The Future Flight Deck

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Abstract. The future commercial flight deck will need to consider the effects of global economic drivers in its design. These issues will considerably alter operating concepts and have a knock-on effect to the human aspects of design and operations. It is argued that 'user-centered' design is limited in considering such factors and a more 'use centered' design approach is required.

Keywords: Macro-ergonomic drivers · Use centered design · Aviation · Flight deck

1 Introduction

There are many projects in Europe looking at the equipment and functions of the commercial flight deck of future aircraft. The Future Flight Deck project was a major research project, part funded by Innovate UK. This was followed by Open Flight Deck (also funded by Innovate UK). On a European scale, in recent years there have been projects such as the Advanced Cockpit for the Reduction of Stress and Workload (ACROSS) project (see http://www.across-fp7.eu/) and REACTOR REducing WorkloAd Through EffiCient TechnOlogy and ProceduRes (an EU Clean Sky 2 programme). The object of such research and development programmes has been to develop new flight deck architectures and their related technologies including displays (Head Up; Head Down and Head Mounted), integrated pilot interfaces, data networks, touchscreen and voice interfaces, haptic interfaces, graphics capabilities and the computer processing on which to implement them. The advanced capabilities will improve the availability of the aircraft by providing the pilot with a fuller picture of the aircraft situation, supporting their decision-making process and optimizing the availability of the aircraft across a range of operational scenarios. Throughout these projects the consideration of Human Factors aspects of the new technology informed design decisions, enabling more radical approaches to flight operations to be evaluated.

Somewhat coincidentally, the Innovate UK-funded Future Flight Deck project commenced almost exactly 20 years after a position paper of the same name was presented, authored by the Flight Operations Group of the Royal Aeronautical Society in conjunction with the Guild of Air Pilots and Air Navigators. In this paper the modern flight decks of the time were subject to analysis and criticism and a view was taken concerning the required developments. In this paper several key areas were discussed:

- The role of the pilot and the development of automation
- Flight deck layout and working environment

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- Instrumentation (the transition to multifunction screens on the flight deck)
- Flight Management Systems (FMSs)
- Autopilot and Autothrust (including feedback through the control column or side-sticks)
- New Technology (encompassing things such as civil Head Up Displays – HUDs and Synthetic Vision Systems – SVSs)

While an interesting (and still relevant) set of areas for development it can be seen that the list of topics was very technology-centric. To a certain extent, the current Future Flight Deck program also adopts such a stance, however it does recognize that the design of the next generation of flight decks will be driven by the requirements to support aircraft operation in a Single European Airspace (SESAR)/NextGen (Next Generation) airspace. Flight decks must support associated concepts such as 4-D (four-dimensional) flight planning and zero visibility landing to extend the operational envelop and offer significant fuel savings. Environment and operating concerns are now starting to drive the pilot interface and much as more traditional factors.

The Aerospace Technology Institute (ATI) in the UK is charged by the government to implement the national aerospace technology research strategy by working collaboratively with industry, government and academia (see http://www.ati.org.uk/about-us/institute/). The ATI has identified key strategic areas for UK Research and Development but has also defined three key time frames: shorter term development goals (running until 2020 with a target for implementation by 2025); medium term goals to exploit new technologies (for implementation by between 2025–30) and longer term strategic goals stretching from 2030 and beyond (2035+).

These time scales may seem far reaching, but when it is considered that the typical design cycle for a modern commercial aircraft is around seven years and that technologies need to be at around TRL (Technology Readiness Level) nine at the beginning of the development cycle if they are to be incorporated in the final design, suddenly the pressure to develop new technologies becomes evident if the next generation of airliners are not to be out of date the minute that they enter service.

However, the greatest problem may not be in anticipating the technologies required but in anticipating the operational environment/context.

