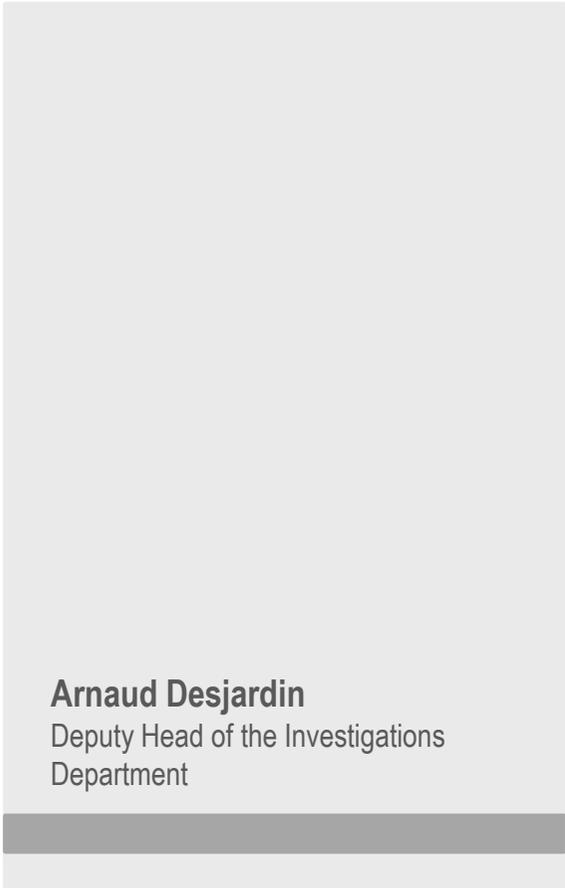




BEA
Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile



Arnaud Desjardin
Deputy Head of the Investigations
Department

Investigation of Human and Organizational factors

*Tratando con factores humanos y
aspectos organizacionales*

ICAO Accident/Incident Investigation Workshop
Oficina Regional NACC de la OACI – Mexico City
21 July 2015





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Bureau d'Enquêtes
et d'Analyses
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de l'aviation civile

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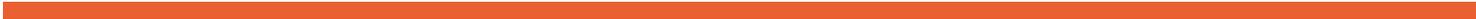
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The BEA



Independence = credibility

- Permanent and independent
- In charge of Safety Investigations
- Sole objective: prevention
- Communication: all reports are made public
- Director appointed for 7 years
- Current staff: 93 including 50 safety investigators

- Operates under the aegis of the Ministry in charge of Civil Aviation
- Functionally independent from the DGAC (French CAA)



administration



BEA

national responsibility

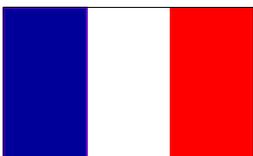
- To collect and analyse **factual information** on accidents and incidents
- To determine **circumstances** and **causes**
- To issue **Safety Recommendations**



- **Chicago Convention** of 7 December 1944 (article 26)
 - ↳ **Annex 13** International Standards and Recommended Practices for Safety Investigations



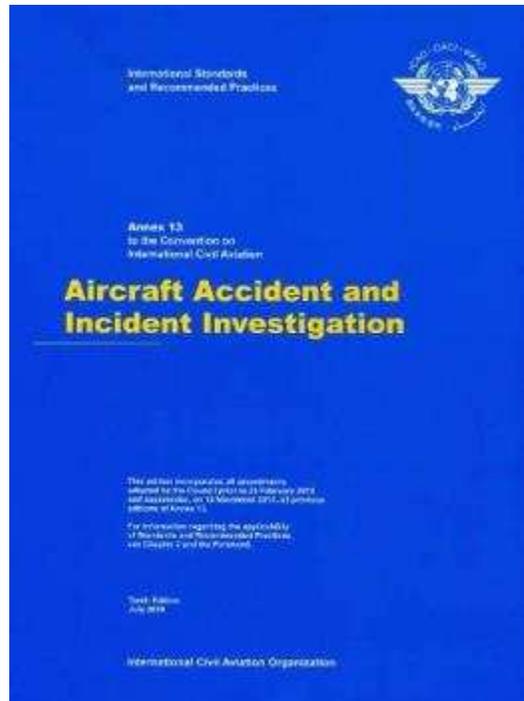
- **European Regulation n° 996/2010** of 20 October 2010
 - ↳ Fundamental principles for safety investigations into accidents and incidents in civil aviation



- French Law as defined in the **Transport Code**



Annex 13



- *“The sole objective of the investigation of an accident or incident shall be the prevention of future accidents and incidents.*
- *It is not the purpose of this activity to apportion blame or liability.”*





- **Permanence and independence** of the **authority** in charge of Safety Investigations
- Role of EASA as adviser for European Safety Investigations
- Creation of the European Network of Civil Aviation Safety Investigation Authorities (**ENCASIA**)
- **Protection of sensitive information** in relation to safety
- **Need to provide information** on the progress of the Safety Investigation
- **Assistance plan** for families of victims of civil aviation accidents

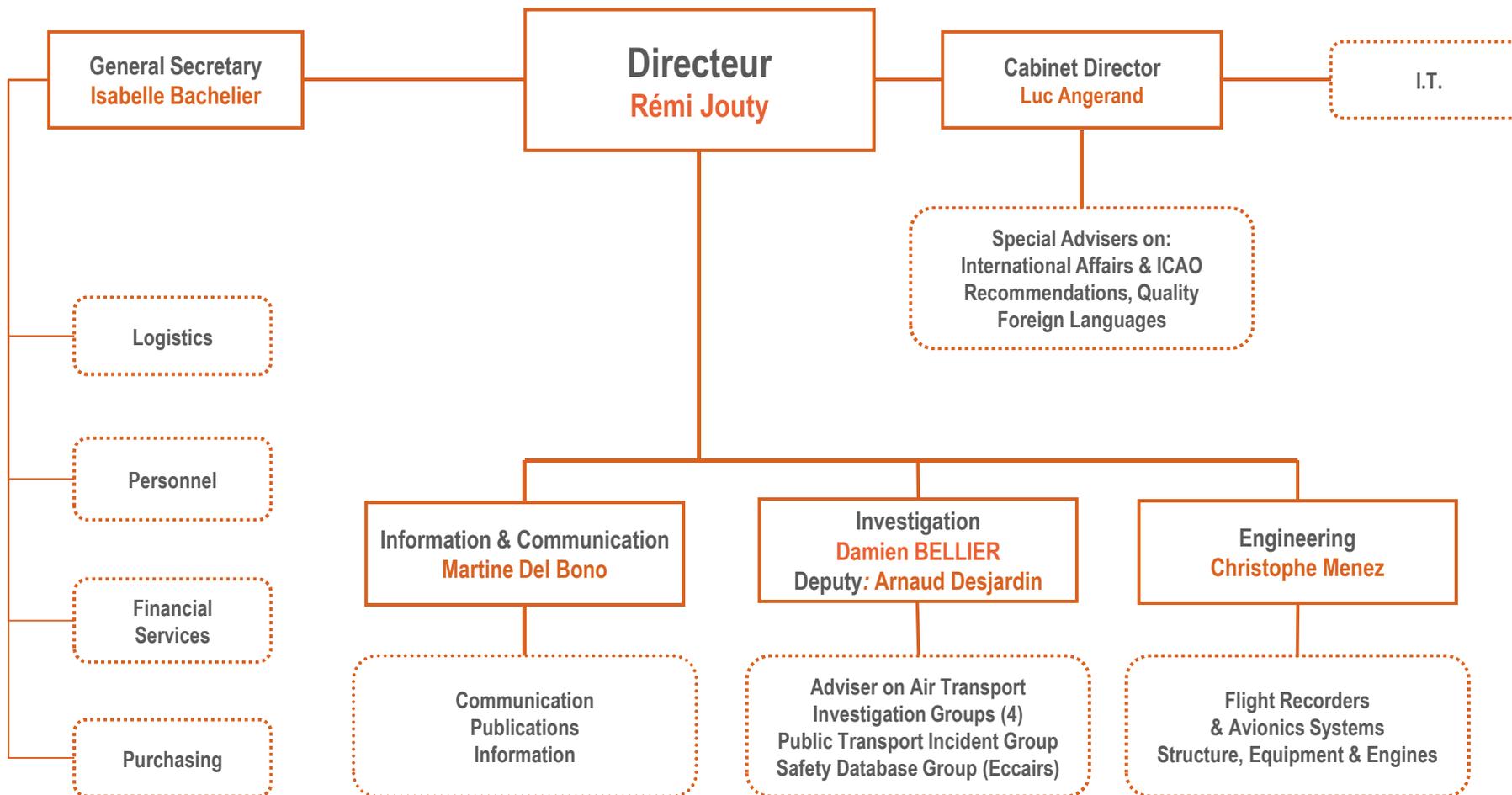
WG1: Network communication and Internet presence
WG2: Best/Good Practices
WG3: Assistance between the EU authorities
WG4: Training
WG5: Peer Reviews
WG6: Safety Recs

- The State of Occurrence conducts the Safety Investigation (Investigator In Charge, IIC)
- Accredited representatives from:
 - State of Registry
 - State of Manufacture
 - State of Operator
 - State of Design

participate in the investigation. They belong to Accident Investigation Authorities and they can be assisted by **Advisers** (from manufacturers & operators) and/or **Experts**

- The State of Occurrence can **delegate** the Safety Investigation to another State or request **technical assistance**

BEA Organisation Chart

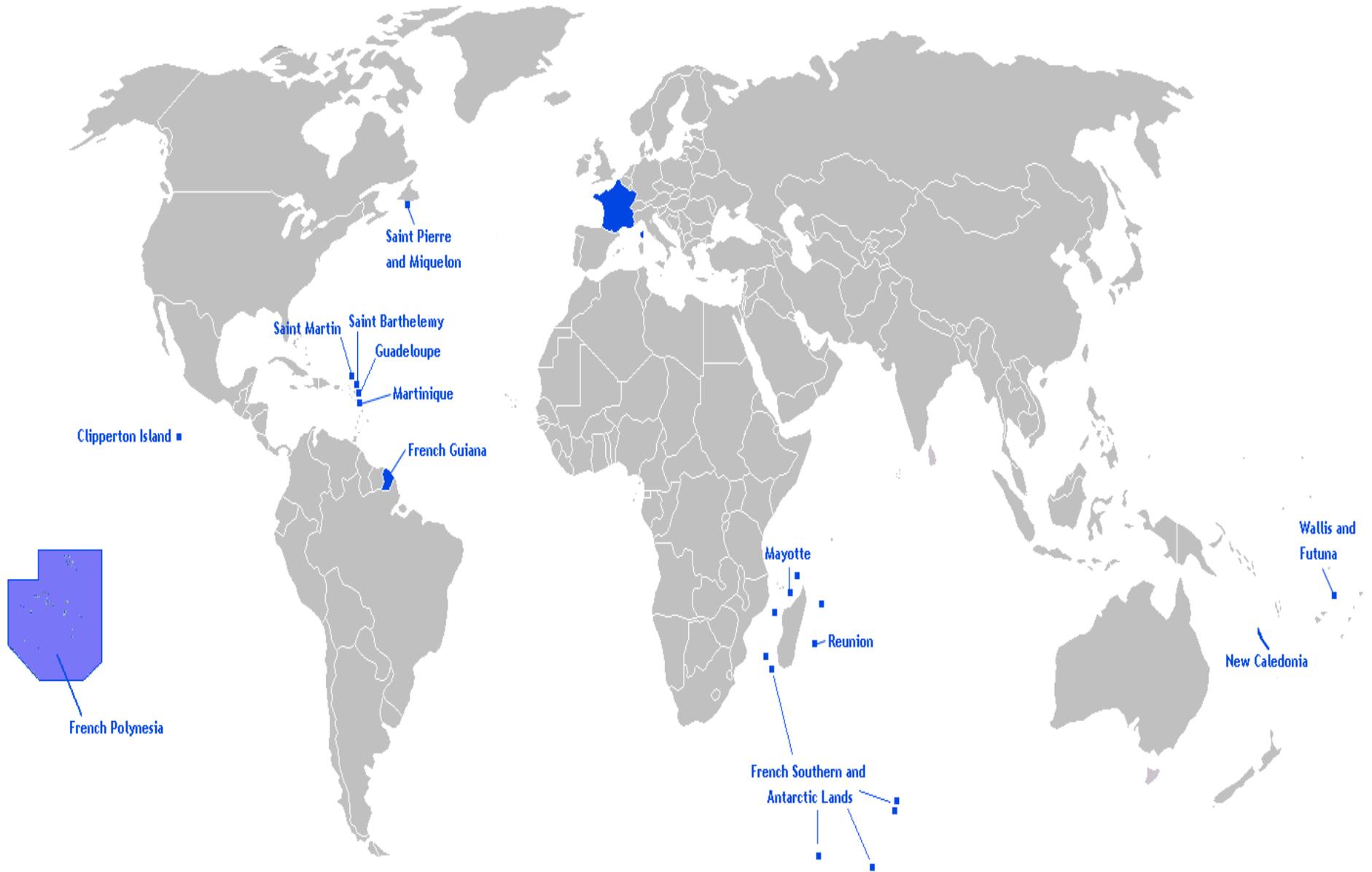


Investigations on French Territory

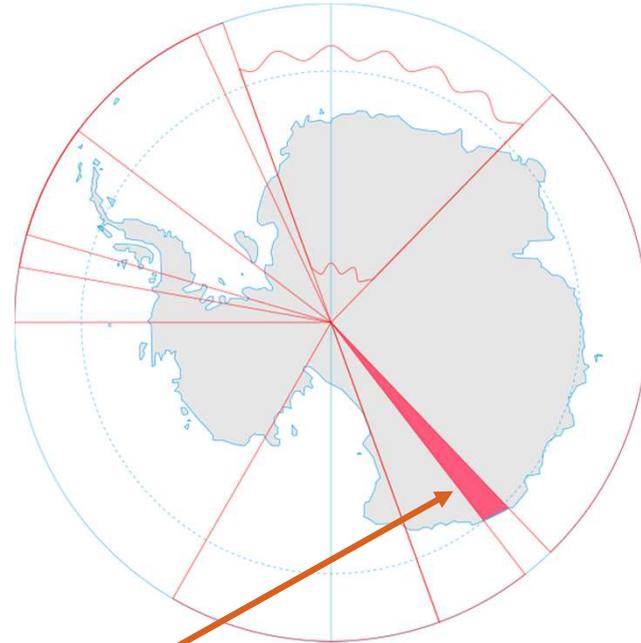
- Headquarters:
Paris Le Bourget
Airport
- 5 regional offices
- Almost 200 Field
Investigators (EPI)



France around the world



But also...



Adélie Land

Area: 432,000 km²

Population: 33

- In France, the BEA launched **139** investigations:
 - ➔ 117 in general / light aviation
 - ➔ 13 in public transport
 - ➔ 9 in aerial work

151 investigations in 2013

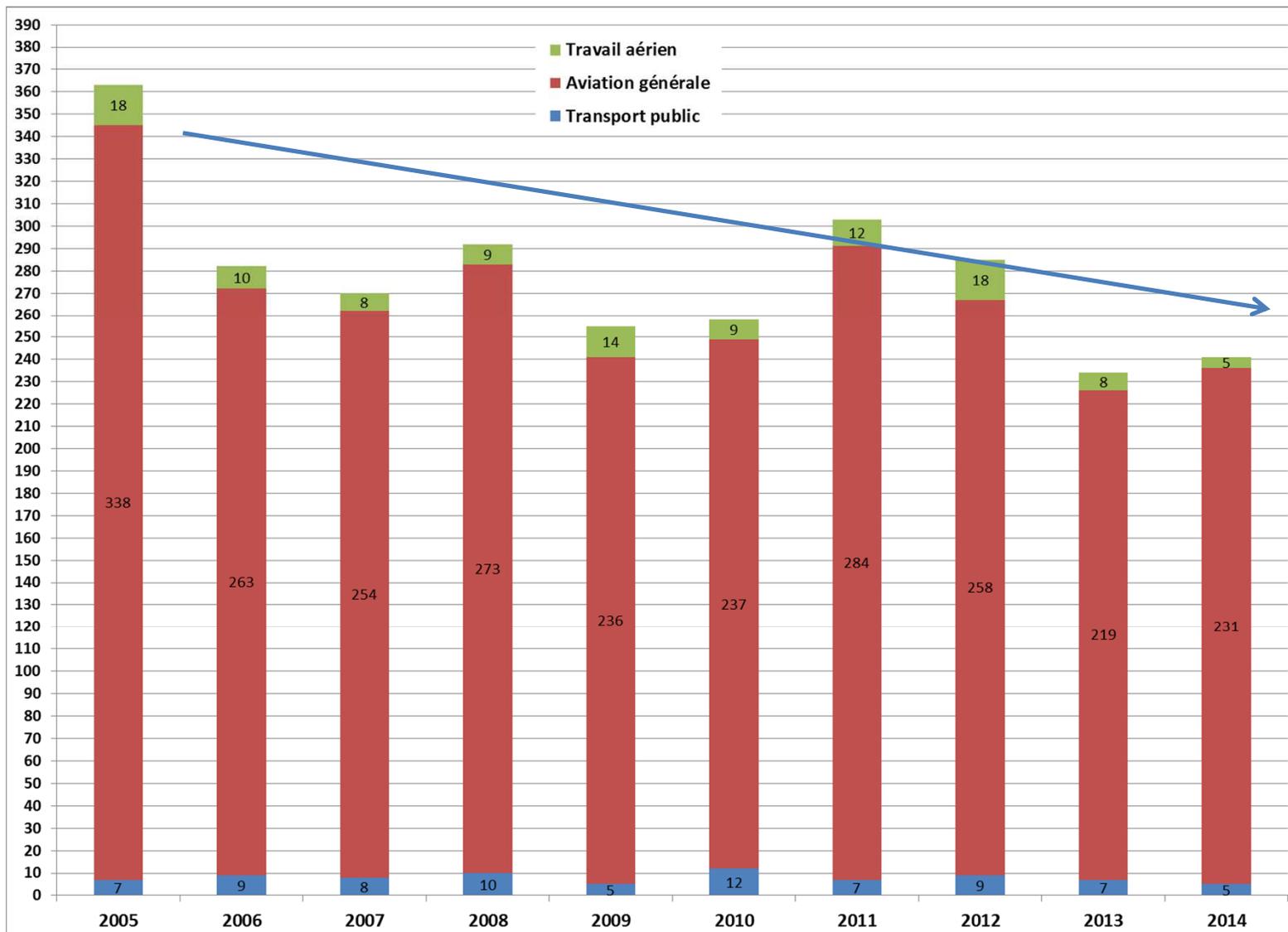
170 investigations in 2012

- The BEA participated in **216** new investigations initiated abroad:

