Flight Test Safety Workshop – New Orleans, 23th to 25th Apr 2013

Embraer Risk Assessment

“Three Flags” Method

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How to avoid accidents during experimental flight testing ?

"WE'D LIKE TO BRING OUR OWN PARACHUTES... JUST IN CASE."

1935 - Prototype crashed on take-off due to locked control surfaces.

1943 - Second of top-secret prototype bombers catched fire 20 minutes after takeoff from an airfield and crashed into a plant.

1970 - First prototype crashed on its second flight after a hydraulic systems failure.

1980 - Second prototype crashed during a simulated landing with no hydraulic power.

1989 - First prototype crashed on its sixth flight, when attempting to land due to airplane-pilot coupling.

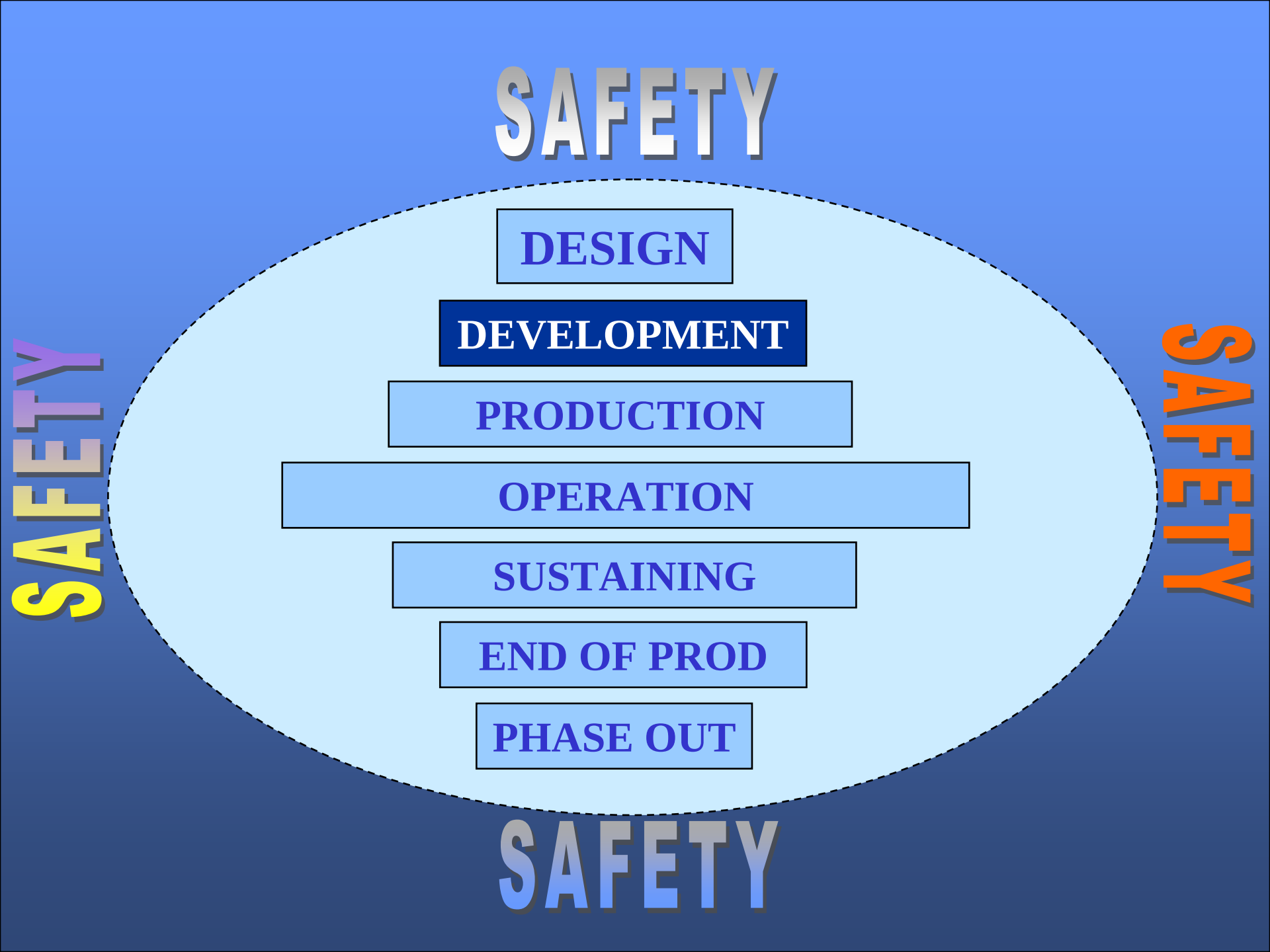
1994 - Prototype crashed while simulating an engine failure on climbout.

