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# Monitoring and Control of Human Implications of New Technology

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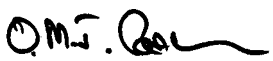
| Signature |  |

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# EXECUTIVE SUMMARY

This document presents a proposed strategy for managing the human and organisational implications of new technologies. Current problems resulting from the introduction of new technologies are highlighted, and the existing manner of managing that introduction is described. All the transport modes are addressed as well as intermodal travel by passengers. The report makes recommendations for action at a European level, but also actions required at a supra-European international level, as well as for complementary actions by national authorities and other regional and local bodies.

The report covers issues of organisation, standardisation, certification and legislation. Particular emphasis has been placed on lessons that can be learned from progress and recommendations made within the aviation arena. The report draws out comparisons with other modes and identifies constraints in those modes. Deficiencies are identified in both modal and inter-modal management of the process of introducing new technologies. To improve the current situation, the report identifies a proposed approach for the strategic and tactical management of the human aspects of the introduction of new technologies.

It is essential that high-level consideration be given to the following:

- the establishment of a technology-watch group, able to make recommendation on key areas where initiatives at a European level may be required;

- an overall approach in the approval of new systems that combines regulation in the form of standards, procedures and guidelines with self-certification by suppliers and systems integrators and with enforcement by appropriate authorities (usually national).

This approach places obligations on various authorities — at the European level to create the technology-watch group and to support the development of certification procedures, and at a national level to enforce adherence to the certification process.

# 1. INTRODUCTION

The HINT (Human Implications of New Technologies) project is developing a European strategy for managing the human and organisational impacts of the new technologies likely to be implemented over the next 10–20 years. The project is funded under the Transport Research Programme of the European Commission. HINT is a project in the Strategic Research area of the programme, and its task has been to study human and organisation factors arising from new technologies. The objectives of the project are to:

- Identify the relevant technologies
- Investigate the human factors, organisational and safety implications of these technologies
- Develop a strategy for managing those impacts.

The approach of the project is multi-modal. It is addressing all the modes of transport — road, rail, air and water — as well as intermodal operations for travel and transport services. The rationale for the cross-modal approach is to enable the human and organisational issues arising from the introduction of new technologies to be assessed generically. The timing and rate of introduction of new technologies often varies considerably between the modes and in some cases the applications that make use of the new technologies are different — this is hardly surprising in the light of the different needs of the modes and the different ways in which they are organised and managed. But the cross-modal as well as the intermodal approaches are able to identify where there are both important commonalities and differences and to identify where the experience of one mode is relevant for other modes and where services have to be addressed in a mode-independent way.

The project has approached the human and organisational issues facing transport with the introduction of new technologies in two ways:

1. By looking at how ***tasks*** in the traffic system are being affected and changed by new technologies. As tasks change, those involved in the front line of the traffic system (particularly “operators”[1] of vehicles and those working in traffic control centres) must adapt and equally so must the organisations and managing running the traffic system.

2. By looking at how transport and travel ***services***, particularly in passenger transportation, are being affected by those technologies. New technologies enable traditional services to be offered in new and more flexible ways and also enable totally new services to be provided.

The overall work flow of the project is illustrated in Figure 1. The initial phase of the project involved the identification of the relevant applications of the new technologies in the coming 10–20 years (Draskóczy, 1997) and the establishment of an analytical framework for the subsequent investigation (Carsten, 1998). In the subsequent “Broad Review”, the identified applications and technologies were reviewed by specialist teams covering road, rail, air, maritime transport and public transport (Draskóczy, 1999). An additional specialist team reviewed the impacts on transport in Central and Eastern European countries. In parallel with the overview obtained from the Broad Review, four more detailed investigations have been conducted.

The final phase of HINT is the proposal of a strategy for managing the human and organisational aspects of the new technologies. This report constitutes the final version of the outcome of that

[1] “Operator” is used here in the sense of the driver of a road vehicle, the captain or pilot of a ship, the driver of a train and the pilot of a plane.

work. A first version of the proposed strategy was presented, discussed and modified at a Workshop in Brussels on 2 March 1999 by a group of policy-makers and experts, and the major outcome of that workshop (Franzén, 1999c) has resulted in a revised version of the strategy, presented in this report.

