ESA Project code (AO 1-7223/12/F/MOS - Sound ergonomics to enhance alarm management)

AUDITORY DISPLAY DESIGN FOR ESA

A theoretical approach to designing auditory warnings for manned and unmanned mission control rooms

Dr. Elif Özcan[a], Dr. Rene van Egmond[a], & Prof. Dr. Judy Edworthy[b]

[a] Delft University of Technology, Faculty of Industrial Design Engineering, Product Sound Design Group

[b] Plymouth University, School of Psychology, Human Factors Group

Executive summary

This document reports the research based auditory display design activities conducted for the ESA Mission Control Rooms at ESOC / Darmstadt, Germany in 2014. The research and sound design team consists of members from the Delft University of Technology, Faculty of Industrial Design Engineering and Plymouth University, School of Psychology. The main team members included one industrial designer specialized in sound design and research and two experimental and applied psychologists specialized in auditory perception and cognition in the field of sound design and application. The main task consisted of three parts: *i.* analysis of the current situation in the mission control rooms in which operators (Spacons and engineers) responded to auditory messages and took further action; *ii*. design of an auditory display with auditory messages (i.e., sounds) that corresponded to the operators' needs and system requirements; and *iii*. evaluation of the designed sounds with operators.

The **analysis phase** indicated that the two sounds currently being used as auditory messages were short of conveying the right message to the operators. It was not immediately clear to the operators what system event caused the sound; consequently, the operators needed to rely on visual cues to pinpoint the cause of the sound. Operators, especially Spacons and engineers, did not have agreement on the exact function of the sounds. Furthermore, sounds went off too often and did not always refer to an alarming situation. That is, there were too many false alarms. All these shortcomings were considered to create a concept for an auditory display design that initially focused on eliciting an intuitive operator response.

Accordingly, the **design phase** resulted in an alarm philosophy that considered three major aspects of the mission control room environment: system events, sound quality and operator response. The system events have been analysed and categorized into five groups depending on the criticality of the situation they are signalling. That is, system events are prioritized and the five levels are organized into non-priority events (two levels) and priority events (three levels). *Non-priority events* are labelled as 'Routine known event' (e.g., acknowledgements, confirmations, file uploaded) and 'temporary problem' (e.g., losses of packets or frames, bad quality data). *Priority events* are labelled as 'Minor error' (e.g., high network load, data overflow), 'Major error' (e.g., task crash, station links unbind or aborted) and 'Fatal error' (e.g., loss of station, loss of carrier, catastrophic failure). Each of these five levels of critical events determined the quality of the sounds that signal these events. Accordingly, the urgency of the

critical events were mapped on the sounds (i.e., auditory messages) which are further labelled as "Confirming', 'Informing', 'Warning', 'Alarming', and 'Urging', respectively ranging from low urgency to high urgency. Furthermore, five intuitive operator responses have been designated for the sounds to evoke the desired operator action. Accordingly, for the non-priority events signalled by the Confirmation and Information sounds, the operator *proceeds* or *logs*, respectively; for the priority events signalled by Warning, Alarming, and Urging sounds, the operator *Logs and monitors closely*, *runs procedure, or calls the engineer*, respectively. Three sets of five sounds, labelled as Water, Wood and Meta, were designed to represent each level and to offer a range of possible solutions. For the design of the sound sets, theoretical and applied knowledge deriving from the fields of acoustics, psychoacoustics, experience design, and users' behaviour have been used.

Finally, in the **evaluation phase**, the designed sounds have been tested with 20 operators in laboratory conditions (not in situ). The user test was comprised of five consecutive stages: *i.* introduction to the alarm philosophy and sounds' function, *ii.* preference test, *iii.* urgency test, *iv.* semantic associations, and *v.* functionality test. Overall, the results indicated that Water sounds scored the best over Wood and Meta sounds. Water sounds were designed to get more complex in their rhythmic and tonal structure as the urgency level of the system events increased. Operators could relate to the design and were able to intuitively respond to then sounds and the functions they indicated. Furthermore, the meaningful associations of Water sounds also were rated as expected: non-priority sounds as pleasant, informing and confirming; priority sounds as intrusive, warning, alarming and urging, progressively as the priority level increased.

This report concludes with the recommendation that all the three sound sets should be tested in situ. For that, a second user test has been presented in detail. However, before the tests, the operators, both Spacons and engineers, should be trained to learn the new sounds, the functionalities and the system events they refer to. During this training, special attention should be paid to unlearning the current systems and the sounds that have been assigned to them.