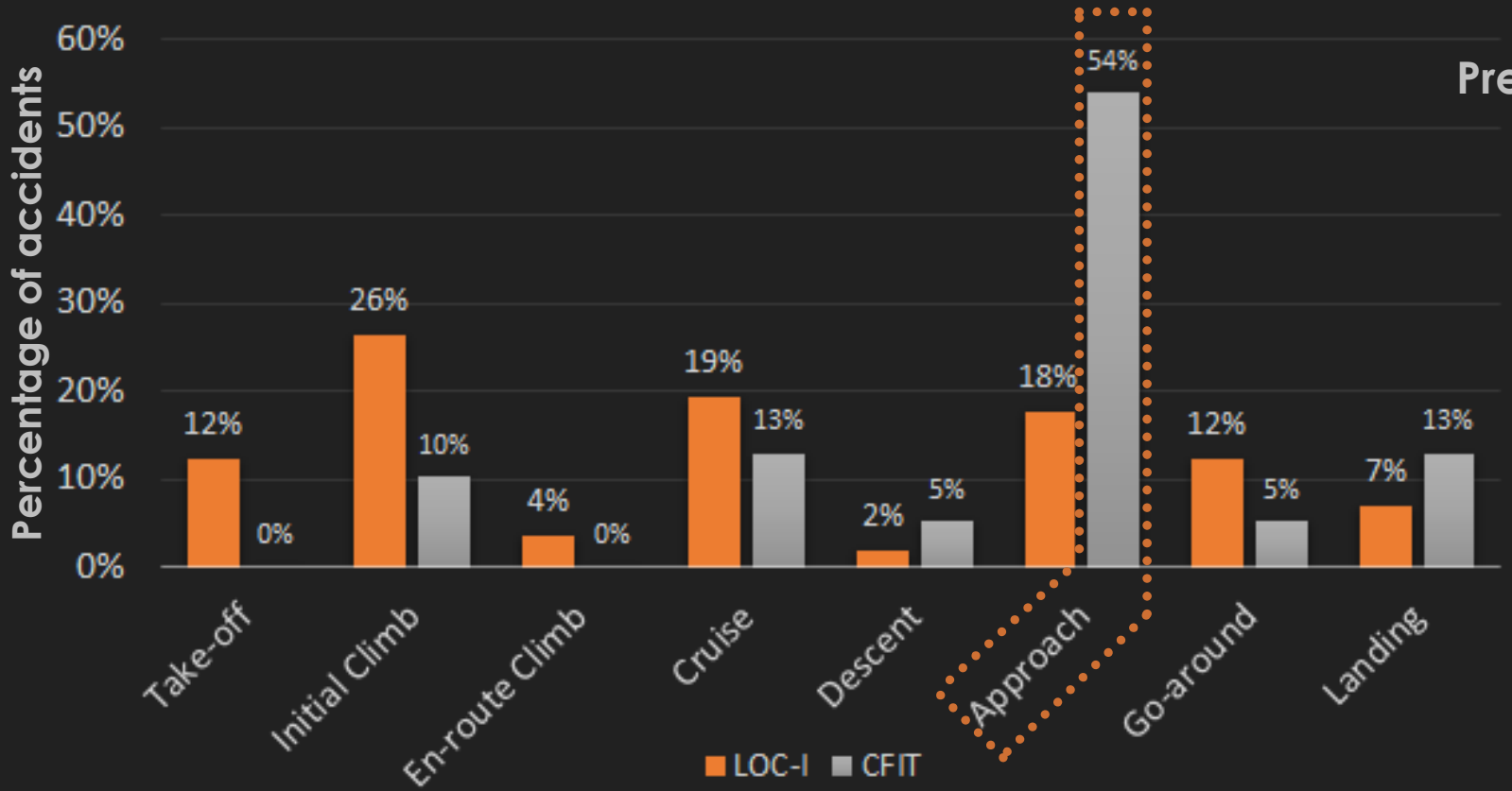
CFIT and LOC-I by phase of flight – 2009 to 2016



Source: (Graph) The author – Data is retrieved from IATA annual Safety Reports - editions 2013, 2014, 2015 and 2016

1 **CFIT** accidents are typically associated with the **approach phase**, whereas **LOC-I** permeates **all phases of flight**

CFIT and LOC-I by phase of flight – 2009 to 2016



CFIT

Predominance: approach

Mitigation: EGPWS, TAWS, ILS

LOC-I

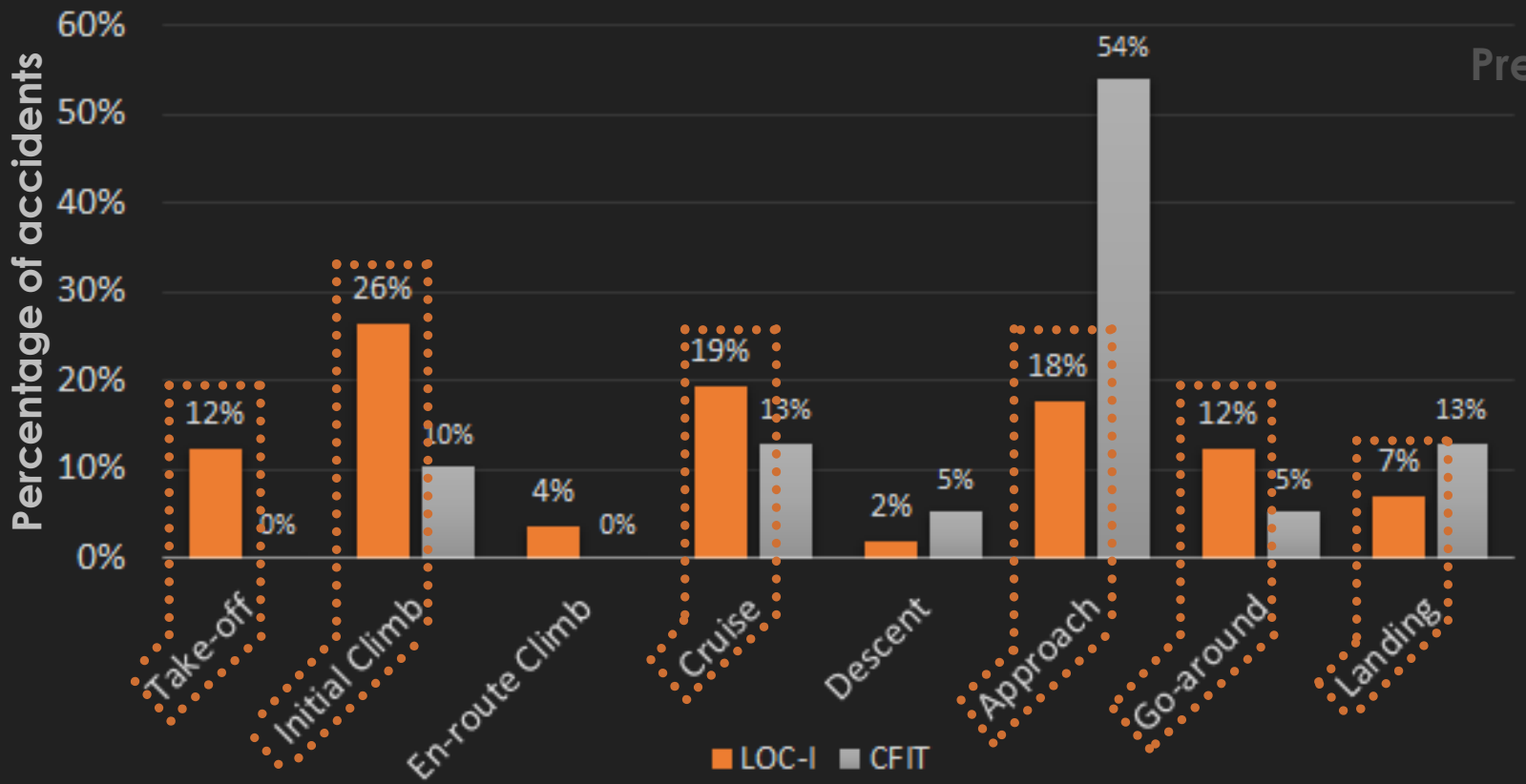
Predominance: ---

Mitigation: "it doesn't lend itself as to one alerting system" [1]

Source: (Graph) The author; (1) Rosenkrans W, Airplane State Awareness, 2015

1 **CFIT** accidents are typically associated with the **approach phase**, whereas **LOC-I** permeates **all phases of flight**

CFIT and LOC-I by phase of flight – 2009 to 2016



CFIT

Predominance: approach

Mitigation: EGPWS, TAWS, ILS

LOC-I

Predominance: ---

Mitigation: "it doesn't lend itself as to one alerting system" [1]

Source: (Graph) The author; (1) Rosenkrans W, Airplane State Awareness, 2015

1 Current panorama
"(...) to prevent **loss of control** accidents (...)"

ANAC

*"Reduzir o número de ocorrências categorizadas como '**alto risco operacional**'"*

EASA
European Aviation Safety Agency

"Include loss of control in flight in **national State Safety Programmes**."

AAIB
Air Accidents Investigation Branch

"'*Aware Today, Alive Tomorrow*' (...) to **prevent loss of control** accidents (...)"

ICAO • OACI • ИКАО
国际民航组织 • منظمة الطيران المدني الدولية

"**High-Risk Accident** Occurrence Categories

- Runway safety related events;
- **Loss of control in-flight**;
- Controlled flight into terrain (...)"

NATIONAL TRANSPORTATION SAFETY BOARD

"(...) accidents involving inflight loss of control (...) **still occur at an unacceptable rate**."

FEDERAL AVIATION ADMINISTRATION

"The FAA and industry are working together to **prevent Loss of Control** (LOC) accidents and save lives."

IATA

"LOC-I accidents have been assessed by the IATA Safety Department and the industry to be the **highest risk to aviation safety**, and deemed to be an area for **increased attention** (...)"

1 Current panorama
"(…) to prevent **loss of control** accidents (…)"

ANAC

*"Reduzir o número de ocorrências categorizadas como '**alto risco operacional**'"*

EASA
European Aviation Safety Agency

"Include loss of control in flight in **national State Safety Programmes**."

AAIB
Air Accidents Investigation Branch

"'*Aware Today, Alive Tomorrow*' (...) to **prevent loss of control** accidents (...)"

ICAO · OACI · ИКАО
国际民航组织 · منظمة الطيران المدني الدولية

"**High-Risk Accident** Occurrence Categories

- Runway safety related events;
- **Loss of control in-flight**;
- Controlled flight into terrain (...)"

NATIONAL TRANSPORTATION SAFETY BOARD

"(...) accidents involving inflight loss of control (...) **still occur at an unacceptable rate**."

FEDERAL AVIATION ADMINISTRATION

"The FAA and industry are working together to **prevent Loss of Control** (LOC) accidents and save lives."