2 Looking Back 20 Years

Two decades ago the first of the UK low-cost carriers, easyJet, has just commenced operations from Luton Airport in the UK using Boeing 737 aircraft. The carrier was based upon the model being used by SouthWest in the United States. Now, 20 years later, much of what was radical in the manner in which the low-cost airlines operated is common practice, even in major carriers. At the same time, navigation practices were still largely based around beacons on the ground and designated airways. Satellite navigation was the exception and not the norm. Air Traffic Control/Air Traffic Management (ATC/ATM) practices across Europe were becoming more harmonized but were still largely dictated by national boundaries.

The military services were also undergoing a period of change, with the introduction of increasing levels of technology coupled with the downsizing of forces. This was starting to result in a shortage of trained pilots emerging from the Air Forces. Around 1998 the global oil price was rising as a result of increasing tensions surrounding Iraq and Iran, and China was emerging as an economic power, entering a period of sustained growth (which would continue). Furthermore, despite these factors the demand for air travel has more than doubled in the last 20 years (between 1990 and 2010 passenger seat kilometers flown worldwide increased from 2,000 billion to over 4,700 billion – [1], with China in particular, showing massive growth in passenger demand, quadrupling in this period.

The point of this brief discussion is simple: the future will not be the same as the present, although what the future holds in the next two decades is difficult to say. However, the aircraft currently being operated are very much the same as those employed by the airlines 20 years ago, albeit with some evolutionary developments.

3 What Does the Future Hold?

The ATI research strategy looks forward, to beyond 2035. Although the shape of the future cannot be predicted, some global drivers (for good or bad) can be anticipated:

- Oil price: There is relationship between oil price, airline operating economics and the demand for air travel. What will happen if the oil price either continues to fall or rises sharply?
- Environmental issues: There will be a continued push for the airline industry to become ‘greener’. Green issues (potentially related to taxes) may also ultimately serve to depress the demand for air transport.
- Capacity: There will be increasing demands on both sector and runway capacity, particularly in the shorter term.
- Cost: To remain competitive and satisfy increasing demand for air travel airlines will strive to contain costs (especially if oil prices or taxation rates begin to rise).
- Emerging markets: South East Asian economies (China, Taiwan, Korea and new players, such as Vietnam) will initially continue to grow but over 20 years also have the potential to slow down or decline. Other markets may continue to grow (India, Brazil) or may suffer the same fate.
- Political instability: Few people could have predicted the rise of so-called Islamic State and the instability in Ukraine, both of which have served to compromise aviation safety.
- Pilot availability: With a decline in the number of trained pilots emerging from the armed forces, coupled with an increasing demand for air travel there may be a chronic shortage of pilots in the next few years. However, if this demand for pilots is satisfied there may subsequently be a glut if global economies slow down.
- New routes: New routes will open, to both smaller airports (more direct routing) or there may be the potential for low cost carriers to start operating on inter-continental routes.

These may all be interesting factors from the perspective of airline operating economics, but what implications do they have for Human Factors in general and the design of future flight decks in particular? It is argued that all of the above have design consequences associated with them which have often been neglected by the Human Factors profession. Furthermore, a subtly different Human Factors design paradigm may be required to satisfy the future requirements of the aviation industry.

4 Design Implications for the Flight Deck of Global Economic Drivers

The future will not be the same as the past, therefore the future flight deck must try and anticipate the effects of macro-economic factors. Human Factors practitioners and researchers need to develop an element of prescience and flexibility in approach. Fortunately, some of the potential knock-on effects of the factors described previously may be anticipated, to a degree.

4.1 Pilot Shortage

There are already signs of a rapidly increasing shortage of commercial airline pilots. Boeing estimate that between 2015–34 95,000 commercial pilots will be required in North America alone versus a potential supply of only 64,000 in this period. This is traditionally seen as a pilot recruitment and training issue. However, there are fundamental design considerations that are driven and can potentially help to alleviate this anticipated shortage. There will be a tendency over the next 20 years for experience across the flight deck to decrease, with many more low-hours captains being teamed with an increasing number of low-hours First Officers.

