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SCD: A 3 States Startle Copying Display to Manage Deleterious Effects of Extreme Emergency Situation.

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The management of cognitive resources are central in the case of a decision-making process by pilots. We undertake a study involving Airbus 400M pilots and allowing to understand these mechanisms and to propose recommendations for the design of a tool to assist in the management of their cognitive resources. We find that in the most critical cases and under strong temporal pressure, the maintenance of control of the situation corresponds to a survival type behavior which alone can allow a return to the metarules (back to basics).

Our display management proposal allows the pilot to maintain control of the situation regardless of his capabilities. It allows a phase of stabilization by a reduction of the stress, then a phase of "soft" recovery of the control and the management of the mission on larger spatiotemporal dimensions. Three modes of entry in the HMI are envisaged: spontaneous, proposed and on demand.

In a previous work (Bey 2016), we described our research project on the management of cognitive resources in the case of a constrained decision process. We have found that in critical situation and under strong temporal pressure, the pilot panel that we analyzed (14 crews of the French Air Force) is divided into two categories: those who implement adaptive strategies ensuring systematically the success of the mission; and those who do not implement this type of strategy and for whom the result is much more random. The adaptive strategies put in place are based on a change of objective. We noticed that successful ones focus on (i) maintaining the aircraft in flight without attempting to resolve the breakdown at first and, because they are aware of the seriousness of the situation, (ii) a survival strategy.

The consequence of this strategy is the refocusing on very short deadlines of around 20 seconds (limited to the return to manual flying, compensation and control of the aircraft). Then, once the control of the plane is assured, they gradually increase the temporal span of their control to longer sequences (of about one minute: joining the axis in safety, passage in manual ILS, parameters of the final). Finally, they allow themselves the control of a much larger time span (of several minutes) on which they will be able to devote themselves to the management of the breakdown and its consequences with a view to the landing (consultation of the ECAM with strong hierarchy in the choice of data retained). They then make their landing in nominal conditions. These conclusions from the experimental approach, show that in the most critical cases, the maintenance of control the situation corresponds to a survival-type behavior ("Survival Skills") which alone can allow a return to metarules ("back to basics"). "). The conditions of entry into survival behavior are: 1) A metacognitive management of the detection of exceptional situations without immediately applicable solution: "Understanding that we do not understand".

Metacognition then allows us to fall back on survival behaviors, in order to re-credit cognitive resources by disengaging them from too high levels, based on rules or knowledge. 2) An acceptance of the transgression as a solution to an exceptional situation. This is conditioned by the pre-exposure (training) to the "backup" transgression. 3) A call for aeronautical "survival skills" grounded FNCM type (Fly, Nav, Com, Manage). As part of this study, our goal is to propose a new management model based on two essential queries: 1) Ensuring immediate survival; 2) Ensuring survival, by limiting temporal swings. The means implemented can be based on the re-crediting of cognitive resources by: 1) lowering the level of stress: 2) lowering the level of information processed (no parallelization, reducing the scope of future possibilities). On the basis of these results, our desire is now to move the HMIs towards help with the recovery of situational awareness and decision-making. These new HMIs should provide help on some or all of the following: 1) To credit time to the pilot (delegation to himself in time, reordering of his priorities); 2) Increase resources by delegation (incentive to delegate to co-pilot or artificial intelligence); 3) Reduce the requirements of the situation (limit constraints, e.g., be content with rough speed management, but sufficient to ensure safety); 4) Change goals (and act on the requirements / resource relationships they involve).

The SCD model: A 3 state Startle Copying Display

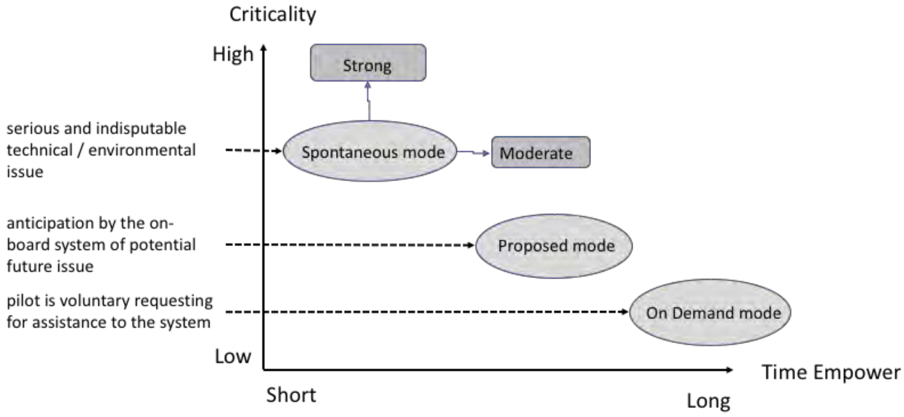


Figure 1. The 3 input modes of the HMI according to the criticality and urgency of the situation.