2003 – Second prototype crashed due to lateral loss of control at high speed characteristics tests.

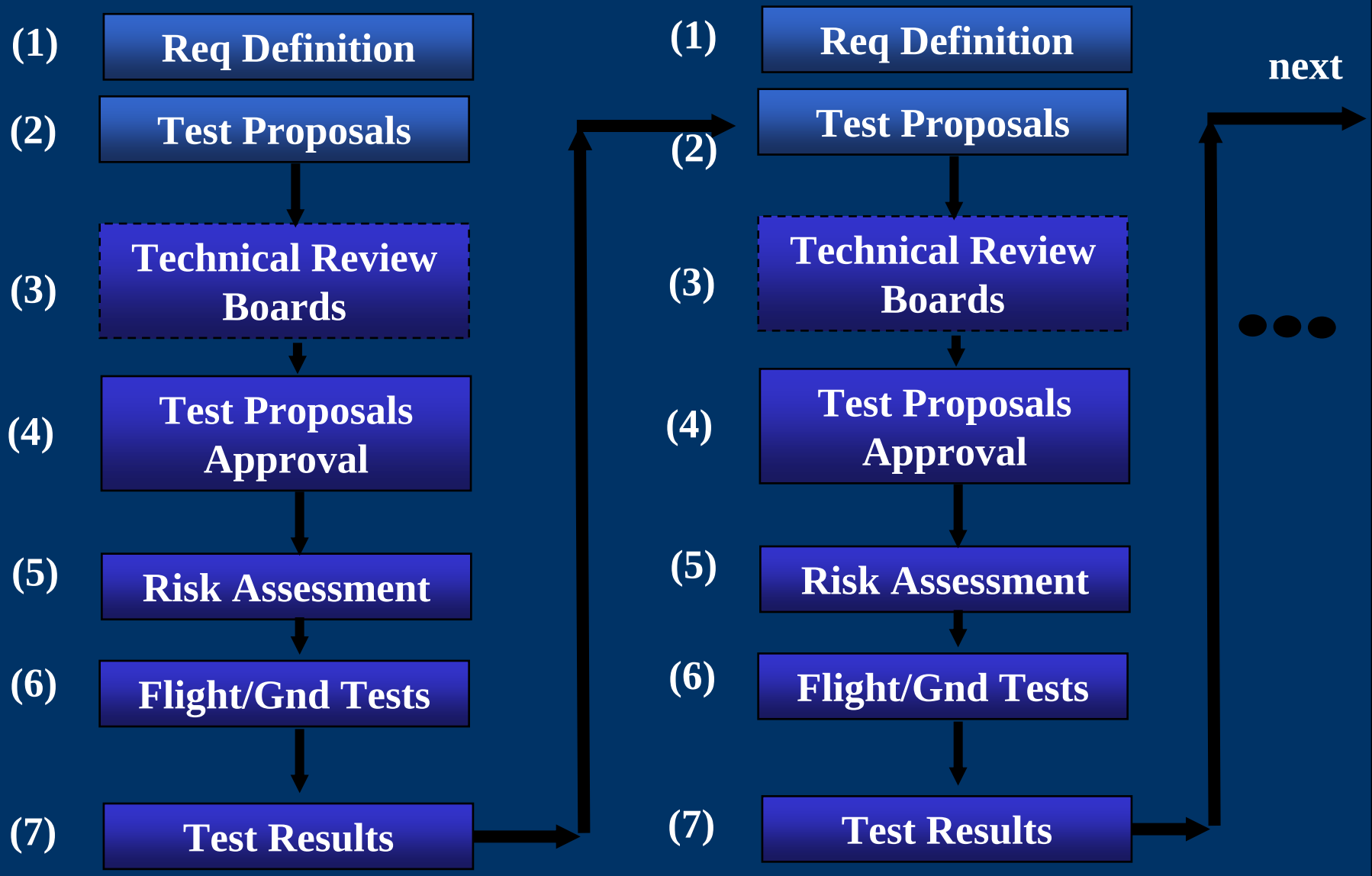
2007 - Second prototype crashed during demonstration flight near the factory due to elevator flutter.