Good human-centred design places the target audience description at the centre of the design process. To accommodate the change in the end user-group the complexity of flight deck interfaces will need to be reduced, which will also have the additional bonus of decreasing training time. It will also be argued that the Human Factors design approach adopted will have to change.

One option to address the potential shortage of pilots and help to further reduce costs is the development of single pilot commercial aircraft. The trend in flight deck design over the past half century has been one of progressive ‘de-crewing’. Aircraft manufacturers and avionics systems suppliers (e.g. Embraer and Honeywell – [2]) are developing the advanced technology for such aircraft, centred upon the development of Intelligent Knowledge-Based Systems and adaptive automation. An alternative design approach proposed initially by Harris [3] uses a distributed systems-based design philosophy utilizing a great deal of extant technology derived from single seater military aircraft and UASs technology. In this case the control and crewing of the aircraft is distributed in real time across both the flight deck and ground stations [4].

4.2 Low Cost Carriers

Low cost carrier concepts of operation are now the norm, even in larger airlines. However, the aircraft being operated have never been designed (from a flight deck viewpoint) for intensive, short(er) range operations with rapid turnaround times on the gate. Many autopilot modes are not necessary for such operations. Airline personnel costs vary between about 11% of operating costs to nearly 25%, depending upon aircraft type, sector length and how much activity is outsourced [5, 6]. Annual accounts from a typical low-cost operator suggest that even for a larger airliner, the crew represent nearly 13% of operating costs (excluding fuel and propulsion – [6]).

Gate time is charged by the minute. Reducing time on the gate can result in considerable cost savings. Pilot training is another major overhead. Reduction of initial and recurrent training time will also both reduce costs and increase pilot availability.

Many low cost carriers also operate into smaller, secondary airports around major cities. These are often less well equipped than the major hubs. While this can serve to reduce delays, in bad weather such airports can be difficult to navigate and have considerable restrictions on arrivals and departures. Increasing aircraft availability by allowing poor visibility approaches, landings and take-offs, in conjunction with aiding low visibility taxiing will considerably reduce operating costs resulting from delays. However, these capabilities must be present in the aircraft and not dependent upon ground infrastructure.

4.3 Green Issues

There are undoubtedly going to be continued demands to make aviation more environmentally friendly, reducing its carbon footprint (e.g. see the major initiative undertaken by the European Union in its Clean Sky and Clean Sky 2 research programs). These have both direct and indirect Human Factors considerations for the future flight deck.

Direct considerations include initiative such as flying direct routings and optimizing climb and descents profiles, both likely to be undertaken in increasingly congested airspace. This will require increased levels of automated assistance for flight planning and execution, and the display of complex departure and arrival procedures. The three-dimensional display of complex routings (especially departure and arrival routes) and 3D depiction of weather – especially winds will aid in this respect. The display of traffic/collision alert information might be useful, especially as under SESAR/NEXTGEN, self-assured separation is a key concept.

Indirect Human Factors considerations will be related to the design of the aircraft. There are concepts being developed for jet transport aircraft which will have high aspect ratio wings, allowing higher, more economical flight but will at the same time considerably reduce the cruising speed of the aircraft. This obviously has implications for pilot fatigue. Research into the operation of long-haul aircraft during the cruise phase using just a single member of flight was undertaken in the Advanced Cockpit for the Reduction of Stress and Workload (ACROSS) project (see http://www.across-fp7.eu/).

This will also reduce the operating costs associated with the need to carry a third pilot during ultra-long haul operations, specifically for the approach and landing phase.

4.4 Political Instability

Political instability may have several effects depending upon its nature and location. Oil process may increase considerably (further enhancing the pressures of on operating costs). However, there are also increasing threats to aircraft from the ground (e.g. ground to air missiles) from insurgent groups engaged in local conflicts. There may be requirements for in-flight re-routing, and updating of threat information (much as the updates of tactical information received by military aircraft).