IATA

"LOC-I accidents have been assessed by the IATA Safety Department and the industry to be the **highest risk to aviation safety**, and deemed to be an area for **increased attention** (…)"

2 | What is LOC-I?

2 **LOC-I** involves situations in which neither the **crew** nor the **autoflight systems** are **capable of controlling the aircraft** flight path

2 **LOC-I** involves situations in which neither the **crew** nor the **autoflight systems** are **capable of controlling the aircraft** flight path

British Airways 38
January | 2008

Air France 447
June | 2009

Asiana 214
July | 2013

Lion Air 610
October | 2018

Ethiopian 302
March | 2019

2 **LOC-I** involves situations in which neither the **crew** nor the **autoflight systems** are **capable of controlling the aircraft** flight path

British Airways 38
January | 2008

Air France 447
June | 2009

Asiana 214
July | 2013

Lion Air 610
October | 2018

Ethiopian 302
March | 2019

2 **LOC-I** involves situations in which neither the **crew** nor the **autoflight systems** are **capable of controlling the aircraft** flight path

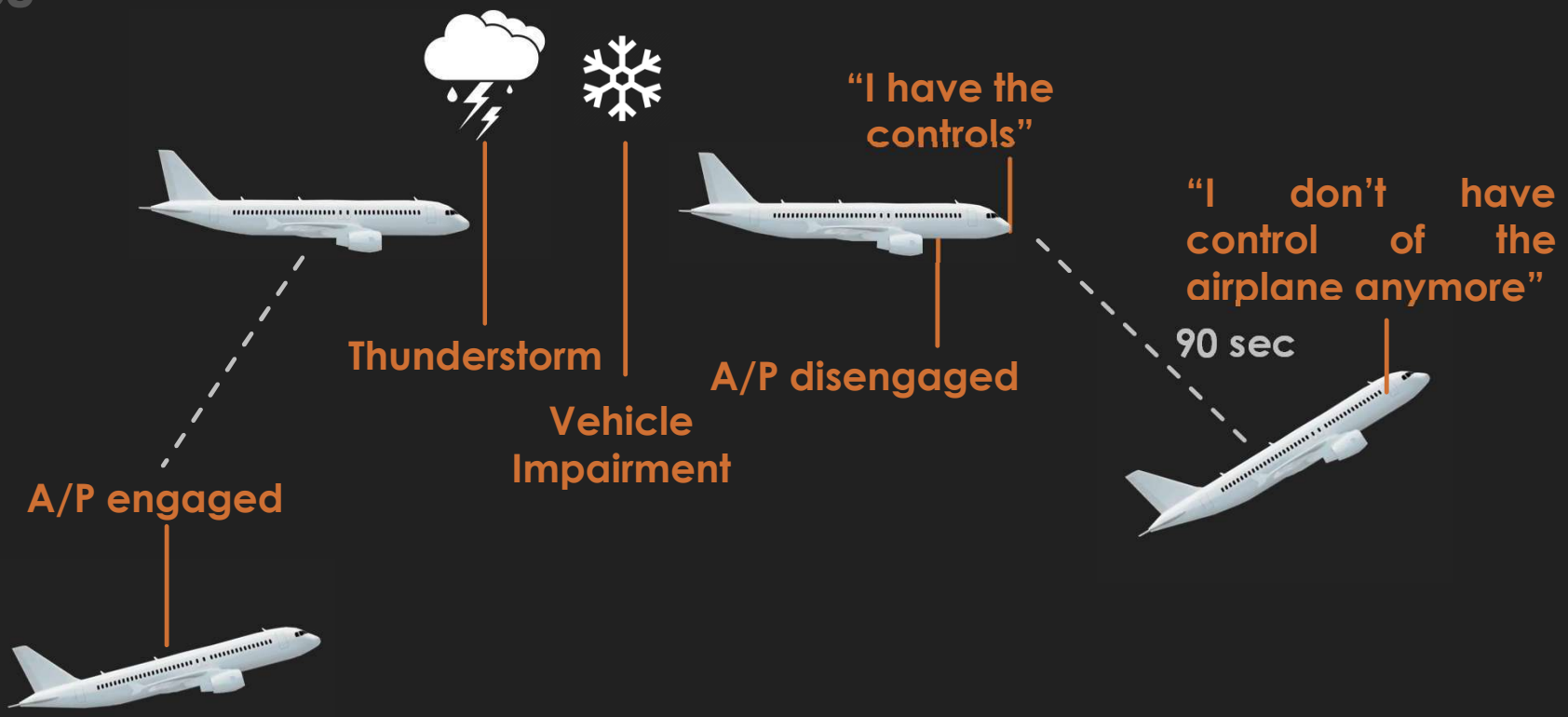
British Airways 38
January | 2008

Air France 447 [1]
June | 2009

Asiana 214
July | 2013

Lion Air 610
October | 2018

Ethiopian 302
March | 2019



Source: (1) Bureau d'Enquêtes et Analyses, Air France 447 – Final Report, 2012

2 **LOC-I** involves situations in which neither the **crew** nor the **autoflight systems** are **capable of controlling the aircraft** flight path

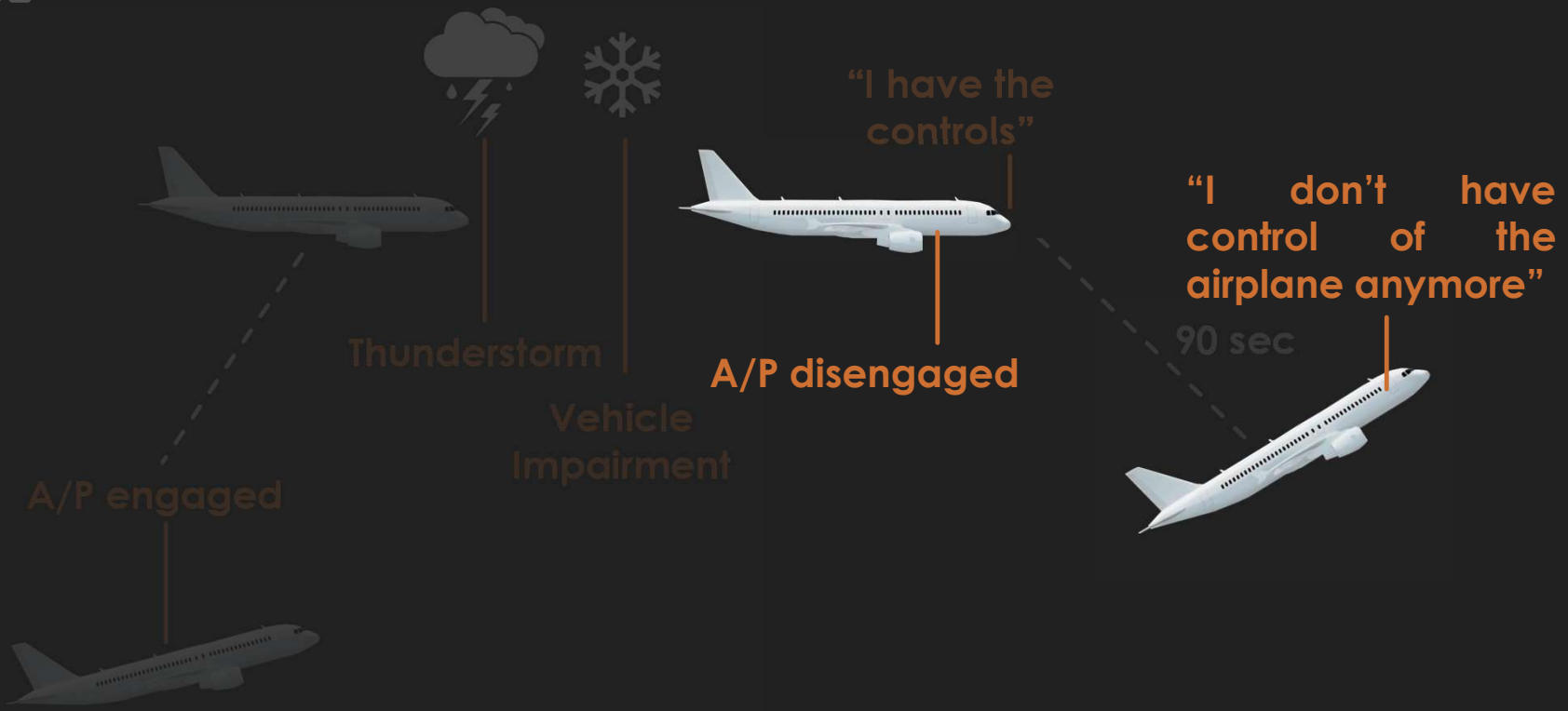
British Airways 38
January | 2008

Air France 447 [1]
June | 2009

Asiana 214
July | 2013

Lion Air 610
October | 2018

Ethiopian 302
March | 2019



Source: (1) Bureau d'Enquêtes et Analyses, Air France 447 – Final Report, 2012

2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

LOC-I precursors

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

LOC-I precursors

Adverse Onboard Conditions

- Adverse Vehicle Conditions
  - Vehicle Impairment
  - System Faults, Failures and Errors
  - Vehicle Damage
- Inappropriate Crew Response
  - Pilot-Induced Oscillation (PIO)
  - Spatial Disorientation
  - Poor Energy Management

External Hazards/Disturbances

- Poor Visibility
- Wake Vortices
- Wind Shear, Gusts, Thunderstorms
- Snow, Icing
- Abrupt Manoeuvrings

Vehicle Upset Conditions

- Abnormal Attitude
- Abnormal Airspeed
- Abnormal Angular Rates
- Abnormal Flight Trajectory
- Uncontrolled Descent
- Stall

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

LOC-I precursors

Adverse Onboard Conditions

- Adverse Vehicle Conditions
  - Vehicle Impairment
  - System Faults, Failures and Errors
  - Vehicle Damage
- Inappropriate Crew Response
  - Pilot-Induced Oscillation (PIO)
  - Spatial Disorientation
  - Poor Energy Management

External Hazards/Disturbances

- Poor Visibility
- Wake Vortices
- Wind Shear, Gusts, Thunderstorms
- Snow, Icing
- Abrupt Manoeuvrings

Vehicle Upset Conditions

- Abnormal Attitude
- Abnormal Airspeed
- Abnormal Angular Rates
- Abnormal Flight Trajectory
- Uncontrolled Descent
- Stall

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

LOC-I precursors

Adverse Onboard Conditions

- Adverse Vehicle Conditions
  - Vehicle Impairment
  - System Faults, Failures and Errors
  - Vehicle Damage
- Inappropriate Crew Response
  - Pilot-Induced Oscillation (PIO)
  - Spatial Disorientation
  - Poor Energy Management