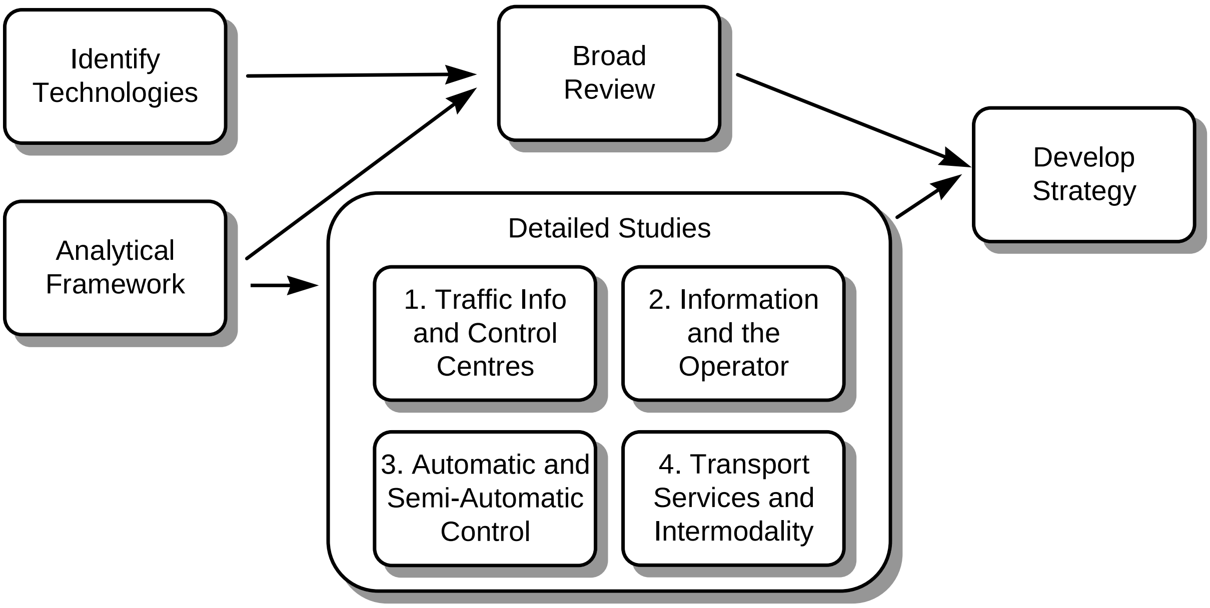


**Figure 1: Work Structure of HINT**

The strategy is intended to address issues affecting the Common Transport Policy. Needs for new policies and perhaps regulations or standards at a European level are intended to be identified, as well as actions that might be more appropriately carried out a local, regional or national level (or even the level of the single organisation).

## 1.1 TASK ASPECTS

The *task* aspects of new technologies were a main consideration of the Broad Review. In addition, for its detailed studies, the project made an *a priori* selection, drawing on its expert knowledge, of a central set of arenas in which tasks were already being modified by new technologies and where modification was almost certain to accelerate in the coming years. These arenas were:

1. Traffic information and control centres, with new systems being introduced both in communications and for assisting or even generally replacing the control-centre operator;

2. Information and the operator — the provision of vast quantities of information though new channels to the *vehicle* operator (pilot, captain, driver);

3. Automatic and semi-automatic control — the replacement of manual operation of the vehicle (plane, ship, train, road vehicle) with semi-automatic and automatic systems. This process is long-standing in aviation and shipping, but is becoming increasingly evident in the other modes.

Each one of these pre-identified arenas constituted a separate workpackage within HINT and for each one there is a separate, detailed report. But if the arenas were different, there was nevertheless a common approach in the form of the HINT framework. This framework (Carsten, 1998) identified a common set of issues and problems in the form of a checklist, that could be applied as a structure across all the HINT work on how tasks would be affected by the new technologies. The major items in the checklist were as follows:

1. System — describe the system and its aims.
2. Levels of intervention — does the system provide information, provide advice/ guidance, provide assistance in control, or does it intervene in control.
3. Task implications — does the system imply major changes in tasks and/or new tasks, does it imply new roles in a crew or team, will it affect workload and are there likely to be problems during the changeover period when the new system is being introduced.
4. Situation awareness[2] — is the system likely to help or hinder situation awareness.
5. Communications — is the application likely to cause communication problems within a crew or between an individual or crew and outside.
6. Locus of responsibility — does the system imply changes in the locus of responsibility and are there possibilities of responsibilities being unclear.
7. Training — is training in system use desirable and how will it be provided.
8. Human errors — will the application reduce errors or will it create new sources of error. How can errors be minimised?
9. System errors — does the system work properly with other equipment and does it have the potential to make serious errors (e.g. in avoiding one incident, create another, worse one).
10. Long-term behavioural adaptation by the user — is this likely and in what form.
11. De-skilling — is this likely and is there provision for skill maintenance.
12. Failure — is the system designed to fail gracefully (revert to a manual mode); are failures likely to be catastrophic.
13. Organisation — does the system require major organisational changes; is disaster planning required, e.g. to deal with terrorism.
14. Geographic — are different countries likely to implement at different rates and if so will this cause problems; are language or cultural difficulties likely to arise.
15. Standards — are the current standards adequate; are there significant differences in standards between the EU countries.
16. Policy — are there any special policy issues that arise at the EU level, at the national level, or at the local level.

