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
Investigation of Human and Organizational factors
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The BEA
Bureau d’Enquêtes et d’Analyses

- 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

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

Investigation of Human and Organizational factors
BEA Missions

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

- **Chicago Convention** of 7 December 1944 (article 26)

- **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**
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
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
Investigation of Human and Organizational factors
Investigations on French Territory

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

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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

The BEA participated in 216 new investigations initiated abroad:
- 205 investigations in 2013
- 228 investigations in 2012
Accidents survenus en France

Investigation of Human and Organizational factors
Reports published 2009-2014

- Année 2014: 104
- Année 2013: 152
- Année 2012: 149
- Année 2011: 208
- Année 2010: 126
- Année 2009: 96
Participation in Foreign Investigations

Number of Investigations

- 8,000 Airbus in service
- 1,100 ATR in service
- 12,000 Airbus Helicopters in service

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Engineering Department Activity in 2014

- **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 in 2014

- Safety Recommendations

Investigation of Human and Organizational factors
Some Recent Investigations

Investigation of Human and Organizational factors
Investigation of Human Factors
Human Factors

[Diagram showing a pie chart with 80% Human Factor causes and 20% Technical techniques.]

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

-No technical failure
-Introduction of «Human Factors»

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

Investigation of Human and Organizational factors
The system fails because of “holes” in the safety barriers.

Safety Investigations aim at determining:

- how the system failed
- where to bring corrective actions

Swiss Cheese Model

- Whose fault is it?
- Who shall we blame?
- Who is responsible?
Accident Rates and Onboard Fatalities by Year

- Pilots technical training
- Technical reliability
- Flight recorders
- Regulations

- CRM
- Ergonomics
- Operation Manuals
- Automation

Systemic failures
- Investigating incidents
- SMS

Rate $\sim 10^{-5}$

Rate $\sim 10^{-6}$

Annual accident rate (per million departures)

Source: Boeing
Human Factors Definitions

- **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

Each agent has his/her
- Limits
- Self-image
- Stress level
- Worries

Investigation of Human and Organizational factors
The SHELL Model

SHELL Model (after Edwards, 1972)

HARDWARE
Cockpit layout, seating, controls, switches, levers, location and direction of movement

SOFTWARE
Procedures, checklists, manuals, symbology, charts etc

LIVEWARE
The Crew

LIVEWARE/LIVEWARE
Interface between people. Flightcrew - Ops staff - ATC engineers, etc

ENVIRONMENT
The aircraft and airspace in which the flight crew operate

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SHELL Model Layout

Coded in ECCAIRS

Use as checklist
Investigation of Human and Organizational factors
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
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
Balance

L’appareil vestibulaire

Les récepteurs proprioceptifs

L’oeil

Source : MOORE et WUYTS, « How to limit disorientation effects on pilots”, 18th Human Factors symposium, 2003
Sensory Illusions

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

Somatogravic 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

Real and perceived pitch attitudes during the missed approach
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.
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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 positive g’s
The Blind Spot

Cover your left eye, look at the cross-hairs
« See and Avoid? »

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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 périphérique 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

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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
Information Processing

- Analogy with a Computer:
  - Inputs
    - Perception
    - Sensory Memory
  - Processes
    - Reasoning
    - Resources
    - Long-term memory
    - Working Memory
  - Outputs
    - Speech
    - Acts
    - Movements
    - Decisions

- ...but with Human characteristics:
  - Intentions
  - Emotions, feelings
  - Meta-knowledge: self-awareness of what we know and what we don’t

Investigation of Human and Organizational factors
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
Attention

- 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

Get information from the outside world
  - Ex: look for flight info on instruments

Execute non-automated tasks
  - Ex: talk to ATC

Access to information stored in memory
  - Ex: what was the take-off time?

Reasoning
  - Ex: Calculate remaining fuel onboard
Video

- Count the passes of the white team...

- Landing gear alarm on TB 20...
Investigation of Human and Organizational factors
Memory
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
Witness 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.
Investigation of Human and Organizational factors
Reasoning, problem-solving capabilities
SRK Model by Rasmussen

Knowledge-based

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

Rule-based

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

Skill-based

Automated/Routine Actions
ex: flap extension

Investigation of Human and Organizational factors
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

### Step-Ladder Model

- **Knowledge-based**
  - Interpretation → Evaluation
  - Task Definition

- **Rule-based**
  - Identification → Choice of procedure
  - Execution

- **Skill-based**
  - Observation → Execution
  - Activation
**Decision-Making**

- **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

**Diagram:**

1. **Known situation?**
2. **Possible Actions [1…n]**
3. **Mental Simulation of action (n)**
   - Will it work?
4. **Implement action (n)**

**Flow:**

- Yes: Proceed to next step
- No: Return to step 2

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**Investigation of Human and Organizational factors**
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...)

Investigation of Human and Organizational factors
Bias of human decisions

- **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
Investigation of Human and Organizational factors
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
The Right Mental Representation

- 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
BEA

Example

+ Low airspeed

⇒ Increase engine thrust

≠

⇒ Decrease AoA: pitch-down to regain airspeed

REALITY

LOC-I

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Investigation of Human and Organizational factors
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
Investigation of Human and Organizational factors
Use of Mental Resources

- Automation of behavior to take advantage of the repetitive features of the world
- 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

(Skill-based from the SRK model)
Investigation of Human and Organizational factors
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

Investigation of Human and Organizational factors
Error Generation

- Personal factors
- Decision-Making Process
- Circumstances & Context
- Consequences on behavior
- Error
- Consequences

- Anomaly
- Event
- Incident
- Accident

Investigation of Human and Organizational factors
- Step-Ladder SRK model

**Error Types**

- **Knowledge-based**
  - Interpretation Errors
  - Evaluation
  - Model Errors

- **Rule-based**
  - Identification
  - Rule-based Errors
  - Choice of procedure

- **Skill-based**
  - Observation
  - Routine Errors
  - Execution

Investigation of Human and Organizational factors
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
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
Safety and Reliability

- **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**
Investigation of Human and Organizational factors
Investigation of Organizational Factors
Swiss Cheese Model

**Organization**
- Management decisions
- Organizational processes
- Corporate culture, etc.

**Workplace**
- Error-producing conditions
- Violation-producing conditions

**Person**
- Errors
- Violations

**Defences**

*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.

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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

Investigation of Human and Organizational factors
Pressure on Organizations

- Production Pressure
- Regulation Pressure
- Risk Level Acceptance Pressure
- Limit of Acceptable Costs
- Limit of Acceptable Risks
- Limit of Acceptable Working Conditions
- Union agreements
- Social Pressure

Area of Acceptable Operation

Investigation of Human and Organizational factors
“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
Investigation into Organizational Factors

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

- 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)
Thank you for your attention