Ergonomic system design in air traffic control – Incorporating a user-centred approach

***"The road to technology-centred systems is paved with user-centred intentions."* David D. Woods**

by André Perrott

User-centred design has been one of the central factors for success in the design of consumer products. The importance of concepts such as usability, intuitive design and simplicity continue to increase in importance alongside the core need for functionality. Instead of technology being the only focus, it is now enlarged by a focus on the users – who can choose the product they prefer.

In Air Traffic Control we have historically seen less of this balanced perspective. But of course the world of aviation differs from the consumer goods market. Air Navigation Services require a highly professionalised use of operational facilities as well as redundant and highly-interlinked systems. This has sometimes resulted in the technology-centred design of conservative systems, which are exceptionally robust (they rarely fail) but which take insufficient account of the context of use (e.g. goals, tasks and other support systems).

Technology-centred approaches to system design are based on the idea that complexity can be broken into chunks that are easy to engineer. The overall solution is thus the sum of various sub-solutions. Each component works perfectly on its own but in connection with other components may show weaknesses such as inconsistent modes of operation, unanticipated system behaviour (automation surprises) or unhelpful display of information in relation to tasks.

User-centred design is not a completely new idea; in fact it is firmly established in various innovative industries. ISO 9241-210 set down and standardised the basic process. The most important characteristics are:

- A significant analytical phase to understand the context in which the technology will be used
- Many iterations with many prototypes, the complexity of the prototypes keeps increasing (from paper prototypes to wireframes to functional beta versions).
- Users included in all phases of the process

A number of advantages accrue from a user-centred perspective. The ergonomic quality of the final product can be increased significantly because the expert knowledge of the user is taken into account. Things that may have gone unnoticed can be recognised and corrected in good time. Another advantage is a higher level of user acceptance. Users identify with the solution they helped bring about and are more likely to accept technical compromises. At the same time, developers and users increase their knowledge base during the course of the development. In addition, development costs can be reduced by early user involvement. When users are in-

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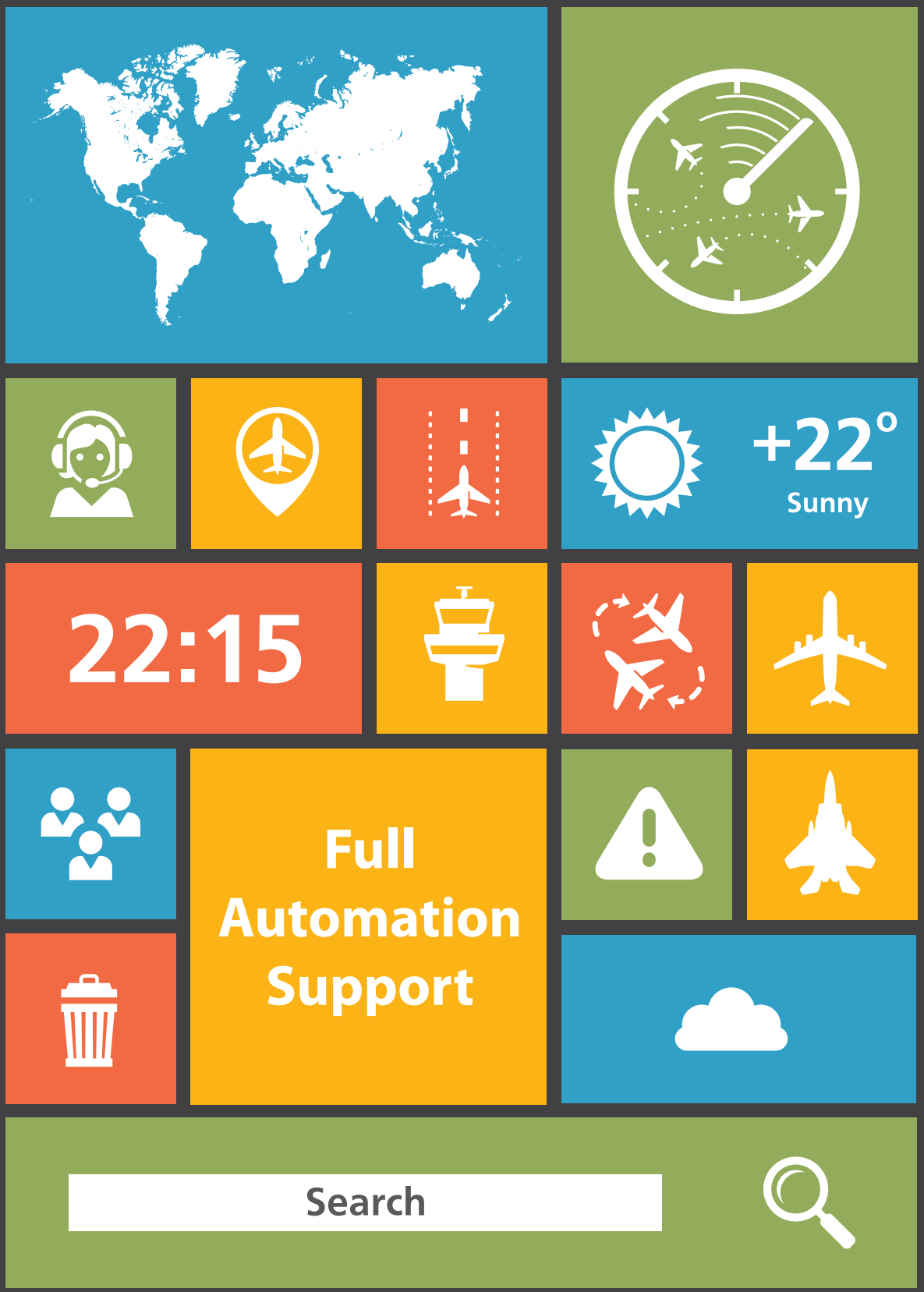

Ergonomic system design in air traffic control – Incorporating a user-centred approach (cont'd)

volved early on in a project, generally 1-2.5 % of the total budget is sufficient for ergonomics. If the system has already been in operation prior to corrective action, costs can multiply from double to ten times depending on the extent of the changes that have to be made.