These then are the major task issues on which HINT has focused. It can be seen that the final set of issues are those of geography, standards and policy, i.e. those at the strategic level.

[2] "Situation awareness" is a term coined by Mica Endsley and according to Endsley (1995) can be regarded as consisting of three levels: (1) perception of elements in the current situation; (2) comprehension of the current situation; and (3) projection of future status.

## 1.2 TRANSPORT AND TRAVEL SERVICE ASPECTS

For the second approach, the project adopted a more systems-oriented approach (Rasmussen et al., 1994; EuroCASE, 1996; Franzén 1999a) looking at how the services themselves were being transformed and examining in particular how new technologies might affect intermodal and other travel services for travellers as well as mode-related transport services for passengers.

Intermodality is an important transport policy issue (CEC 1996; European Commission 1998), and a clear distinction must be made between intermodal and multimodal transport. Any trip is *multimodal*, i.e. any travel plan normally will use different transport modes (including the human legs) for its realisation. In reality, when a person with a plan to move from A to B decides to make the trip and thus becomes a passenger, he or she has to make sure that the transport option chosen for the travel plan links are found and that any necessary transition between modes will take place. The passenger can be seen as being actively involved in the production of the transport service.

In an *intermodal* case, the traveller only has to choose between different options for travel between A and B, and “someone else” (the transport organiser) will take care of any disturbance that could occur in the transport process. In an intermodal system, the traveller is given a guarantee that the destination will be reached as planned, and that any problem in the transport process that might occur will be solved without any burden on the passenger. What is clearly stated here is that intermodal travel (door-to-door or seamless travel) requires that the transport process is modified to include both a feedback loop and a controller (the transport organiser) with access to relevant and timely “control actions”. This will make sure that every planned travel link, indicating a transport option demand, will be realisable regardless of any disturbance.

In a recent document form the European Commission (1998) a step-by-step action list towards this ideal situation is presented. It is said that in several areas an integrated approach towards intermodality should be chosen. In practice this means that the starting point should be the identification and the integration of already existing (but mode specific) transport system functions. In parallel, an extended mode-independent travel information service, related to the need for movement which the traveller has, must be introduced.

New technologies offer tremendous scope for creating “seamless” travel, whether they are in the form of information systems for travellers and passengers, ticketing systems, information exchange between operators, etc. But the provision of all these new services will also require tremendous organisational change, including co-operation between organisations which have hitherto competed with each other, exchange of information across language barriers, co-operation between the modes, etc. Here there are likely to be important policy implications and, as in the case of the task aspects, strategic actions at a European level may be required.

A first step towards a better understanding of the person transportation process, seen as a complex human-machine system, has recently been taken (Franzén, 1999b). The emphasis at this stage is on the necessary systems perspective and the identification of the different types of human actors and organisations on several functional levels. These qualitatively different levels represent the processes of accessibility, travel, transport, traffic and motion, and the related decision makers such as policy makers/administrators/planners, travellers, transport organisers, traffic control operators and drivers/pilots respectively. The realisation of intermodal travel and transport services would require that perspectives of both travel and transport processes are combined and that a function as “intermodal organiser” is introduced (Franzén, 1999a). For the moment it seems evident that society must take the responsibility for such an integrated approach towards "intermodal services".

# 2. ISSUES AND PROBLEMS

## 2.1 INTRODUCTION

This section summarises the main results of the HINT Broad Review and of the more detailed investigations in terms of the major human and organisational problems that were identified. First, the salient issues in terms of *tasks* in traffic are identified across the modes. Second, there is a more detailed discussion of the impacts of new technologies on tasks in air traffic. Air traffic is singled out because of the greater impact thus far of the new technologies and the greater concern in that mode with human factors issues. Finally, there is a discussion of the impact of new technologies on transport *services*.