Our display management proposal must allow the pilot to maintain control of the situation regardless of his capabilities. It allows a phase of stabilization by a reduction of the stress, then a phase of "soft" recovery of the control and the control of the mission on larger spatiotemporal dimensions. To achieve this objective, it deals hierarchically with the following 3 points: 1) Accompany the reduction of temporal and spatial spans; 2) Prioritize actions and reinforce the return to basics and the application of "airmanship"; 3) Accompany the re-extension of temporal and spatial control spans (allow the progressive extension of the temporal span of anticipation -cf. Lini, 2015-). However, it must be considered that the widening of temporal empanels increases the field of possibilities and consequently the cognitive cost of anticipation. To manage the harmful effects of an extreme emergency, we propose a HMI system based on three modes of entry according to criticality and urgency: on demand, spontaneous and proposed (figure 1).

Presentation of the proposed new HMIs

These screens allow pilots to have aggregated and contextualized information regarding the objectives of their mission. They are the result of interviews conducted with participating crews about the level of integration and abstraction of the information they need to decide on the solution to be implemented in the face of the stakes and risks encountered.

The screen in Figure 2a shows the status of the main systems: ENGINES, FUEL, SYSTEM, COMMS, NAVIGATION, FPL, TIMING. For each of them a color label defines the state of the system (i.e. nominal, degraded or broken down).

The screen in Figure 2b shows the situation point in the form of a radar diagram. This visualization presents the environmental dimensions, systems and critical oil, related to the success of the mission. In the example proposed, a system state (typically a plane equipment failure) combined with a limitation of communications, loss of a backup, and this in the context of an unforeseen weather degradation, presents a critical risk on the success of the mission, especially during the landing phase.

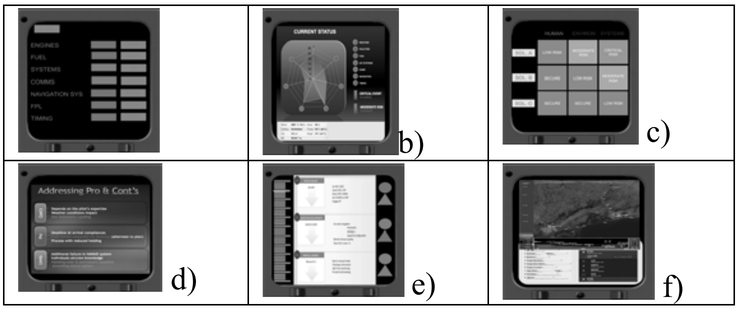


Figure 2. New proposed HMIs. 2a) presentation of the state of the systems, 2b) of the situation point in the form of a radar diagram. 2c) possible solutions with indication of their criticality according to 3 parameters (Human, Environment, System), 2d) advantages, disadvantages and limits of the selected solution, 2nd) Do list "with associated timeline. 2f) Briefing, presentation of the activation of the selected solution.

The screen of Figure 2c presents possible solutions with an indication of their criticality. 3 parameters are considered: Human, Environment, System. This representation makes it possible to assess the difficulty of setting up the chosen solution considering the airplane state, the weather environment in particular (TAF, METAR), but also the reception infrastructures (NOTAM) and the Crew state in terms of airmanship and situational awareness. The color codes used are: Green for Safety, Blue for Low Risk, Orange for Moderate Risk, and Red for Critical.

The screen in Figure 2d shows the advantages, disadvantages and limitations of the selected solution. For each solution, the list of advantages and disadvantages is addressed, as well as the limits of the scope of application. This visualization makes it possible to choose the most suitable solution for the dynamic environment and the airplane and crew state.