Oil is traded in dollars. Brexit has had the effect of increasing fuel prices in the UK as the exchange rate between the pound sterling and US dollar deteriorates.

4.5 Culture and Emerging Markets in South East Asia

Boeing market analysis suggests that the Asia Pacific Region will require substantially more aircraft over the next two decades making it the largest airline market in the world (2012 fleet - 5,090 aircraft; projected 2032 fleet - 14,750 aircraft). Thirty-five percent of the world fleet will be domiciled in this region.

However, cultural issues on the flight deck run deeper than issues in Crew Resource Management [7]. The operating philosophy on civil flight decks is based upon two pilots cross-monitoring the other's actions. The system of 'monitor and cross-monitor' and 'challenge and response' is predicated upon the assumption that crew will speak up and alert each other to irregularities and errors but this is implicitly based upon a Western cultural assumption. There are also fundamental differences in the mental models of people in European/North American and Chinese cultures. Westerners adopt a function-oriented mental model connected to a task-oriented operating concept (where specific actions are performed to achieve well-defined results) resulting in a preference for a sequential approach to undertaking tasks. The Chinese preference is for a more holistic integrated, thematic approach hence the task-oriented operating concept contradicts their preferred method of working. A multi-configurable flight deck interface may provide manufacturers with a competitive advantage in some markets.

4.6 Cost

Cost drives everything. Pilot shortages increase the market price of pilots, increasing cost. Longer routes to avoid areas of political instability increase costs. Aircraft that fly more slowly to reduce fuel burn will also decrease utilization, potentially offsetting the decrease in operating costs attributable to reduced fuel burn. Green issues may restrict routing options and departure/arrival times.

5 User vs. Use Centered Design

The Human Factors profession has traditionally been dominated by a 'user-centered design' approach, and the aerospace industry is no exception. Emphasis has been placed on primarily on ensuring that equipment and procedures on the flight deck are commensurate with the skills, knowledge and abilities of the end users (i.e. pilots).

'Use-centered' design adopts a more socio-technical system oriented stance, which includes the work domain as a third component of the system [8]. The work domain provides further constraints on the work system. The envisaged global economic drivers fall into this category. It is argued that the macro-global trends may require a change in the Human Factors approach to be adopted. While the human operator (pilot) is still placed at the center of the flight deck design process, placing emphasis on 'use' as opposed to 'user' requires a change to a more problem-centered focus for flight deck design.

This can be expressed another way: if was can't get enough of the current type of pilot we will need to design aircraft for a different type of pilot that we can get enough of.

6 Flight Deck Design: Re-visiting the Past

Many of the complexities on the flight deck result from the fact that they are full of outdated systems, a legacy of the old technologies that were implemented on the flight deck of aircraft over three decades ago. To make change even more difficult, these are now mandated in the international airworthiness requirements (for example the US Federal Aviation Requirements and the EU Certification Specifications for large aircraft). These complexities partially dictate the skills and knowledge required of the modern pilot; they serve to limit the number of potential candidates for pilot training; increase the complexity of training, and hence increase the market price and availability of trained, experience aircrew.

What is more, these complex, old-fashioned legacy systems are no longer required. For example, with satellite-based technology a pilot know can know exactly how high they are. Barometric altimetry, which used the changes in air pressure with altitude, required at least three different definitions of 'height' when flying: height relative to the local terrain; height above mean sea level (altitude) and Flight Level (a notional altitude where everyone set their altimeters to be calibrated to 1013 mb). These demanded a series of transition altitudes around airports and in airspace. Speed was a similar nightmare. Ground speed is speed over the face of the Earth; true airspeed is the relative velocity between the aircraft and the surrounding air mass, which is effected by headwind or tailwind components; indicated airspeed is the speed on the airspeed indicator on the flight deck, but this is also effected by altitude and temperature (density), so becomes increasingly divergent from ground speed as the aircraft climbs. Mach is aircraft velocity relative to the local speed of sound… Keeping the aircraft flying is a problem in airspeed; navigation is a problem in ground speed. Heading refers to compass heading, which is relative to magnetic North (not true North) and indicates which way the aircraft is pointing – but not which way it is travelling because of the effects of cross winds. Track refers to the path of the aircraft across the face of the