External Hazards/Disturbances

- Poor Visibility
- Wake Vortices
- Wind Shear, Gusts, Thunderstorms
- Snow, Icing
- Abrupt Manoeuvrings

Vehicle Upset Conditions

- Abnormal Attitude
- Abnormal Airspeed
- Abnormal Angular Rates
- Abnormal Flight Trajectory
- Uncontrolled Descent
- Stall

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

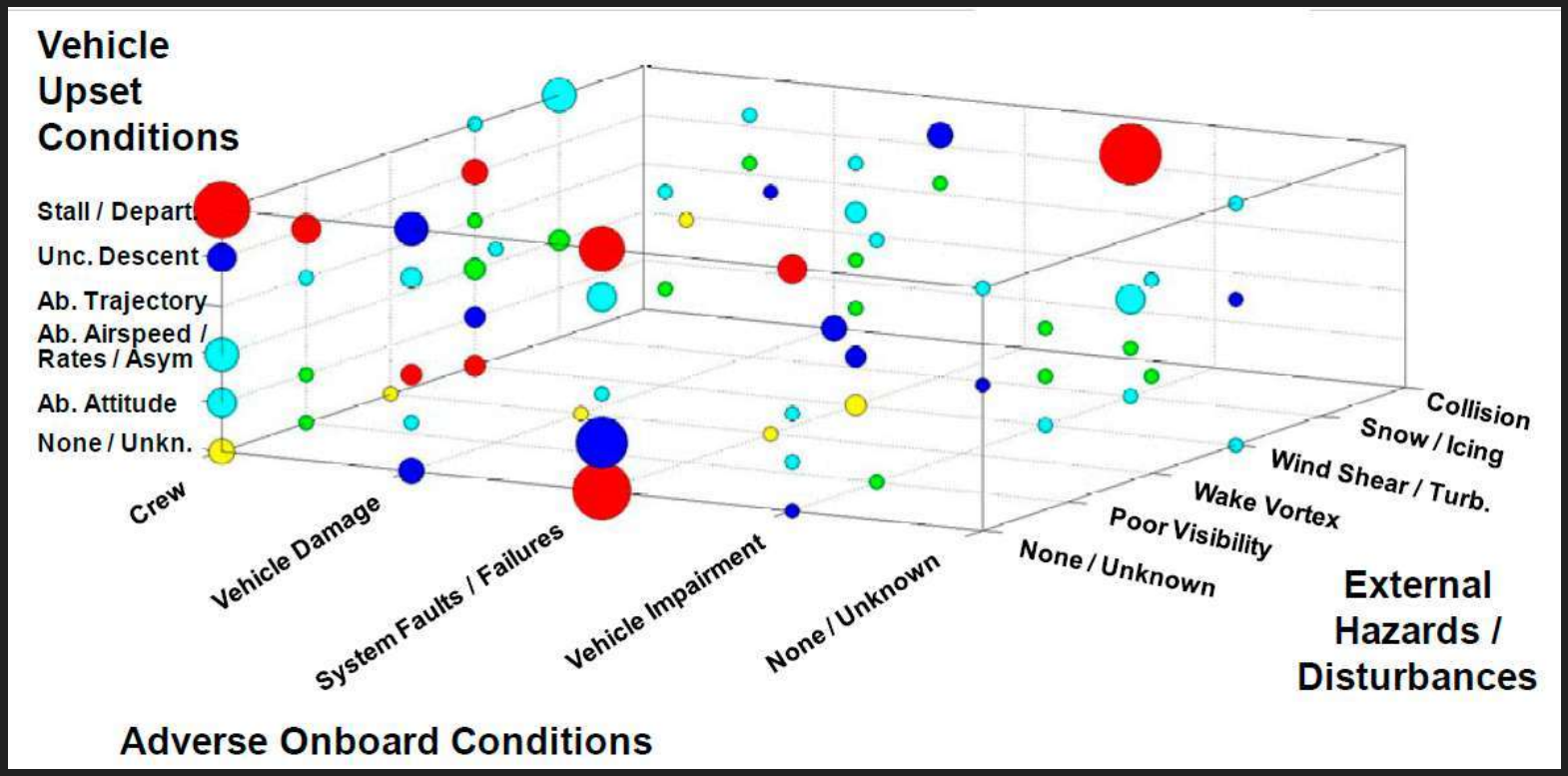
2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

Worst-case precursor combinations

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

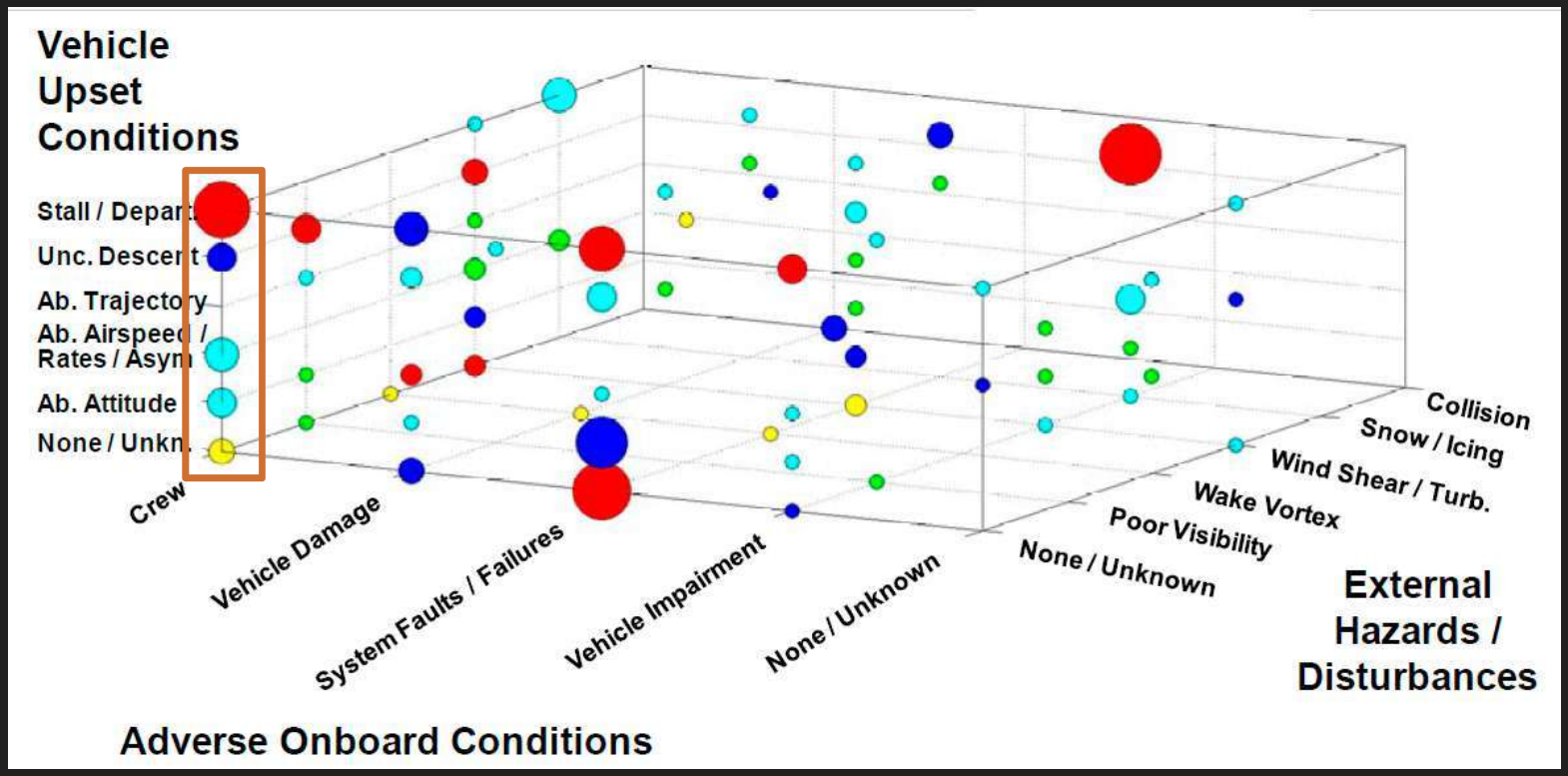
Worst-case precursor combinations



Source: (1); (Graph) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 "(…) **no single** [contributing factor] **category** is **solely** responsible for loss of control accidents (…)" [1]

Worst-case precursor combinations



Fatalities

- 0
- 1-99
- 100-199
- 200-299
- 300-More

Crew action

Vehicle upset

Source: (1); (Graph) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

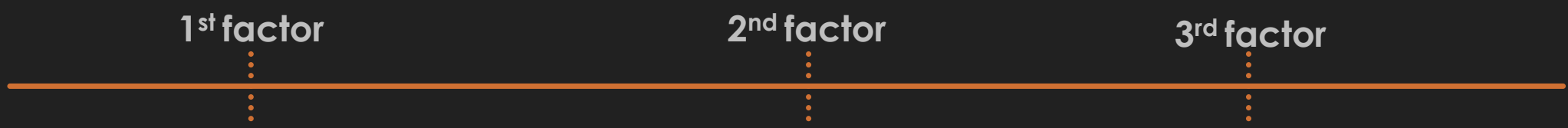
2 LOC-I accidents "occur when **combinations** of breakdown happen across **human and engineering** systems and often in the presence of **threats** posed by the **external environment**" [1]

Worst-case precursor temporal sequences

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 LOC-I accidents "occur when **combinations** of breakdown happen across **human and engineering** systems and often in the presence of **threats** posed by the **external environment**" [1]

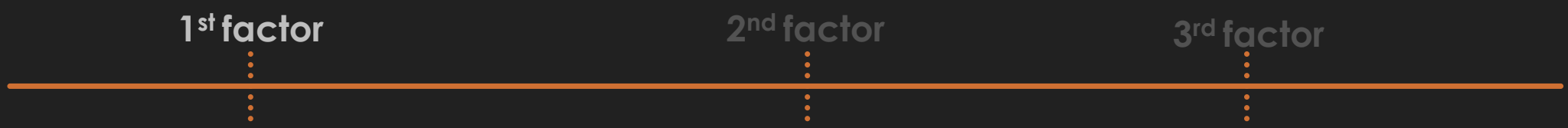
Worst-case precursor temporal sequences



Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 LOC-I accidents "occur when **combinations** of breakdown happen across **human and engineering** systems and often in the presence of **threats** posed by the **external environment**" [1]

Worst-case precursor temporal sequences



Adverse onboard condition

- System faults
- Inappropriate crew response

External hazard/disturbance

- Snow/Icing
- Wind Shear/Gusts/Thunderstorms

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 LOC-I accidents "occur when **combinations** of breakdown happen across **human and engineering** systems and often in the presence of **threats** posed by the **external environment**" [1]