## 2.2 SUMMARY OF EXPECTED IMPACTS OF NEW TECHNOLOGY ON TRAFFIC

The areas of human implications identified by each transport mode are concentrated mainly on the traffic level. The main issues in air traffic are flight-deck automation and air traffic management and control, in the maritime area the impacts of new systems on on-board and control centre operators both on open waters and in harbour areas and narrow straits. Automation in train operation is the main issue in rail traffic, and its impacts on rail operators and the public using rail information sources. In road traffic the main target group of new systems and their impact is the group of drivers, but also traffic control centre personnel and road users in general will be affected.

The main areas of possible human impacts have mode-specific as well as common issues across modes. The main problems identified by each transport mode using the above mentioned areas of possible impacts are presented in Appendix 1. The most important common issues are as follows:

1. **Modification of situation awareness of the operator.** Automation of the function of different operators is a common issue across modes, even though the level of automation expected in a 10–20 years perspective is different. Awareness of automated system status, system intent, current actions and rationale for those actions are the main issues that have to be taken into account as important human impacts. System feedback is becoming more and more processed and the mode of presentation of this information is decided by the design engineer. Feedback therefore needs to be *managed,* to ensure comprehension and to prevent sensory overload. Information systems have the potential to increase situation awareness by providing information on aspects of the environment that machines can better perceive than the human senses.

2. **Modification of communication between different actors in transport.** The amount of information exchange via new information technologies will increase enormously in every transport mode and take the place of direct human communication. New communication procedures have to be learnt, and communication failures eliminated.

3. **Change of locus of responsibility**, or uncertainties about the locus of responsibility. Responsibility for the safe operation of the vehicle will remain on the operator in every mode, even if some tasks will be automated or taken over by new supporting systems. Intervening systems may produce uncertainties about the actual locus of responsibility, and these issues have to be clarified and appropriately regulated. Sharing responsibility between control centre personnel and vehicle operators in case of guidance given by a control centre to the vehicle operator is an other issue that has to be clarified.

4. **Issues of training and re-training.** Training for the future has to take into account the demands of new systems, and information technology in general in all transport modes. Introduction of some new systems may demand re-training of the personnel that operates it. Increased sophistication and innovation in automated devices will also require innovative training methods.

5. **Influence of new technologies on the number and quality of human errors.** The philosophy behind many new systems — mainly information, guidance and assistance systems — is to eliminate perceptual, motor and decision errors of the operator. It is, however, unavoidable that new human errors are generated by the new systems in the new operating environment. It is, therefore, essential that the behavioural response of the users of each new system is carefully studied before the wide scale implementation, and it is ensured that the sum effect of the system is positive so that human errors can be managed and their consequences are not catastrophic

6. **Issues of system error** are highly mode-specific because of the different levels of automation, different safety policies, etc. In air traffic it will be necessary to develop highly redundant concepts of fail-safe automation, instead of reverting to manual control. Also, it can be expected that system errors may be more difficult to detect. In maritime transport sophisticated technology on board may create vulnerability because of lack of expertise to maintain or repair on board. In rail transport it is paramount that safety functions be kept independent of the driving function to avoid unnecessary fragility. In road traffic lack of system integration and interference between add-on systems may be sources of system errors. Standards on system development and guidelines on combination of in-car systems are needed.

7. **Long term behavioural adaptation** of the operators to the functioning of new systems means that if a change is introduced in a human operated transport system, the operators adapt their behaviour to the change and this adaptation is not always in line with the intention of the initiators of the change. The main common issue across transport mode in this respect is complacency and over-reliance on new, often automatic systems. Delegation of responsibility on newly implemented system may be an other dangerous form of behavioural adaptation.

8. **Issues of de-skilling and skill maintenance** of the operator. Automation, which is a central issue in expected new transport technology, even if its degree is different in the different transport modes, will produce a loss in traditional driving and vehicle operation skills. Occurrence of situations where those skills are needed can be expected in each mode, therefore, skill maintenance in some way is an important issue. In addition, there will be a need for *re*-skilling. There may be a need for *more* skilled people on complex flight decks and in traffic control rooms — the pressures are greater with increasing traffic density and system complexity is increasing through the process of automation.

9. **System failures** — their occurrence and consequences. It is an important task at the introduction of new systems to ensure that system failures are clearly and immediately reported to the operator, and that the operator be able to take over control over the system. There is a need to have well defined and practised procedures by which the operator can counteract system failures and take over command of the system.