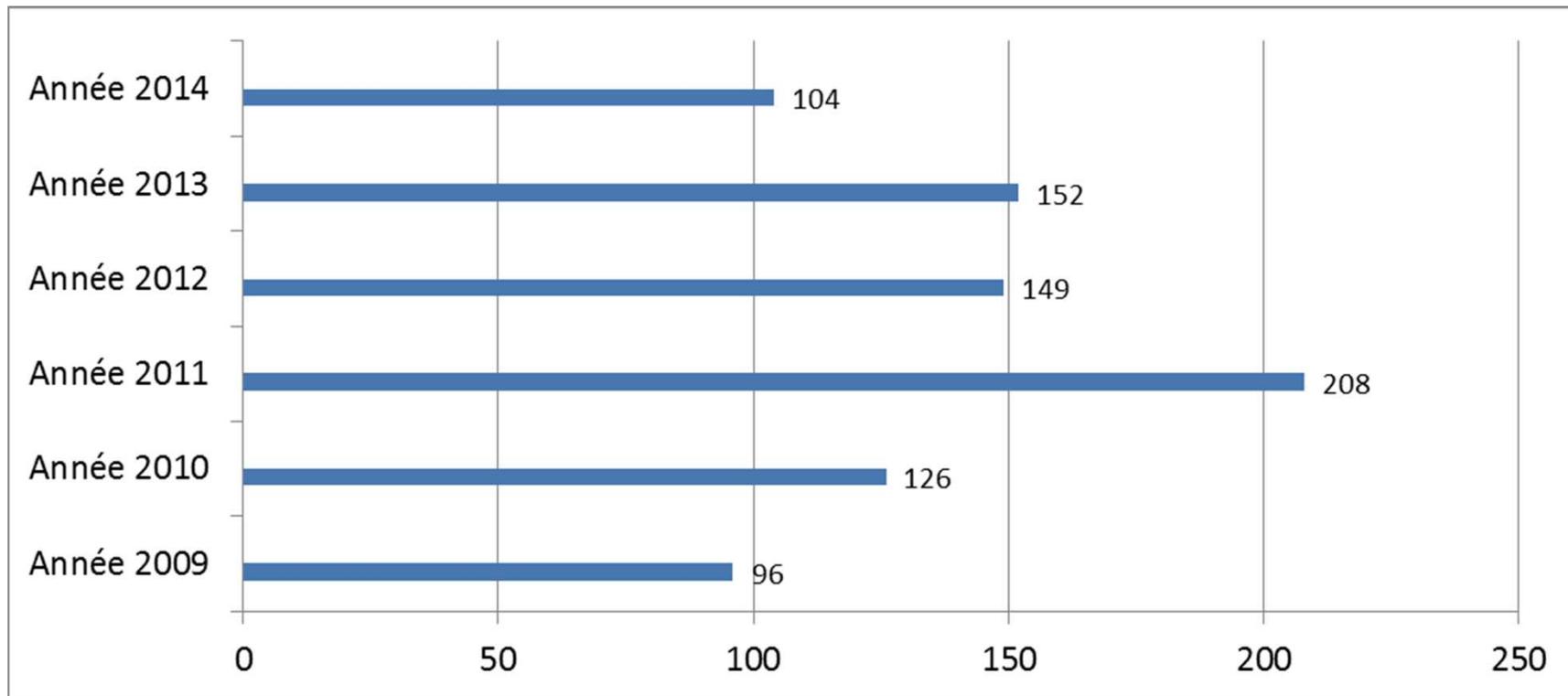
205 investigations in 2013

228 investigations in 2012

Accidents survenus en France

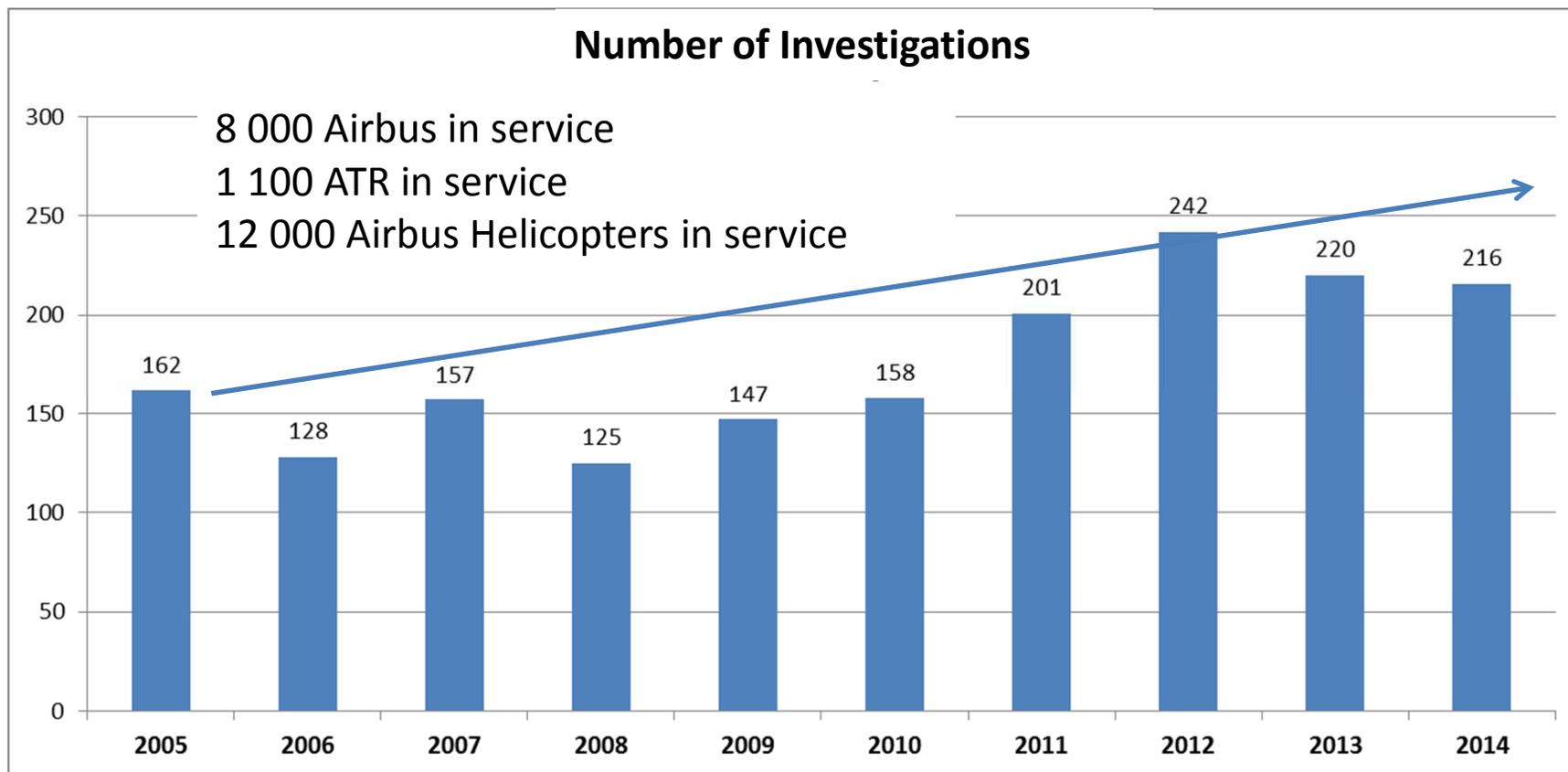


Reports published 2009-2014





Participation in Foreign Investigations



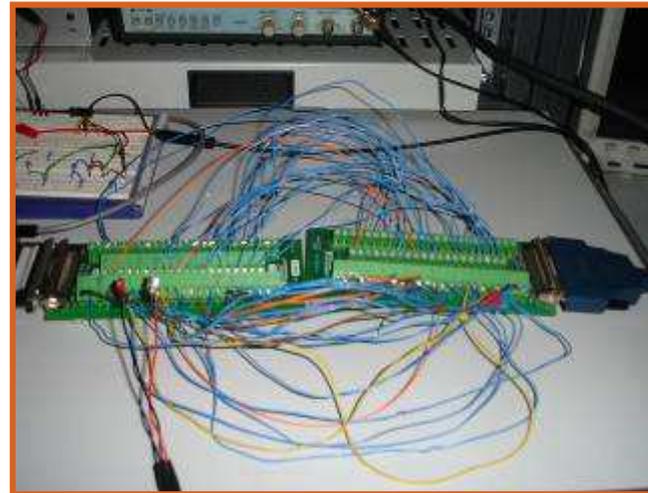
- 69 flight recorder readouts :
 - ➔ 29 for BEA investigations
 - ➔ 35 for work as ACCREP
 - ➔ 5 for technical assistance

96 readouts in 2013

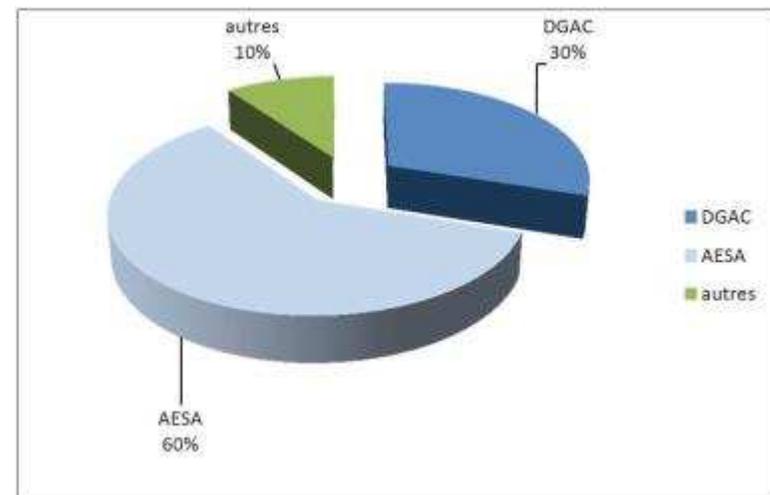
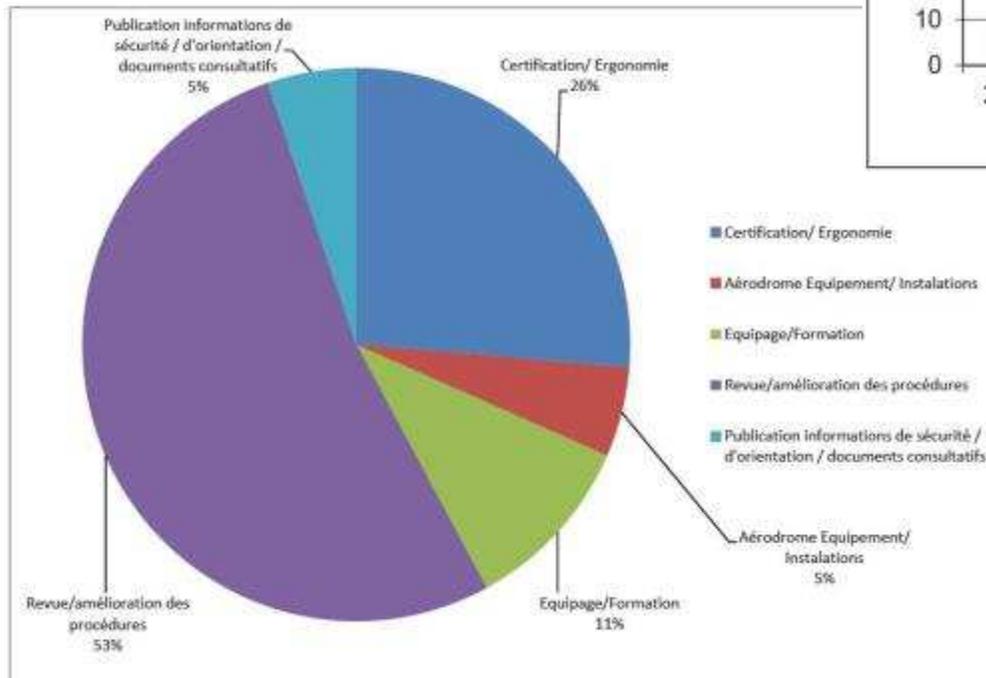
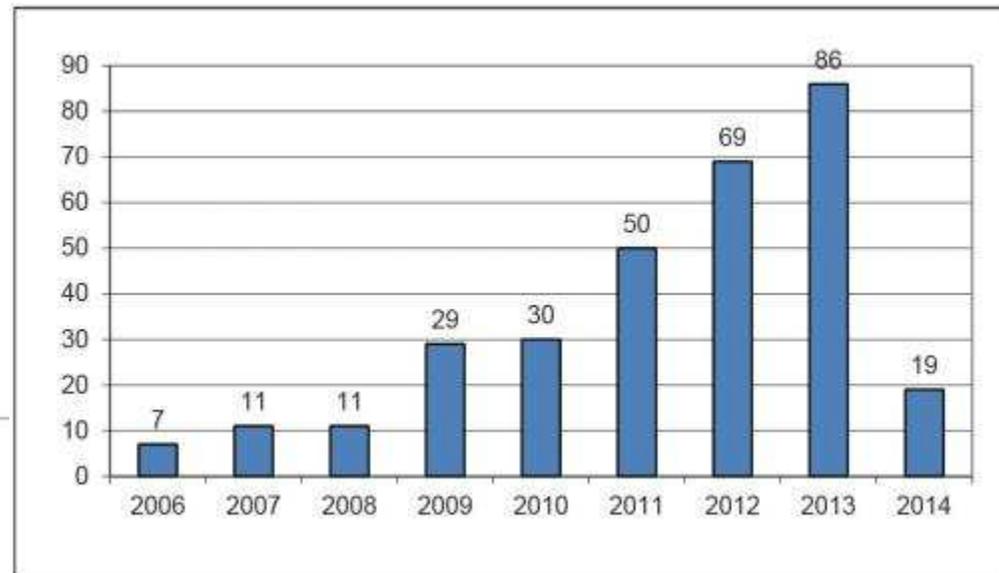
87 readouts in 2012

- 45 GNSS (global navigation satellite system) computers
- 66 on-board computers
- 10 ATM audio/video recordings
- 124 structure and parts examinations

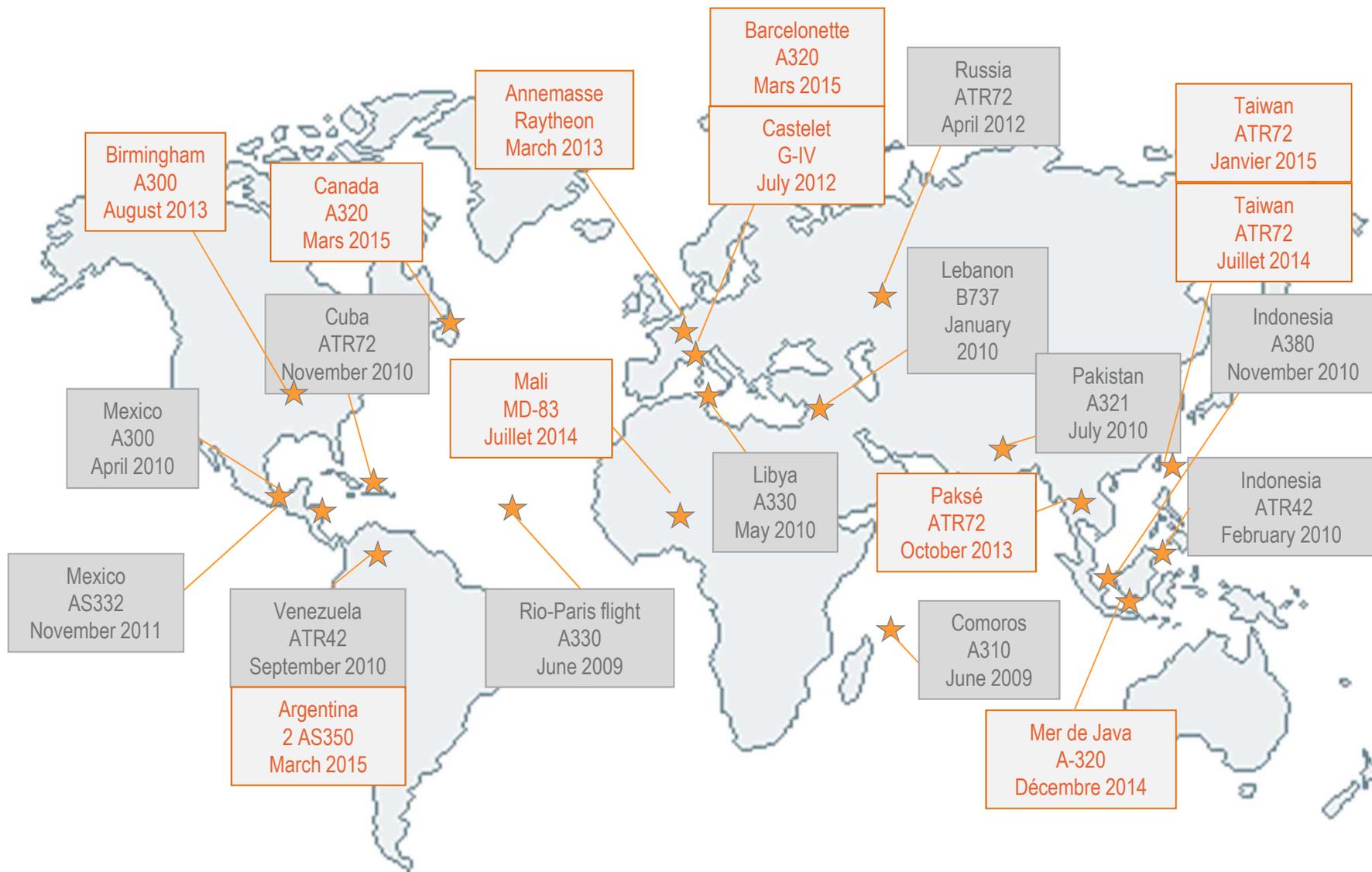
- The BEA may also offer technical assistance for flight recorder/avionics equipment readouts



■ Safety Recommendations



Some Recent Investigations

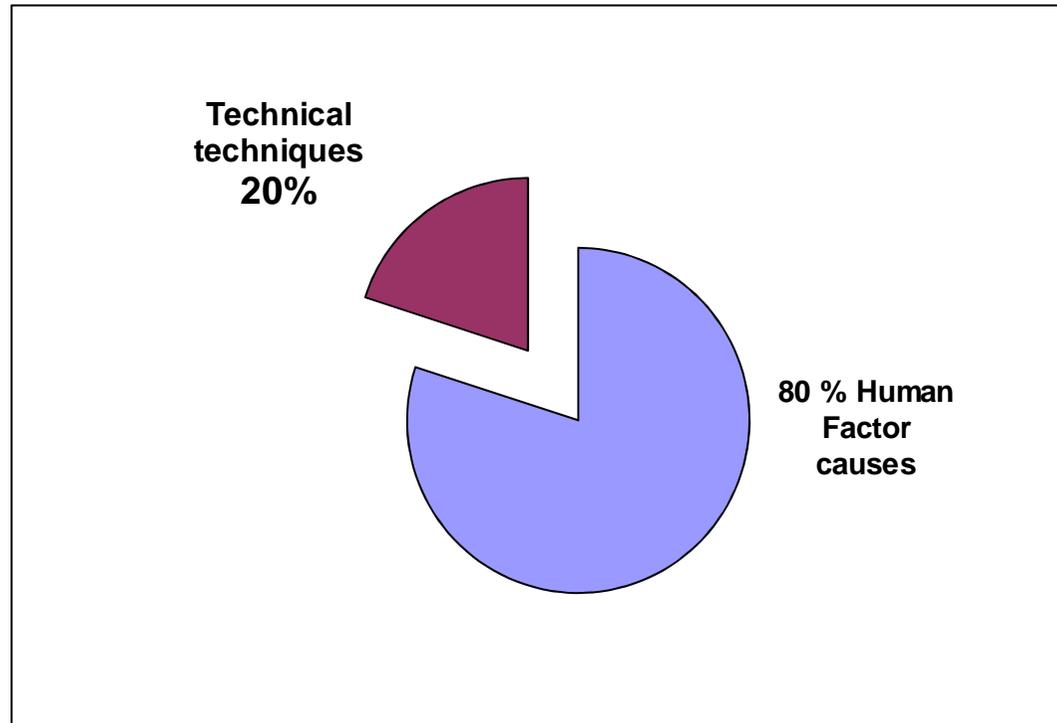




Investigation of Human Factors



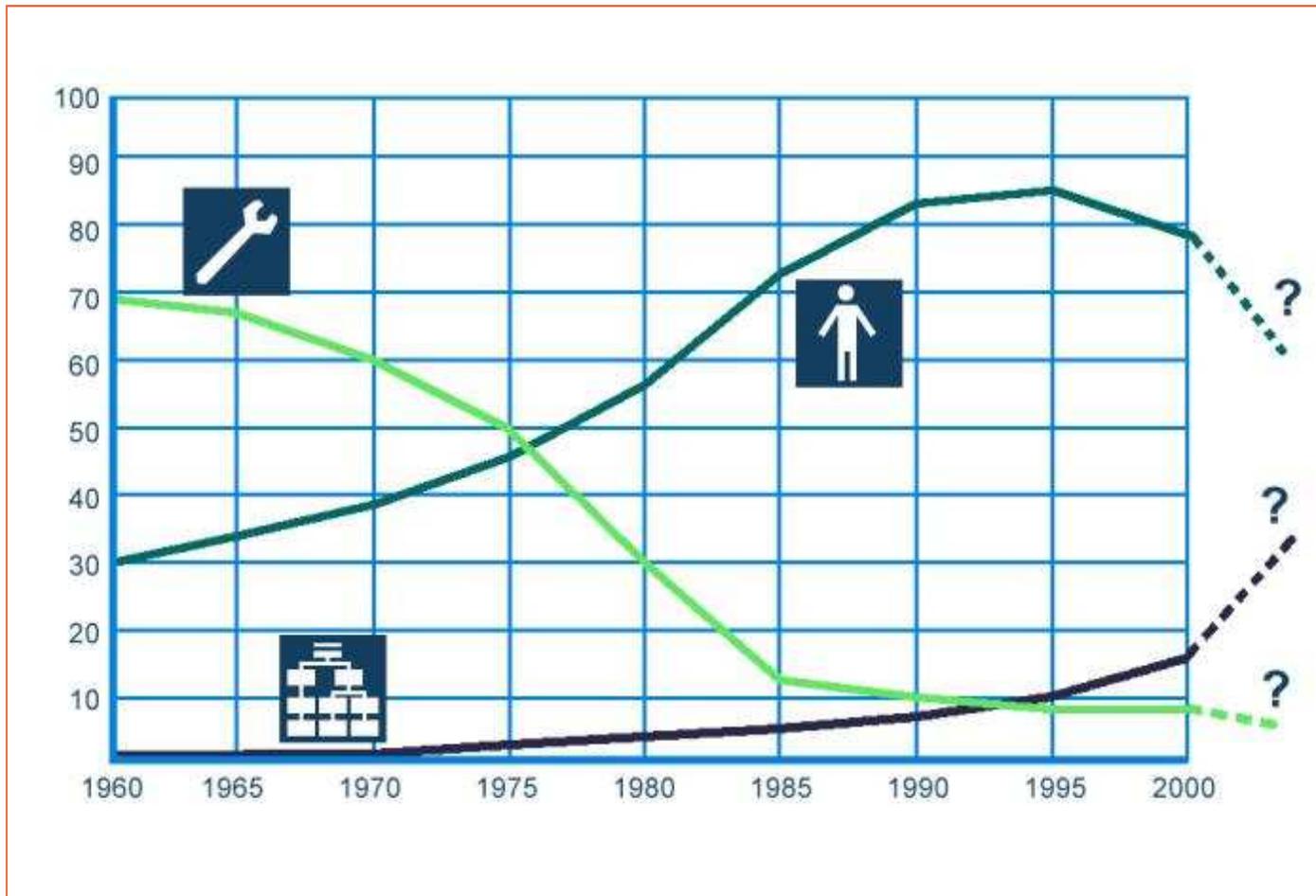
Human Factors



What do you think ???



