HILAS: Human Interaction in the Lifecycle of Aviation Systems – Collaboration, Innovation and Learning

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Abstract. The aims of the paper are to describe a particular network in the European aviation sector, to explain what is innovative about this network and to describe ways in which the network may evolve in the future. The paper describes the current state of the literature on human factors in aviation and shows how HILAS partners collaborate to innovate in the field of human factors. The paper highlights to what extent the HILAS partnership is novel, and wherein specifically lies that novelty. The network is sectoral rather than locational. It is an inter-organisational, cross-national, intra-sectoral, virtual cluster of actors, brought together for the purpose of a particular innovative project. The paper is about both the network and the nature of its innovation.

Keywords: Innovation, networks, human factors, risk management system.

1 Introduction

The paper draws on fieldwork carried out in the context of a European Union-funded project called HILAS (Human Integration into the Lifecycle of Aviation Systems) [1]. The aim of the project is to develop a model of good practice for the integration of Human Factors (HFs) across the lifecycle of aviation systems. The idea is to improve flight safety through the integration of HF knowledge into all aviation related activities. This will reduce the risk of human error and the danger that human error can pose for safety in the operation of aircraft. In substance, the project is a formal network focused on innovation in HF management and integration. The change process involves incorporating HF knowledge into innovation in general, whether in flight operations, maintenance processes, technological design, organisational or industrial change. Of the total of 40 partners in the project, most are industrial partners from each of these strands of the sector; there is a small number of university and research centre partners.

HILAS is a project financed by the Sixth Framework Programme (FP6) of the European Commission. Like previous Framework Programmes its objective continues to be the development of a Europe-wide scientific community and the promotion of Europe's international competitiveness through the strengthening of its scientific and technological base. The programme also aims at solving major societal questions and

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at supporting the formulation and implementation of other EU policies [2]. The programme's expenditure will reach €17.5 billion. This represents the third largest operational budget line within the EU's overall budget after funds dedicated to the agricultural policy and funds promoting cohesion among the 27 countries of the block [3]. To reach the necessary critical mass at the EU level, FP6 introduced new instruments, such as networks of excellence and integrated projects, HILAS being an example of the latter. Among the seven targeted thematic priorities of FP6 was the one in which HILAS is situated, "aeronautics and space" (including "aircraft safety" and "increasing operational capacity and safety of the air transport system").

The HILAS project is expected to contribute to the European strategy for air transport ("European Aeronautics: A vision for 2020") which in view of the substantial growth in traffic has set itself a target of an 80 percent reduction in aircraft accidents; ensuring effective and reliable human performance would be a key contribution to the projected accident reduction [4].

2 What Are Human Factors?

The origin of the concept of human factors dates from World War II when psychologists were asked to investigate airplane accidents [5]. It was revealed that pilots had certain expectations of how things should work (how they could locate the landing gear and activate it, for example) and that these expectations were violated by aircraft designers [6]. So human factors were relevant in design; better design could reduce the likelihood of pilot error.

Human factors is a systems-oriented discipline, which promotes a holistic approach in which considerations of physical, cognitive, social, organizational, environmental and other relevant factors are taken into account [7]. Most or all are of relevance in the study of safety in aviation.

Human error is present in 100 percent of aviation accidents [8]. Errors can occur at the level of the maintenance of aircraft, their design or their operations. The major cause of all aviation accidents is pilot-error [9] though accidents are often a result of a chain of events in which the pilot is the last link in the chain. Traditionally, accident investigations led research to focus on finding factors related to pilot-error, rather than examining the chain of events and, more broadly, systemic factors. This was a reactive approach. Such an approach would be based on the statistical study of accidents. Pilot-error would typically be associated with environmental factors, aircraft factors, airline-specific factors and pilot-specific factors [9]. These traditional approaches have been challenged in recent years; as Maurino [10] puts it, 'there is a need to attack causes rather than symptoms of safety deficiencies'. The author argues that: 'Paramount to a revised paradigm is to distance from the allocation of blame those at the operational end of events in favour of the macro appraisal of the aviation system…' [10]

Thus all components of the aviation system have to be taken into account, not just those that failed. The approach must become more pro-active and systemic; it must be understood that where there is failure – for example by pilots in the context of their 'normal' activities – this is an expression or symptom of deficiencies of the deep foundations of the system [11]. A new safety paradigm must rest on the consideration of safety as a social construct in which human and organizational performance are inseparable from the contexts within which they take place. In short, ‘pro-action must replace reaction’ and conventional views on human error must be challenged [10].