10. **Organisational issues.** Organisational issues at transport company level, such as company policy, the culture of the company, crew resource management, regulations, etc. are a central success factor at the implementation of new systems. At some areas the reduction of personnel will be a major organisational issue. In road transport, which is much less integrated, traffic information collection, processing and dissemination on an international level demand new organisational forms.

11. **Standardisation** is a procedure that follows the development — and sometimes implementation — of new technology. It is, however, a key issue in each transport mode, even if the main concerns and necessary procedures are different at the different transport modes.

The main issues that have to be dealt with by policy in the different transport modes have been defined by the expert teams in the Broad Review as follows:

- Air transport: Policy must be focused on ensuring that the challenges and implications of automation are not underplayed or peripheralised and that human factors issues are addressed in the design cycle as well as contributing to certification initiatives. In other words, it is not sufficient to acknowledge that problems may exist or even to carry out detailed studies on these problems. In the final event, some form of compulsion is required to ensure compliance with standards.

- Maritime transport: The maritime sector is looking for ways to improve its performance in a cost-benefit sense, as well as for ways to guarantee sufficient safety at sea. The latter is particularly relevant from the policy point of view, since the sector is being looked upon with some suspicion both by administrations and the public because of a series of disasters that have raised doubts about the sector's capabilities of running its own business properly. It should be possible to accomplish one aim as well as the other, provided that certain human factors principles are taken into account.

- Rail transport: As regards the automatic operation of trains, there are no major policy issues foreseeable, except for some turbulence in the arena of personnel management. On a wider scale, evolution towards automation may result in standards adopted in technologically advanced countries being forced on less rich countries. This may create oligopolistic situations, by de facto restricting competition. Indirectly, wide-scale automation involves policy issues. There are major social implications due to job loss and reclassification resulting from automation, and to drainage of financial resources to invest in automation. Implications may be observed at all levels: local, national, and European. Finally, largely automatic services and unattended infrastructures raise critical long-term issues. The lack of a physical presence of agents in vehicles or stations, and increasing dehumanisation, increase the sense of anonymity. This in turn pushes people to feel less responsible, and leads to vandalism and to higher aggression rates. An interesting issue at the European level is that there is no clear situation for Automatic People Movers certification. It is not always clear in a particular country, or at European level, which entity or administration is responsible to certify a particular APM.

- Road transport: The stated aim of developing and implementing new transport technology in the EU is to improve transport safety, efficiency and environmental quality. It seems that systems which promote efficiency get priority in practice, and the conflict between different actors of new transport technology development and application leads to compromises that promote momentary interests, and the long term community interests of traffic safety and environmental protection is forgotten. There is a need that the aims of new technology application in road transport are clearly defined on local, national and European level, and those aims penetrate practical work, too. Traffic safety is influenced by a multitude of factors, and many aspects of the human implications of new systems have never been studied appropriately, so that their impact on traffic safety could be stated with certainty. Further work should not only concentrate on the technical development, but also on the human impacts that this new technology will have.

## 2.3 NEW TECHNOLOGY AND AIR TRANSPORT

### *2.3.1 Introduction*

The air mode is discussed in greater detail in the following sub-sections. The air mode has been singled out partly because there has been greater penetration of new technologies in air than in the other modes and therefore more experience with their effects, but also because in air there has been considerable concern about how to manage the influx of new technologies and substantial research on human factors aspects.

### *2.3.2 Background*

Technology is not a new arrival in the air domain and advances have been considerable since the early days of flying where navigation was carried out by looking at the names of railways stations that were painted on the appropriate roofs and the only cockpit display was a tachometer (Blackburn Type B aircraft, 1912). Where there was one display, they are now numerous. This increase in complexity and functionality has arisen not only because of technological advances which have allowed greater capability in terms of flight envelope, navigation systems and aided control, but also because of the need to maintain safety and reduce the numbers of accidents in a context of ever increasing traffic density.