Earth. With regard to vertical navigation (VNAV) no current aircraft control modes relate directly to the three-dimensional navigation solution as they are aircraft referenced, not Earth referenced (with the exception of approach mode which is referenced to a fixed point on the planet – the runway). In other words, they do not directly support the pilots' primary task. There are several aircraft-referenced modes (vertical speed; flight path angle; climb-to-speed). The pilot cannot, however, follow a prescribed tack in three-dimensional space (which is actually what Air Traffic Control requires).

With modern inertial, Doppler radar and or satellite navigation systems none of these distinctions (and separate parts of instrumentation) are now required; speed is speed; height is height and heading is heading. All of these issues are easily solved with on-board computing technology and digital fly-by-wire systems. The technology is available to make flying an aircraft manually almost as simple as driving a car in three-dimensional space (well, to an extent)! This now changes the nature of the potential user (pilot). By changing from a user-centered design perspective driven by current pilot aptitudes to a use-centered design perspective, where the method of operating the aircraft is driven by the environment (work domain) and the technology available, a whole new potential population from which pilots can be drawn is liberated.

However, the flight deck design regulations are now inhibiting change [9] and hence also constraining other aspects of the sociotechnical system of airline operations (e.g. pilot selection and training).

This will not be a popular perspective. Nevertheless, it serves to illustrate that the Human Factors profession should not always be driven by user centered design or 'fitting the job to the person' [10]. Perhaps a new perspective - 'fitting the new person to the new job' is required?

References

1. IATA: World Air Travel and World Air Freight Carried 1950–2010. http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/evolairtransport.html. Accessed 3 July 2010
2. Keinrath, C., Vašek, J., Dorneich, M.: A cognitive adaptive man-machine Interface for future Flight Decks. In: Droog, A., Heese, M. (eds.) Performance, Safety and Well-being in Aviation Proceedings of the 29th Conference of the European Association for Aviation Psychology, Budapest, Hungary, 20–24 September 2010. European Association of Aviation Psychology (2010)
3. Harris, D.: A human-centred design agenda for the development of a single crew operated commercial aircraft. Aircr. Eng. Aerosp. Technol. **79**(5), 518–526 (2007)
4. Harris, D., Stanton, N.A., Starr, A.: Spot the difference: operational event sequence diagrams as a formal method for work allocation in the development of single pilot operations for commercial aircraft. Ergonomics **58**(11), 1773–1791 (2015)
5. Ryanair: Full Year Results (2009). http://www.ryanair.com/doc/investor/2009/q4_2009_doc.pdf. Accessed 17 November 2017
6. easyJet plc: Annual report and accounts 2013 (2013). http://corporate.easyjet.com/~/media/Files/E/Easyjet-Plc-V2/pdf/investors/result-center-investor/annual-report-2013.pdf. Accessed 27 June 2014

7. Harris, D., Li, W.-C.: Cockpit design and cross-cultural issues underlying failures in crew resource management. Aviat. Space Environ. Med. **79**(5), 537–538 (2008)
8. Flach, J.M., Dominguez, C.O.: Use-centered design: integrating the user, instrument, and goal. Ergon. Des. **3**(3), 19–24 (1995)
9. Harris, D.: Human Performance on the Flight Deck. Ashgate, Aldershot (2011)
10. Kroemer, K., Grandjean, E.: Fitting the Task to the Human, 5th edn. Taylor and Francis, London (1997)