Equipment is not ‘culture neutral’. Aircraft are designed with particular safety solutions in mind from a particular cultural perspective. The use of aircraft and their maintenance and of aspects of their design in different contexts may become problematic since there are cultural issues involved in the transfer of technology. Designs follow the originating cultural standards but users do not always share these. Thus one cannot expect to successfully export a safety solution to a different context without taking into account culture, social bias, perceptions of status, mental models and education. Different contexts generate specific problems and require culturally specific solutions [10]. A good illustration of the importance of cultural factors is offered by Braithwaite et al [8]. In their study of Australia’s reputation as a ‘lucky’ country in terms of aviation safety, they analyse the influence of culture at national, industry and organisational levels. At the national level, for example, they conclude that rather than luck, it is the high levels of individualism and ‘low power distance’ in Australia that are important. These result in junior crew members feeling unconstrained about pointing out errors on the flight deck. Elsewhere failure to cross-check actions in the flight deck is among the highest rated human factor problems in aviation.

An aspect of culture at the enterprise or sectoral level is the relationship between management and pilots. Airlines in which there is a high level of co-operation between management and pilot associations enjoy fewer safety incidents and lower pilot turnover [12].

To sum up and following Reason [11], human factors studies need to focus on what makes organisations (and culture) relatively safe instead of focussing upon their moments of un-safety. Thus there is a need for safety investigations to go beyond accident investigation and to look at how positive human factor analysis can help us design much safer socio-technical systems.

3 What Is Novel about the HILAS System?

HILAS is a formal, innovation-focused network. The project aims at the transformation of the aviation industry by improving flight safety through the integration of human-factor knowledge into all aviation-related activities. What this means is the reduction of risk of human error and the danger that this can pose for safety in the operation of aircraft.

IPR and trust issues arise, particularly in relation to technological – mainly software – R&D and innovations in HILAS. Where necessary, such innovations will be protected by IPRs. The innovative – though non-technical – organizational and informational aspects of the HILAS project are just as important. Here it is less possible to protect such innovation. There is awareness in HILAS that sharing best practices and the subsequent improvements in safety are more desirable than the protection of such innovations.

HILAS has therefore been able to develop a prototypical innovation cluster around the notion of human factors knowledge as a source of innovation in aviation systems. This cluster is illustrated in Figure 1. So far there are no national authorities or regulatory organisations involved in this cluster. This framework of collaboration has

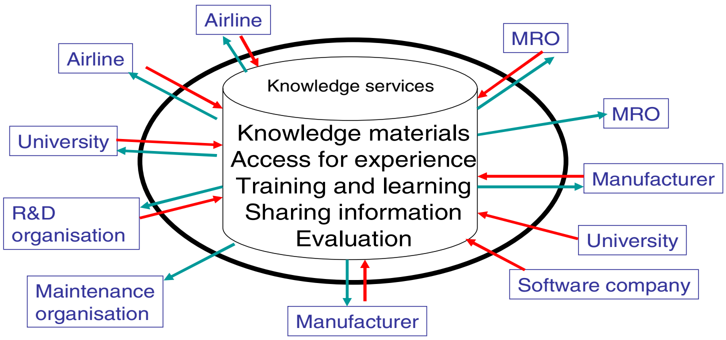

Fig. 1. Structure of the HILAS Innovation Cluster

facilitated the sharing of knowledge and supported the implementation of HILAS processes across the different industrial partners, with a range of support from human factors and software development partners.