The screen in Figure 2e shows a "Do list" with an associated timeline. On the left vertical strip, the time scale is represented in a chronological way, if possible in a coherent and coherent way of the temporality of the realization of the different actions to carry out. On the vertical banner on the right the difficulty to realize the step of the do-list is materialized by the disks, while the criticality is represented by the triangles. Color codes are always applied according to the same display philosophy. Red for Critical, Orange for Severe, Yellow for Moderate, and Green for Easy.

Finally, the screen of Figure 2f presents the briefing. It is the activation of the selected solution. A cartographic background makes it possible to visualize the trajectory and the possible alternatives (clearance and diversions). A horizontal strip, located just below, represents the vertical section of this trajectory. On the left side, a time scale with associated schedules is shown. In the lower part of the screen, on the left side in the synthetic version, a briefing is presented to remind the action plan. In the right-hand part, the remarkable points of the flight plan and the criticality associated with these markers are displayed in tabular form.

The different modes available

On-demand mode

It corresponds to a request from the pilot who asks for assistance from the system. The pilot feeling overwhelmed (feeling "behind the plane") or absent can request the activation of the HMI "on demand" to facilitate his understanding of the current state and the resumption of his involvement in the control of the aircraft. In this case, we assume that there is no critical situation or committed alarm. The system's response will be proposed in the form of successive briefing steps (the pilot validating the progress from one to the other). The proposed IMH sequence (Figure 3) therefore dynamically illustrates the presentation of futures according to the context of the mission and potential vulnerabilities ("what-if"): situation report, matrix solutions, solution example, checklist, briefing, exit.

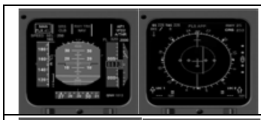
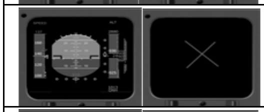
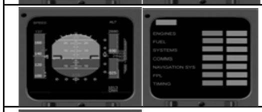
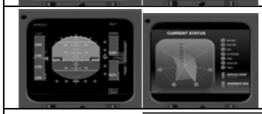
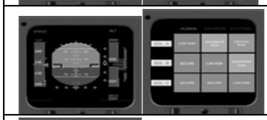
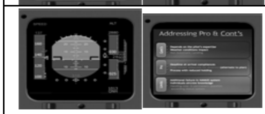
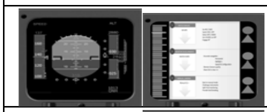
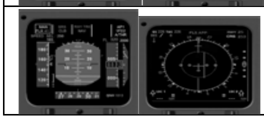
	Step 1: Nominal status of displays (PFD and ND).
	Step 2: Entering priority control mode (simplified PFD and neutralized ND).
	Step 3: Entering System Status mode (simplified PFD and ND on the Aggregate System Status page).
	Step 4 : Entry into Mission Constraint Projection mode (simplified PFD and ND on Situation Point page).
	Step 5: Entering Solution Selection Mode (Simplified PFD and ND in Risk Matrix)
	Step 6: Entry in advantages and disadvantages mode of the solution (simplified PFD and ND on advantages / disadvantages page)
	Step 7: Entry in page application mode of the selected solution (simplified PFD and ND on page Do-List)
	Step 8: Entering Briefing and Realization mode (simplified PFD and ND on Briefing page)
	Step 9: Return to standard mode, output after event resolution (PFD and ND classic)

Figure 3. Proposed HMI sequence for on-demand management.

The spontaneous mode.

It corresponds to an instantaneous display without intervention or acceptance by the crew. It occurs following a serious and indisputable technical / environmental problem (e.g. loss of both engines) or in the event of detection by the aircraft's monitoring system of a condition "incompatible" with the operation of the aircraft (considering the flight data, the system deduces that the pilots' response is inadequate without prejudice to the reasons for this behavior). In this case, the dispensed information is only the data essential to flight control (speed, altitude, variometer, artificial horizon, available energy - such as engine revolutions). In this input mode, corresponding to a critical case, these basic data will override all others. Two display options are possible: strong simplification and weak simplification.

Spontaneous with strong simplification. In this case, only the main screen is kept with the simplified display (Figure 4). The other screens are off (Second screen, parameter screen, FMS and ECAM interfaces). In this input mode, the risk of "startle effect" is high. One way to minimize this risk will be to gradually manage the system's alarm escalation, or even modify its procedures (for example, limit audible alarms).