2009 - Third prototype crashed during a high speed run.

2011 – Sixth prototype crashed during takeoff performance tests.


SAFETY
DESIGN
DEVELOPMENT
PRODUCTION
OPERATION
SUSTAINING
END OF PROD
PHASE OUT
SAFETY
SAFETY
SAFETY

Dev/Experimental Phase Steps



What can be added in these steps to enhance safety ?

1. Introduction
2. Objective
3. References
4. Flight Envelope Analysis
5. Test Point Exec Analysis
6. System Failures Analysis
7. Risk Management
8. Conclusions

Introduction

Risk Assessment Methodology has a **key** impact on safety during flight and ground tests.

It is considered that the Methodology MUST be **concise**, **effective** and should have the **ability to unveil the hazards** involved in the tests.

Objective

The goal of this presentation is to show the "**Three Flags**" Flight Test Risk Assessment Method.

References

- Embraer ENS 00650 rev 6 – Risk Assessment
- FAA Order 4040.26A/B Aircraft Certification Service Flight Test Risk Management Program

EMBRAER FT RISK ASSESSMENT PHASES

MANEUVERS TO BE EXECUTED

Flight Envelope

- Screen Factor
- Operational Envelope
- Design Envelope
- Limited Envelope

Test Point Execution

- Three Flags

System Failures

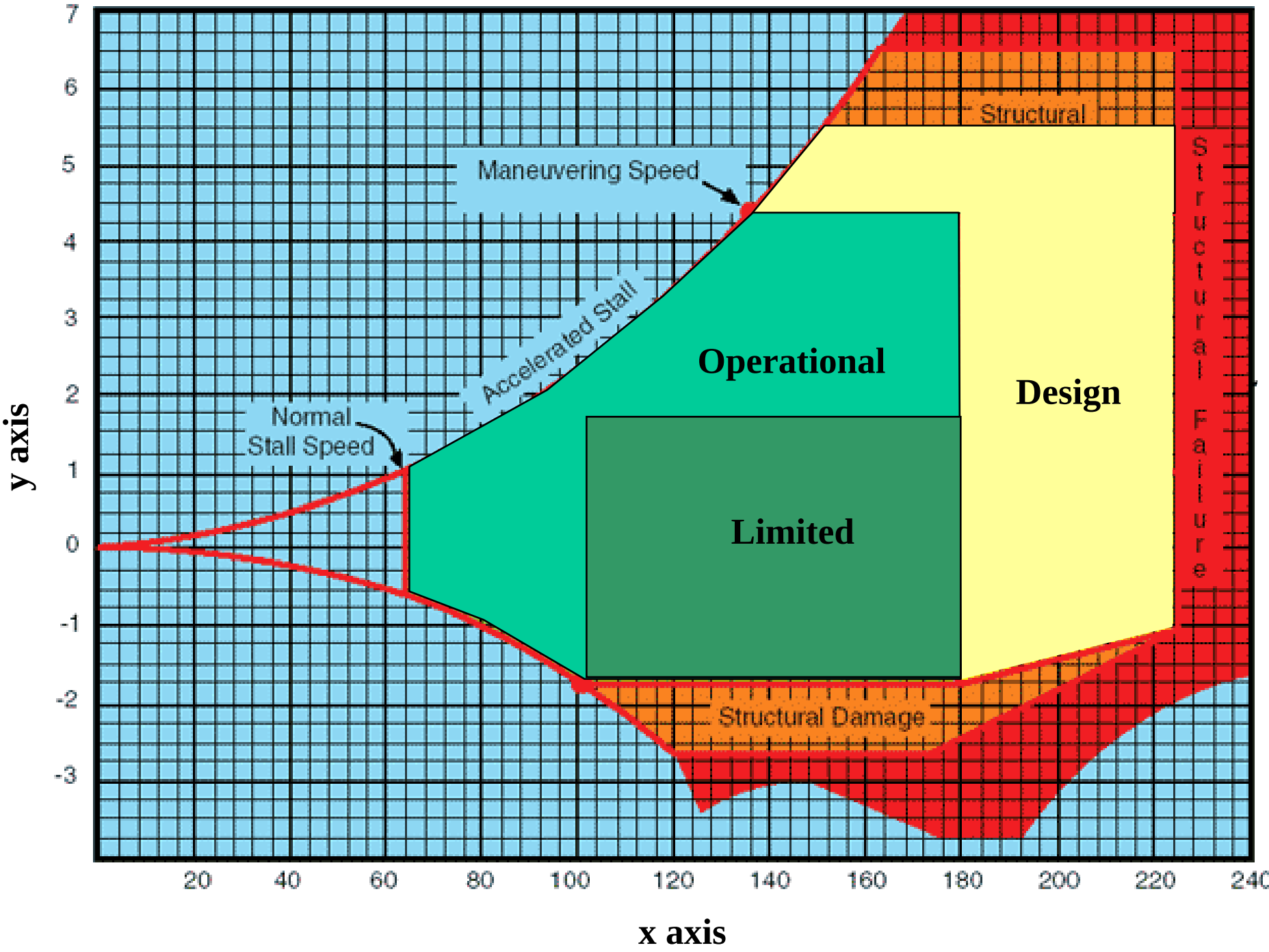
- AMJ 1309 evaluation combined with flight test effects to each failure