4 The HILAS System

The HILAS project has developed an integrated set of processes for designing, managing and improving the people part of the aviation system. It has three components: 1. Management of operational performance, risk and change in flight operations and maintenance; 2. Human factors evaluation in cockpit system design; 3. Inter-organisational sharing, learning and innovation.

4.1 Operational Performance, Risk and Change

Fig. 2 below describes the three processes – real-time operational support, tactical management and strategic management – that are linked in a collaborative learning system at the industry level. These processes are facilitated by a set of software modules (see Section 6, below). For example, in the real-time operational support process, time-critical risk information is fed into an intelligent flight plan; task support for maintenance operations is provided; and data for operation reports are gathered. In the tactical process reported events generate risk assessments, established channels for change, and routine system performance monitoring. At the strategic level, risk analyses lead to the identification of complex system problems, system change and evaluation.

This integrated organisational system more than satisfies new regulatory requirements (ICAO SMS requirements to be translated into European regulation). It provides the basis for a resilient operational system, adapting and transforming itself to meet competitive and regulatory requirements. It also creates the capability to produce the data and knowledge which are critical to new integrated system design and development.

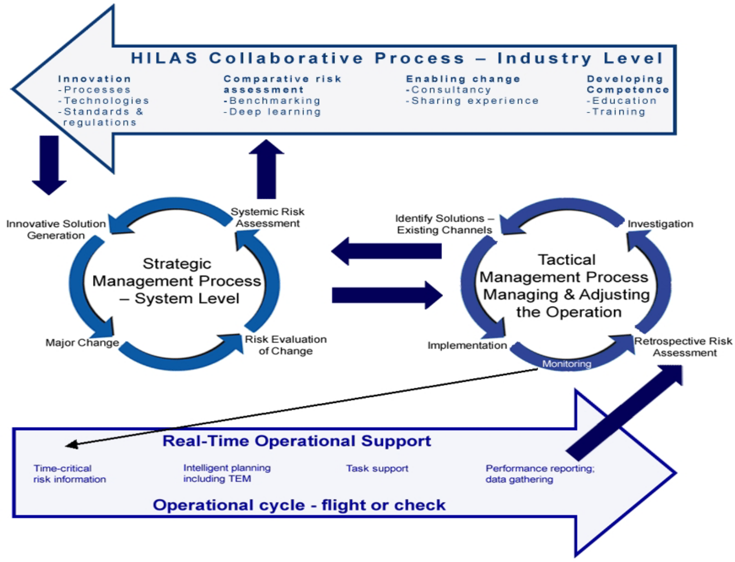

Fig. 2. The HILAS System of Operational Support, Tactical and Strategic Management and Organisational Learning

4.2 Human Factors Evaluation in System Design

A comprehensive set of human factor tools and methods supports human factors evaluation of new applications of technologies. These can be deployed either in a flight simulation environment or in operational settings. This fulfils EASA human factors requirements for certification.

4.3 Innovation and Learning between Organisations

The HILAS Knowledge Management System is a collaborative exchange for all documentation. The KMS facilitates sharing of organisational experience and operational data, and is designed to manage training and advanced learning programmes. It currently supports the active collaboration and learning between partners. Establishing this collaborative learning framework is a major achievement of the project – creating a form of 'social capital' which can leverage innovation and change. Emerging exploitation plans are built around this framework continuing and intensifying after the project is completed.

5 The 'Human Factor Support Tools'

How did HILAS evolve? To achieve the double task of improving their competitiveness through lean and cost-effective flight operations while at the same time enhancing safety and reliability, any new tool or methodology in aviation must encompass HF-related information to continuously improve processes. 'Research suggests that the design of such tools takes second place to continuous improvement behaviour itself. This involves a suite of behaviours, which evolve over time, rather than a single activity' [13]. These behaviours cluster around several core themes, for example, the systematic finding and solving of problems, monitoring and measuring processes, and strategic targeting [14].