Worst-case precursor temporal sequences

1st factor	2nd factor	3rd factor
Adverse onboard condition System faults Inappropriate crew response	Adverse onboard condition Vehicle impairment Inappropriate crew response	
External hazard/disturbance Snow/Icing Wind Shear/Gusts/Thunderstorms	Vehicle upset Stall Abnormal attitude	

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 LOC-I accidents "occur when **combinations** of breakdown happen across **human and engineering** systems and often in the presence of **threats** posed by the **external environment**" [1]

Worst-case precursor temporal sequences

1st factor	2nd factor	3rd factor
Adverse onboard condition System faults Inappropriate crew response	Adverse onboard condition Vehicle impairment Inappropriate crew response	Vehicle upset Stall
External hazard/disturbance Snow/Icing Wind Shear/Gusts/Thunderstorms	Vehicle upset Stall Abnormal attitude	Adverse onboard condition Inappropriate crew response

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

2 LOC-I accidents "occur when **combinations** of breakdown happen across **human and engineering** systems and often in the presence of **threats** posed by the **external environment**" [1]

Worst-case precursor temporal sequences

1st factor	2nd factor	3rd factor
Adverse onboard condition System faults Inappropriate crew response	Adverse onboard condition Vehicle impairment Inappropriate crew response	Vehicle upset Stall
External hazard/disturbance Snow/Icing Wind Shear/Gusts/Thunderstorms	Vehicle upset Stall Abnormal attitude	Adverse onboard condition Inappropriate crew response

Source: (1) Belcastro C and Foster J, Loss-of-Control Accident Analysis, 2010

3 | Motivation and Objectives

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

If so well described, why **LOC-I accidents still occur at an unacceptable rate** or even why we **could not incorporate widespread defences** to prevent it from happening?

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon.

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

LOC-I accident

Qualitative

- Human pilot assessment

Quantitative

- Physical outputs
- Engineering variables

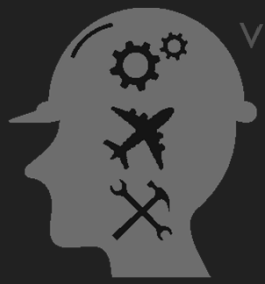
3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

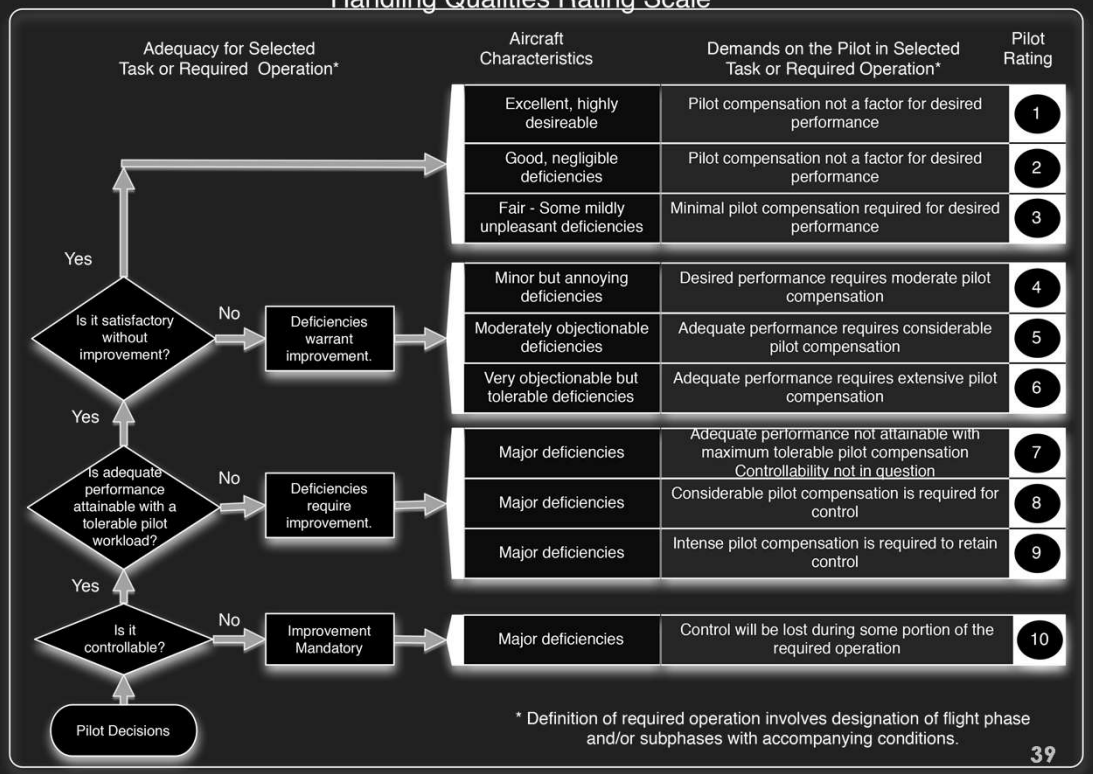
LOC-I accident

Qualitative ····· **Quantitative**

- Human pilot assessment
- Physical outputs
- Engineering variables



Handling Qualities Rating Scale



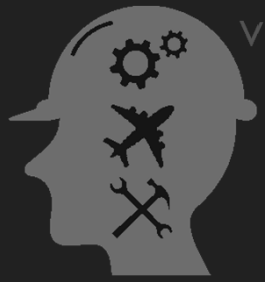
3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

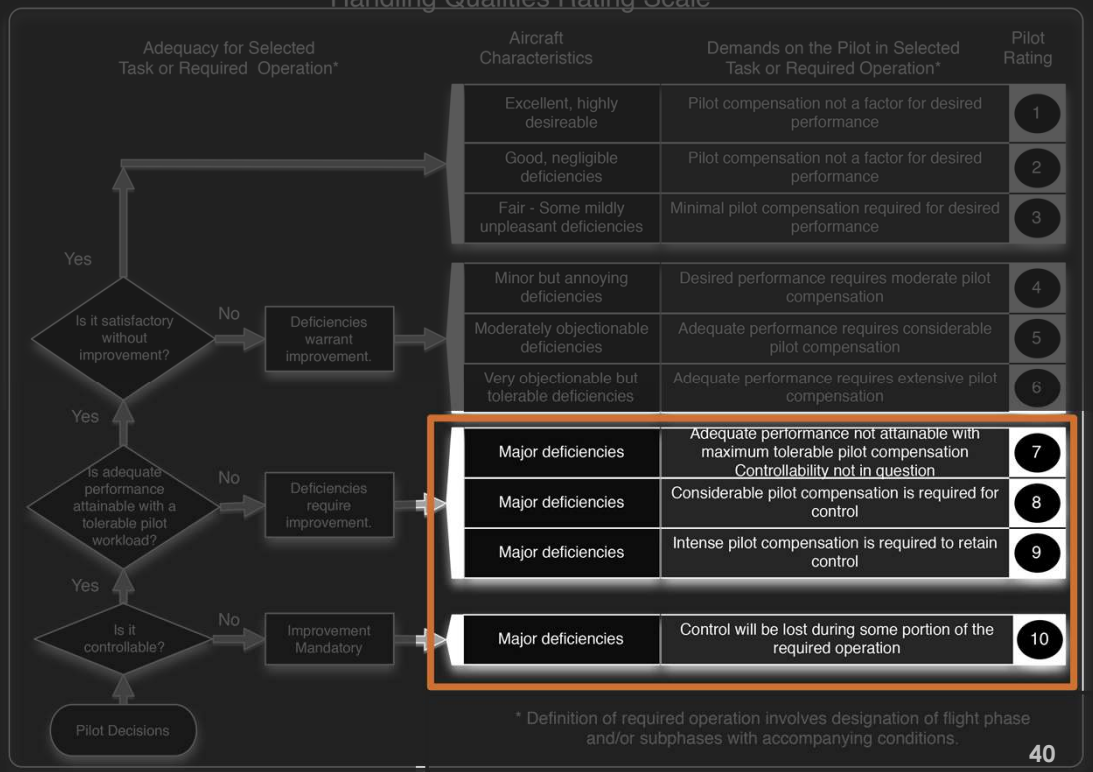
LOC-I accident

Qualitative ····· **Quantitative**

- Human pilot assessment
- Physical outputs
- Engineering variables



Handling Qualities Rating Scale



3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

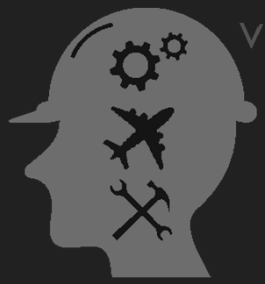
LOC-I accident

Qualitative

- Human pilot assessment

Quantitative

- Physical outputs
- Engineering variables



Adequate performance not attainable with **maximum tolerable pilot compensation. Controllability not in question**	**7**
Considerable pilot compensation is required for control	**8**
Intense pilot compensation is required to retain control	**9**
Control will be lost during some portion of the required operation	**10**

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

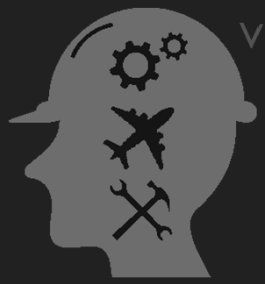
LOC-I accident

Qualitative

- Human pilot assessment

Quantitative

- Physical outputs
- Engineering variables



Adequate performance not attainable with **maximum tolerable pilot compensation. Controllability not in question**	**7**
Considerable pilot compensation is required for control	**8**
Intense pilot compensation is required to retain control	**9**
Control will be lost during some portion of the required operation	**10**

Near-LOC-I

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

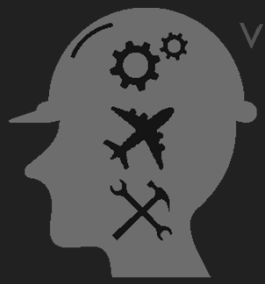
LOC-I accident

Qualitative

- Human pilot assessment

Quantitative

- Physical outputs
- Engineering variables



Adequate performance not attainable with **maximum tolerable pilot compensation. Controllability not in question**	7	Near-LOC-I
Considerable pilot compensation is required for control	8	
Intense pilot compensation is required to retain control	9	
Control will be lost during some portion of the required operation	10	LOC-I

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

LOC-I accident

Qualitative

- Human pilot assessment

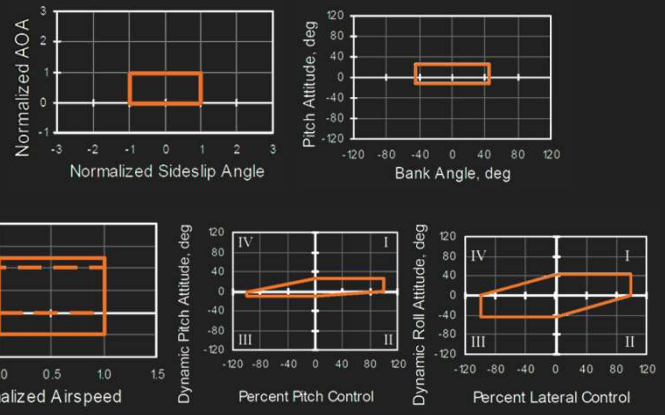
Quantitative

- Physical outputs
- Engineering variables

Quantitative Loss of Control Criteria – QLC

Methodology: parametric analysis

- **Flight dynamics**
- **Aerodynamics**
- **Structural integrity**
- **Flight control use**