RISK MANAGEMENT

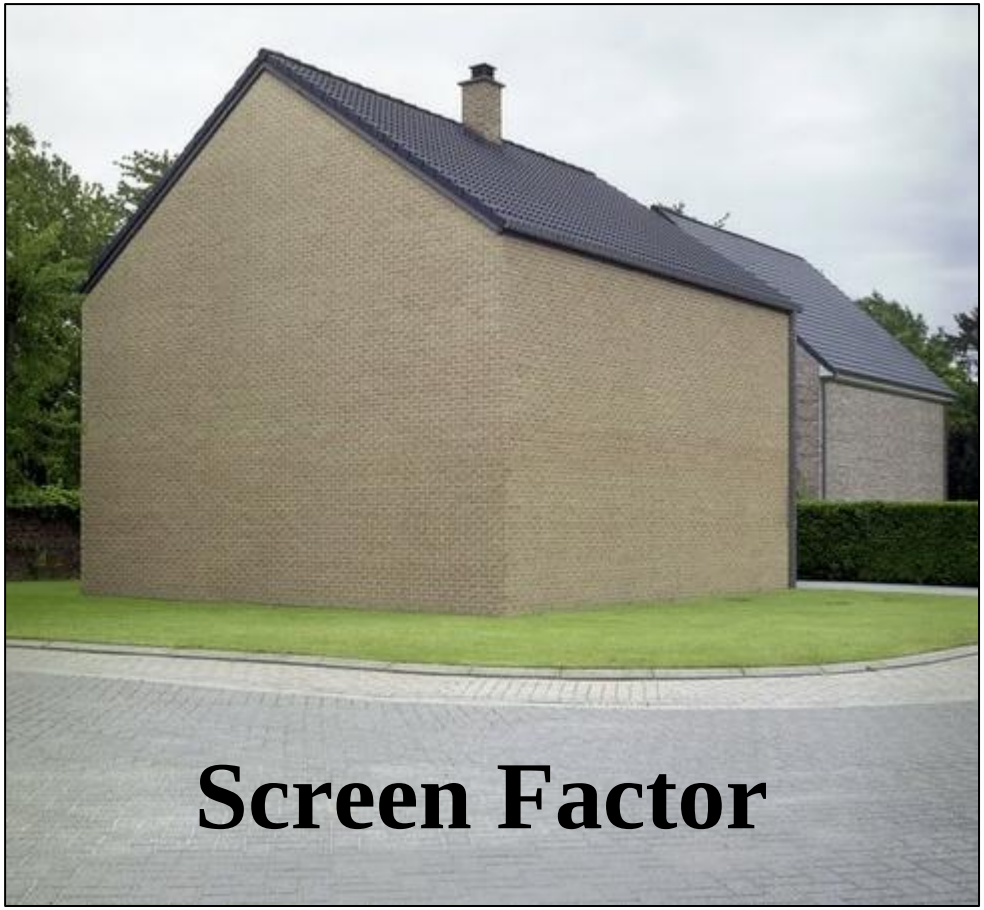
Flight Envelope

Definitions