As an example of continuous improvement of behaviour in aviation, Cahill and Losa [15] show how the definition of new 'task support tools' for crew evolved within the HILAS framework, through a participatory process involving several airlines. Information was gathered in a variety of ways (including in-depth interviews, jump-seat observations and workshops) from participants working in flight planning, active flight operation (dispatch, cabin crew and maintenance), safety and quality. It is clear that the introduction of 'task support tools' involves changes to task practices and their overall process; it is not just a matter of installing a new piece of technology into the cockpit.

The need for social, organisational and routine changes is understood outside HILAS, too. Rather than just reacting to accidents and incidents, and to regulatory changes, airlines are developing preventive safety-management approaches, including: scientifically based risk-management methods, a non-punitive culture of incident and hazard reporting, company commitment to the management of safety, the collection and analysis of safety-related data from normal operations and the sharing of safety lessons and best practices. A variety of risk/safety management systems, and associated monitoring and evaluation tools, have been developed in response to these needs. What had not been developed until recently was a system that will allow airlines to gather, integrate, analyse and communicate all airline information (commercial, operational and safety) in real time. The HILAS system offers this, supporting the airline's safety strategy by providing analysis of information on safety and risk, and also improving the airline's safety culture through better reporting and sharing of safety related information [15].

HILAS proceeded by defining four HF 'tools' or modules (A, B, C and D). These tools, the key technical innovations of HILAS, aim to help airline operators and maintenance companies understand why certain events take place and to draw conclusions and learn lessons that can lead to the design of new systems that take into account human needs and characteristics. These tools gather (A), store and integrate (B), facilitate analysis (C) and provide a new framework for organisation and change (D). Here we have space only to discuss A.

Tool A concentrates on communication and information gathering. The tool offers task support, performance feedback and reporting capability. It can be used by flight and cabin crews as well as maintenance and ground operators. In substance, Tool A is the main tool for allowing operational crew (both in the air and on the ground) to communicate (including feedback and reporting) amongst themselves[1]. To perform these functions, various hardware devices can be used including Electronic Flight Bags (EFBs)[2], workstations in the office, Personal Digital Assistants (PDAs) and

[1] Tool A also has reporting functionality for roles other than crew, e.g. cabin crew and dispatch, and thus the tool is more than 'flight-crew-centric'. The tool also includes an observer-reporting facility [17].

[2] On EFBs, see [17], [15], [18], [19], [20], [21].

mobile phones. Flight data will be recorded continuously during each flight and feedback will be provided to the crew if deviations from the norm are identified. In these cases – when reporting is mandatory – pilots will be able to report electronically instead of on paper as is the case today.

The tool makes it possible for pilots to explain why their performance did not comply with the benchmark parameters. This means that in addition to providing raw data, the system aims to collect qualitative data, which could reveal ‘important latent conditions and human factors issues’ [16]. These crucial qualitative data may explain why certain flight parameters or (unsafe) events deviate from the norm. In turn, once this is done, it opens the way to establishing common causes for certain situations; procedural changes to tackle problems at the systemic level can then be developed. The tool also allows pilots to see, either immediately after the flight or later, what their performance was; this facilitates their own learning process (a kind of real-time benchmarking) [16]. The performance feedback is especially relevant when pilots are required to complete a mandatory HF report possibly linked to a safety-critical event discovered in the Flight Data Monitoring (FDM) where flight technical data are recorded [17]. The above process of data collection and benchmarking is also complemented with the ability to file optional reports electronically. In these reports, pilots can offer feedback, highlight weaknesses in operations, suggest known ‘workarounds’ or other, experience-based, constructive suggestions. Archived reports are also available (crews have access to prior reports) and can update and edit them and get information as to what the safety department is doing about the issues raised. This is an improvement in the information loop (reporting and getting feedback from the report).

Tool B is essentially the server, and Tool C is a data analysis/mining and reporting tool; it offers risk analysis, process improvement and information flow analysis. Overall, Tool C is both an organizational and technology tool for safety and risk management. Tool D is not a technology tool but rather an overall organizational system that defines safety management, process improvements, procedures, roles, safety culture and responsibilities. Tool D defines the information flow logic for the other three tools and its users will include everybody in the airline.

