INTRODUCING CAST METHOD INTO THE SAFETY INVESTIGATIONS OF FRENCH STATE AIRCRAFTS INCIDENTS AND ACCIDENTS

Anthony Vacher, Anne-Emmanuelle Priot, Léonore Bourgeon

March 27, 2018 – STAMP Workshop 2018

Armed Forces Biomedical Research Institute
Brétigny sur Orge (France)
Research and expertise activities

**ACTION & COGNITION IN OPERATIONAL SITUATION DEPARTMENT**

**PERCEPTION UNIT**
How military environment constraints impact human perception and adaptation?

**COGNITIVE ERGONOMICS UNIT**
Study of the cognitive & social determinants of **decision-making** in risky environments
State Aircraft Fleet

MINISTRY FOR THE ARMED FORCES

MINISTRY OF INTERIOR OTHER MINISTRIES

MINISTRY FOR THE ARMED FORCES

MINISTRY OF INTERIOR OTHER MINISTRIES

KEY FIGURES 2017

≈ 1,600 aircrafts: 837 airplanes, 604 helicopters, 103 UAVs, 66 gliders

5 accidents and 8 serious incidents | ≈ 360,000 flight hours

3.7 events (including 1.4 accident) per 10^5 flight hours
Independent body created in 2003, attached to the Ministry of Armed Forces, distinct budget

Responsible for the safety investigations of incidents and accidents involving state aircrafts

Legal context: ICAO Annex 13, European and French legislation, Armed forces policies

10 permanent safety investigators
- 9 with technical and operational expertises
- 1 ergonomist (> 2014)

Public final safety report (most of them)
Accident Analysis Models and Methods Used

2003

CAUSAL-TREE METHOD

To overcome the traditional limits of traditional accident analysis methods => CAST method
Introduction of CAST method into SAAIB’s safety investigations

Approach followed

- For an accident for which a **HF expertise was commissioned by the SAAIB**, as a supplement to other usual methods

- **Analysis based on:**
  - Information gathered by the investigation team (FDR, CVR, documents, interviews, final report,...)
  - Other available public information (Parliament reports, Ministry of Armed Forces documents)

- For a **recurrent type of accidents in military aviation: “Brownout” or “sudden degradation in visibility due to the dust cloud generated by the helicopter’s rotor”**
Helicopter dust landing – Daytime

https://www.youtube.com/watch?v=N6dCW1SFroA
Helicopter dust landing – Night-time

Courtesy Dr. A.E. Priot, NATO RTO Working Group, 2012
Event Summary

- **July 17, 2013 – 8:00 PM**
- **Sahara Desert (Africa)**
- **“Sabre” Counterterrorism Task Force**
- **Airbus Helicopters H225M Caracal**
- **4th Special Forces Helicopter Regiment** "Nowhere without us!"
- **Crew:** Captain, Pilot, Flight Engineer, 2 Commandos in Cargo
- **Mission:** Transport of 10 commandos from a rear operating base to the bivouac area of a motorized unit in the desert
Event Summary

- **Patrol flight** (with a light helicopter)
- **Tactical night flight** (to overcome possible threats) **with NVG**
- **Extreme environment:** heat (41°C), dust, sand, hostile territory
- During the landing, the helicopter drifted to the left, hit the ground, and rolled over onto its side
Hazard and Loss Identification

Hazards

H-1: Abnormal landing zone contact

Losses

L-1: Slight physical injuries (crew, soldiers in the cargo)
L-2: Loss of mission (operational mission disrupted)
L-3: Damage to helicopter (material & financial losses)
### Proximate events leading to the accident

<table>
<thead>
<tr>
<th>Before flight</th>
<th>Crew asked for a SF simplified marking of the LZ (one IR strobe light)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T0 – 1H</strong></td>
<td>Take-off from rear operational base</td>
</tr>
<tr>
<td><strong>T0 – 40 sec</strong></td>
<td>Descent begin</td>
</tr>
<tr>
<td><strong>T0 – 28 sec</strong></td>
<td>Captain and pilot decide to land in a «manual» mode</td>
</tr>
<tr>
<td></td>
<td>Correct approach slope and speed for a dust landing</td>
</tr>
<tr>
<td><strong>T0 – 14 sec</strong></td>
<td>PF announces “visual on the strobe light”</td>
</tr>
<tr>
<td></td>
<td>Captain ask Flight Engineer to announce the height regularly</td>
</tr>
<tr>
<td></td>
<td><strong>No communication in the cockpit during 11 sec</strong> – Vertical speed: 64ft/min</td>
</tr>
</tbody>
</table>
# Proximate events leading to the accident