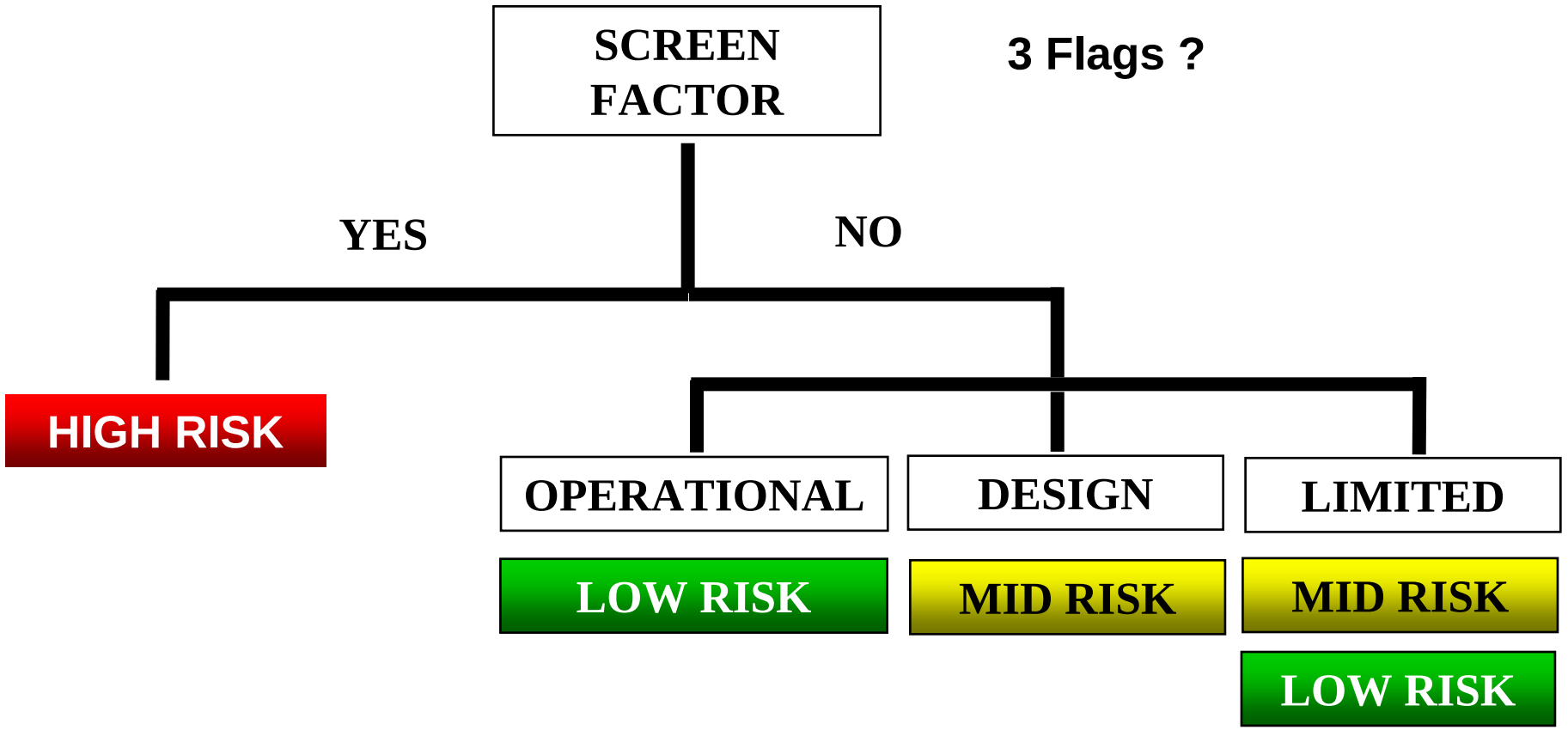
- Operational Envelope
- Design Envelope
- Limited Envelope
- Screen Factor