6 Theoretical Framework

There is a literature on systems of innovation – within the broad field of institutional economics – that helps to explain and evaluate many aspects of the HILAS project. The idea of a system of innovation was first applied to national economies in the late 1980s [22]. The concept evolved as analysts found it informed their study of innovation in regions (regional systems of innovation) and, recently, of innovation in sectors (sectoral systems of innovation – SSIs) [23].

The SSI approach offers a multidimensional, integrated and dynamic view of sectors in order to analyze innovation. The notion of SSI places great emphasis on knowledge, learning, interactions (through the market or outside markets) and institutions. Firms are active participants at the centre of a web of interactions that shape their technological and market environment.

We can consider HILAS to be an embryonic element of a sectoral system of innovation. Although there have been research plans involving specific participants, the actual networks that have evolved within the consortium have to varying extents been voluntary, cutting across the plans and strands of the project. What HILAS attempted is new and innovative; it has no precedent in the aviation sector. Among the concomitants of this is a great deal of uncertainty, with participants unsure about whether what they are doing is correct or appropriate. The theoretical backdrop of SSI provides some support for the direction that HILAS took and validation for the type of multi-networking around which the new operational system is evolving.

What the literature suggests about the process of diffusion of organisational innovation is that there is a combination of relationship and operational factors that facilitate and accelerate this diffusion. As expressed by Liou and Liou [24], 'Firms in clusters benefit from linkages (among firms, workers, financiers, and so forth) and spillovers as well as complementary assets in skills, technology, and economic information'. Among the key relationship factors is trust, which enhances the flows of information and the voracity of the knowledge among the participants. The absence of trust does not necessarily obviate these flows but in its absence other factors must be present. For example, contractual undertakings can, in some cases, substitute for trust. Operational factors that facilitate – or impede – innovation diffusion include regulatory regimes, supply chain interdependence, and technological standards.

There have been high levels of trust, tight networking relationships, and progress in development of and participation in HILAS processes among sub-sets of the 40 members of the consortium. However, the whole system has not been implemented by all members of the consortium. Can this embryonic element of a system of innovation survive and evolve beyond the life of the EU-supported project?

Among the possible evolutionary paths of the HILAS system is some form of commercialisation of the results. The literature on private, club and public goods [25] suggests ways in which this might occur. A private good is one that is "ownable", i.e. a property right to it can be held. There are goods that are not ownable; such goods (or services) are known as public goods. A "club" good (or service) is one that is available only to members but, once a member, it can be freely used.

The HILAS system is generated by a multiplicity of private and club goods. Small networks of firms in HILAS, clustering around centres of excellence, derive the benefit of the private knowledge – for example about risk management – of a leading partner. This small network now has a shared knowledge, or club good. When all club goods of the small HILAS networks are combined, they contribute to the HILAS system which then becomes a good (or service) available to all the members of HILAS. The HILAS club can, if the system is in some sense desirable to other, non-HILAS firms in aviation, sell it on. HILAS becomes an owner of a system that is sold, as a private good (or service) to non-club members. Alternatively, other firms can join the HILAS club and use the system as a club good.

All this is contingent on the HILAS system being seen as desirable, both by the HILAS members and, as a consequence, by other, non-HILAS firms in aviation. The better – more attractive to other firms in the sector – the HILAS sub-sectoral system of innovation, the more likely it will be that the result will be commercially sustainable. Even if HILAS is seen by some to be an improvement, it will require a great deal of effort for its results to be sustained and developed.