Evolution of accident causes



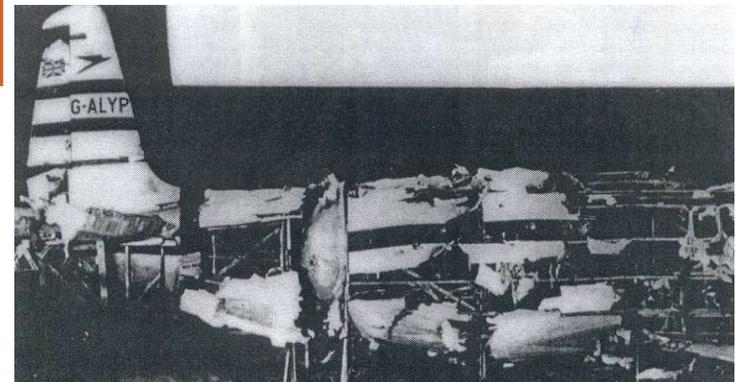
Source : Erik Hollnagel - Barriers And Accident Prevention 2004



Technical Improvements

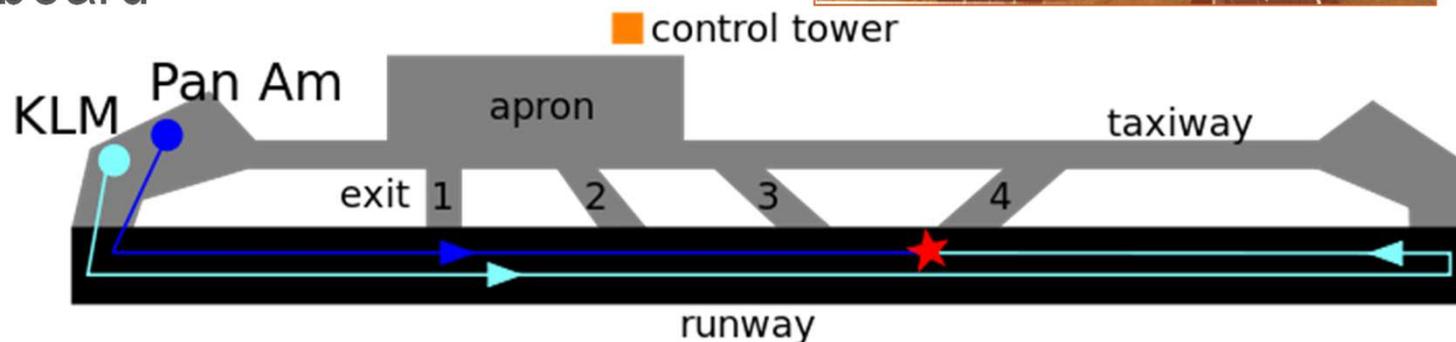
- 1950s: Comet accidents
- Better understanding of pressurized structure fatigue

Safety
=
Pilot skills + technical reliability



Tenerife

- 27 March 1977
- Collision of two B747
- 583 fatalities / 644 persons on board

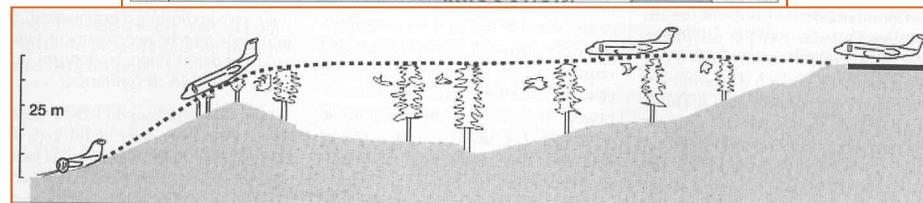
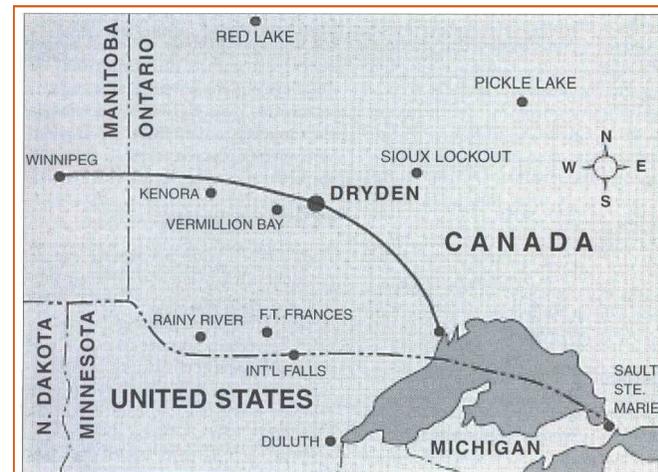


http://lessonslearned.faa.gov/ll_main.cfm?TabID=1&LLID=52&LLTypeID=2#null

- No technical failure
- Introduction of « **Human Factors** »

Dryden Accident

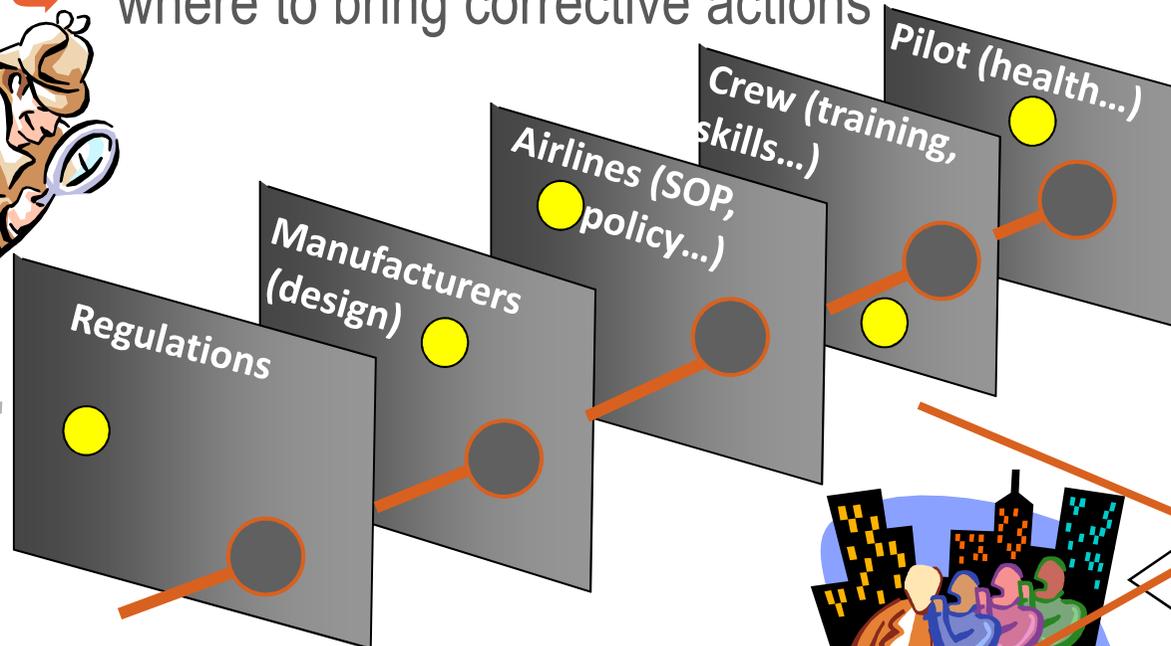
- 10 March 1989
- Fokker 28
- Flight Air Ontario 1363
- Ground Icing



- Introduction of **systemic** aspects
- Introduction of the Reason model (Swiss cheese model)

Swiss Cheese Model

- The system fails because of “holes” in the safety barriers
- Safety Investigations aim at determining:
 - ➔ how the system failed
 - ➔ where to bring corrective actions



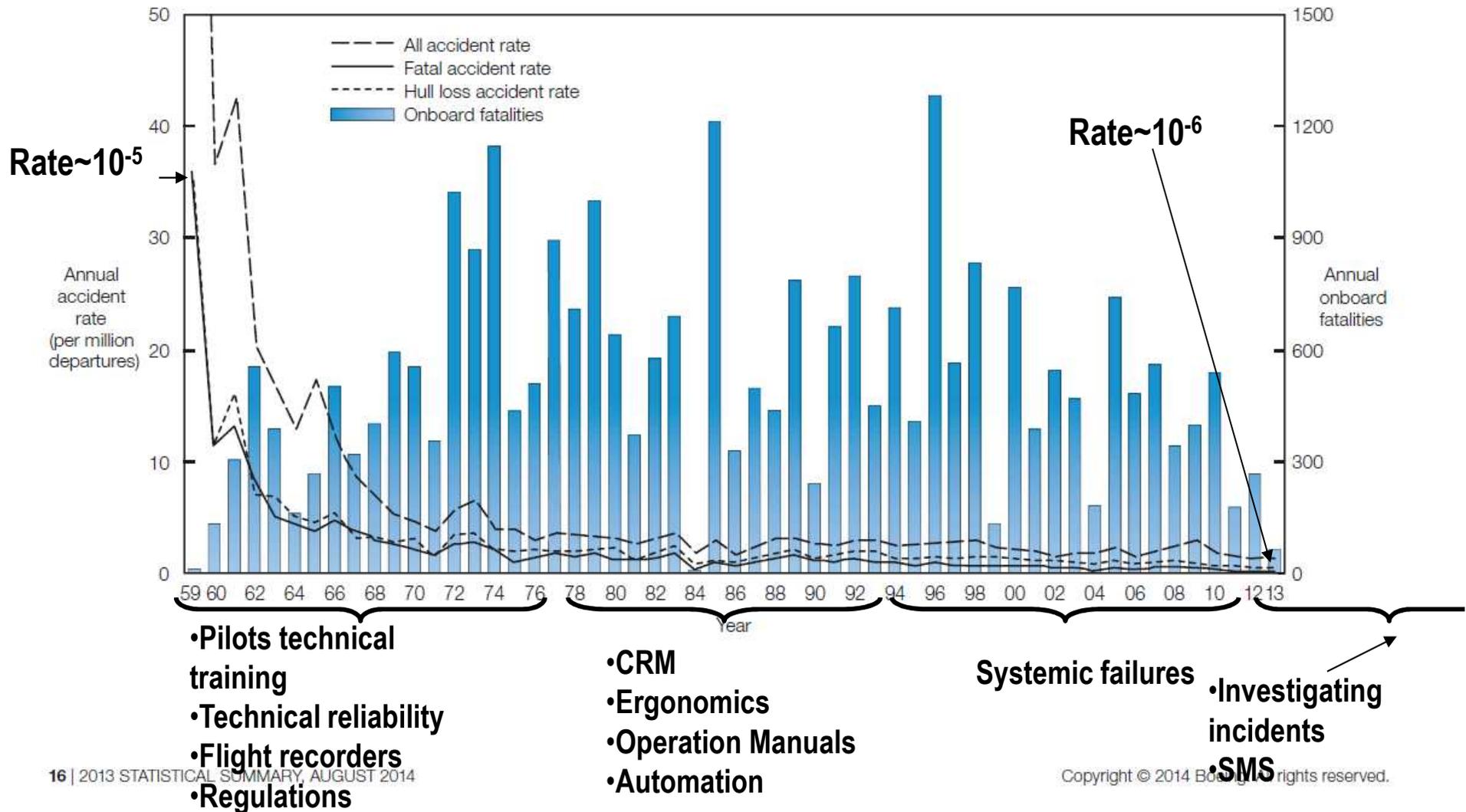
Accident

Whose **fault** is it?
Who shall we **blame**?
Who is **responsible**?



Investigation of Human and Organizational factors

BEA Accident Rates and Onboard Fatalities by Year



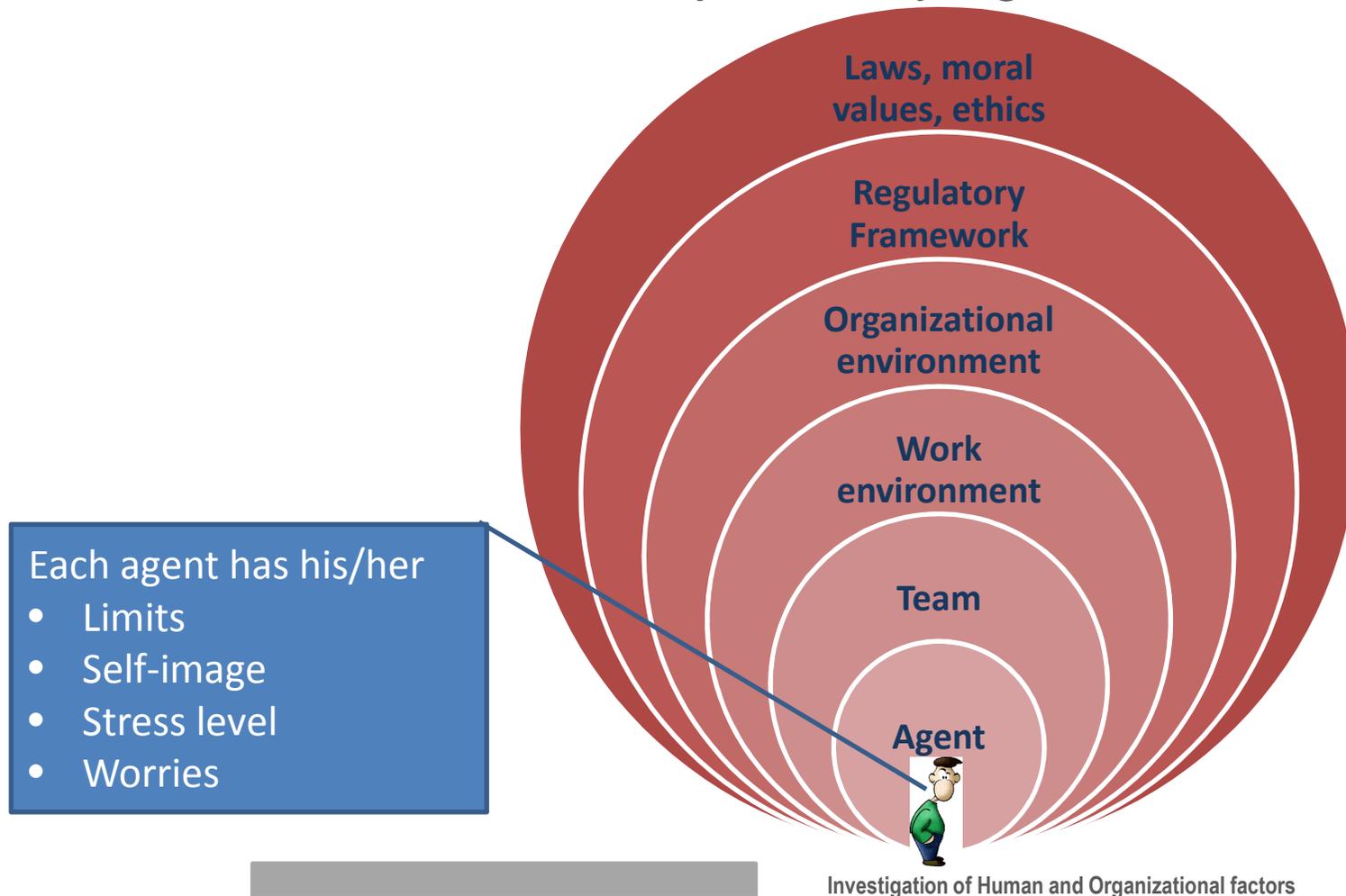
- **Human Factors:** “...*the technology concerned to optimize the relationship between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering.*”

Wiener & Nagel, 1988

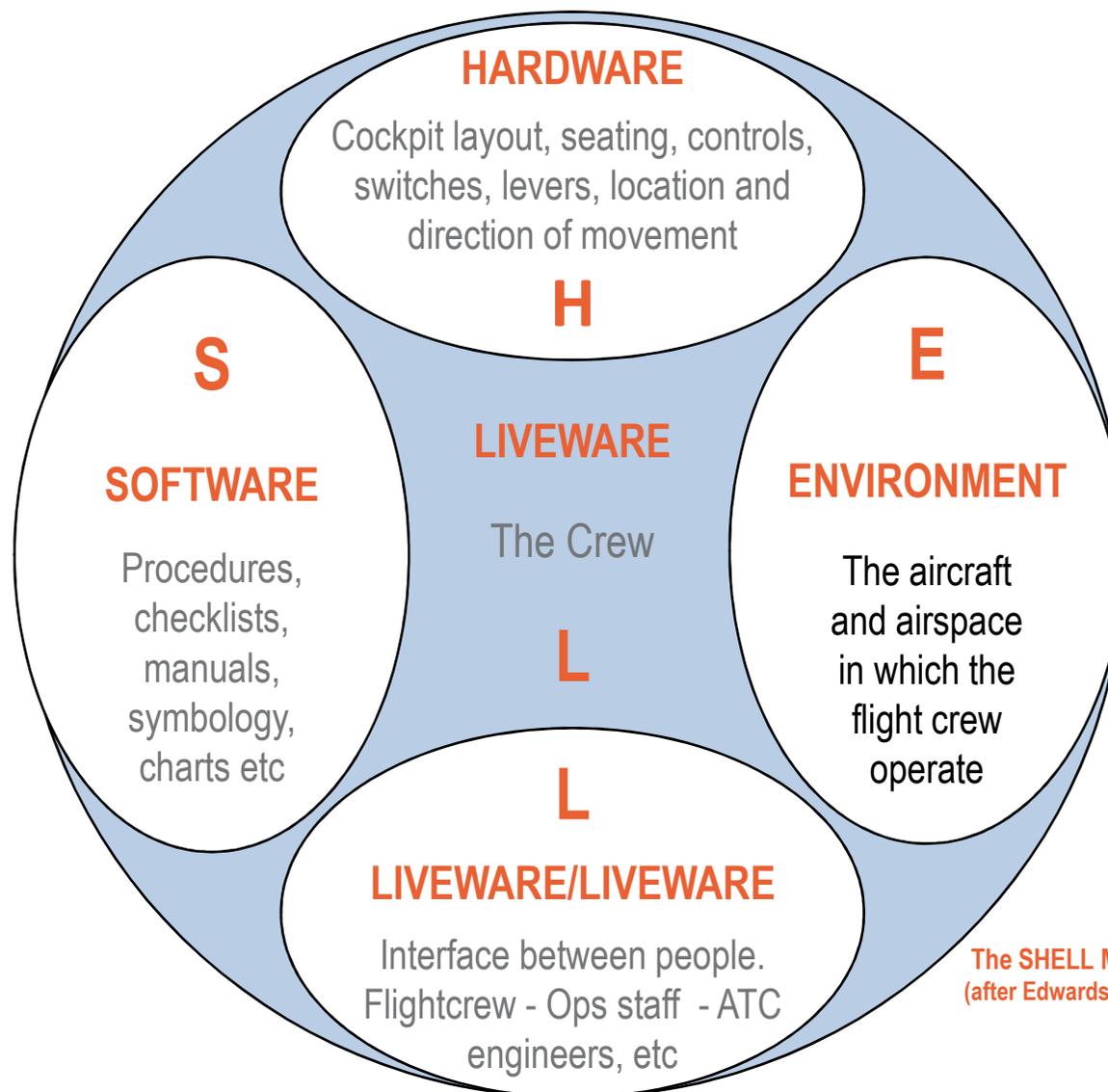
- Include:
 - ➔ Physical capacities and Physiology
 - ➔ Cognition
 - ➔ Human Error and Reliability
 - ➔ Ergonomics
 - ➔ Collective Performance