Structural
Maneuvering Speed
Accelerated Stall
Operational
Design
Normal
Stall Speed
Limited
Structural Failure
Structural Damage
y axis
x axis
7
6
5
4
3
2
1
0
-1
-2
-3
20
40
60
80
100
120
140
160
180
200
220
240

Definitions



Flight Envelope Analysis



THREE FLAGS

Screen Factor Tool

I – Detect Expertise on the Proposed Tests

Previous tests are sufficient to predict a safe behavior of the new proposed tests ?

II – Detect Limitations of Modeling Tools

Best available modeling tools are sufficient to predict a safe behavior for the new proposed tests?

III – Detect Type of Possible Effects of the Proposed Tests

Hazardous or catastrophic effects might result from the proposed tests if predictions are incorrect?

Test Point Execution

Test Point Execution

Considering that you might NOT have performed the maneuver ever before, the pilot can count only with:

(1) Flight Experience

(2) Expertise on the aircraft

(3) Expertise on that type of maneuver

(4) Lessons Learned

THREE FLAGS

Test Point Execution SCALE

I – Detect training or gradual approach

Necessities Is { Try-outs / Training / Gradual Approches } Needed ? And Can the lack or necessity of these affect Safety ?

II – Detect Errors Tolerances

Do { Test Tolerances / Positioning Tol. } Affect safety if extrapolated or disregarded ? And Are they Considered to be tight ?

III – Detect Recovering or Discontinuing Possibilities

When { Recovering / Discontinuing } The maneuver, is there a probable chance to get into an unsafe situation ?

System Failures

System Failures Analysis

- Based on AMJ 1309 Safety Assessment (FAA Fail Safe Design).
- Takes credit of the System Safety Assessment reports.
- However, flight test crew **MUST** define failures effects.