7 Description of the Commercial Future of HILAS

The key HILAS competence is capability to use human factors knowledge as a source of innovation in the aviation sector. Three interlocking but distinct activities constitute a virtuous cycle for continuing to develop this capability (see Fig. 3):

- Knowledge services support the interchange of process knowledge (including about risk), learning from others' experience and sharing operational data (where it is advantageous to do so);
- Training and education (particularly at Masters and Professional doctorate level) develops the capacity to absorb and use the knowledge services in a process of organisational development and change, and provides a framework which can support implementation and evaluation of such change. This is a significant knowledge gap in the industry.
- Continuing research and development further develops and refines the cutting-edge knowledge that ensures that the knowledge services are constantly advancing the state-of-the-art. The research component of a professional doctorate can help ensure the maximum industrial impact of a continuing RTD programme (particularly where the in-house RTD capacity is currently very weak, as in the operational sector).

Each corner of the triangle is, in principle, relatively independent but each potentially interpenetrates the others and supports and enhances their activities. Fourth Level education, for example, has a strong research component and can lead to the provision of knowledge services. Each part of the triangle contributes to a benign cycle of learning and development that could not happen so effectively with isolated initiatives.

Some elements of this triangle are public, some are club goods, and some are private goods. Where firm-specific consultancy services are offered, these constitute private goods, paid for at market prices. Sharing data and the analytical possibilities

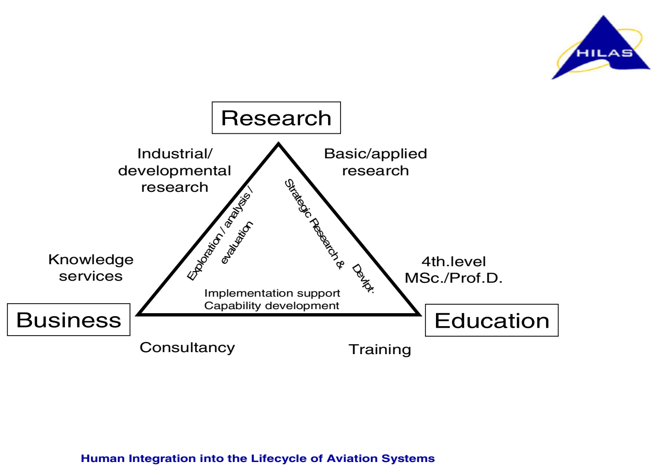

Fig. 3. Knowledge-Based Innovation

emerging from shared data are more appropriately developed as club goods. Some of the research – particularly on safety – has to be diffused as a public good, in the public interest. Overall, the elements of the triangle – public and private, governmental and corporate, educational and club based – will all enhance the sectoral system of innovation in aviation.

8 Conclusion

Innovations, both in technologies and in ways of organising and operating, are essential for the objectives of increased efficiency and safety to be realised. A research, development and implementation programme has to address three aspects of this nexus: the design process; the operational system; and how the two can work together, managing knowledge, to transform the capability to deliver large scale social goals.

Improvement in operational aspects of aviation should drive design, both of aircraft and of the organisation of aviation. This requires much more sophisticated data and analyses of the functional characteristics of operational systems. This is precisely the kind of operational data and knowledge which is required to manage and regulate large integrated operational systems in a proactive and strategic manner. Feedback up the lifecycle stages thus becomes an imperative despite competitive relationships – and despite prisoner's dilemma impediments to such flows. However, this in turn can create the capability of integrating the design, operational and regulatory phases in a new manner – design for safety, security and environmental sustainability can become natural extensions of the design for operability and maintainability. Creating an integrated framework for design, management and regulation will be necessary to leverage the possibilities of system transformation to deliver radically improved performance across the range of demands. Creating an innovation process capable of transforming and transferring this knowledge across the system lifecycle (design, operations, maintenance and regulation) can synergise the development and transformation of such systems to meet these demanding and urgent social goals.

HILAS and other European projects have provided a platform upon which to develop this trajectory: modelling and analysis methodologies; organisational systems for managing performance, analysing risk and managing change; human factors evaluation of new technologies and design for operability concepts; collaborative systems between organisations that create learning and innovation. This is only the first step in developing a sectoral system of innovation which can enable the aviation system to deliver the change in design, operations and regulation which society requires.

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