The Human Element in a Set of Environments

- A set of non-technical dimensions influence and contribute to the activity of every agent



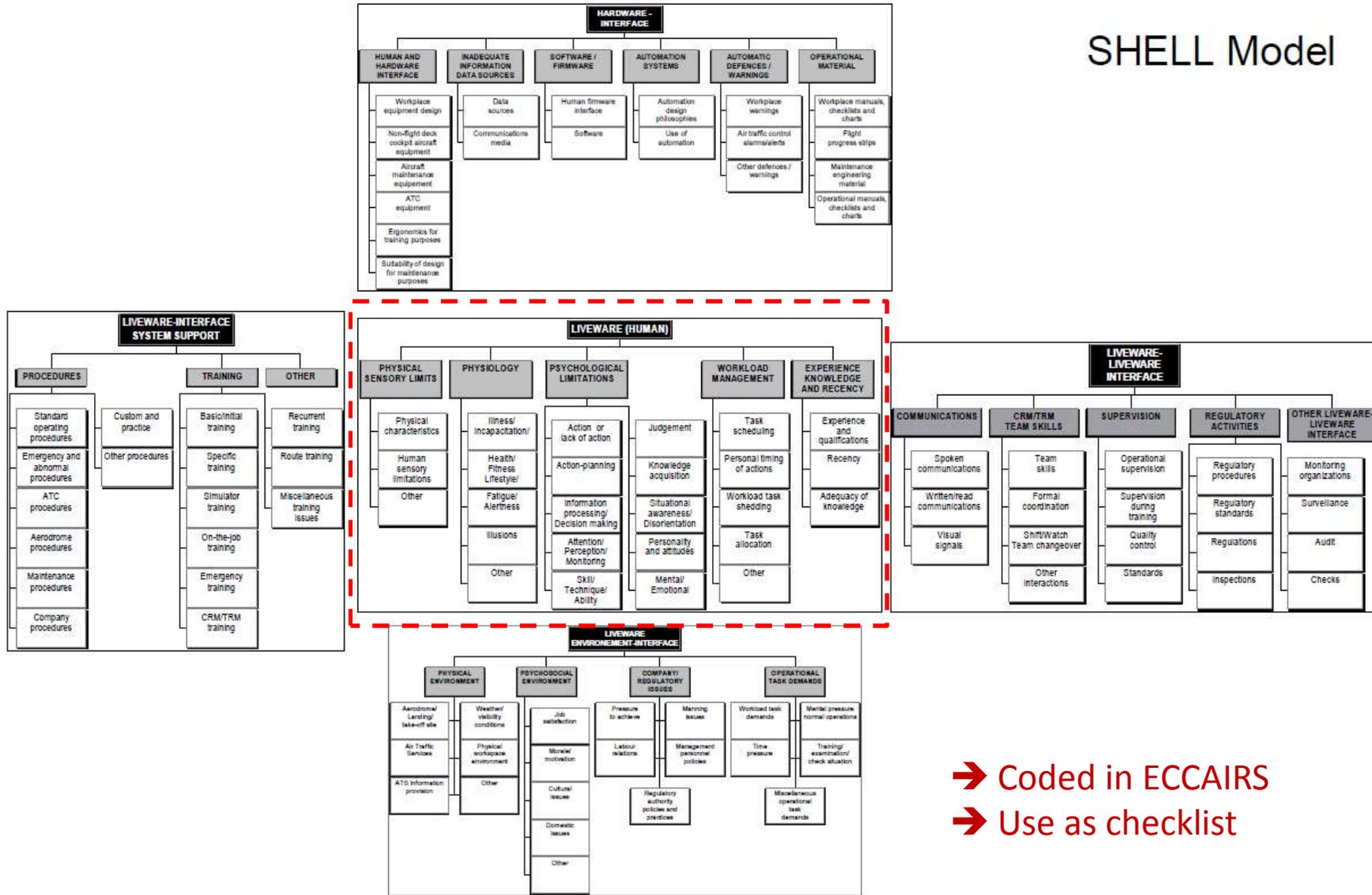
SHELL Model



The SHELL Model
(after Edwards, 1972)

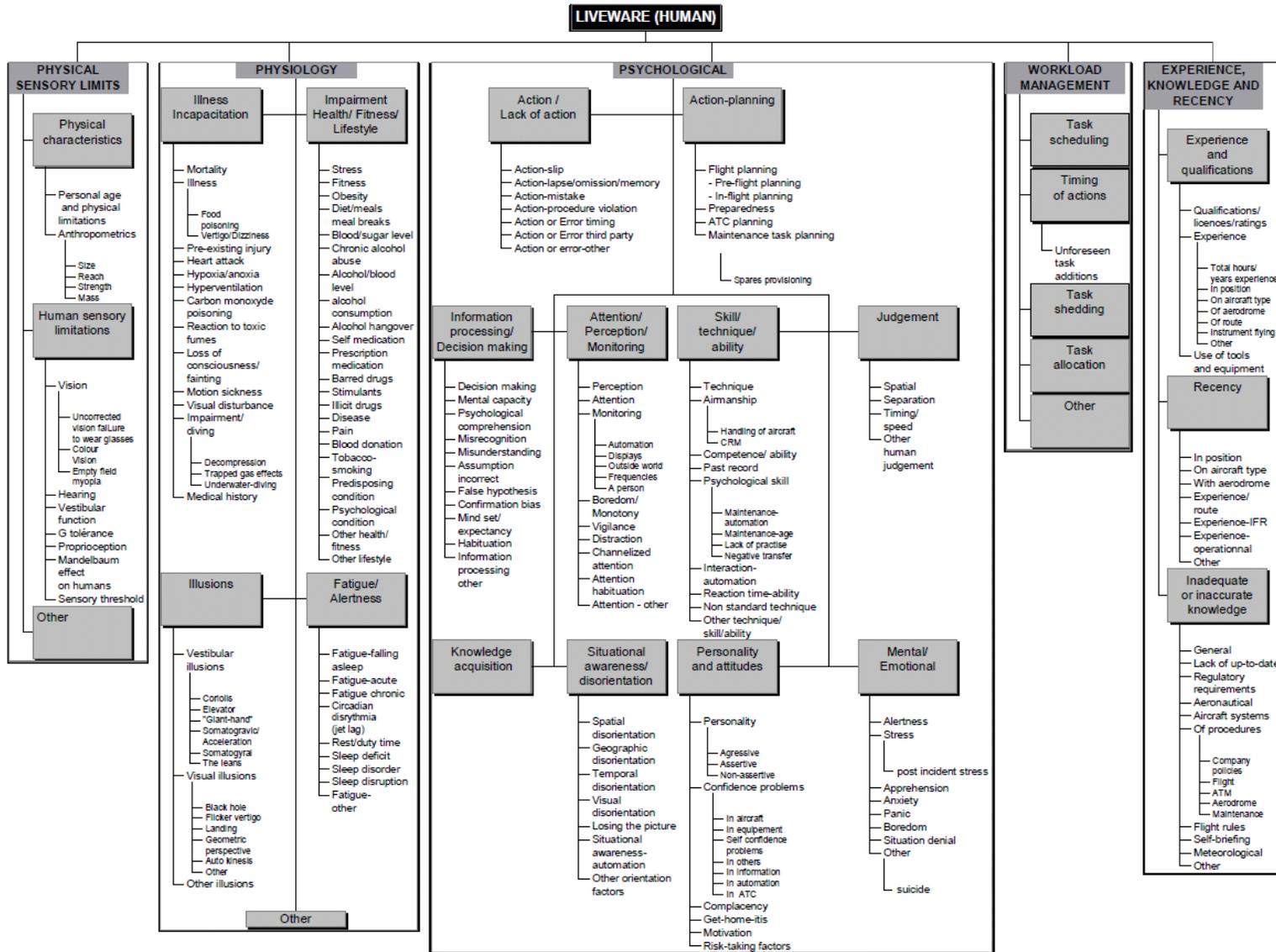
SHELL Model Layout

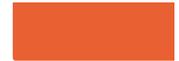
SHELL Model



→ Coded in ECCAIRS
 → Use as checklist

SHELL – Liveware (Human)



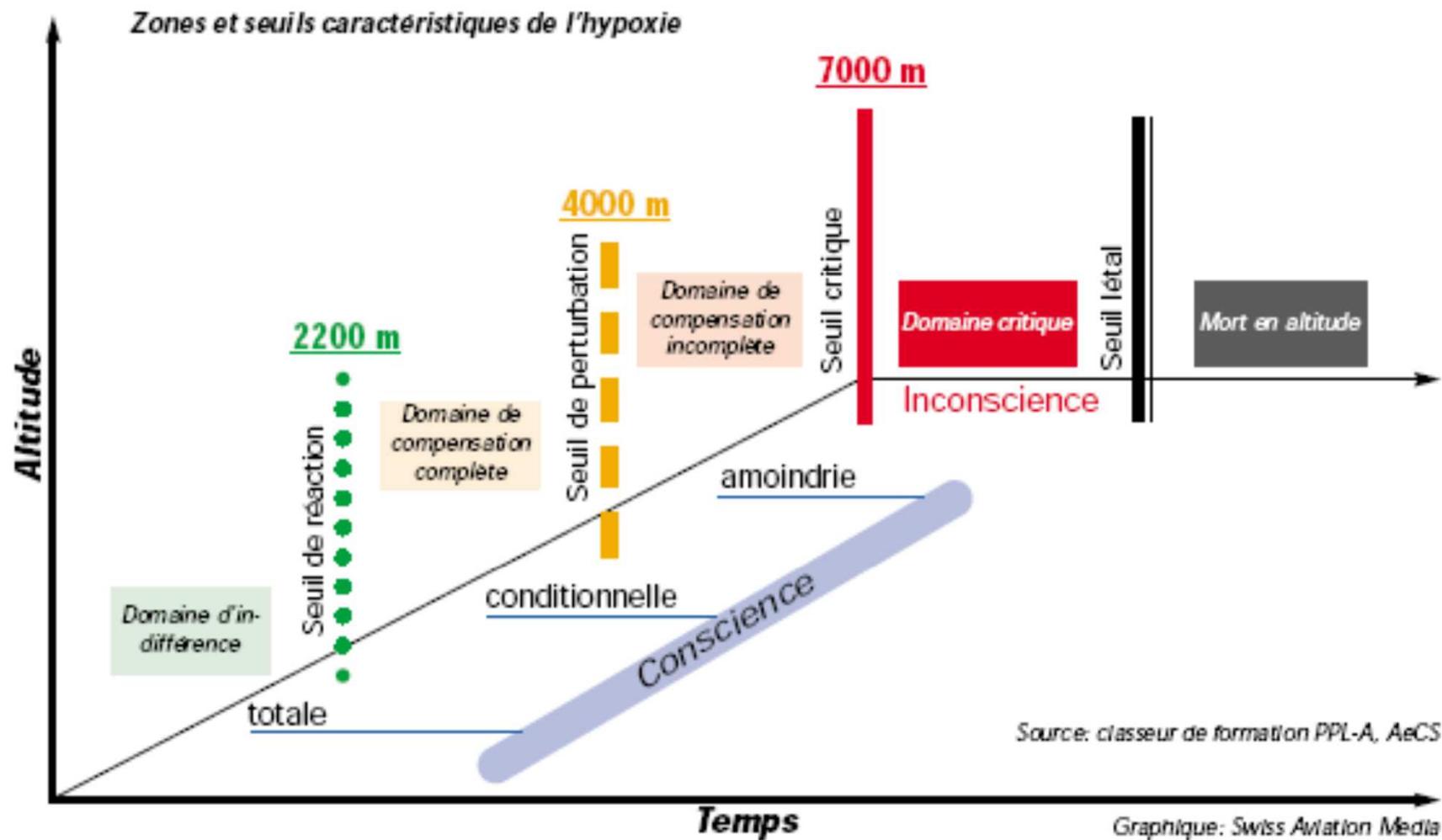


Physical capacities & Physiology



- As oxygen level decreases, the body compensates by
 - ↳ Increasing the heart beat
 - ↳ Increasing the breathing rate
- If not enough: \Rightarrow **HYPOXIA**

Hypoxia : a few numbers

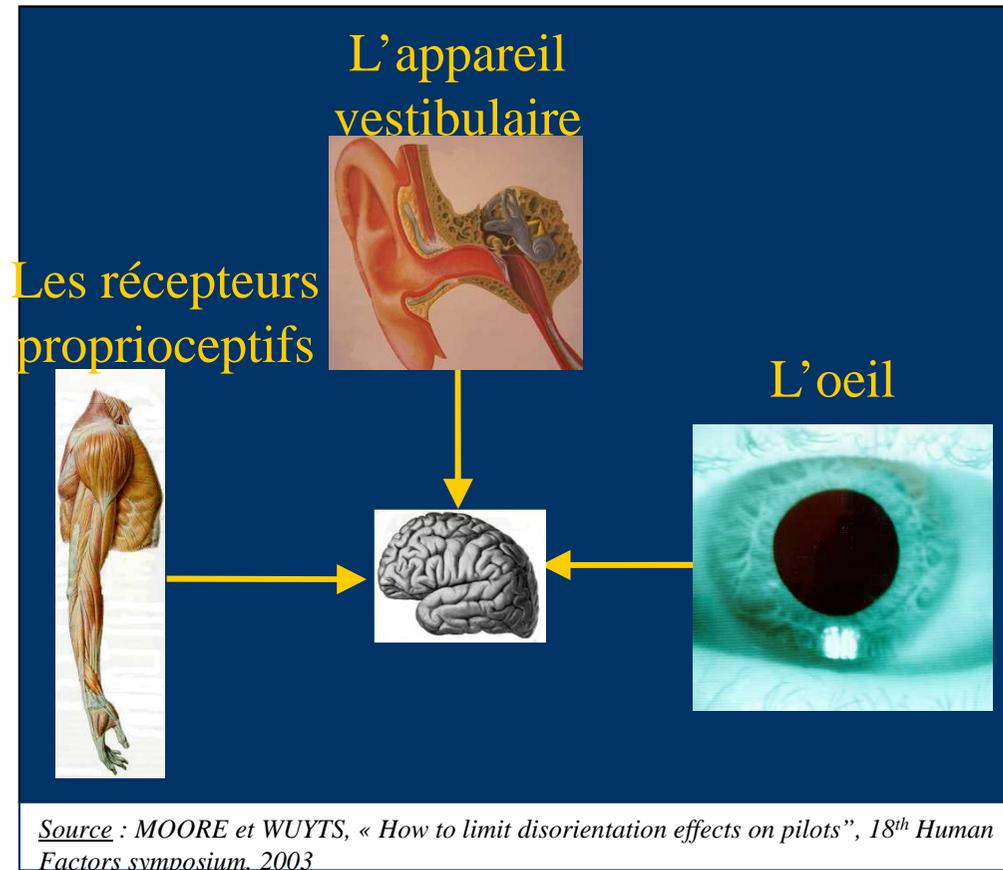


Source: classeur de formation PPL-A, AeCS

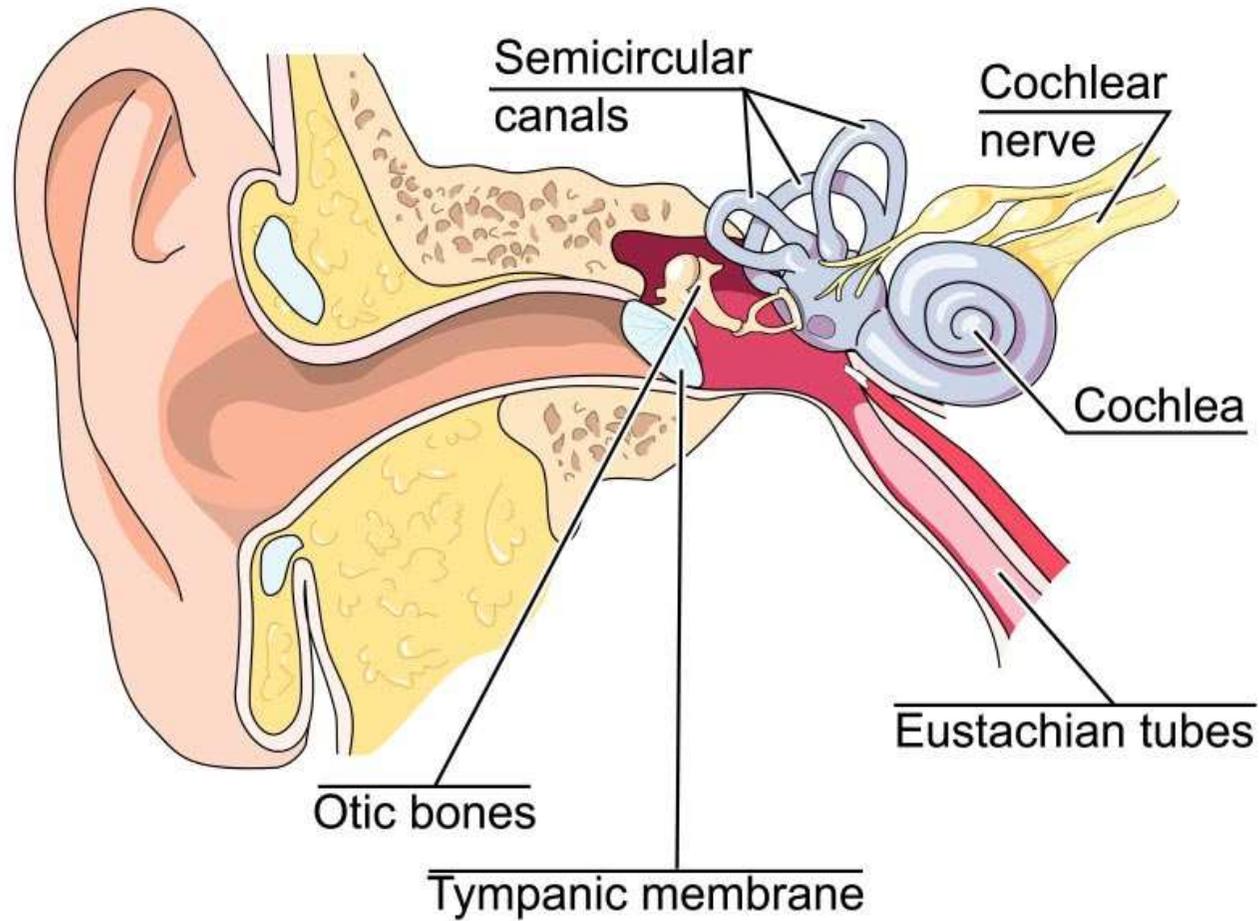
Graphique: Swiss Aviation Media

Impacts on the body

- First impacts at 5000 ft to 12000 ft
 - Reduced night vision,
 - Tiredness,
- Additional impacts at 12000 ft to 19000 ft
 - Impaired Judgment
 - Difficulty to concentrate,
 - Memory does not work as well,
 - Mood disorders (euphoria...),
 - Headaches, nausea
 - Feeling sleepy,
 - Impaired vision.
- Critical zone impacts above 19000 ft
 - Loss of Consciousness