Source: (1) (Graph) Wilborn J and Foster J, Defining Commercial Transport Loss-of-Control: A Quantitative Approach, 2004

3 LOC-I: a redefinition based on qualitative **and** quantitative approaches
Motivation and objectives

The development and incorporation of defences to LOC-I accidents depend on the **better characterisation** of the phenomenon. In order to accomplish a redefinition, the strategy is to correlate **human assessment** and the **physical behavior** of the aircraft

LOC-I accident

Qualitative

- Human pilot assessment

Quantitative

- Physical outputs
- Engineering variables

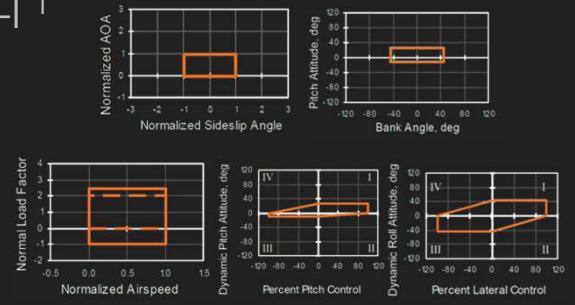
Quantitative Loss of Control Criteria – QLC

Criteria: number of envelopes crossed

One envelope: normal manoeuvres, even if aggressive

Two envelopes: borderline LOC-I condition

Three envelopes: "seems to be a good working definition" for LOC-I [1]



Source: (1) (Graph) Wilborn J and Foster J, Defining Commercial Transport Loss-of-Control: A Quantitative Approach, 2004

4 | Flight Test Simulations

4 The **handling qualities** of the aircraft are **evaluated** in a **full-flight simulator** for a set of **LOC-I test scenarios** and **different pilots**

4 The **handling qualities** of the aircraft are **evaluated** in a **full-flight simulator** for a set of **LOC-I test scenarios** and **different pilots**

EESC-USP's 6DOF flight simulator

Boeing 777-200ER

4 The **handling qualities** of the aircraft are **evaluated** in a **full-flight simulator** for a set of **LOC-I test scenarios** and **different pilots**

EESC-USP's 6DOF flight simulator

Boeing 777-200ER

10 scenarios

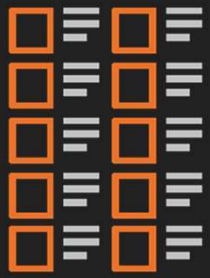
*"Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery", **Christine Belcastro**, **NASA** Langley Reasearch Center*

4 The **handling qualities** of the aircraft are **evaluated** in a **full-flight simulator** for a set of **LOC-I test scenarios** and **different pilots**

EESC-USP's 6DOF flight simulator

Boeing 777-200ER

10 scenarios



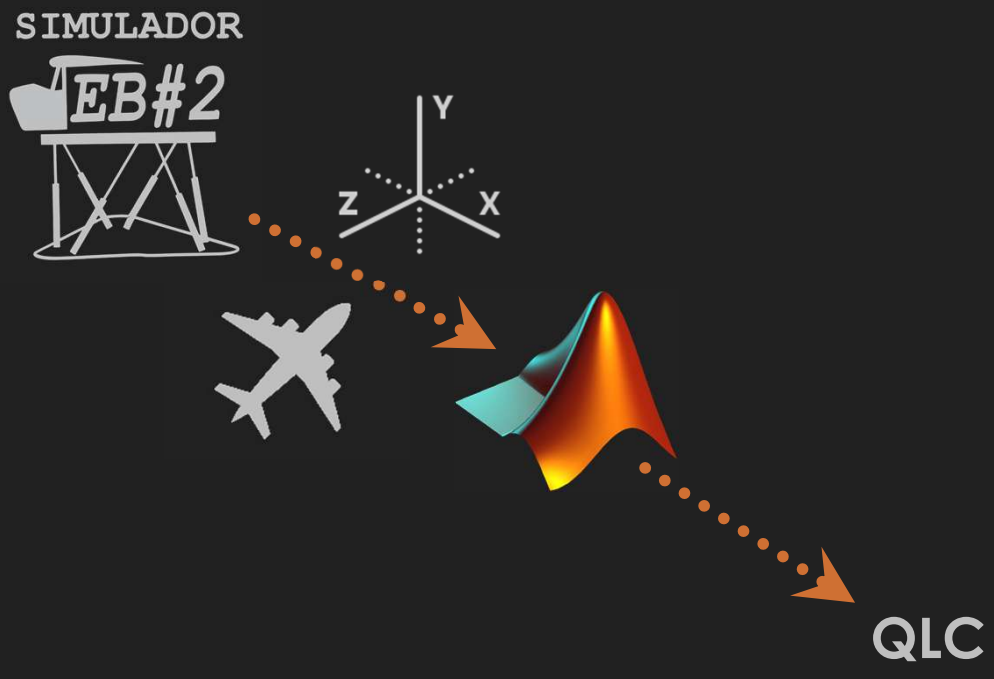
3 pilots

4 The **handling qualities** of the aircraft are **evaluated** in a **full-flight simulator** for a set of **LOC-I test scenarios** and **different pilots**

From each simulation, **pilots** are asked to **provide a rating within the Cooper-Harper scale** and the **simulation software is paired with MATLAB** to **transmit and save** the **variables of interest**

7
8 ***Near*-LOC-I**
9

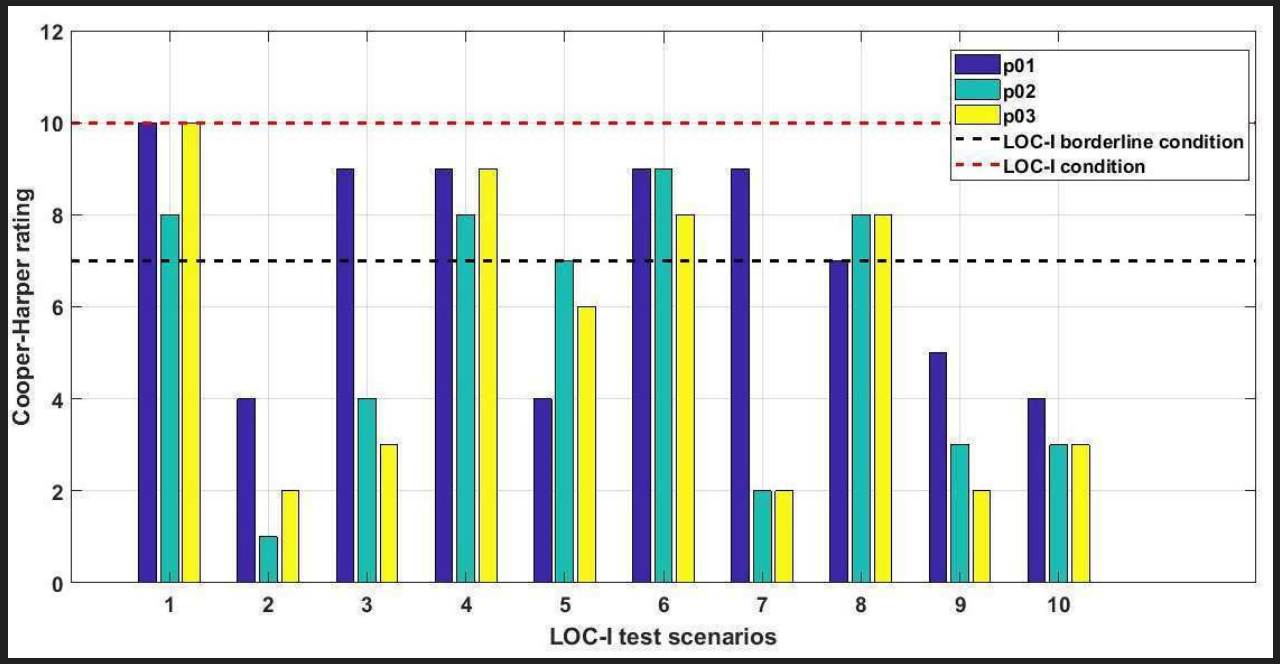
10 **LOC-I**



5 | Results and Discussion

5 **Individual agreements**, although no correlation

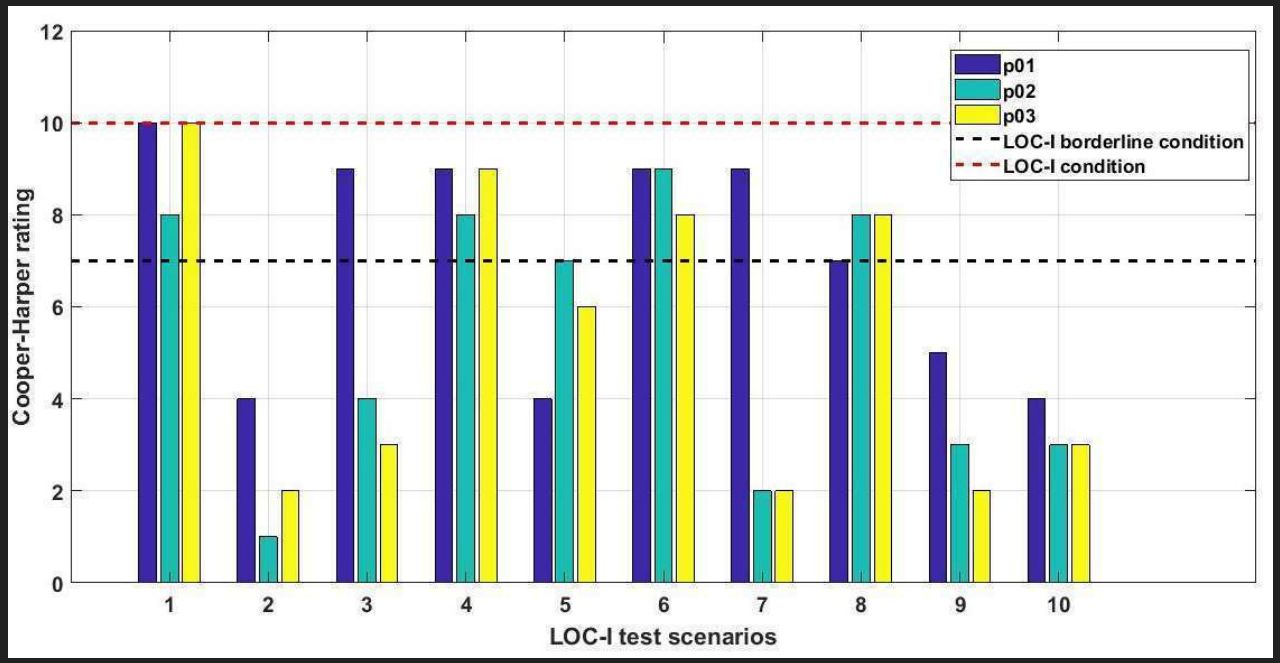
Human assessment – Cooper-Harper Rating Scale