<table>
<thead>
<tr>
<th>Time (T0)</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before flight</strong></td>
<td>Crew asked for a SF simplified marking of the LZ (one IR strobe light)</td>
</tr>
<tr>
<td><strong>T0 – 1H</strong></td>
<td>Take-off from rear operational base</td>
</tr>
<tr>
<td><strong>T0 – 40 sec</strong></td>
<td>Descent begin</td>
</tr>
<tr>
<td><strong>T0 – 28 sec</strong></td>
<td>Captain and pilot decide to land in a «manual» mode</td>
</tr>
<tr>
<td></td>
<td>Correct approach slope and speed for a dust landing</td>
</tr>
<tr>
<td><strong>T0 – 14 sec</strong></td>
<td>PF announces “visual on the strobe light”</td>
</tr>
<tr>
<td></td>
<td>Captain ask Flight Engineer to announce the height regularly</td>
</tr>
<tr>
<td></td>
<td>No communication in the cockpit during 11 sec – Vertical speed: 64ft/min</td>
</tr>
<tr>
<td><strong>Short final</strong></td>
<td>Sudden degradation in visibility: “Brownout”. Captain loses visual references. No announcement. Captain seek to regain it</td>
</tr>
<tr>
<td><strong>T0 – 7 sec</strong></td>
<td>Radio altimeter alarm: 30 ft. Unintended action on the flight commands by PF (Cycling pitch) =&gt; The helicopter skids to the left</td>
</tr>
<tr>
<td><strong>T0 – 3 to 1 sec</strong></td>
<td>Radio-altimeter alarm: 15 ft. Captain looks at the “Hover screen” and announces: “We skidding on the left, Go around!” V. speed (-317 ft/min)</td>
</tr>
<tr>
<td><strong>T0</strong></td>
<td>PF announces “I lost visual references”. The left skate of the helicopter strikes the ground. The uncontrollable helicopter overturns</td>
</tr>
</tbody>
</table>
Safety control structure to protect against abnormal landing zone contact

4th Special Forces Helicopters Regiment

- Maintenance Unit
- Crew Qualification & Training Centre
- Ground Markers Training Unit

Commando Regiment

Special Operations Command in Sahel

Flight Crew

- Flying-Pilot
- Captain
- Flight Engineer
- 2 Gunners

H225M Helicopter automation

- Advanced Automatic Flight Control System
- Sensors
- Automated flight control
- Set mode, targets, etc.
- Current mode, targets, etc.

Landing Zone

- LZ markers (ground commando unit)
- Select an appropriate landing area for helicopters
- Realize a complete marking of LZ
- Presence of any easily identifiable object (rocks, trees, etc.)

Physical H225M Helicopter Processes

- External visual environment through NVG
- Other sensory information
- Human Machine Interface
- Manual flight control

Report skills and qualifications issues
- Developing and Maintaining skills & qualifications
- Qualification check Local training
- Report issues

Report skills qualifications issues
- Training, Qualification check, Develop S.O.P.
Safety control structure to protect against abnormal landing zone contact

Ministry of Armed Forces (Ministère des armées)

- General Directorate of Armaments
  - General staff headquarters of the Armies (État-Major des armées)
  - Army Headquarter
  - Army Light Aviation
  - Army Special forces Brigade

Manufacturers

- Integrated Maintenance Structure
- Qualification, Training, SOP development
- Technical availability

Maintenance companies

- 4th Special Forces Helicopters Regiment
  - Special Operations Command in Sahel
- Commando Regiment

- Flight Crew
  - LZ markers
  - Landing area

- H225M Helicopter automation
  - Physical H225M Helicopter Processes

Define Operational contract
H225M Helicopter “Caracal”

Some specifications

- Medium-class helicopter
- Five-blade rotor, powered by two engines
- Advanced Automatic Flight Control System
- Gradual arrival in units from the mid-2000s

Main missions

- Combat Search and Rescue
- Tactical transport / Special operation
- Casualty / Medical evacuation

Technical failure: none

Unsafe interactions: Contact with the landing zone when the trajectory was unstable (5kt lateral left-hand drift, −400 feet/ min)
Crew composition and experience