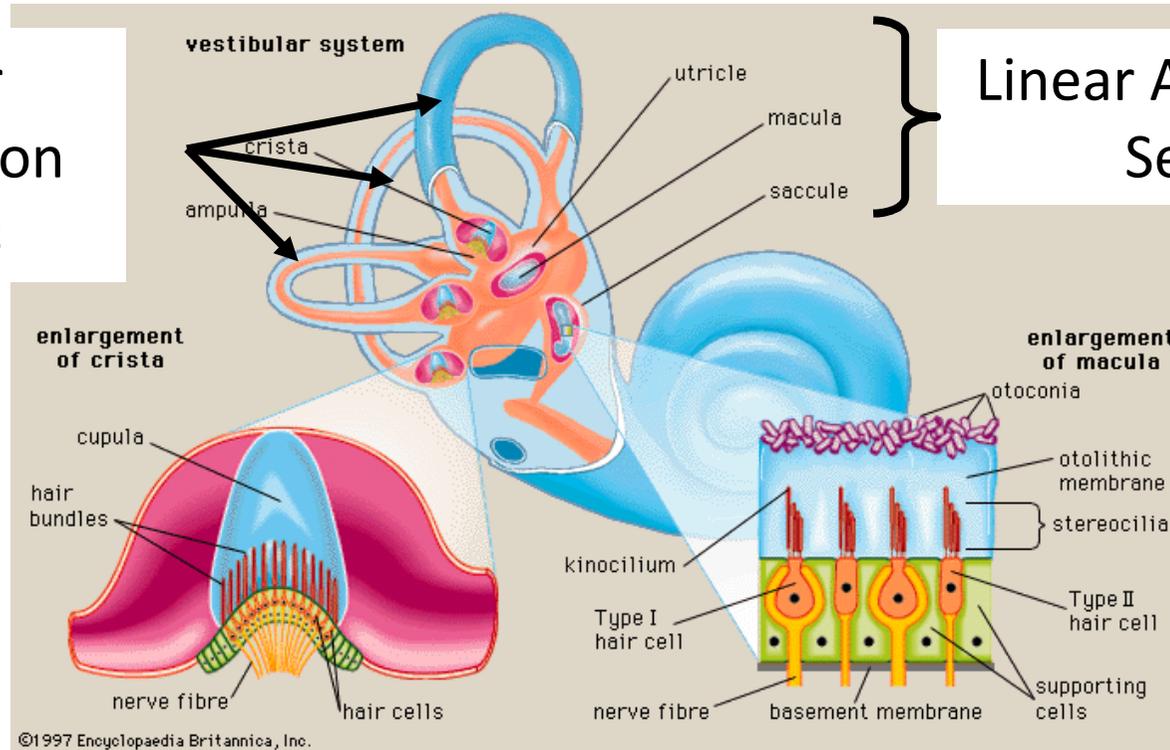


The Ear

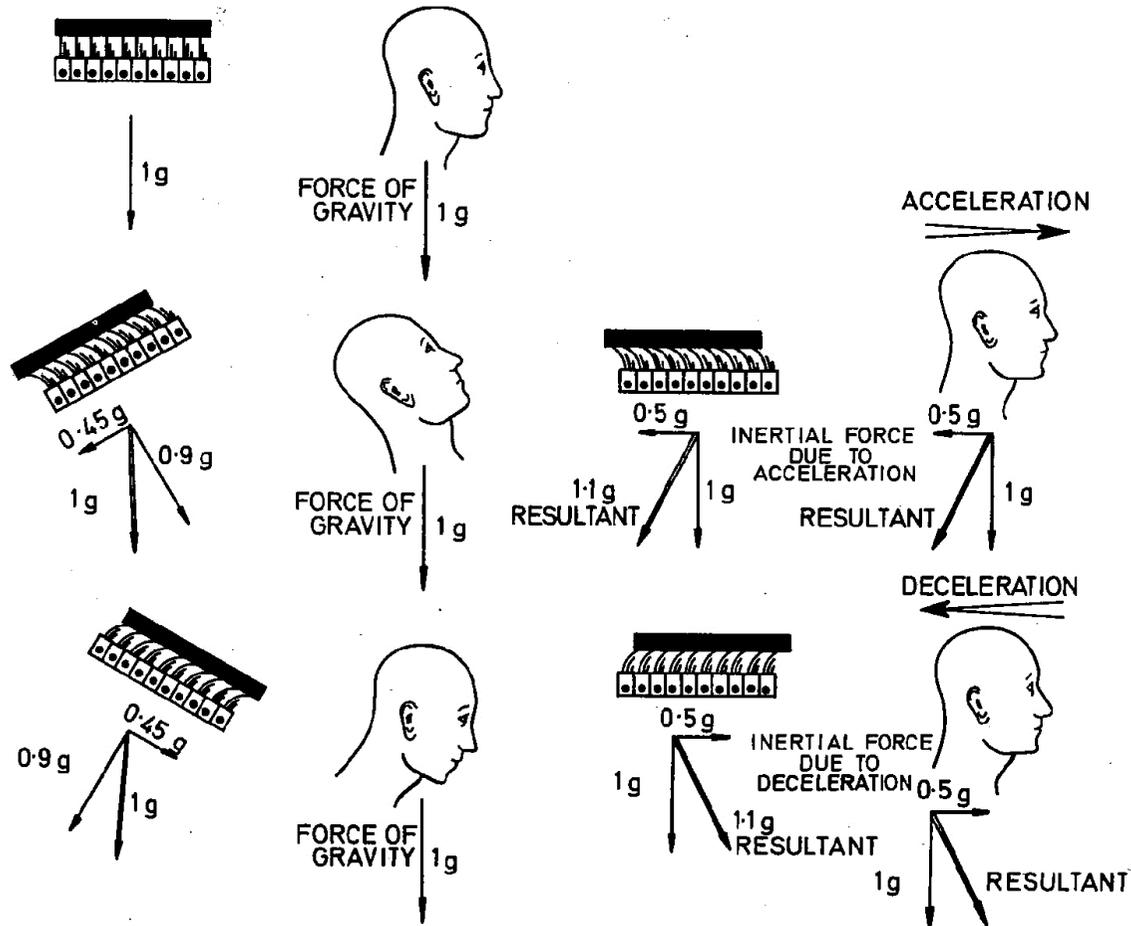


Angular
Acceleration
Sensors

Linear Acceleration
Sensors



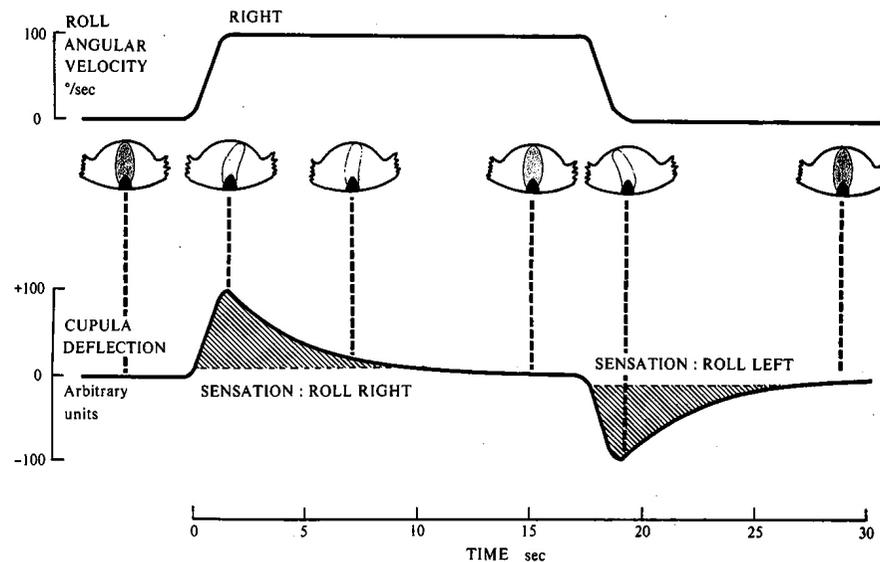
Sensory Illusions



- Confusion between acceleration and pitch
- Detection thresholds (angle or acceleration)

Somatogravic Illusions

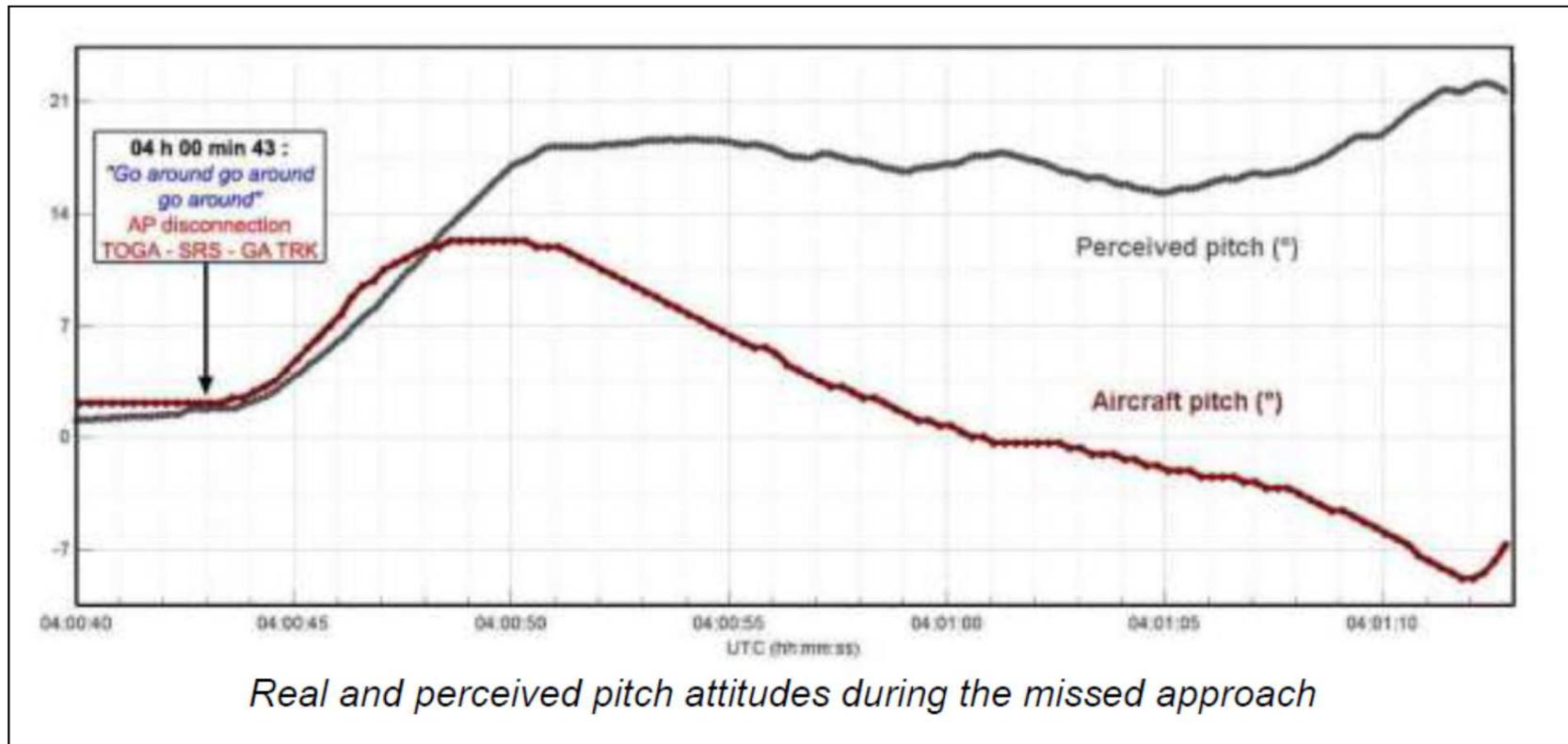
Sensory Illusions



Semi-circular canals detect accelerations over a certain threshold :
→ weak angular acceleration not detected,
→ difficulty to perceive long and regular rotations.

Head movements mix up yaw, pitch and roll angular accelerations
Somatogyral Illusions

Perceived Pitch during go-around





Acceleration (positive g's)

- Blood accumulates in the lower part of the body, and less in the upper part
 - Field of Sight narrows (grey-out then black-out),
 - Loss of consciousness,
 - Increased heartbeat.



Tolerance to g's

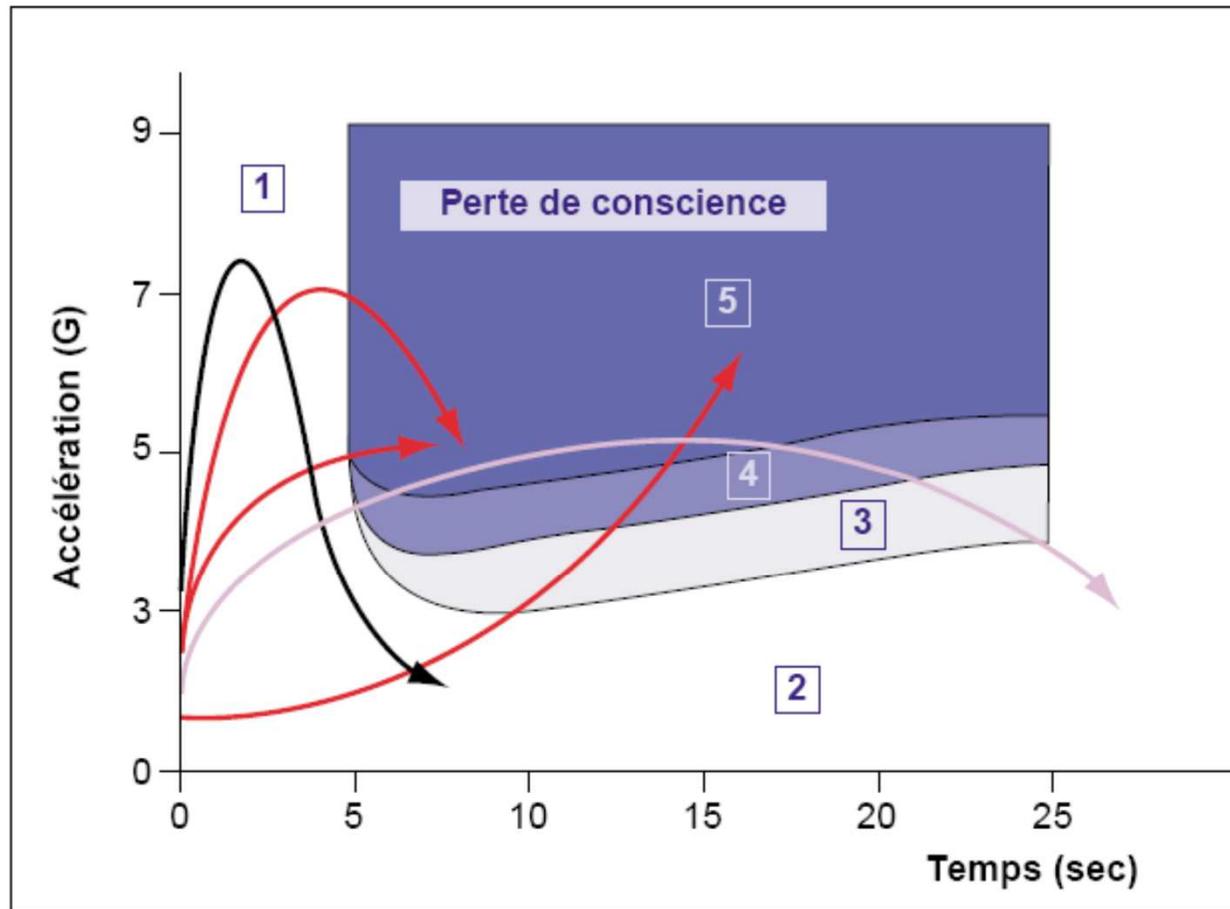


FIG. 2 – Effets de la variation de l'accélération sur le risque de perte de conscience. Zone 1 : protection par la réserve interne d'oxygène des tissus neurosensoriels. Zone 2 : protection par les réactions cardiovasculaires. Zones 3 et 4 : symptômes des voiles gris et noir. Zone 5 : perte de conscience.

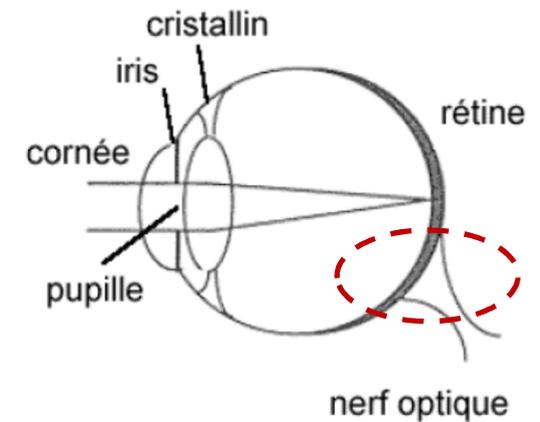


Acceleration (negative g's)

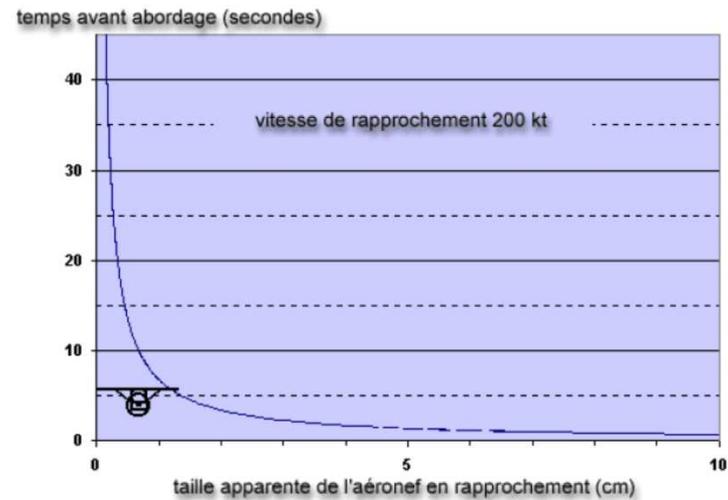
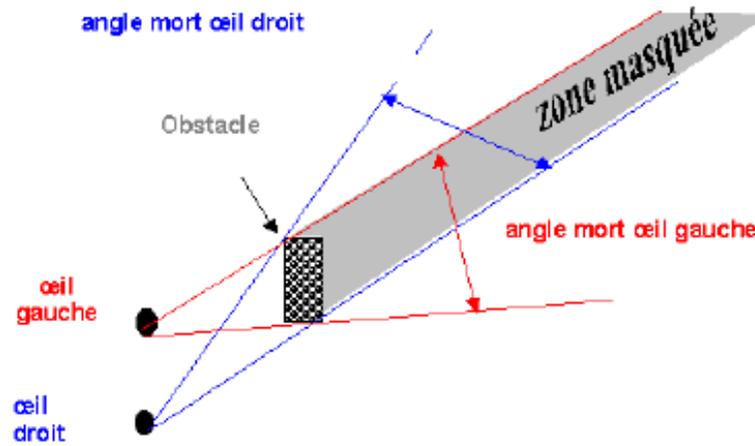
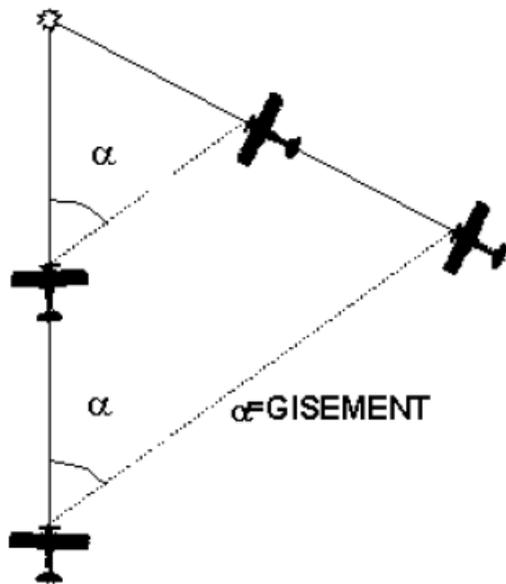
- The blood accumulates in the upper part of the body
 - Reduced heartrate,
 - Headaches
- Lowers the tolerance to future postive g's



Cover your left eye, look at the cross-hairs



« See and Avoid? »



Exemple (accident de Quiberon)



fig. 3



fig. 4

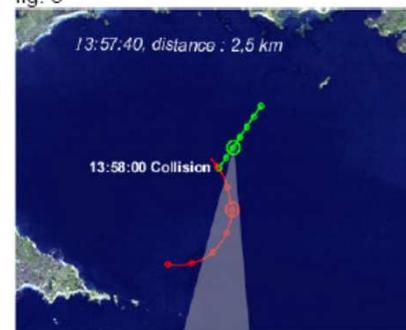


fig. 5

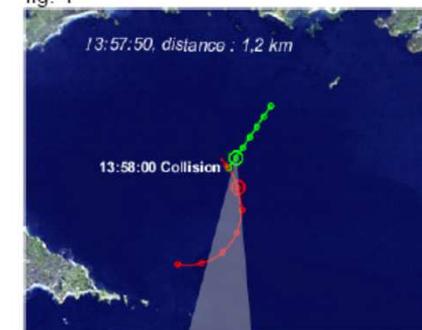


fig. 6

A partir du temps 13 h 57 m 20 s, le Beech 1900D entre dans l'angle mort du Cessna 177 (cf. § 1.16.4). Il est plus que probable que, sans changement de position du pilote du Cessna 177 sur son siège, le Beech 1900D lui sera resté invisible pendant environ trente secondes (cf. fig. 4, 5, 6). Lorsque le Beech 1900D, ayant passé cet angle mort, pouvait être de nouveau visible par le pilote du Cessna 177, il se trouvait alors en totale périphérie de son œil. De son côté l'équipage du Beech 1900D, alors en fin de virage, préparait son arrivée sur Lorient.