5 **Individual agreements**, although no correlation

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

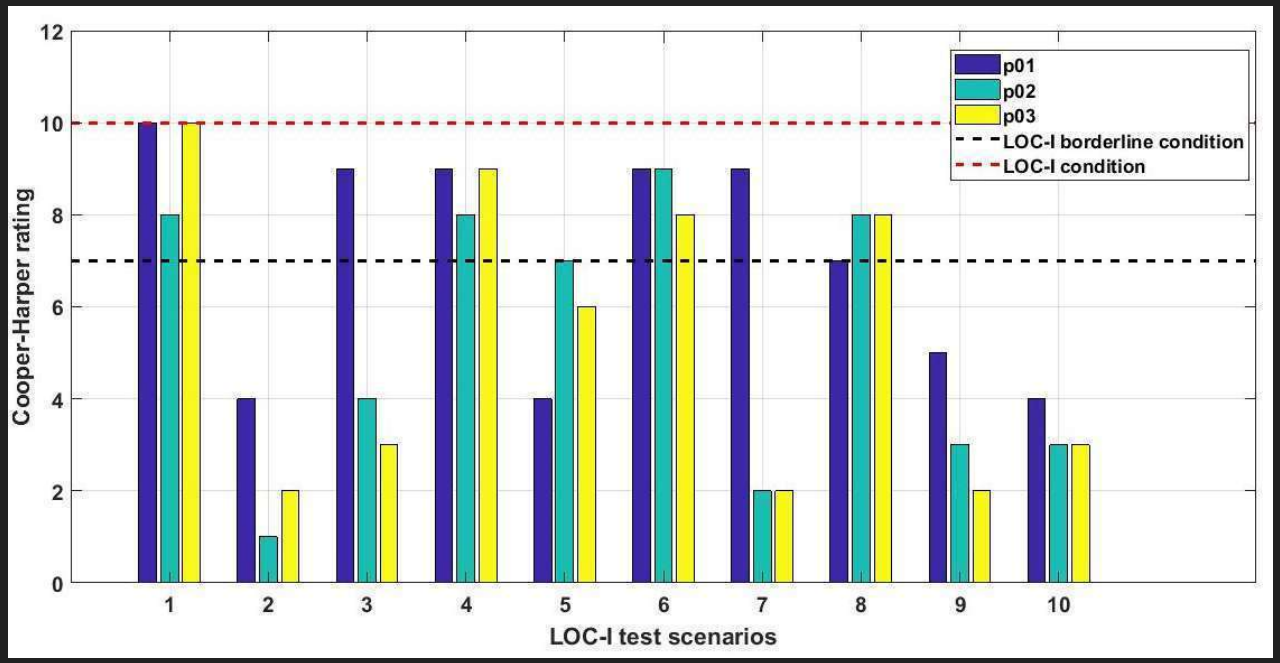
Human assessment – Cooper-Harper Rating Scale



5 **Individual agreements**, although no correlation

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

Human assessment – Cooper-Harper Rating Scale



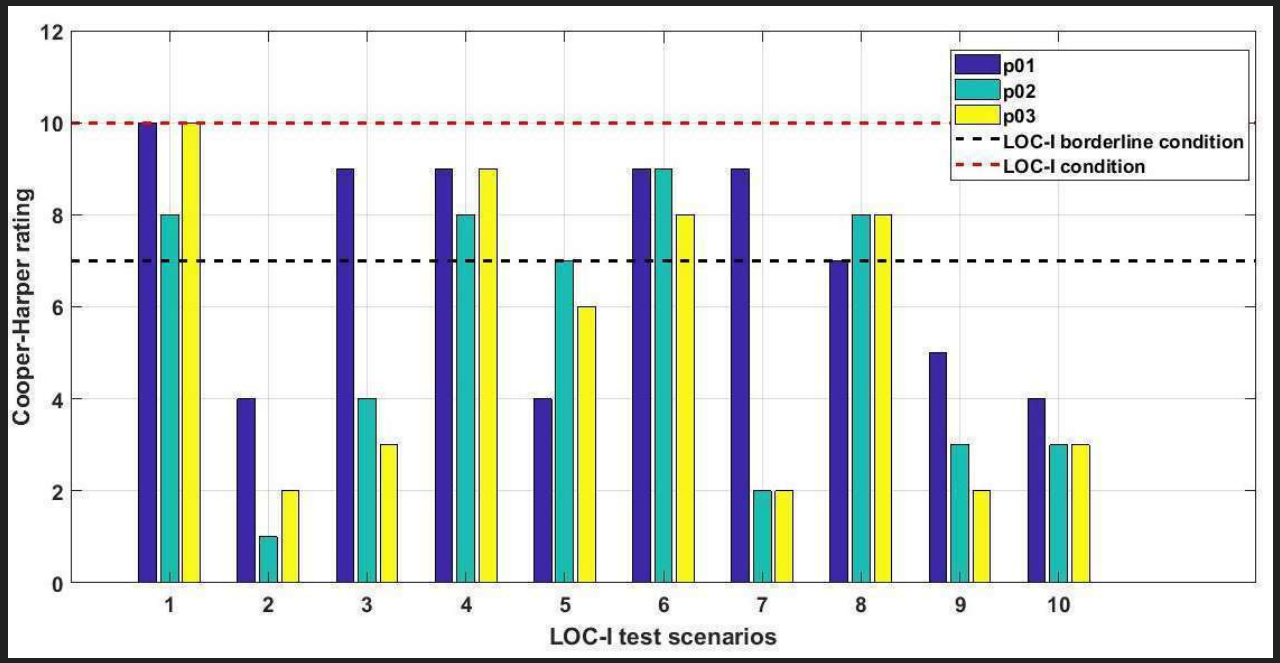
1

Agreement about the handling quality category for the majority of the pilots

5 **Individual agreements**, although no correlation

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

Human assessment – Cooper-Harper Rating Scale



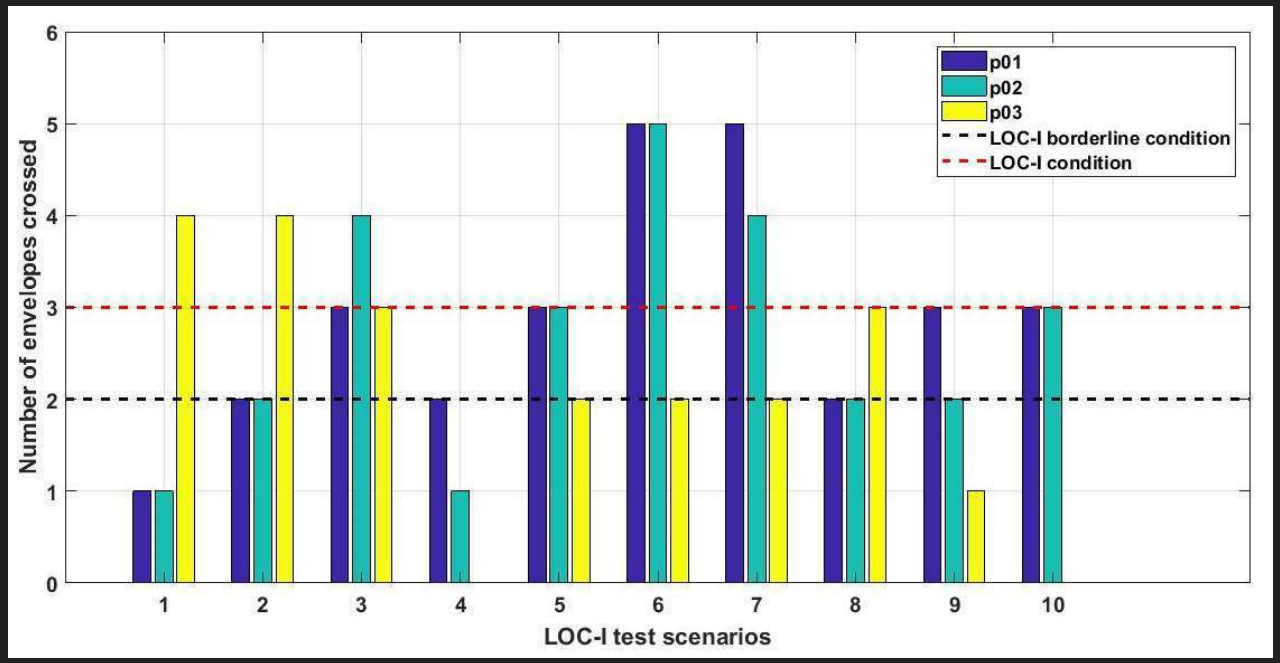
1 **Agreement about the handling quality category** for the majority of the pilots

2 Most of the scenarios were capable of bringing at least one of the pilots to a **controllability threshold** (ratings 7 to 9) or even to the **loss of control** condition (rating 10)

5 **Individual agreements**, although no correlation

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

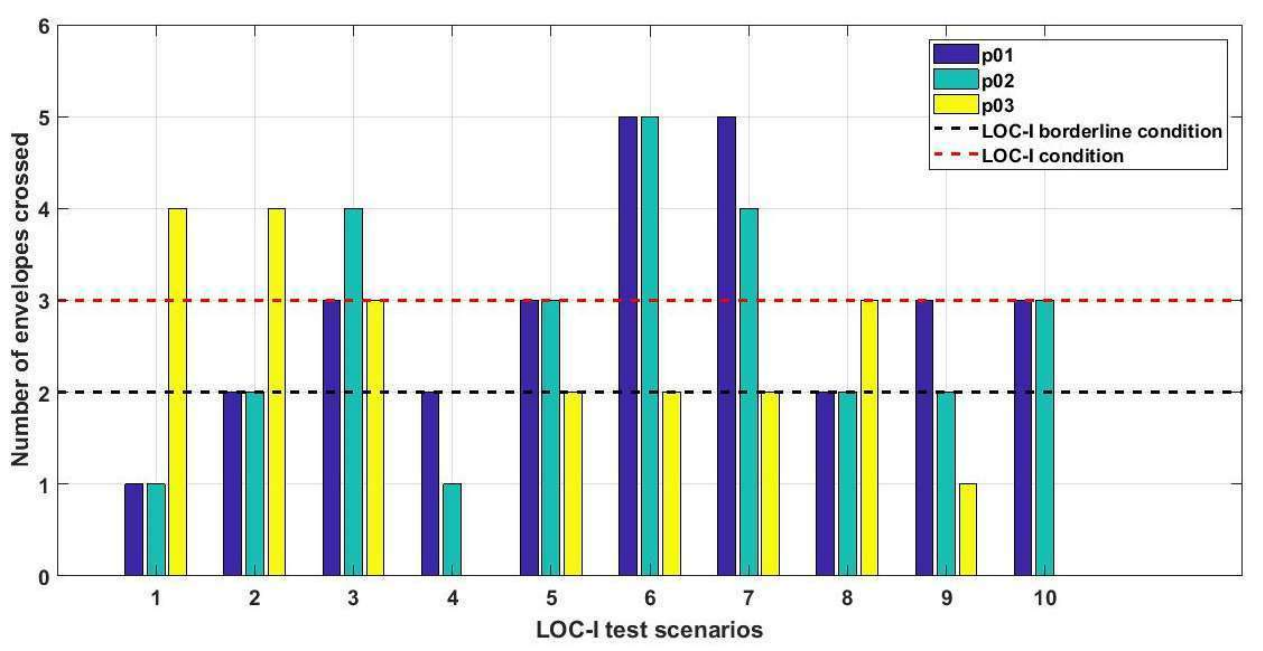
Aircraft behaviour – Quantitative Loss of Control Criteria