Accidents are attributed to human error in between 60 and 80% of all cases, and significant efforts have been made to reduce the impact of error as a causal factor, largely by allocating tasks to machines in the hope that this will cure the problem. This has worked in some instances where research into accident causes has shown that if a specific piece of equipment had been available, the accident may not have happened. In other cases, further and unpredictable errors have occurred as a result of the technology and of the changes in operating procedures and attitudes. Pilots are now removed from the real control surfaces and system response feedback has to be appropriately provided by the system designer rather than happening as a result of the control action. Furthermore, multifunction displays mean that a very large amount of information can be contained within one display, and the pilot has to negotiate his way around the software to find the information that he needs. Increases in automation are such that many functions are now completely autonomous and the pilot now finds himself carrying out a *monitoring* task rather than even a system *managing* task. Flight modes are complex and many, and some may only rarely be used. Thus the pilot needs to understand what the flight systems are doing and how they interact under all conditions in order to be ‘in command’ of the aircraft.

In parallel to the increased complexity of the flightdeck, traffic density is increasing and new technologies are enabling safety to be maintained with reduced separation, increased landing and take-off frequencies and precision landing that may enable parallel runways. The pilot is expected to adapt to all these developments, but in some instances he/she may not be able to adapt enough because of other factors such as training and organisational pressures. Many of these issues are well documented in the human factors community literature, but may not necessarily be appreciated by a wider design / system engineering audience.

### 2.3.3 Major changes due to technology that will need management

**Role changes**

The major role change for pilots is that they have been driven by the introduction of technology to take over different parts of the flying task. This has resulted in the pilot having to *manage* automated systems, i.e. to select modes and to initiate automated systems. In the most automated flightdecks, this has grown to mean a largely monitoring role for the pilot where he has few decision making or problem solving tasks, and even if something goes wrong he may be unable to override the automated systems' solution of the problem.

This has been called de-skilling, but this is really rather a misnomer. The pilot's manual flying skills may be less necessary, and certainly are practised less often meaning that competency may suffer, but the pilot is learning a whole new set of tasks which include being an aerospace engineer and an information technology expert.

Training programmes must appreciate this change and ensure that pilot competencies are appropriate for the type of flying. This is particularly important for transition training from one type of aircraft to another. The Flight Safety Foundation has quoted examples of problems when pilots change from single seat aircraft to two seat aircraft and do not talk to each other, and similarly has shown how much more successful it is for pilots to train as a crew rather than individually.

In the drive for better use of airspace and to cope with the increasing air traffic, technology has meant that new ways of flying are possible. This is largely to do with satellite and digital datalink technologies, which allow pilots to know where they are much more accurately in both space and time. This means that separation can be safely reduced, and that new ways of navigating and negotiating flight paths may now be possible (e.g. free flight). This has significant implications for both pilot and air traffic controller roles.

**Cultural Issues**

It is assumed that flying is a generic task and that automated systems are used and understood in the same way by *all* pilots. This is not a true statement and studies (James et al, 1991; Abbott et al, 1996; Sherman et al, 1997; Tenney et al, 1998) have shown that there are significant differences between organisations and between nationalities. This does not only relate to language differences but also to attitudes towards automation in terms of behaviour under high workload to the extent that some pilots may let the automation do more under these conditions and some may revert to manual control. The Federal Aviation Administration Human Factors team report has recommended that:

> The FAA should ensure that research is conducted to characterize cultural effects and provide better methods to adapt design, training, publications, and operational procedures to different cultures. The results of the research should

also be used to identify significant vulnerabilities, if any, in existing flight deck designs, training or operations and how those vulnerabilities should be addressed.

Reason (1997) cites cultural drivers as causal factors in accidents, namely:
- time pressure
- cost cutting
- indifference to hazards
- blinkered pursuit of commercial advantage
- forgetting to be afraid

Reason also discusses the significance of culture in that the defences, barriers and safeguards take many different forms and widely distributed within the organisational system, and he concludes that perhaps the only factor that can have a systematic effect is organisational structure. It is clear that effort should be committed to understanding organisational culture better.

**Delineation of Responsibility**

Pilots are responsible for the safe transit of their passengers, crew and aircraft. Air traffic controllers (ATCos) are responsible for the maintenance of safe separation distances between all aircraft in their sector. There are incidences however where this delineation is not so clear. For example, although Air Traffic Control (ATC) is legally responsibly for maintaining aircraft separation, if a pilot responds to a Traffic Collision Avoidance System (TCAS) alert, responsibility for vertical separation passes to the pilot until the aircraft returns to its previously assigned altitude clearance once the conflict has been resolved. The occurrence of this grey area may increase when datalink is used for flight path negotiation and pilots accept separation responsibility in free flight environments.