- A380 / CRJ700 ground collision at JFK 11 April 2011
- [..\..\..\Enquetes\A380_AirFrance_F-HPJD+CRJ700_COMAIR_N641CA-2011-04-11\1 Renseignements de base\1.16 Essais et recherches\Animation\F-HPJD_2011 07 19.isv](#)

BEA

A380/CRJ 700 Collision JFK

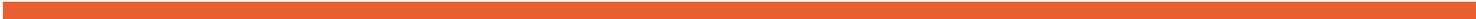


Investigation of Human and Organizational factors



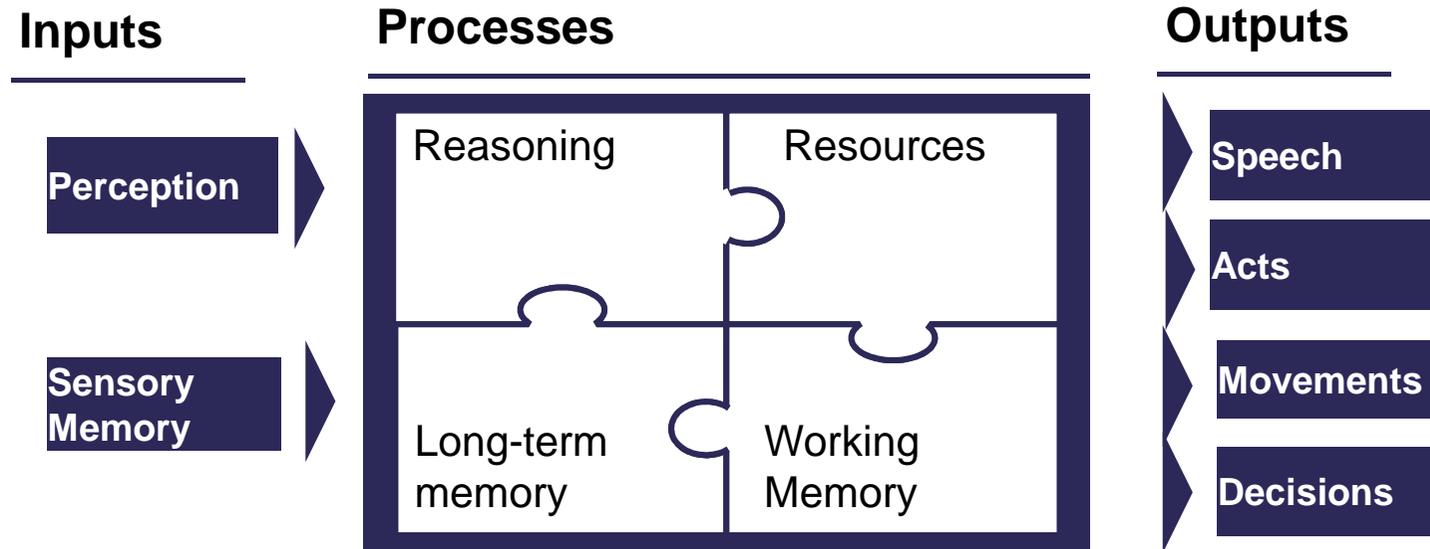


Cognition



- Mental abilities and limitations
 - ↳ Perception and Attention
 - ↳ Memory
 - ↳ Reasoning, problem-solving capabilities
 - ↳ Mental representation
 - ↳ The management of mental resources

- Analogy with a Computer:



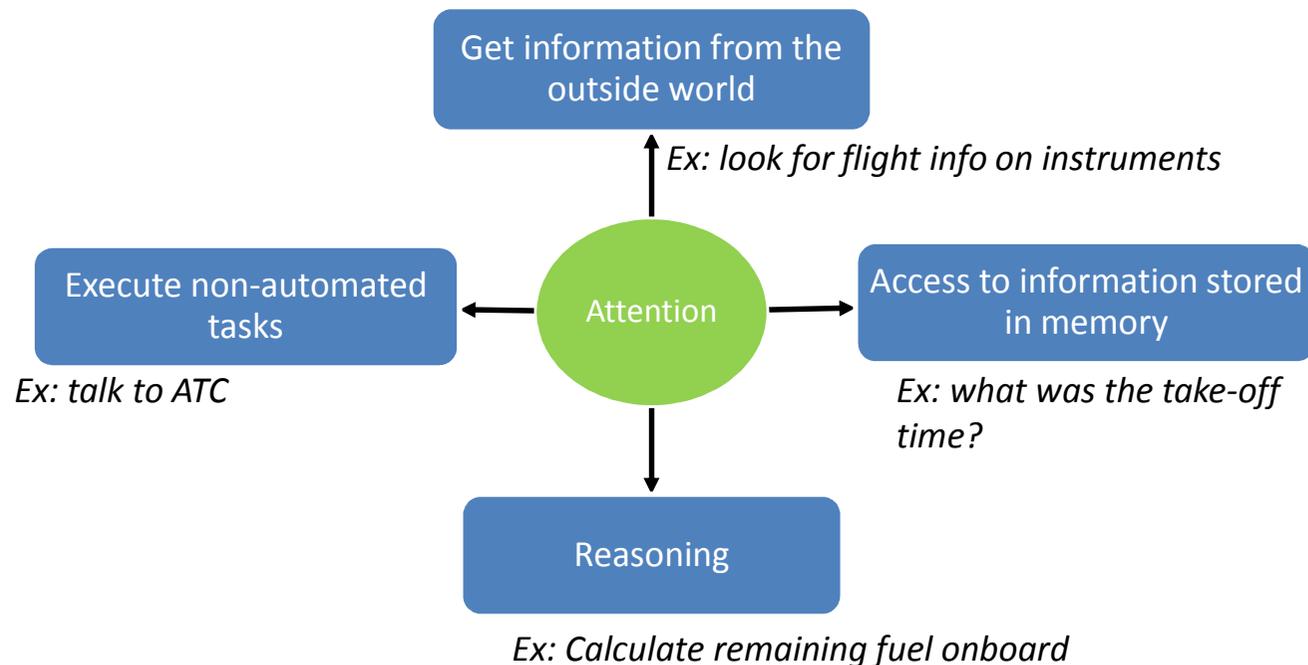
- ...but with Human characteristics:

- Intentions
- Emotions, feelings
- Meta-knowledge: self-awareness of what we know and what we don't

- Active construction of an object by the brain
 - By sorting and combining several perceived clues
 - To build an image coherent with our knowledge of the world



- Voluntary focus of one's cognitive resources to a particular object of interest



- The attention cycles through the various areas of interest
 - ➔ The area of interest is “protected” from competing tasks

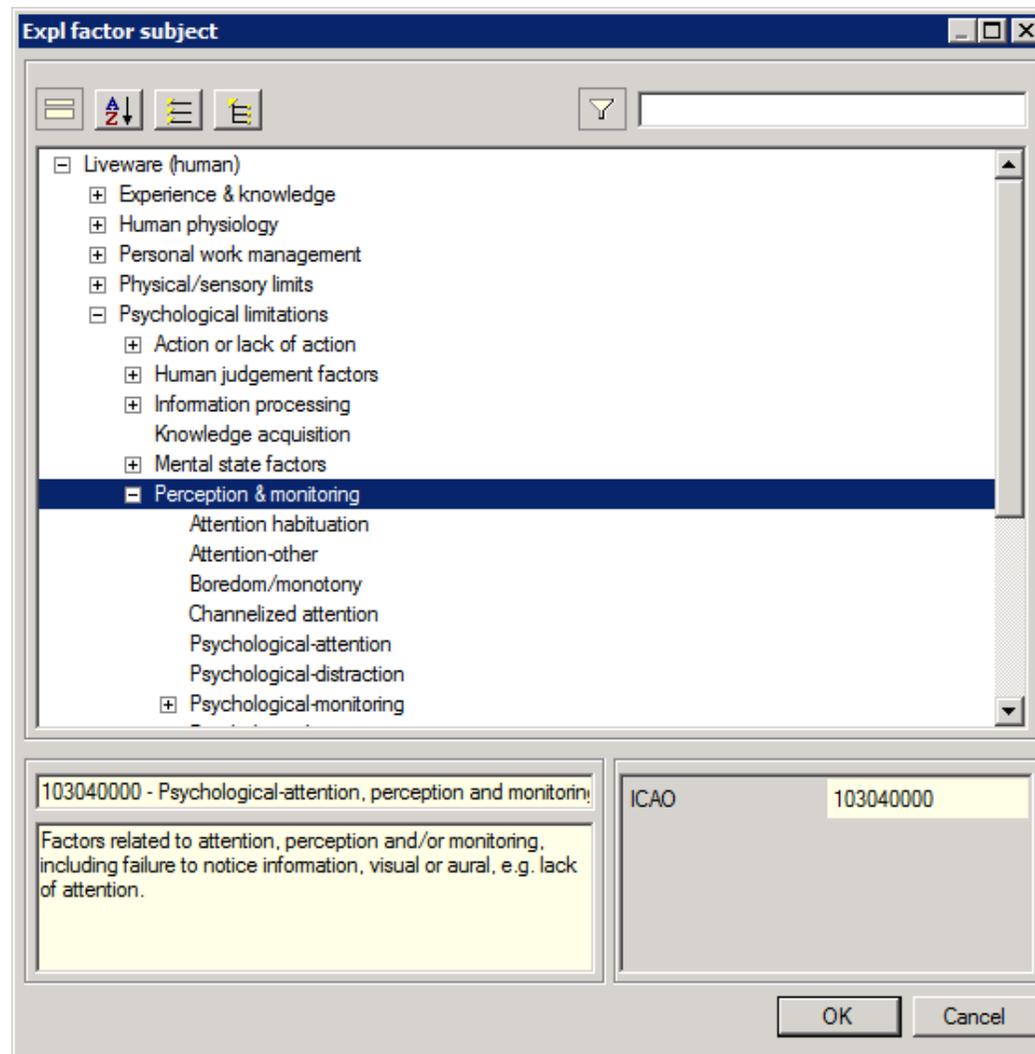


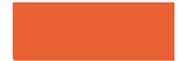
- Count the passes of the white team...



- Landing gear alarm on TB 20...



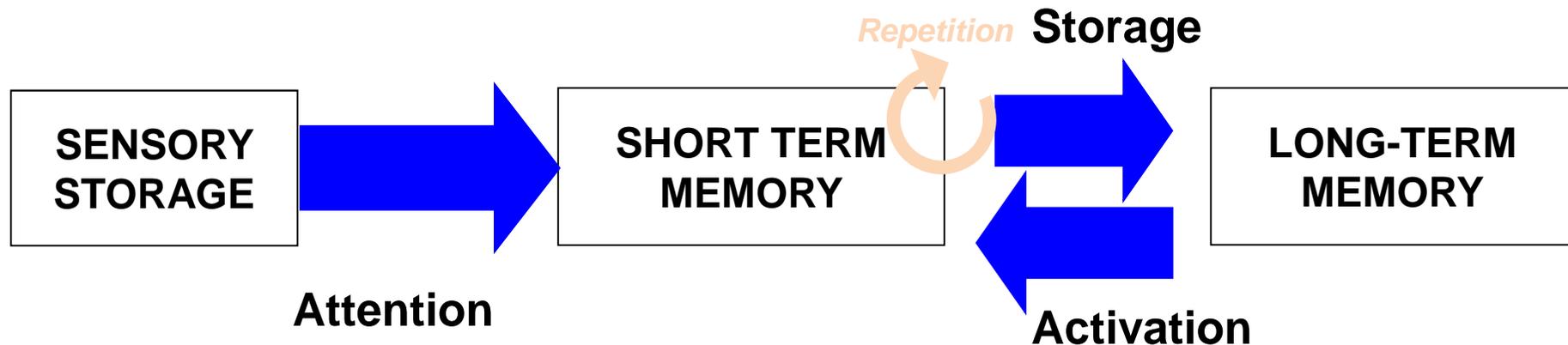




Memory



Memory Storage



- Information from stimuli in the environment initially held very briefly and put into “buffers”
- Some of it will then be transferred to the short-term memory, processed and used for the current actions, then forgotten
- Finally, some of the information is stored in the long-term memory, especially if used frequently in the short term memory

- For witness interviews, keep in mind:
 - ➔ **Leveling bias:** Memory distortions introduced by the loss of details in a recollection over time, often concurrent with
 - ➔ **Sharpening bias** or selective recollection of certain details that take on exaggerated significance in relation to the details or aspects of the experience lost through leveling.
 - ➔ Both biases may be reinforced over time, and by repeated recollection or re-telling of a memory





Expl factor subject [min] [max] [close]

Liveware (human)

- Experience & knowledge
- Human physiology
- Personal work management
- Physical/sensory limits
- Psychological limitations**
- Liveware-environment
- Hard/software interface
- Human v system support
- Interface between humans

103000000 - Psychological limitations

Factors related to anything which involves thinking or acting (not including physiological issues) such as learning, memory, personality or attitudes.

ICAO 103000000

OK Cancel



Reasoning, problem-solving capabilities

SRK Model by Rasmussen

Knowledge-based

Knowledge
ex: $Lift = 1/2 \rho S v^2 \cdot CL$

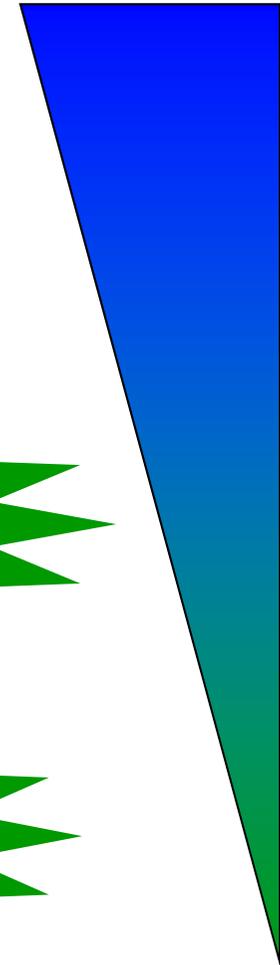
Rule-based

Rules
ex: «If oil pressure is low,
check oil temp»

Skill-based

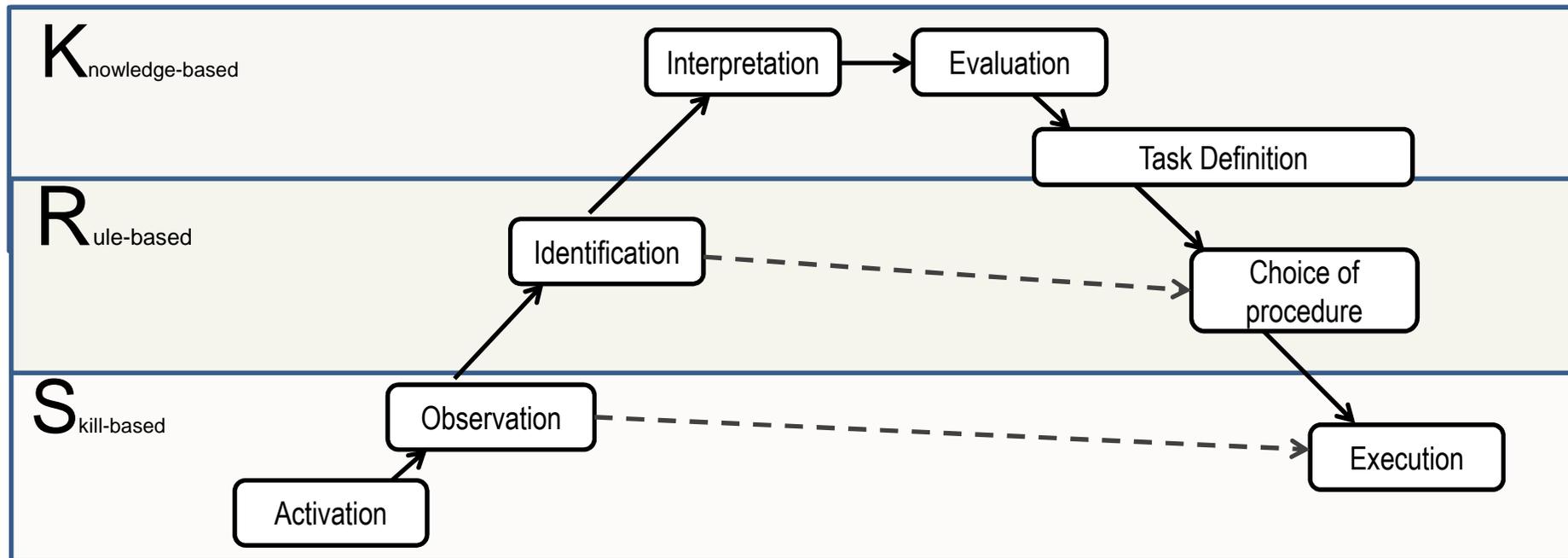
**Automated/Routine
Actions**
ex: flap extension

Cost



Step-Ladder Model

- The complete cycle represents a step-by-step cognitive process, including reasoning and use of knowledge (K) in 8 steps:
 - ➔ Shortcuts possible to reduce the demand on resources
 - Rule-based (R)
 - Skill-based

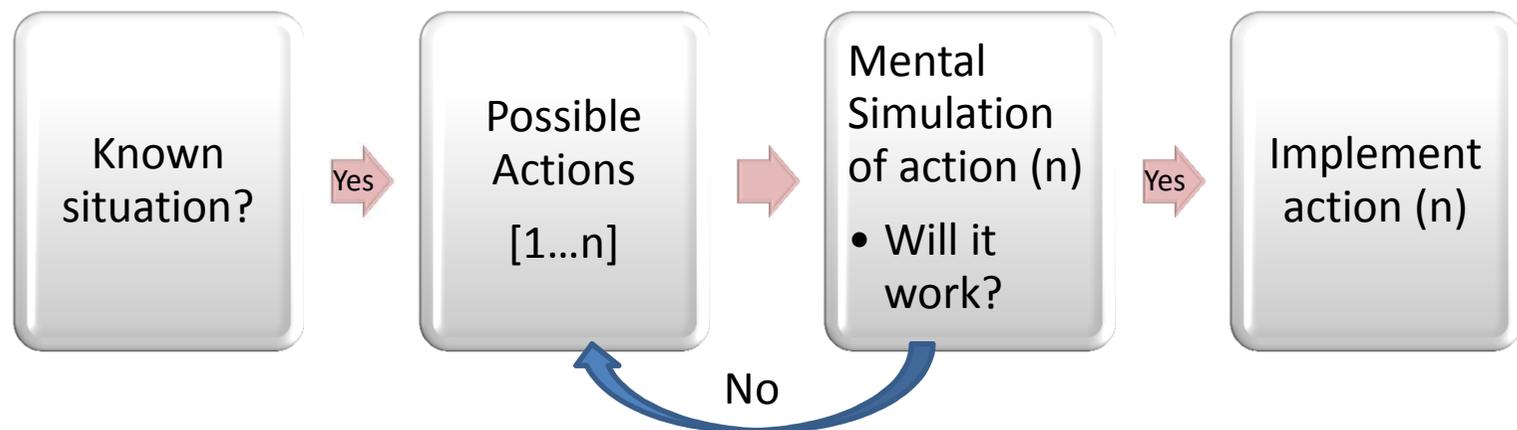


■ Normative models

- ➔ Based on analytical approach, math-based to obtain the optimal decision

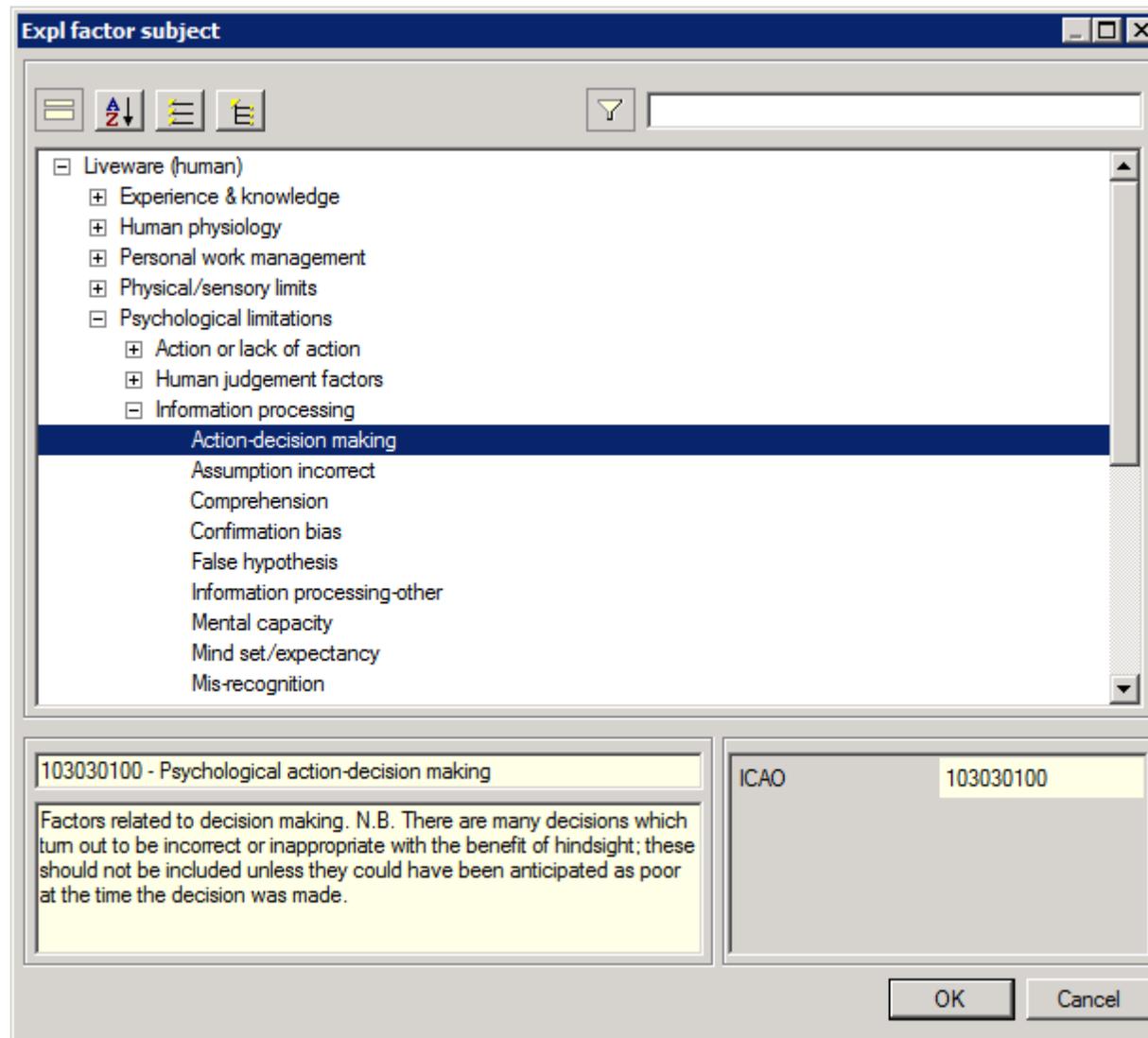
■ Naturalist models

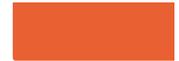
- ➔ Taking a decision is often not as rigorous for safety-critical occupations (like pilots or controllers)
- ➔ Loop: situation evaluation / simulations of options



- Pilot's decisions are results of a risk assessment:
- Two types of risks:
 - ➔ External: risk of accident
 - ➔ Internal: being unable to implement a solution due to the pilot's lack of know-how, or insufficient time to apply it
- Several studies show that pilots prefer to accept an external risk (which they believe they can control) instead of creating an internal risk (work overload, poorly-controlled situation...)