User-centred design also involves certain hazards. These result from the ambivalent perspective on user participation, which can range anywhere on a spectrum between pseudo-participation (all decisions have been carried out in advanced and the user just give their blessing) to democratic design (the option with the most votes is implemented). Both of these extremes should be avoided and the design objective ought to be somewhere in the middle.

This is why it is important to have a clear understanding of the roles of system developers and users. If we compare the complimentary roles of users and technical system developers, it is suggested that:

Users should:

- be experts in their field
- explain their approaches to work and the objectives of their work
- communicate their needs, requirements and interests
- evaluate the appropriateness of various solutions
- point out problems with various solutions

Developers should:

- establish explicit requirements
- identify implicit requirements
- understand typical working methods at the working position
- use appropriate methods to transform subjective statements made by users into objective ones
- use a range of future scenarios to ensure that a design is resilient to likely change
- be able to convert user insights into design concepts and solutions
- facilitate user evaluation of a prospective design solution in a structured and methodical way

The DFS experience of incorporating users in system design

The focus on users and ergonomics is often understood as an addition to the normal design process, which also generates additional costs. But this assumption neglects the reality of complex design project where a large number of sub-systems are closely linked to the user and place high demands either directly on the user or on the tasks they must perform. A system design that is both lean and ergonomic is not a contradiction in such a context. Rather, the two can complement each other. Looking for quick solutions under complex conditions leads to exactly what one was trying to avoid – long development times and weak ergonomic system design.

To illustrate the user-centred process, we can look at an example at DFS in which user involvement was extremely beneficial.

The starting point was the change from a negative screen polarity (bright symbols on a dark background) to a positive one (dark symbols on bright background). The first phase of this project examined the priority of the objects displayed in colour from the ATCO perspective. Controllers were not asked which colour they preferred the most (democratic design) but were instead engaged in a discussion about their task. One important subject was matching the perceived priorities to the physical colour differences between foreground elements and the background. In this way, the participants discussed about their task instead of the possible colour combinations. Human factors experts were then able to convert their feedback into ergonomic requirements based on objective physical colour parameters.

In addition, the various existing systems at all DFS units were recorded. One finding was that colours were being used differently across units even though they shared the same system with the same functionality. The topic of discussion was whether differences between the units were actually necessary for operations or had just historically evolved. It was concluded that none of the colour sets being used followed any overall rationale, they had just been selected and then subsequently optimised based on trial-and-error.

This initial phase was followed by five iterations. After each iteration, the colour proposals were refined. Over time, the complexity of the prototypes increased steadily. The first evaluation was carried out in a laboratory whereas the final one was made under realistic conditions in the new control room in Langen. The evaluations involved users from all the units. The result was the introduction of a uniform colour concept that provided a basis for all colours displayed on the radar screen.

Regardless of whether the design task includes the implementation of

a completely new ATM system, the exchange of old hardware or just the adjustment of colours, the same principles apply. Changes are likely to mean that the complexity of the whole ANS system increases. Numerous interdependencies can lead to a solution that seems adequate in isolation but does not necessarily blend effectively into the overall system 'landscape'. The result is a patchwork of sub-systems which do work together as required but the behaviour of which is no longer understandable to the users. Typical symptoms are unplanned system behaviour, inconsistent use of colours, variation in fonts and variation in the structure of tables and other visualised objects which do not mesh with each other.

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User-centred principles and concepts are needed to integrate several system philosophies and to work against undesirable developments. They must to reflect the fundamental working methods of the entire system. They can provide a clear direction for development, be used as benchmarks and show whether a development is on track or not.

For this, the following questions need to be addressed from a user perspective:

- Why is a new development even needed?
- Who are the users?
- Which tasks are to be conducted by using the technology?
- Which current problems can be solved?
- How would new technology change the current working methods?

Answering these questions provides the opportunity to take a step back and observe the overall situation. Are we actually working on the real problem or are we just fighting the symptoms? For example, in the example described above, there were clear indications that labels in certain colours were being overlooked. One idea was just to change this colour (fighting the symptom). But a careful analysis showed that the individual colour was not the problem after all, rather the overall colour concept was not in line with the priorities of operations.

Some Conclusions

ANS system developments take too long and frequently have high expenditures that often arise long after the system has been introduced. The question how usable systems can be developed and introduced in an acceptable amount of time remains unanswered. However, user-centred design provides a crucial basis for a solution to this problem.

A paradigm shift has already started at DFS. Positive experiences from previous projects are being adopted and negative developments are being questioned and analysed systematically so that lessons are learned. Projects now employ a user-centred approach from the very beginning as planning and analysis progress.

An important factor in the successful establishment of a user-centred perspective has been the commitment by DFS management. This led to the establishment of the Ergonomics Board which was given responsibility for steering and coordinating central ergonomic issues, including the development of integrated ergonomic concepts that involve automation, information display and user interaction.