Currently pilots do not view separation as their responsibility in active air traffic managed areas. However in some areas of the globe, ATC is not viewed as reliable and therefore pilots will take on the task of separation maintenance. TCAS 4 will provide aircraft position and intent. As air traffic management changes with the introduction of digital messaging and digital flight plan negotiation, free flight and other schemes for increasing aircraft and airline autonomy, pilots' roles will change and the task of maintaining separation of aircraft may be a much more common requirement than it is today.

**Air Traffic Control**

Air traffic management systems are undergoing a revolution in the way that they deal with the growing traffic load. Organisational changes to reduce individual ATCo workload by reducing sector size have run their course and there is no more to be gained from that route. Coupled with the fact that there are not enough ATCos and that recruitment does not look likely to be able to supply the shortfall, significant changes are necessary. In addition, the technological developments on the ground have not kept pace with the changes happening on flightdecks and the time has come to bring the two systems in line particularly since the advent of datalink will require ground control and the flightdeck to be much more closely connected with data about routing, weather, clearances and so on, being passed both ways.

There are distinct variations in the quality of air traffic control globally, and pilots carry out tasks differently depending on which part of the world they are flying over (for example, using TCAS for separation maintenance in Africa rather than relying on air traffic control).

Even though English is the required language of Air Traffic Control, this is not always the case and pilots may lapse into their mother tongue when under stress, or when talking to other pilots.

Clearly there are many issues that need addressing at the highest level, but the harmonisation of air traffic control world-wide will take time to achieve. The key human factors issues are to ensure that ATCos are involved in the development process of new systems and that behavioural trials are carried out to understand issues of situation awareness and the big picture, how support tools will work in reality, how procedures should be changed and so on. How free flight as a concept will affect ATC will need to be carefully considered and the IFATCA statements in Appendix 5 give a good idea of the issues. The role of automation on the ground needs just as much consideration as in the air, more in some ways, since complete computer failure will lead to unassisted control. It is also proposed to have virtually autonomous control, with management of conflicts only. In future control regimes, for example free flight and 4D flight, control will be by exception, i.e. when a conflict appears the ATCo will deal with it but that the rest of the air traffic is opaque to the operator.

One of the biggest challenges will be the transition period from the old systems to the new.

**Liability**

Some companies collect incident data with a view to adding technology to reduce the number of incidents. This can lead to increased liability because if a problem once highlighted is not fixed before there is an incident involving that area then company could be liable. This is a ‘Catch 22’ situation since if the airline does not gather information then it is not liable.

**Equipment level as a marketing lever**

Operators may use equipment level as a buy-in to preferential treatment from air traffic control to achieve more expeditious use of air space. This may result in a poor level of service for less-equipped aircraft. Whatever happens there will be a significant period of aircraft equipped to very different degrees, with only a small percentage of aircraft having the capability to fly 4D flight.

### *2.3.4 Problems areas*

Although the aerospace industry is well regulated and has a very complex management structure, accidents still occur and as traffic density increases there is significant pressure to maintain and if possible increase current safety levels. There are multiple bodies responsible for the regulation and certification process; there are multiple strategies with sometimes diverse objectives; the paymasters are various, and individual goals may conflict — it is after all a competitive business. There is a lack of general awareness of human factors problems, and human factors involved at too late a stage even though human factors is explicitly covered in the top-level strategies. Human centred design is still not the norm, with the result that pilots have had to be able to adapt and cope. The pilot can adapt, and has done this up to now, but we may be nearing the point beyond which they may not be able to consistently cope, especially with reduced separations, and added tasks such as route negotiation and taking on the role of flight engineer as well as pilot, and manager and monitor instead of pilot.

In summary, the problem areas and whether they are addressed correctly can be seen as follows:
- Human Factors research — yes, this is on-going.
- Evaluation of systems — yes, this does occur.
- Human Factors strategies and design methodologies — yes, this is happening.
- Tools to assess performance — there are some.
- Analysis of behaviours and situation awareness — there is some.
- Human Factors integrated into design cycle — no, this is not happening.

- Feedback of research findings back into design cycle — sometimes.
- Feedback of behaviour analysis and situation awareness findings back into training design and implementation — there is some of this.
- Assessment of causes of accidents — yes, this happens.
- Looking further than 'pilot error' for the real causes of the accident or incident — this is beginning.
- Training — there is enough, just. More is needed in some areas, particularly in transition training.
- Pilot adaptation — this is being pushed to limits. The problem is how to ensure quality not quantity of automation so as to ensure that workload is truly reduced and that the pilot has enough spare capacity to maintain good situation awareness and be 'in command' of the aircraft.
- New pilots have different types of experience — more automated flying, less manual flying. Selection and training programmes need to reflect this and there is a need to identify what skills are needed in the glass cockpit.