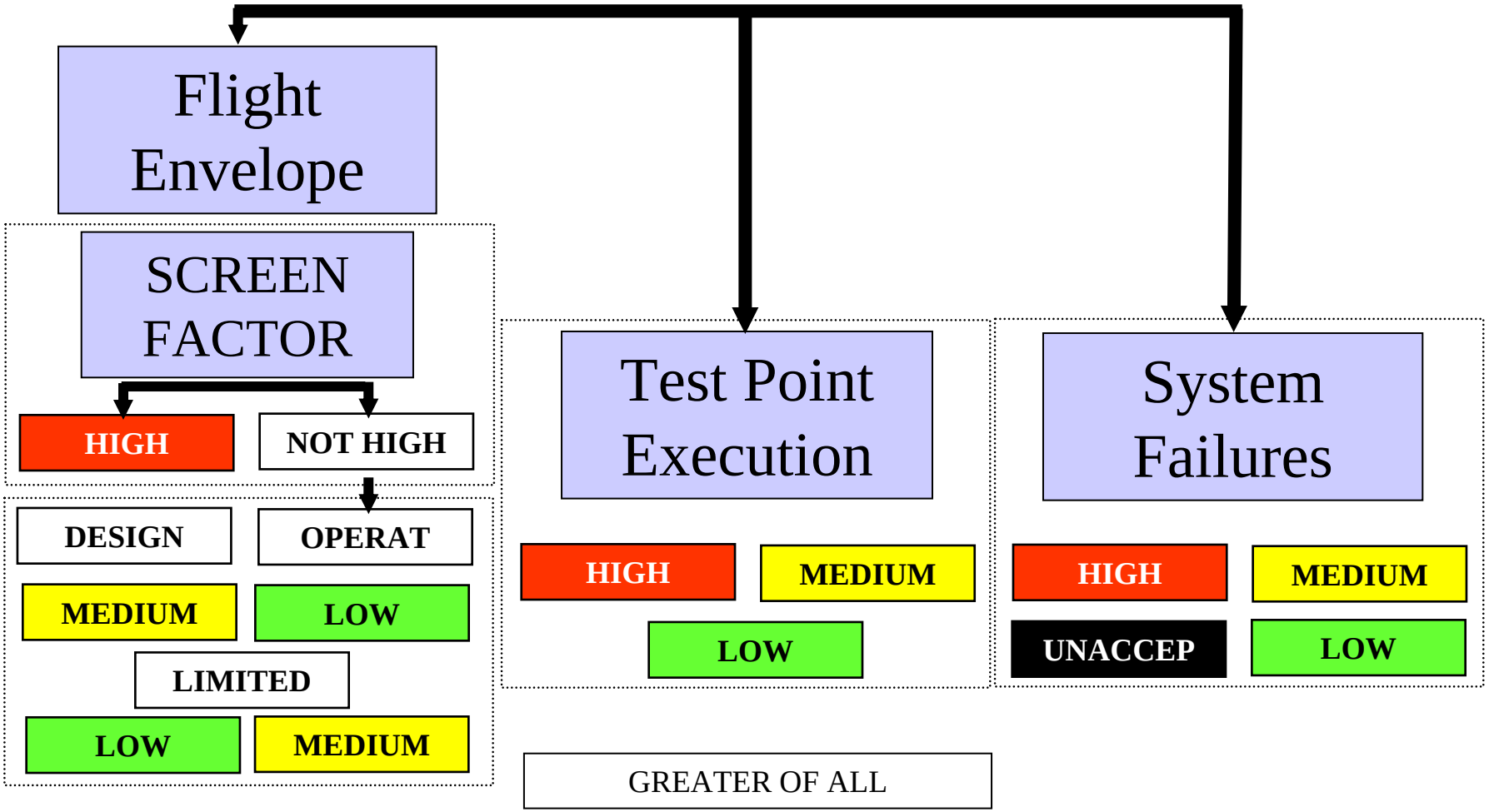
SYSTEM FAILURES EVALUATION

FINAL PROBABILITY	NO SAFETY EFFECT	MINOR	MAJOR	HAZARDOUS	CATASTROPHIC
HIGHLY PROBABLE P > 10e-3	LOW	MEDIUM	HIGH	UNACCEPTABLE	UNACCEPTABLE
PROBABLE 10e-3 > P > 10e-5	LOW			HIGH	UNACCEPTABLE
REMOTE 10e-5 > P > 10e-7	LOW	LOW			HIGH
EXTREMALLY REMOTE 10e-7 > P > 10e-9	LOW	LOW	LOW		MEDIUM
IMPROBABLE P < 10e-9	LOW	LOW	LOW	LOW	
	FAILURE EFFECT				