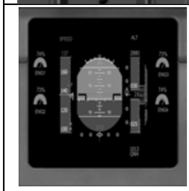
	a): Nominal status of displays (PFD and ND).
	b): Main screen proposal in simplified display mode. The screen information is condensed from the original PFD and increased by the representation of the energy management (effective thrust) This allows a real-time management of the dynamic monitoring of the aircraft situation.

Figure 4. Representation of PFD and ND displays. a): Nominal status of displays (PFD and ND); b) Representation of the main screen proposal in simplified display mode

The sequence of the appearance of the different screens in spontaneous mode in Strong Simplification Option (Figure 5) would be as follows : 1) Simplified PFD appears on the classic PFD screen after the event has been detected (Figure 5, step 1); 2) The Simplified Navigation page appears automatically, once the system detects that the aircraft is under control or at the request of the pilot (Figure 5, step 2); 3) The System States appear on the second screen, once the trajectory has been secured or at the request of the pilot, in the form of a list associated with a performance index (Figure 5, step 3); the PFD is always in a simplified version. The pilot identifies the event and chooses to deal with the incident; 4) Switch to problem solving mode with the Do-List on the left page (Figure 5, step 4); 5) Return to nominal display once the incident is resolved or at the request of the pilot (Figure 5, step 5).

Spontaneous with own simplification option. In this case, the simplified screen (Figure 4b) is displayed on the main screen (PFD). The other screens are maintained as is.

The proposed mode

It corresponds to a projection of the system on a more distant term. It proposes to anticipate a potential future criticality and leaves the pilot the prerogative to choose or not an assistance within the framework of an alternative strategy. In this case, the "pilot in the loop" flight management approach is preserved. This anticipation may occur if the aircraft's monitoring system detects a lack of performance in the operation of the aircraft. Although not used in this context, flight data are already available, such as the monitoring of pilot actions on the interactors (detection of the rate of production of errors or non-actions symptomatic of a state of fatigue or advanced stress). They will be considered in the design of the new HMI and associated AI. In other cases, the aircraft's monitoring system analyses the flight data in real time and projects them into a future adapted to the mission context (oil, meteorology, infrastructure, flight plan, etc.). It proposes a refocusing on immediate objectives (maintaining flight control), but above all it complements it with adaptive strategic proposals (including what-if management). In this mode, the management of the pages viewed can be inspired, either by the spontaneous mode in high or low version or by the on-demand mode, depending on the criticality and origin of the incident envisaged by the system.

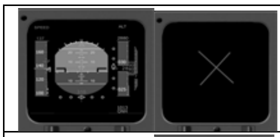
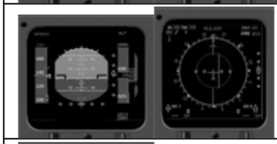
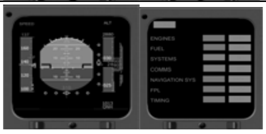
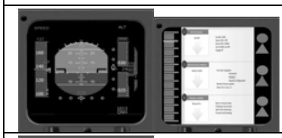
	Step 1: Entering "piloting" mode first when the critical incident occurs (simplified PFD and neutralized ND). Realization of FLY.
	Step 2: Entry into the "navigation" mode, once the piloting has been carried out (simplified PFD and ND scale adapted to time). Realization of NAVIGATE
	Step 3: Entering the "System Status" mode, once the trajectory has been secured (simplified PFD and ND on the Aggregate System Status page). MANAGE realization.
	Step 4: Entering the application page mode of the solution (simplified PFD and ND on Do-List page). Realization of MANAGE & COM.
	Step 5 : Return to standard mode, after the event has been resolved (PFD and ND classic).

Figure 5. Description of the sequence of the appearance of the different screens in spontaneous mode in option strong simplification

Conclusion

Beyond the modification of interactions with the cockpit (HMI) it is clear that pilot selection and training are key factors in performance and risk management in mission execution. The conclusions of our research show the relevance of airmanship training and the interest in also developing the pilots' ability to adapt their time projection to the criticality of the event (time span). The solutions proposed in this work are based on these findings. In crisis situations in constrained times, the 3 levels of assistance (Startle Copying Display) allow pilots to be guided back to the basics of aircraft control. 1) Accompany the reduction of temporal and spatial spans. 2) Prioritize the actions to be taken and reinforce the return to basics and the application of "airmanship". 3) Accompany the re-extension of temporal and spatial control spans (allow the progressive extension of the temporal span of anticipation).

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