- **Repetition bias:** choice of the most frequently used solution: “I have done it 100 times, it works! It has already happened to me..”
- **Familiarity bias:** choice of the most familiar solution, even if it is not optimal « I know it works »
- **Confirmation bias:** tendency to search for, interpret, focus on and remember information in a way that confirms one's preconceptions
- **Groupthink / Herd behavior bias:** tendency to do (or believe) things because many other people do (or believe) the same.
- ..and many more



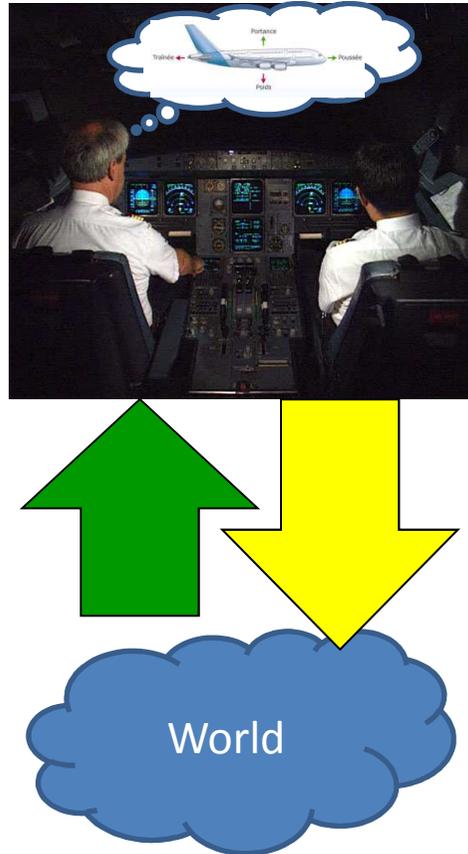


Mental representation



Mental Representation

- Bottom-up Approach
 - ➔ Signals sent by the outside world help build a coherent concept



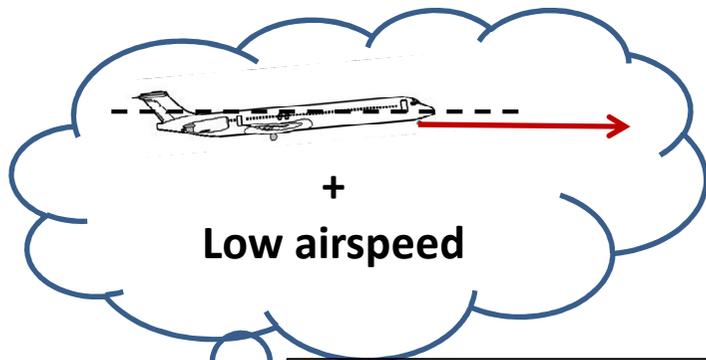
- Top-down Approach
 - ➔ The concept that is built depends on what we are looking for, and our past experience
 - ➔ We perceive mainly what we want to perceive

Mental representation = Part of the real outside world + internally generated expectations

- Right balance between:
 - ↳ **Relevance**: with the intended objective
 - ↳ **Consistence**: with reality
 - ↳ **Stability**: changes occurring too often would hurt the understanding of a situation, making it difficult to control
 - → Find the optimal update rate

- Often a contributing factor in accidents/incidents
- A mental representation can remain **stable** for a long time, while neither **relevant**, nor **consistent with reality**
 - ➔ As long as the reactions of the operators to their representations contribute to generate a reality that can be perceived as consistent with those representations
 - ➔ An operator may reject any contradicting information and keep anything that remains consistent with the expectations

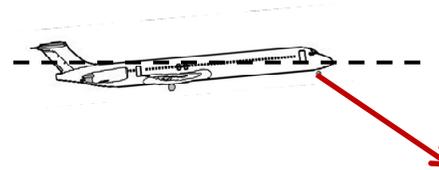
Example



Low airspeed

≠

REALITY



⇒ Increase engine thrust

⇒ Decrease AoA: pitch-down to regain airspeed



LOC-I





Expl factor subject [min] [max] [close]

[list icon] [undo] [redo] [list icon] [list icon] [filter icon] [input field]

- [-] Liveware (human)
 - [+] Experience & knowledge
 - [+] Human physiology
 - [+] Personal work management
 - [+] Physical/sensory limits
 - [-] Psychological limitations
 - [+] Action or lack of action
 - [+] Human judgement factors
 - [+] Information processing
 - Knowledge acquisition
 - [+] Mental state factors
 - [+] Perception & monitoring
 - [+] Personality/attitude
 - [+] Psychological-ability
 - [+] Psychological planning
 - [-] Situational awareness
 - Geographic disorientation
 - "Losing the picture"
 - Situational awareness
 - Spatial disorientation
 - Temporal disorientation
 - Visual disorientation
 - Other orientation factors

103080000 - Human knowledge acquisition factors situation

Factors related to situational awareness. Situational awareness refers to a person's consciousness of the aeroplane's status in relation to operational and environmental conditions.

ICAO 103080000

[OK] [Cancel]

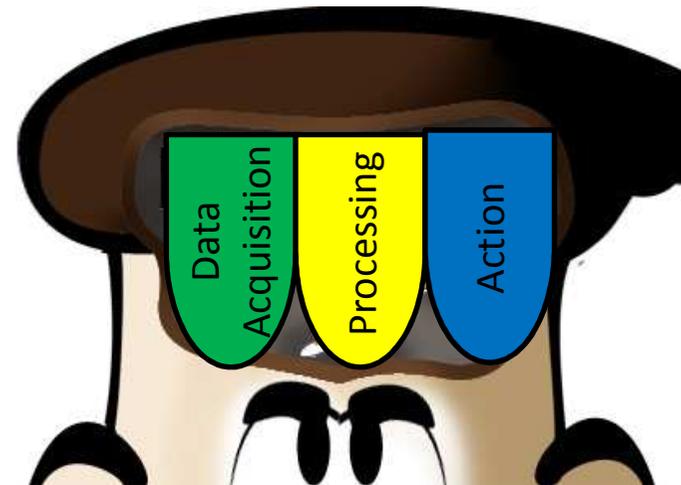


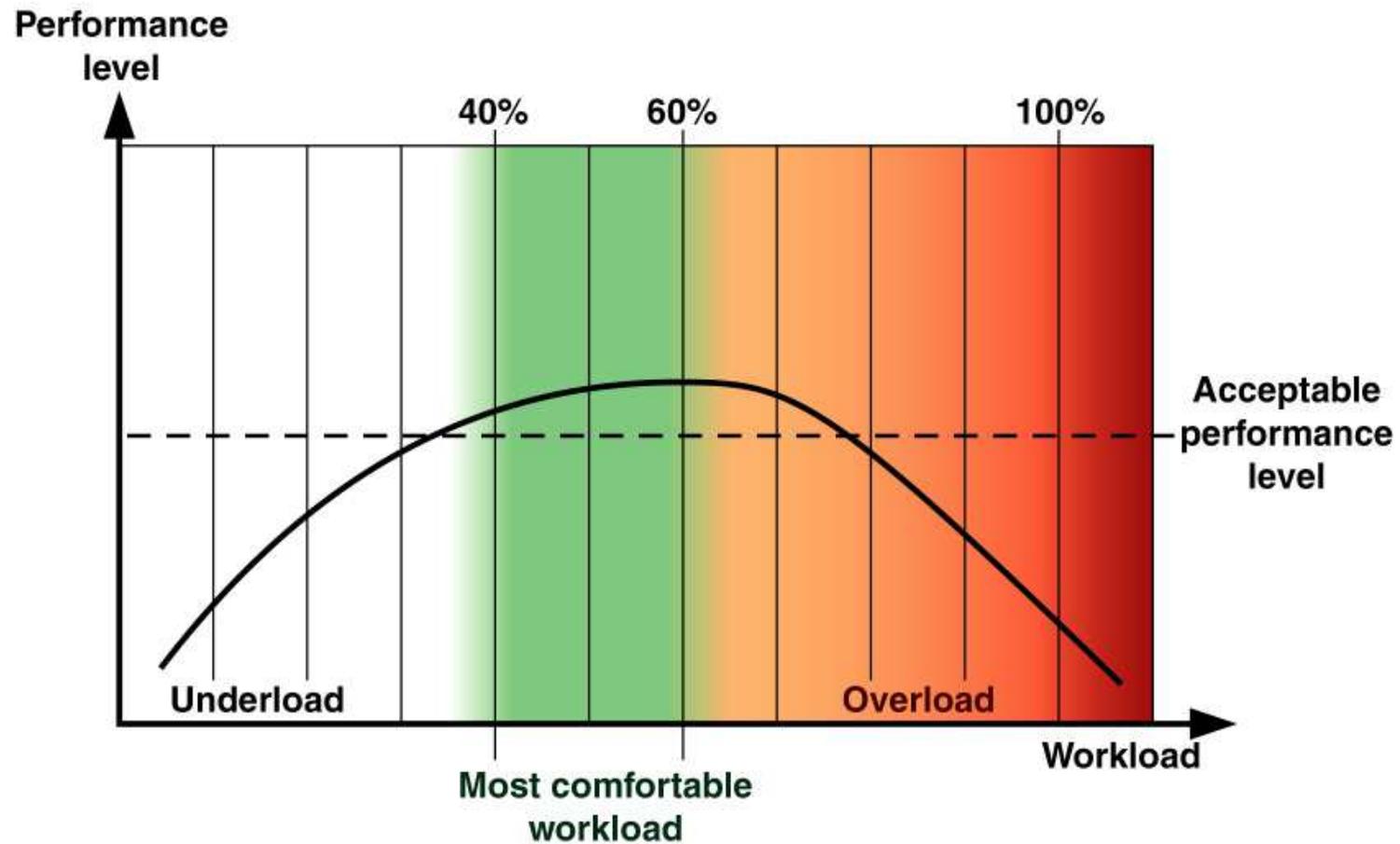


The management of mental resources

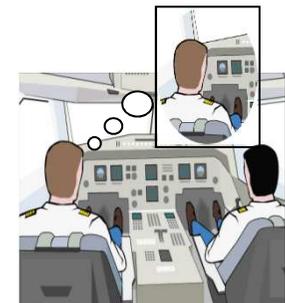


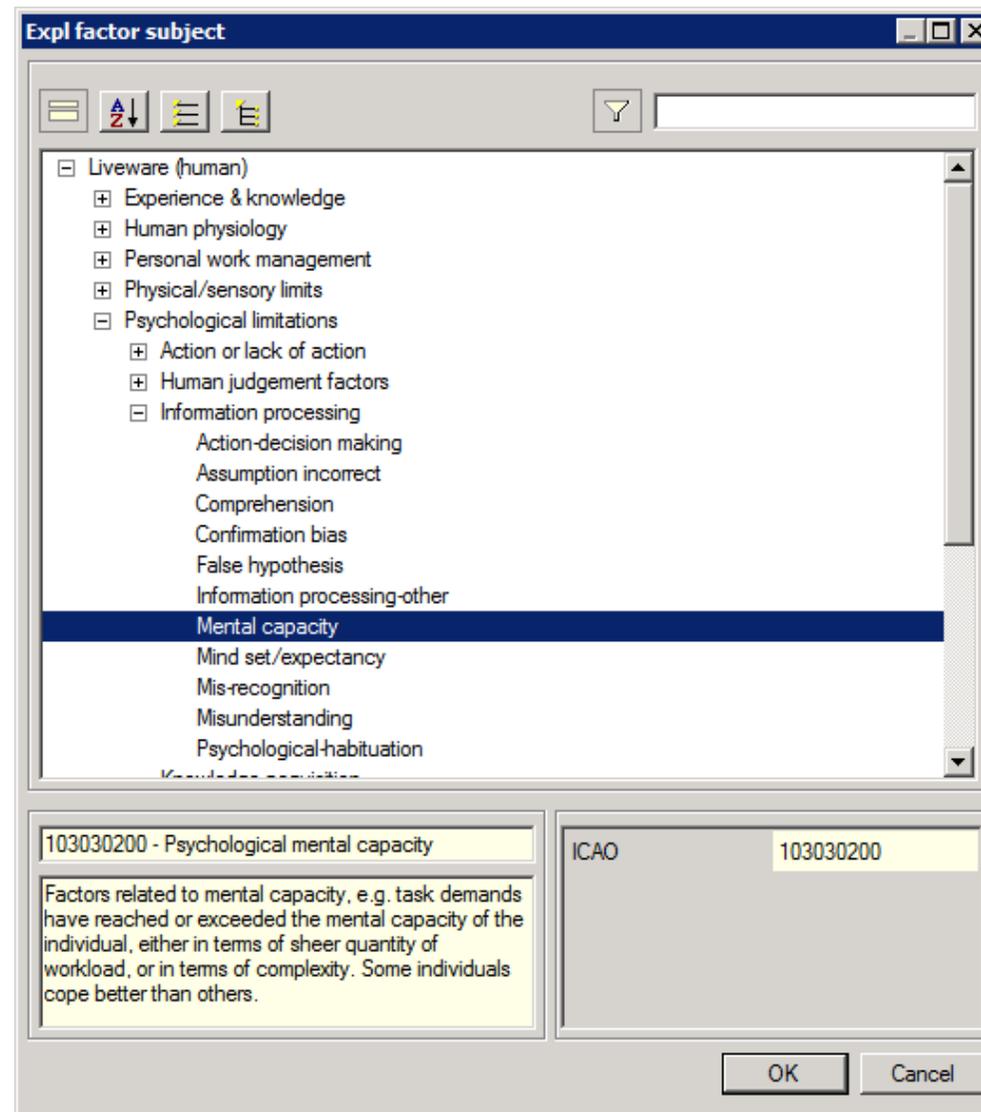
- Like a computer, Human performance depends on
 - Personal capacities
 - The way they are used
- Three resources “tanks”
- Performance is good if simultaneous tasks use different resource types
 - Drive and listen to the radio: OK
 - Listen to ATC and read an ECAM message: very difficult





- Automation of behavior to take advantage of the repetitive features of the world → (Skill-based from the SRK model)
- Management of attention to prevent resource misuse
- Anticipation of the situation
 - Briefings
 - Pre-activation of the Long-term Memory
 - To stay “ahead of the aircraft”
- Build an action plan
 - Includes what-ifs scenarios
 - Can be costly in terms of mental resources to change (see biases)
- Knowledge of our strengths and limitations to plan only feasible and controllable solutions







Human Error and Reliability



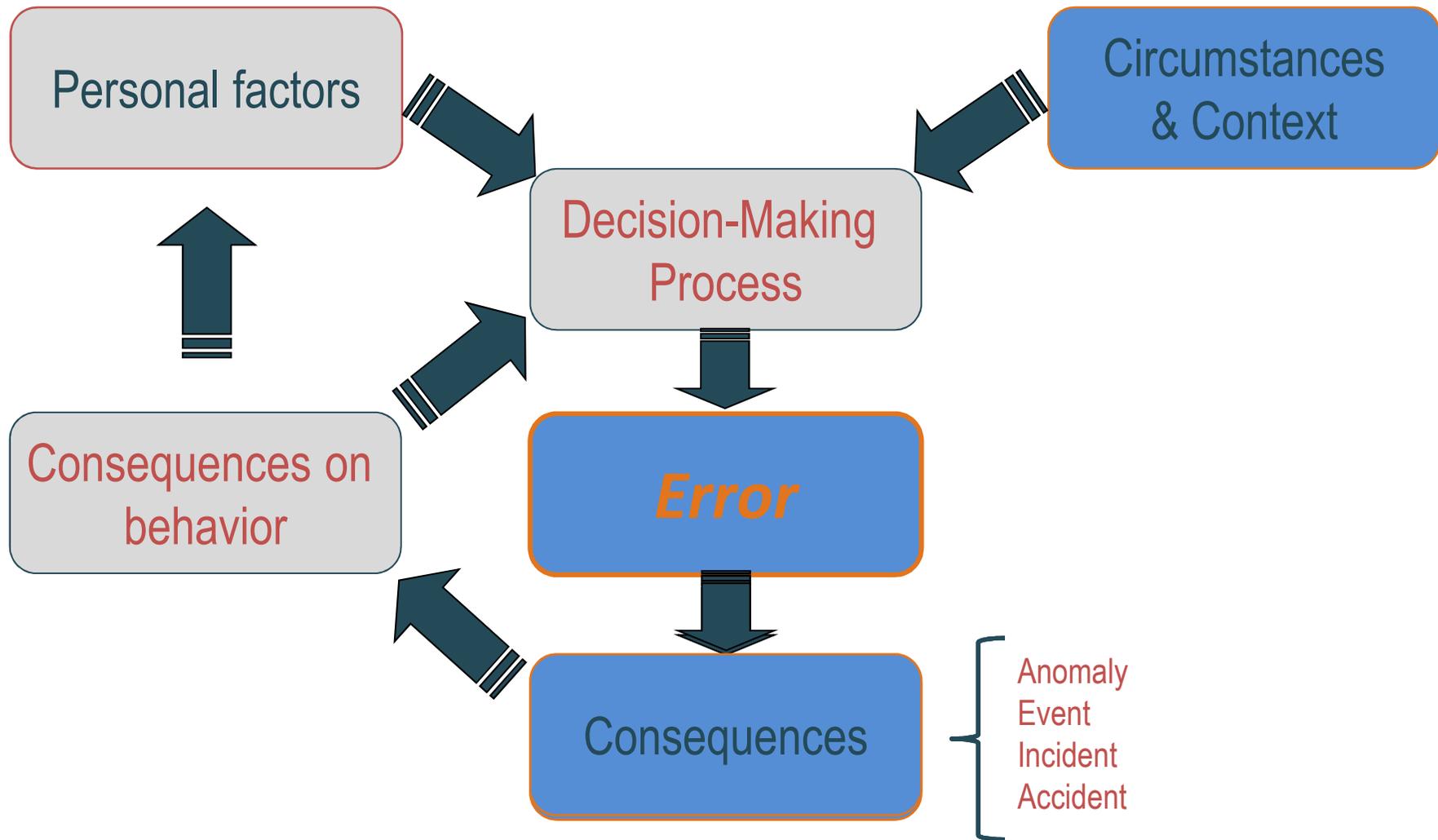
Error and Consequences

- All is in the context

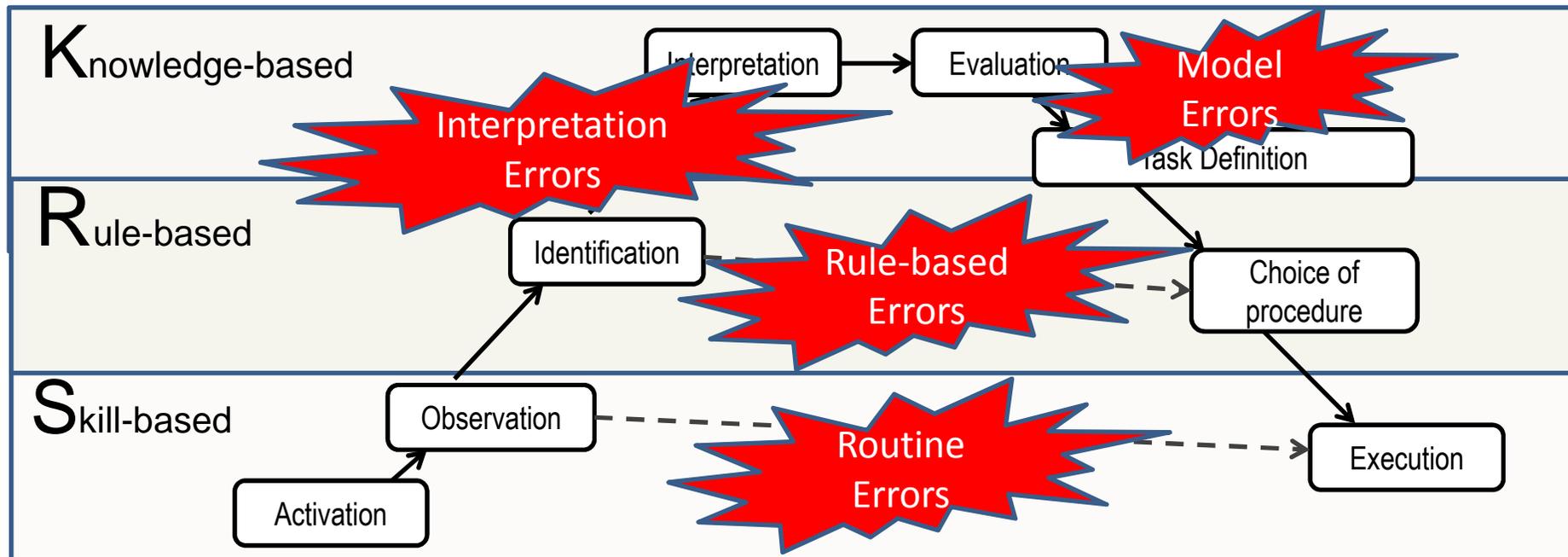


- The severity of consequences depends on the faculty of a **system to be error-tolerant**