AMJ 1309 Analysis – Fail Safe Design

RISK DETERMINATION

MANEUVERS TO BE EXECUTED



RISK CLASSIFICATION (CR)

Management

Risk Management

-As many as you want.

-Emphasize main hazards of the test.

-Agree upon Minimizing and Mitigation procedures.

-Agree upon EMERGENCY Procedures.

Ex.

V_{MCG}

- HAZARD: Landing gear collapse.
- CAUSE(S): Shimmy and ground/flight loads;

Pro-ACTIVE

- RISK MINIMIZATION:
  1. According to the theoretical predictions the new caster is conservative in relation to shimmy. However, the new landing gear shimmy characteristics were not simulated. A ground test with and without the steering spring will be performed to access the shimmy and control characteristics of the new nose landing gear.
  2. The landing gear loads predicted are 1% higher than in previous design.

Re-ACTIVE

- RISK MITIGATION
  1. Firefighters standing by.
  2. Ambulance standing by.
- EMERGENCY PROCEDURES
  1. REDUCE ENGINES to IDLE.
  2. USE STEERING to CONTROL the Aircraft.

DESIRABLE BYPRODUCTS OF THE METHOD

METEOROLOGICAL CONDITIONS

Risk Classification	METEOROLOGICAL CONDITION (TEST AREA AND DESTINATION/ALTERNATIVE)
LOW	VMC/IMC (according to test requirements)
MEDIUM	VMC/IMC (according to test requirements)
HIGH	VMC (necessary)
1ST FLIGHT	VMC (necessary)

CREW MINIMUM REQUIREMENTS

Pilots

Classification	Experience (years)	Total Flight Experience (flight hours)	Minimum Pilot Crew Parte 23	Minimum Pilot Crew Parte 25
LOW	≥ 1	≥ 1.000	1 PPA(1)	2 PPA (1)
MEDIUM	≥ 2	≥ 1.000	1 PPA (1)	2 PPA (1)
HIGH	≥ 5	≥ 1.500	2 PPA (1)	2 PPA (1)
1st Flight	≥ 10	≥ 2.000	2 PPA (1)	2 PPA (1)

Flight Test Engineers

Classification	Experience (years)	Total Flight Experience (flight hours)	$FTE_{(3)}$ Rate
LOW	-	≥ 10	C
MEDIUM	≥ 1	≥ 100	B
HIGH	≥ 3	≥ 200	A
1st Flight	≥ 5	≥ 500	A*

EXAMPLE

Is it possible to avoid accidents during experimental flight testing ?

Conclusions

- The method is **easy** to use.
- Uses the **Expertise Accumulated** on SSA.
- Get together **Design+Development+Production Philosophies.**

Conclusions

- The method is **ALIVE** and depends on the experience of the team.
- It depends on **INFORMATION**.
- **CANNOT** substitute the discussions and analysis.
- The Three Flags Risk Assessment Method is a **TRUSTWORTHY** guide for test preparation.

Thank you!

FOR THE JOURNEY | EMBRAER

Embraer Risk Assessment

“Three Flags” Method

“Safety doesn't happen by accident.” Anonymous

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“Three Flags” Application Example

Maneuver	Condit	Screen Factor	Envelope	TPE	SF	RC
Roll Response	Spd/Alt W/CG	1-1-1	Operat	1-1-1	LOW	MID
	Spd/Alt W/CG	1-1-0	Limited	1-0-0	MID	MID
	Spd/Alt W/CG	1-0-0	Design	1-1-0	LOW	MID