5 **Individual agreements**, although no correlation

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

Aircraft behaviour – Quantitative Loss of Control Criteria



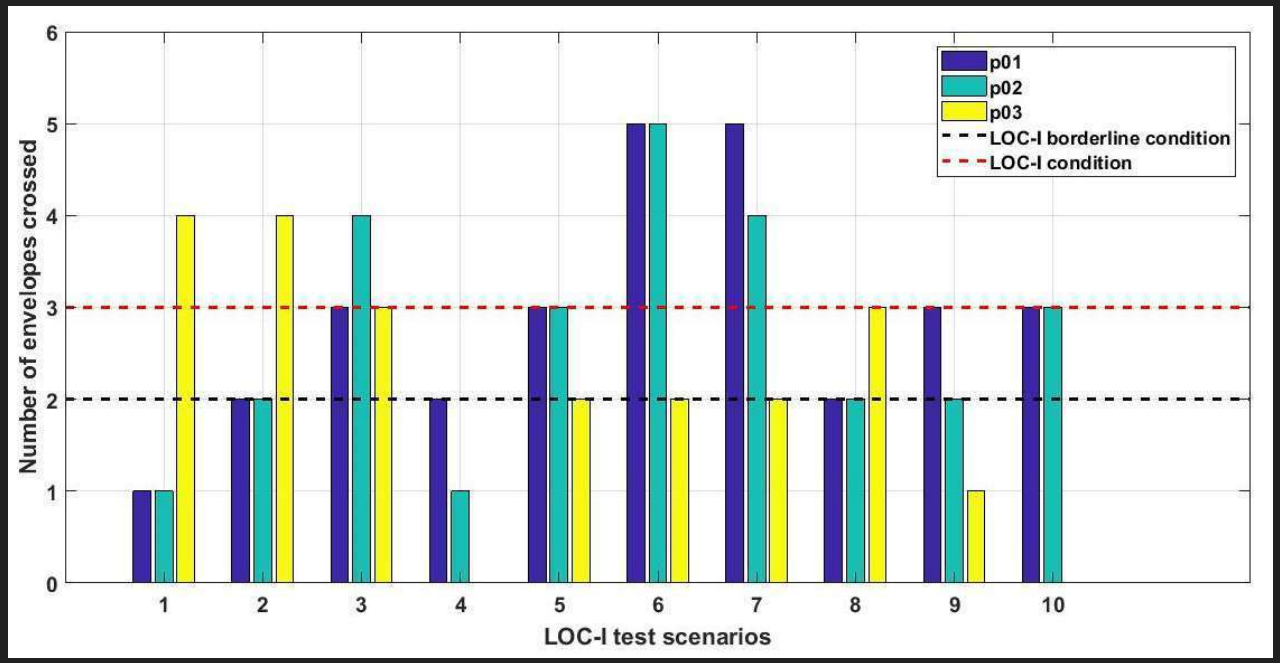
1 **Agreement about the QLC category** for the majority of the pilots [1]

(1) Exception made for scenario 9

5 **Individual agreements**, although no correlation

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

Aircraft behaviour – Quantitative Loss of Control Criteria



1 **Agreement about the QLC category** for the majority of the pilots [1]

2 Every scenario was capable of bringing at least one of the pilots to a **borderline LOC-I condition** (2 envelopes crossed) or even to the **loss of control** situation (3 envelopes crossed)

(1) Exception made for scenario 9

5 Individual agreements, although **no correlation**

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

Human assessment **and** Aircraft behaviour

Scenario	1	2	3	4	5	6	7	8	9	10
Cooper-Harper	LOC-I	-----	-----	Near-LOC-I	-----	Near-LOC-I	-----	Near-LOC-I	-----	-----
QLC	-----	Near-LOC-I	LOC-I	-----	Near-LOC-I	LOC-I	LOC-I	Near-LOC-I	-----	LOC-I

The Table reflects the results for the majority of the pilots

5 Individual agreements, although **no correlation**

Despite the **consonance between pilots** when **individually** looking at the human factor perception about LOC-I potential occurrences and the quantitative definition of the accident, **joint observation** of data reveals that, indeed, there is **no correlation between the approaches**

Human assessment **and** Aircraft behaviour

Scenario	1	2	3	4	5	6	7	8	9	10
Cooper-Harper	LOC-I	-----	-----	Near-LOC-I	-----	Near-LOC-I	-----	Near-LOC-I	-----	-----
QLC	-----	Near-LOC-I	LOC-I	-----	Near-LOC-I	LOC-I	LOC-I	Near-LOC-I	-----	LOC-I

The Table reflects the results for the majority of the pilots

5 Individual agreements, although **no correlation**

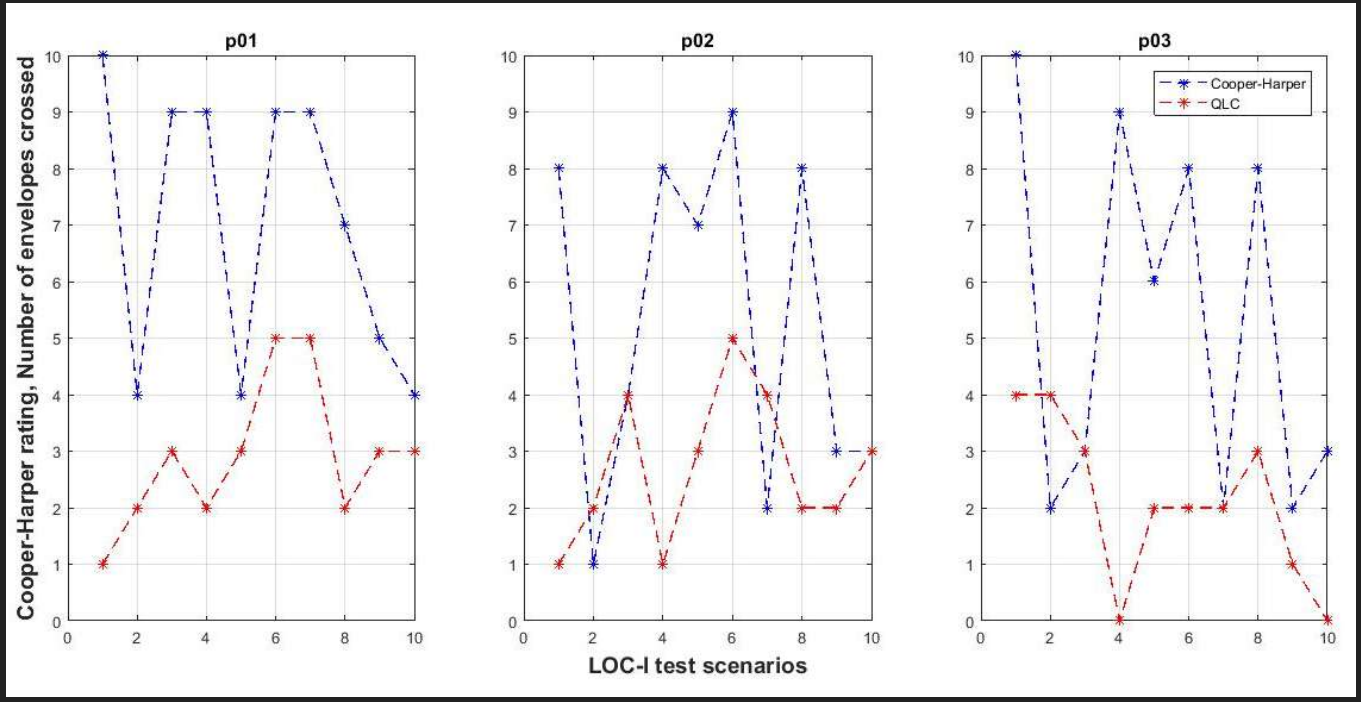
Human assessment and Aircraft behaviour

In fact, **not even a trend exists** between Cooper-Harper ratings and number of envelopes crossed

5 Individual agreements, although **no correlation**

Human assessment and Aircraft behaviour

In fact, **not even a trend exists** between Cooper-Harper ratings and number of envelopes crossed



6 | Conclusion and Future Work

6 Concluding Remarks and Future Work

Explore the outputs of the **parametric analysis** in which the QLC is based

6 Concluding Remarks and Future Work

Explore the outputs of the **parametric analysis** in which the QLC is based

Parametric analysis of 10 aircraft variables

QLC

1. **Number** of envelopes crossed

New proposal

1. **Number** of envelopes crossed;
2. **Magnitude** of the envelope **excursions**;
3. Total **time** spent **outside** the envelopes;
4. **Data** concentration **patterns;**
5. **Critical window**

6 Concluding Remarks and Future Work

Explore the outputs of the **parametric analysis** in which the QLC is based

Parametric analysis of 10 aircraft variables

QLC

1. **Number** of envelopes crossed

New proposal

1. **Number** of envelopes crossed;
2. **Magnitude** of the envelope **excursions**;
3. Total **time** spent **outside** the envelopes;
4. **Data** concentration **patterns;**
5. **Critical window**

Development of a LOC-I-specific rating scale, as it may be fundamental for future flight test campaigns analysing the validity of possible LOC-I defences