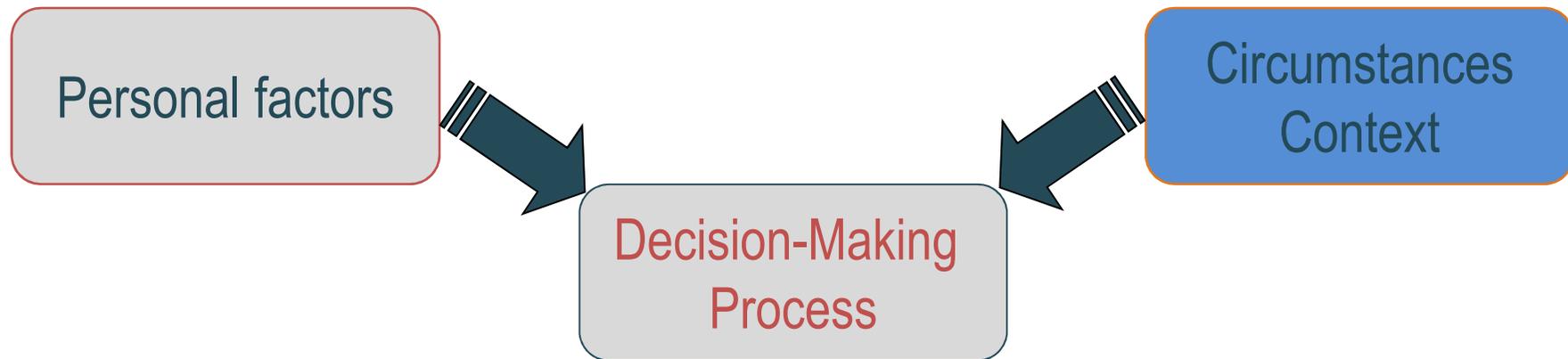
Error Generation



- Step-Ladder SRK model



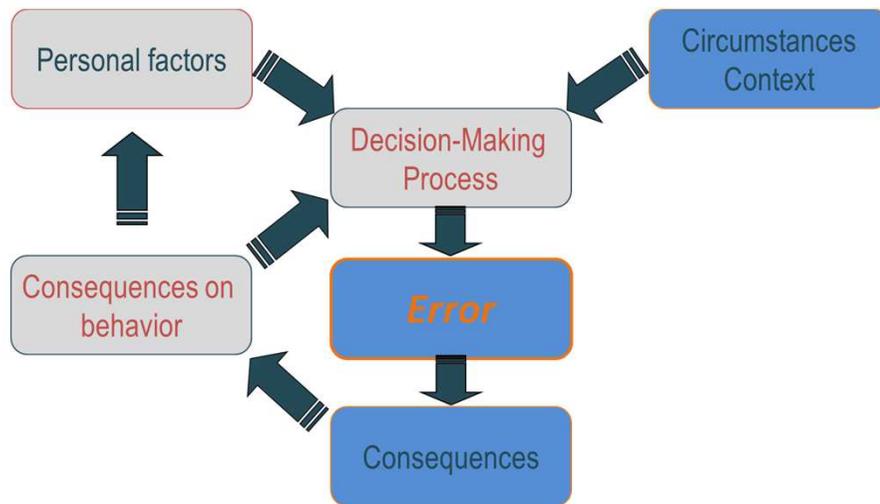
Approach to Error (SMS and Safety Investigations)



Generally, people do logical and reasonable things, based on

- What they know
- What they know how to do
- What they perceive from the environment
- Their objectives

Approach to Error (SMS and Safety Investigations)



Errors are:

- Consequences of the context (can be complex)
- Is not an explanatory factor of an accident
- Part of normal Human behavior
- Often detected and corrected
→ learning lessons

During a safety investigation:

- Separate the error from its consequences
- Draw your attention to the context generating the errors
- Look at the error-catching process

**Contain
Safety
Lessons**

■ Reliability

- ➔ Faculty to accomplish a task under given conditions, timeframe and with adequate tools and resources
- ➔ If a system is reliable, there is **no error**

■ Safety

- ➔ Capacity of a system to work without accidents
- ➔ **Errors do exist**
 - Learn from them
 - Build a system resistant to errors (the ones that are known!)

■ Reliability does not mean Safety



Expl factor subject _ □ ×

Liveware (human)

- Experience & knowledge
- Human physiology
- Personal work management
- Physical/sensory limits
- Psychological limitations
 - Action or lack of action
 - Action-slip
 - Action-lapse/omission
 - Action-mistake
 - Procedure violation
 - Psychological error-other**
 - Timing
 - Third party
- Human judgement factors
- Information processing
 - Knowledge acquisition
- Mental state factors

103010700 - Psychological action or error-other

Factors related to psychological action or error other than those listed above.

ICAO 103010700

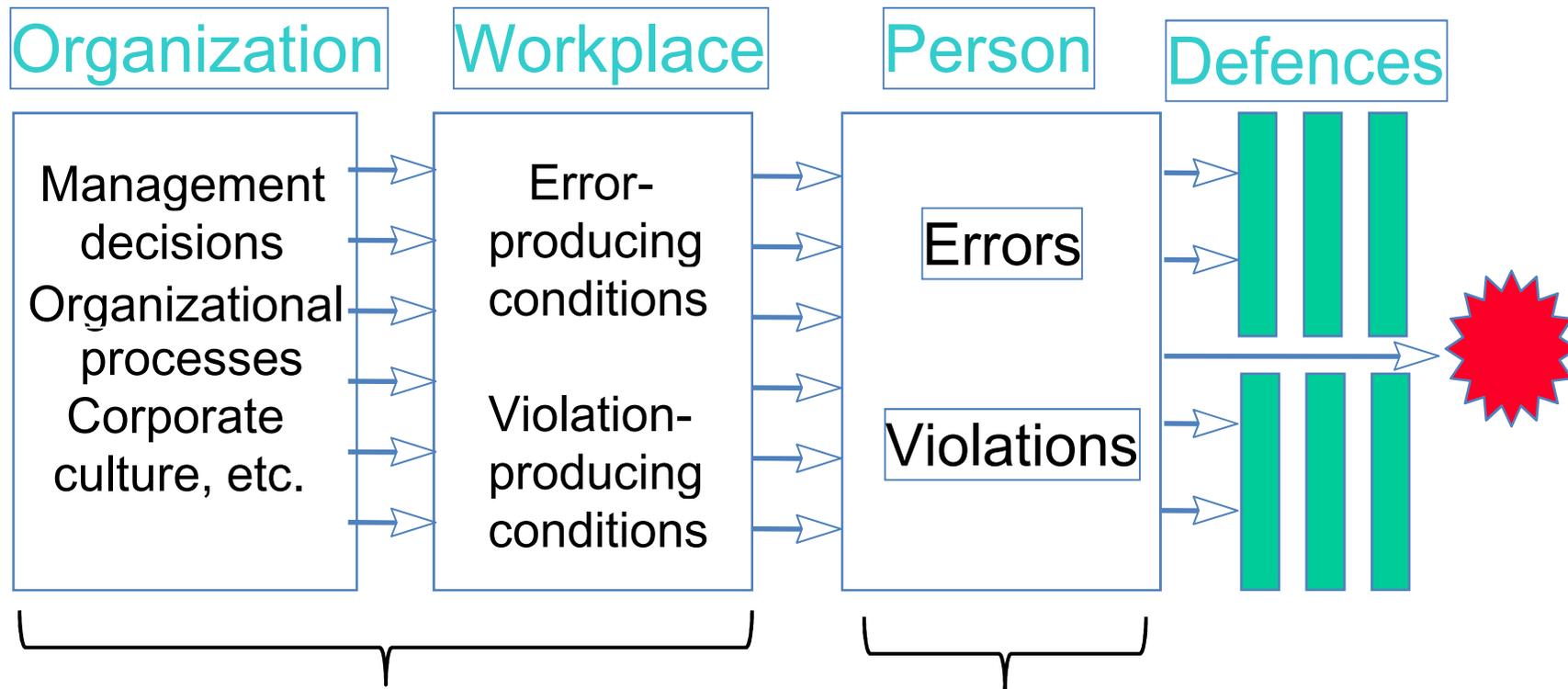




Investigation of Organizational Factors



Swiss Cheese Model



Latent failures: their effects can appear a long time after they have been created, if the right conditions are met.
 Difficult to detect

Active failures: their effects appear right away
 Easy to detect



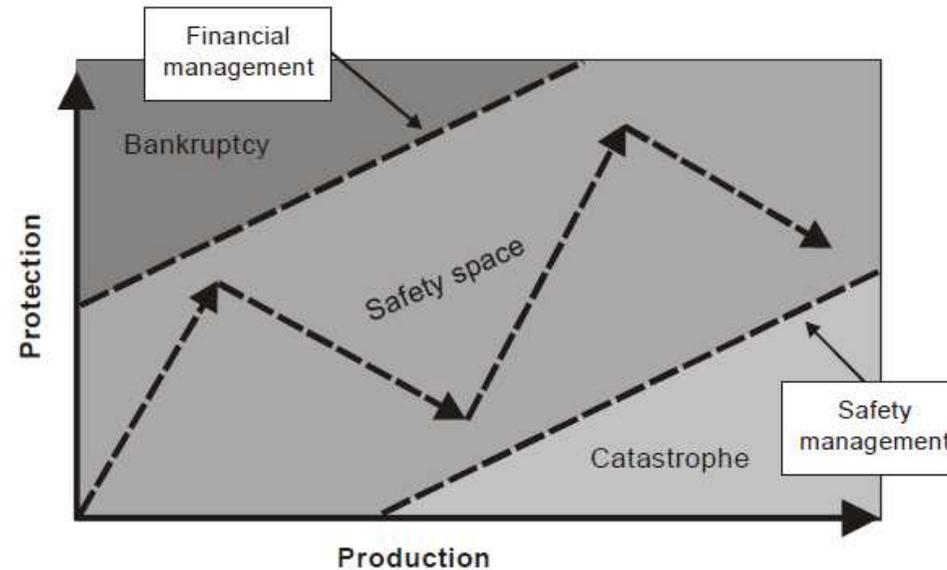
Example : Colgan Air accident



NTSB report.

- strategies to prevent flight crew monitoring failures,
- fatigue,
- remedial training,
- Federal Aviation Administration (FAA) oversight,
- flight operational quality assurance programs,
- the FAA's use of safety alerts for operators to transmit safety-critical information.

Production vs. Protection



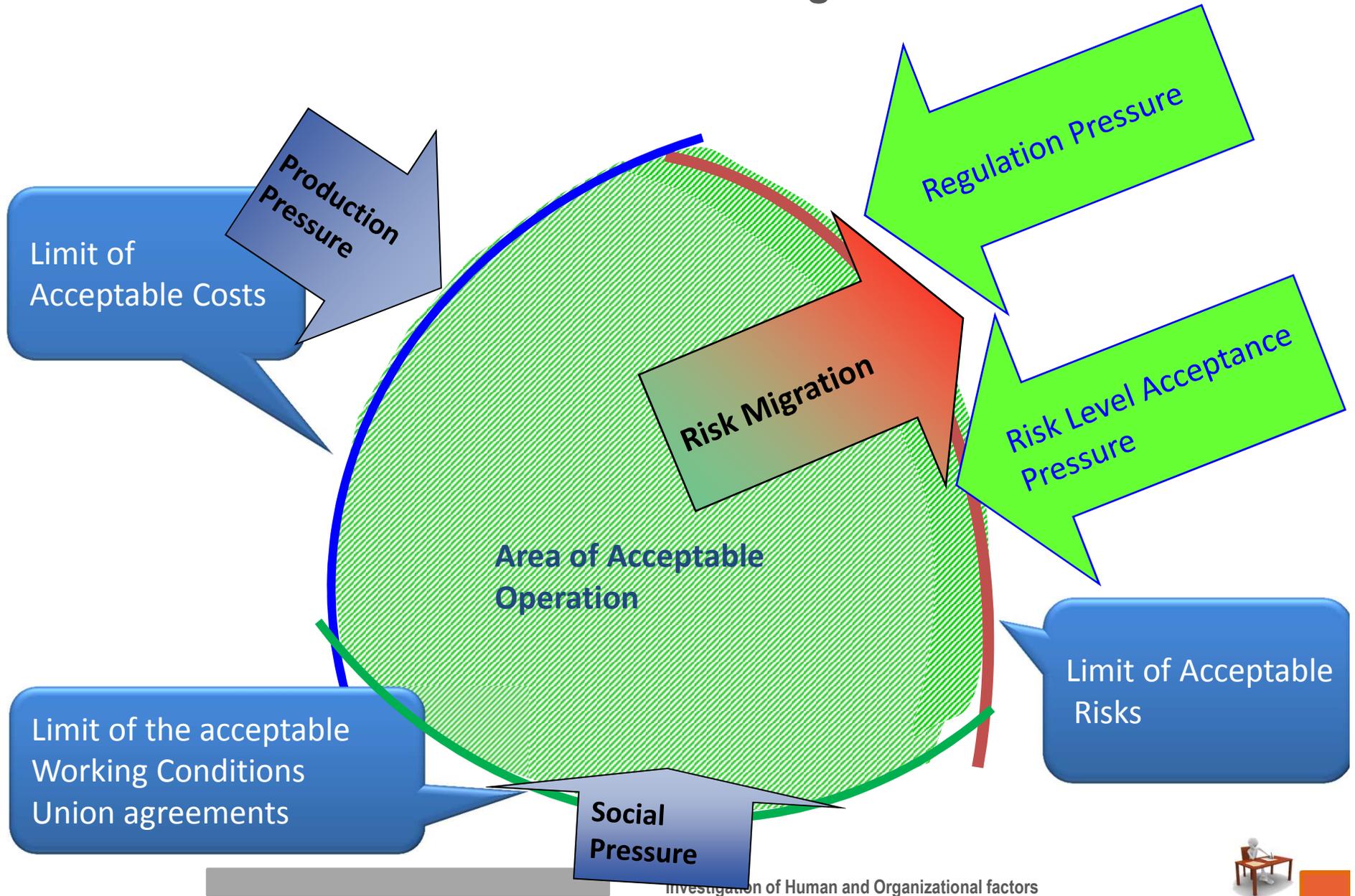
PRODUCTION = CENTRAL OBJECTIVE

- Predictable results
- Clear causes
- Short-term benefits
- Observable successes
- Clear and reliable indicators

SAFETY = EXTERNAL CONSTRAINT

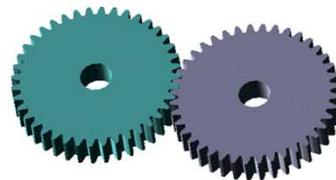
- Rather unpredictable results
- Blurry causes
- Long-term benefits
- Only failures are visible
- No clear indicators

Pressure on Organizations



“Normal” Accidents

- When an accident occurs even though all specifications, requirements, rules and regulations were met.
- Can be the result of either:
 - ➔ The fact that the risk of this type of accident was accepted, because it was considered unlikely to occur,
 - ➔ A failure to identify beforehand that this type of accidents could occur,
 - ➔ A poorly understood combination of failures modes (resonance, tight-coupling) in a complex system



- Do not limit your investigation to front-line actors
- See their managers
- Understand their working conditions
- Study their SMS.

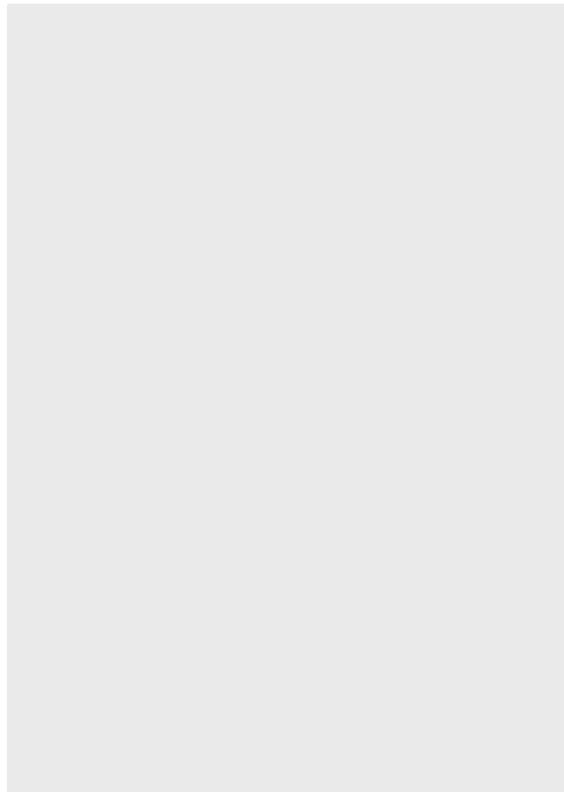
ORGANISATION	<ul style="list-style-type: none">• Training<ul style="list-style-type: none">◦ Design◦ Delivery◦ Standardisation◦ Evaluation• Workforce management<ul style="list-style-type: none">◦ Rostering◦ Staffing levels◦ Tasking and workload• Risk Management<ul style="list-style-type: none">◦ Hazard identification◦ Risk assessments◦ Control measures◦ Effectiveness• Organisational and safety culture<ul style="list-style-type: none">◦ Safety management systems◦ Reporting processes◦ Response to occurrences• Accountability<ul style="list-style-type: none">◦ Management commitment to safety◦ Responsibility for safety• Communication<ul style="list-style-type: none">◦ Information dissemination◦ Standardised processes◦ Feedback
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- *Human Factors Training Manual (Doc 9683)*
- *Human Factors Digest No. 7*
 - *Investigation of Human Factors in Accidents and Incidents*
 - *Circular 240*
- *Safety Management Manual (Doc. 9859)*



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Thank you for your attention