Unit: 4th Special Forces Helicopter Regiment - 3rd squadron

On the theater since two months, previous deployments on theater

**CAPTAIN**
- 33 years old
- Patrol & Squadron leader
- 1,300 flight hours total
- 600 on H225M, 250 with NVG

**PILOT FLYING**
- 31 years old, Operational Pilot
- 1,400 flight hours total
- 800 on H225M, >300 with NVG

**LEFT DOOR COMMANDO**
- 36 years old
- 300 flight hours on H225M
- including 70 by night

**FLIGHT ENGINEER**
- 44 years old, Chief Warrant Officer
- 2,200 flight hours total
- 58 flight hours and first operational mission on H225M

**RIGHT DOOR COMMANDO**
- 35 years old
- 150 flight hours on H225M
- including 80 by night
Safety Requirements and Constraints:
- Operate the helicopter in accordance with 4th SFHR procedures
- Choose the landing mode during the pre-flight briefing
- Manage the flight path for a safe landing (speed, roll,..., drift) in manual mode
- Perform an alternate visual sweep inside and outside to control the trajectory
- Maintain external visual references until contact
- Initiate a go around if visual references are lost

Unsafe Control Actions:
- Chose the landing mode to late
- Focused only on external visual cues. Did not check inside the cockpit
- Made an unintended action of the cyclic pitch control
- Did not detect the skid
- Did not initiate a go around when the strobe lamp disappear from its visual field
Feedbacks:

- (Too few) visual references in a DVE: NVG, sandy, dusty and flat LZ without any clear visual clues
- Inner ear and somesthesic feedbacks (but not accurate and reliable enough, especially in a vibrating machine)
- Information from the electronic flight instrument system (but not check)
- Information from the other crew members (but no verbal communication)
- No visual or audible alarms to warn for a skid
Mental model flaws:

- Though that the mission had **no unusual risks** => Short preflight briefing, mission used for training (simplified LZ marking procedure and manual mode landing)

- **Fear of losing the few external visual references** in case of instrument check => PF did not perform alternate visual scans inside/outside

- Believed the helicopter’s trajectory was correct. **The skidding of the helicopter was perceived as an IR strobe movement due to the rotor blades**
Captain – Non-Flying Pilot

Safety Requirements and Constraints:
- Operate the helicopter in accordance with 4\textsuperscript{th} SFHR procedures
- Request (complete) marking of the landing zone before flight
- Choose the landing mode during the pre-flight briefing
- Ensure effective Crew Resources Management (collective SA)
- Perform an alternate visual sweep inside and outside the cockpit to precisely control the helicopter’s trajectory during landing is correct
- Ensure security (look at potential threats outside and on IR camera screen)

Unsafe control Actions:
- Failed to request a complete marking of the landing zone
- Chose to train in manual mode during an operational mission
- Chose the landing mode to late
- Failed to establish an effective CRM during flight
- Did not announce the loss of visual references
- Has detected the lef-skid on the Hover screen too late
Mental model flaws:

- Though that the mission had **no unusual risks** => Short preflight briefing, training (simplified LZ marking procedure and manual mode landing)

Feedbacks:

- (Too Few) visual references in a DVE
- Inner ear and somesthesic feedbacks (not reliable)
- Information from the electronic flight instrument system
- Information from the other crew members (but no communication)
- No visual or audible alarms to warn for a skid

Context:

- No dust landing procedure was available for H225M
- Training: only 5 flight hours during the 2 month between two deployments
- Captain aware of the absence of qualified marker for helicopter LZ marking
- Possible presence of enemies
Flight Engineer

Safety Requirements and Constraints:
- Operate the helicopter in accordance with 4<sup>th</sup> SFHR procedures
- Announce the evolution of flight parameters (including radio-altimeter height, vertical speed, pitch angle, available power, ...)
- Monitor the IR camera on board
- Ensure security (look at potential threats outside and on IR camera screen)

Unsafe Control Actions:
- Did not announce height and vertical speed
- Failed to detect the excessive vertical speed and lateral drift

Feedbacks:
- Information available on flight panel

Mental model flaws & Context:
- First operational dust landing on H225M, no prior training...
- Attention mobilized on the IR camera management: seeks to position it on the light of the IR strob
All aircrew members

**Context of decision-making:**
- No dust landing procedure for H225M
- Fly on both old and new helicopter generation
- High pace of deployments: ≈8 month aboard per year
- Minimal annual quota of flight hours not reached (only 150 FH), very little flight devoted to train at landing in dust
- Training in France: only 5 hours in the 2 months preceding their mission
- No local dust landing training on the arrival in Sahel

The CAST method helps to change the way we represent crew’s behavior:

Shift from an “overconfident” helicopter crew (initial temptation...) to well-motivated aircrews members that take advantage of every opportunity to maintain their operational skills (smart and necessary adaptation to systemic constraints)
Landing Zone markers – Commando Unit

Safety Requirements and Constraints:
- Choose and prepare an adequate landing zone for airplanes and helicopter (basic requirements of commando units)
- Realize a complete or a simplified marking of the landing zone

Unsafe Control Actions:
- Chose a flat, dusty and sandy LZ lacking of any clear visual references
Mental model flaws:

- Did not know the requirements for the design of a LZ for helicopter dust landing: visual clues (rocks, tree, bush, objects), avoid flat and sandy area
- Though they had chosen the “least bad” available LZ

Context:

- The 4th SFHR did not train commando to the marking of helicopter LZ
4th Special Forces Helicopter Regiment

Safety Requirements and Constraints:
- Develop special forces operating procedures for safe landing in dust, specific to H225M helicopter (day-time and night-time)
- Define policies for the use of the two landing modes in operation
- Monitor the crew’s skills for the two landing modes
- Provide sufficient aircrew training and aerial activity
- Train markers for the LZ marking

Unsafe Control Actions:
- Failed to provide guidance for safe landing in dust, specific for H225M
- Failed to develop a policy for the use of the two landing modes
- Fail to monitor the crew’s skill for the two landing modes
- Failed to train aircrew sufficiently
- Failed to train markers in ground commando units
Mental Model Flaws:

- Procedures were seen primarily as constraints and not as resources to guide crews in their risky activities

Context:

- High pace of operations, increased demand for interventions, staff turnover,…
- Low technical availability of the H225M helicopter fleet

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Army Light Aviation H225M Technical availability</td>
<td>57%</td>
<td>53%</td>
<td>43%</td>
<td>33%</td>
<td>31%</td>
</tr>
</tbody>
</table>
Safety Requirements and Constraints:

- Establish public contract with maintenance companies and manufacturers
- Ensure technical availability of the helicopters that allow units to comply with their “operational contract” mandated by Army Special Forces Command and Army Light Aviation Command

Unsafe actions:

- Failure to ensure sufficient technical availability
Integrated maintenance structure

Context: unanticipated maintenance needs

- **Evolution of helicopter missions**: from C-SAR to an intensive and permanent use in operations

- **Evolution of military operational theatre and their constraints**
  - Camel grass: *obstruction of air inlets* (not designed for this environment)
  - Fine sand and dust, extreme heat => *premature wear of turbines*

⇒ Usual expected “life expectancy of turbines: 3,000 flight hours
⇒ Observed "life expectancy": between 60 and 106 flight hours
⇒ 24 engines replaced for a flat rate of 15 engines per year (2014)

*From Information report N°3323, Assemblée Nationale, 2015*
Safety Requirements and Constraints:

- Define the “operational contract” that mandate the contribution of each army branch and unit
- Provide the resources needed to implement the objectives defined in the “operational contract”
- Control the ability of the armed forces to carry out their missions

Unsafe actions:

- Allow operational units to work within the limits of the “operational contract” mandated to them
- Failure to maintain sufficient technical availability of H225M helicopter
- Failure to control the ability of the armed forces to carry out their missions (crew training under the minimal requirements)
Dynamics and changes in the system and the safety control structure related to the accident

**Budget constraints on departmental budgets**, including the Ministry of the Armed Forces (financial crises, control of public debt and public spending)

**Geopolitical context and location of operational theatres:**

=> Increased demand for long range missions, commitment of the units within the limits of their “operational contract”, exposure to extreme environments

**Technologies used:** Glass-cockpit helicopter with advanced avionics system

=> Need to (re)define the task allocation inside cockpit and the SOP design

---

Puma - SA 330, 1960s  
H225M, 2000s
Conclusion & Perspectives

CAST method advantages:

- Provides a **useful framework for accident analysis and the identification of pertinent safety recommendations**
- Makes it possible to go beyond the “person approach” and allows a real systemic perspective on safety
- Focus mainly on the prevention of next accident, not who has failed?

Next steps:

- Use of CAST method for all SAAIB expertise requests (4 to 8/year)
- Introduce STAMP model for patient safety management in “pharmacological clinical trial” and military “trauma centers”
Thank you for your attention

The views expressed in this presentation are those of the authors and do not necessarily reflect the official policy or position of the French Ministry for Armed Forces or the Military Air Accident Investigation Board.

Credits: Airbus