6 Concluding Remarks and Future Work

Explore the outputs of the **parametric analysis** in which the QLC is based

Parametric analysis of 10 aircraft variables

QLC

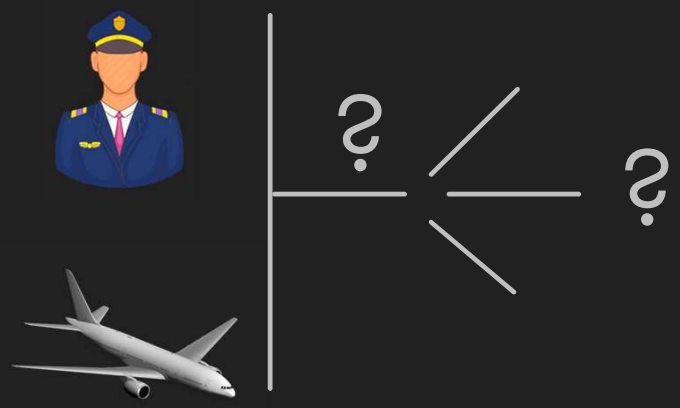
1. **Number** of envelopes crossed

New proposal

1. **Number** of envelopes crossed;
2. **Magnitude** of the envelope **excursions**;
3. Total **time** spent **outside** the envelopes;
4. **Data** concentration **patterns;**
5. **Critical window**

Development of a LOC-I-specific rating scale, as it may be fundamental for future flight test campaigns analysing the validity of possible LOC-I defences

LOC-I rating scale



6 Concluding Remarks and Future Work
Does it “solve” the issue?

6 Concluding Remarks and Future Work
Does it “solve” the issue?

No…

6 Concluding Remarks and Future Work
Does it "solve" the issue?

No…

…but it shows

- **Meagre understanding of LOC-I accidents**
- **Mismatch between its current definitions**
- **Necessity of correlating pilot and aircraft**

6 Concluding Remarks and Future Work
Does it "solve" the issue?

No…

…but it shows

- **Meagre understanding of LOC-I accidents**
- **Mismatch between its current definitions**
- **Necessity of correlating pilot and aircraft**

Solely with a clearer characterisation defences can be effective to prevent LOC-I accidents from happening and make aviation considerably safer

AERONAUTICAL ENGINEERING
USP SÃO CARLOS

Many thanks for your attention

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

EESC · USP®
São Carlos School of Engineering
University of São Paulo

João Paulo Macedo

Aeronautical Engineer | MSc student

joao.macedo@usp.br

Jorge Henrique Bidinotto

Prof. Ph.D. | Advisor & Researcher

jhbidi@sc.usp.br

7 | Extra Slides

How Scenarios were chosen

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Choice of scenarios

60 LOC-I test scenarios were developed based on a data set comprising 126 accidents of this type and 6087 fatalities occurred as consequence of them [1]

The approach is to **select a feasible number of LOC-I test scenarios**, considering:

- Representativeness of the problem;
- Research objectives;
- Deadlines

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

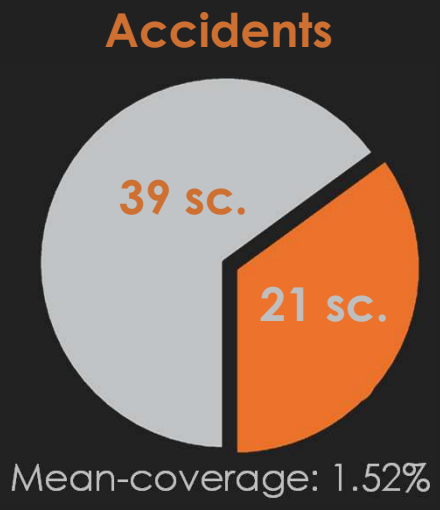
7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Choice of scenarios

60 LOC-I test scenarios were developed based on a data set comprising 126 accidents of this type and 6087 fatalities occurred as consequence of them [1]

The approach is to **select a feasible number of LOC-I test scenarios**, considering:

- Representativeness of the problem;
- Research objectives;
- Deadlines



Below-average
Above-average

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

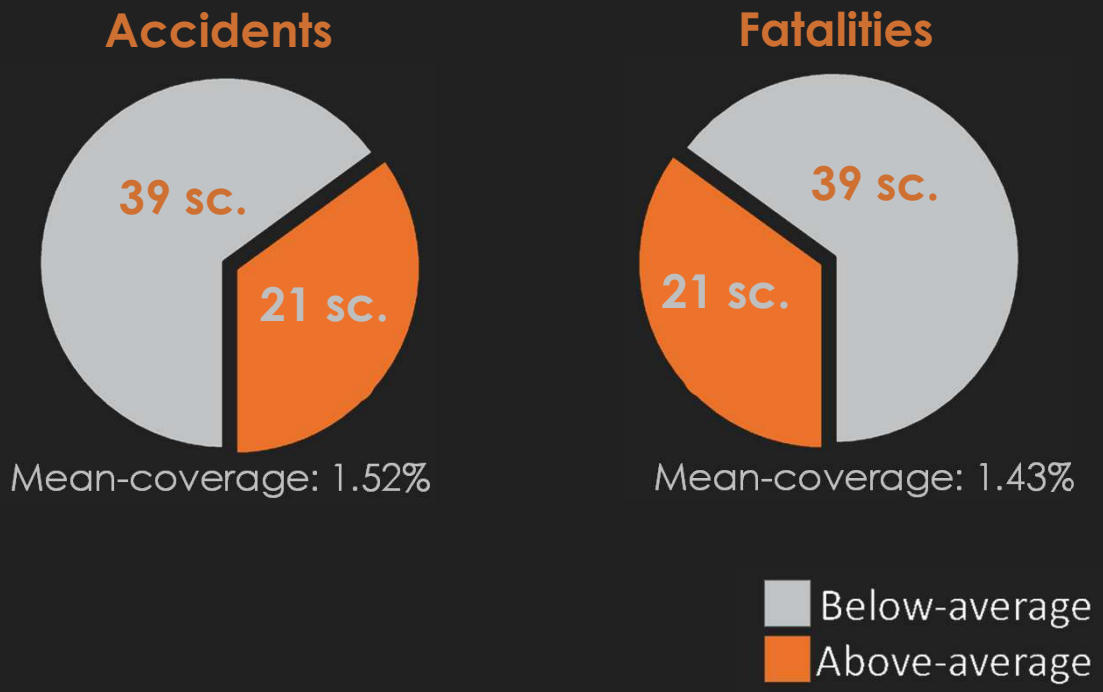
7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Choice of scenarios

60 LOC-I test scenarios were developed based on a data set comprising 126 accidents of this type and 6087 fatalities occurred as consequence of them [1]

The approach is to **select a feasible number of LOC-I test scenarios**, considering:

- Representativeness of the problem;
- Research objectives;
- Deadlines



Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

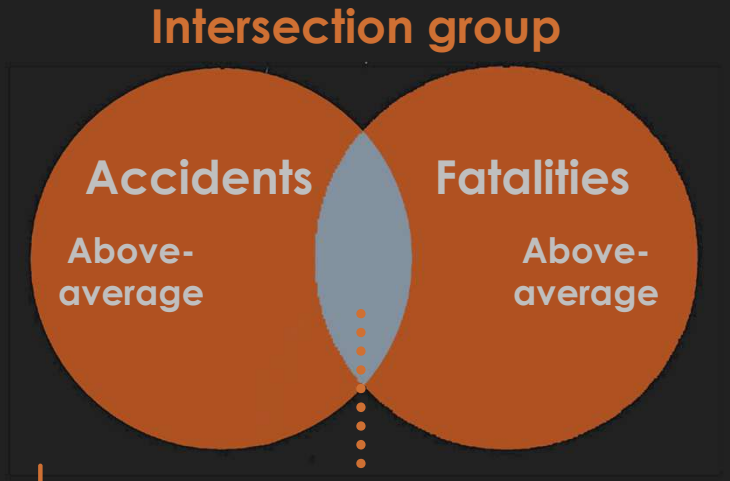
7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Choice of scenarios

60 LOC-I test scenarios were developed based on a data set comprising 126 accidents of this type and 6087 fatalities occurred as consequence of them [1]

The approach is to **select a feasible number of LOC-I test scenarios**, considering:

- Representativeness of the problem;
- Research objectives;
- Deadlines



13 scenarios
45.20% (56) of the accidents
54.25% (3302) of the fatalities

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(...) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 1 - Control surface failure during take-off

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	Loss of 100% of the elevator effectiveness	----------	----------

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(...) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 2 - Engine failure during take-off

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	100% thrust reduction of an engine	----------	----------

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(…) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 4 - Unresponsive engines during approach

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	Engine(s) response at 50% of the total available thrust, independently of the engine controller lever position	----------	Low speed stall Uncontrolled descent

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(...) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 5 - Icing impairment during take-off

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	**Elevator:** 75% loss*; **Aileron:** 50% loss, reversed*; **Rudder:** 50% loss, no-actuation for half course*; **Engine:** 2/3 of the total thrust	----------	Abnormal attitudes Stall

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(…) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 6 - Microburst encounter during final approach

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	----------	Severe microburst occurrence positioned at 2.0 nm from the runway threshold • 50 fps (≈ 30 kts) – Cessna* • 200 fps (≈ 120 kts)– Boeing*	Abnormal trajectory Stall

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(…) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 7 - Instrument indication failure together with inappropriate crew response during approach

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	Instrument failure • Altimeter – Cessna* • Airspeed – Boeing* Exacerbating control inputs Sidestick and rudder pedals six-time augmented actuation	----------	Low speed stall

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(...) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 9 - Spatial disorientation together with inappropriate crew response during approach

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	Exacerbating control inputs Sidestick and rudder pedals six-time augmented actuation	Night approach 1/2 nm visibility Airport bathed by the sea	Stall Unusual attitudes Spiral dive

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(…) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 10 - Microburst encounter together with inappropriate crew response during approach

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	Exacerbating control inputs Sidestick and rudder pedals six-time augmented actuation	Severe microburst occurrence positioned at 2.0 nm from the runway threshold • 50 fps (≈ 30 kts) – Cessna* • 200 fps (≈ 120 kts)– Boeing*	Velocity excursions Rapid descent Stall

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(…) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 11 - Bad meteorological condition together with control surface jamming during approach*

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	Rudder pedals jamming	Turbulence activity, crosswind (45°) and gusts • 7/10 kts – Cessna • 35/40 kts – Boeing	Attitude excursions Stall

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012

7 The strategy is to **reproduce** some **LOC-I test scenarios** in a **full-flight simulator**

Scenario adaptation for simulation purposes

"(…) aircraft LOC-I can result from a wide spectrum of hazards, often occurring in combination, which **cannot be fully replicated during evaluation**" [1]

Scenario 12 - Improper vehicle setting during a go-around

Phase of flight	Adverse Onboard Conditions	External Hazards/ Disturbances	Vehicle Upset Conditions
	High-lift devices fully extended*	----------	Abnormal trajectory

Source: (1) Belcastro C, Validation of Safety-Critical Systems for Aircraft Loss-of-Control Prevention and Recovery, 2012