### *2.3.5 Where to go from here*

How to integrate human factors into the design cycle is a key issue (Courteney, 1998a). Having human factors specialists as an integral part of a multi-disciplinary team and not working in isolation is one way of addressing this. Understanding the role of automation in both cockpit and air traffic control situations is critical so that the *quality* and not necessarily the *quantity* of automation is considered.

As a result of the HINT studies the following points have emerged:

- design implications of new technology — consider for the ultimate user
- certification implications (who to test, what to test, what is 'acceptable')
- operational implications — what happens when the equipment is used in conjunction with existing equipment, existing procedures, ATC view of capability
- pilot and controller roles — allocation of function between man and machine
- allocation of responsibility — who is ultimately responsible? is there a grey space where it is unclear?
- conflict handling in the context of digital flight negotiation and new flight regimes such as free flight
- risk assessment/ error tracking — errors will always be present but how can potentially harmful effects be minimised
- training for complex systems — should training be for 98% of all conditions? how does one deal with functionality that may only rarely be used?
- reliance on pilot understanding what the Flight Management System (FMS) is doing and will do given certain inputs
- the need to appreciate pilot role as pilot rather than aerospace engineer, and to consider the *new* skills the pilot must have in addition to the traditional flying skills.

In all these areas it is still a problem to know in what *context* to evaluate and who should do the evaluation — test pilot crews or line pilot crews. *What* to certify is another issue — is it the individual equipment, whole system, system plus pilot; under what conditions: normal, non-normal (if so how defined).

Certification of second and third hand aircraft, and retrofitting of equipment is another area of concern.

Some areas are inherently difficult to research such as situation awareness — to induce a level of workload under which situation awareness may be impaired or to generate realistic situations under which situation awareness in situations with specially created anomalies might be assessed. It is also difficult to obtain simulators and pilots to participate in experiments, and moreover to get pilots when the simulator slots are free. Moreover it is difficult to make it clear that it is not the pilots' performance that is being monitored so much as his/her reaction to a specific set of technologies.

## 2.4 EXPECTED IMPACTS OF NEW TECHNOLOGY ON TRAVEL AND TRANSPORT

An effective integration of similar functions found in individual transport modes as well as advanced support systems for the choice among public transport alternatives when a travel plan is to be realised are essential for the future development of travel and transport services. The main element of this integration — taking into account expected technical possibilities in a 10–20 years perspective — is the construction of interconnecting travel and transport infrastructure, bringing together all public transport modes into a harmonised operating environment (Franzén, 1999a). From the users' point of view (i.e. the travellers and passengers) it means that travel information, ticketing, etc. are provided to them in an integrated way that fits their needs, i.e. arriving from their origins to their destinations in the most time- and cost-efficient way.

One major area of expected change is travel information that is not only relevant for one transport mode, but covers different kinds of public transport means in an integrated way. Information on timetables, prices, connections, etc. is going to be presented by information systems at the homes, offices, etc. of future travellers using mobile terminals, information centres, etc. This service will also provide opportunity to direct booking and most probably the payment of tickets. Such an integrated travel information may attract also people who at present use mainly private transport.

On the other hand, some people may be negatively affected by the fact that the introduction of electronic, home-based information presentation will allow transport companies to reduce human operated desks in stations, in order to save operational costs. In turn, this trend may create two categories of users: those with electronic access, benefiting from a fast and painless service, and second-class citizens, who have to use a slow and understaffed desk service. Also, computer based information system may be difficult to handle for some people (especially for the elderly and for people with lower education) even if terminals will be available in public places, therefore the possibility of direct human communication needs to be ensured, at least for a transitory period. However, as the introduction of travel (and transport) related information at stops, interchanges and terminals will be more common, every user of public transport means will become an "informed traveller", regardless of the access to private "electronic means".

Ticketing of passenger transportation can also be expected to be revolutionised by new technology. One positive human impact of smart card technology will be to provide simpler and faster ticketing when e.g. entering a bus or other public transport vehicles. Electronic payment systems can also provide technical background for more flexible pricing policies, and also provide the user with larger flexibility, allowing the selection of transport means according to the momentary situation. Ultimately, we are going to see a more dynamic interaction between passengers and the system and this development can be seen as one necessary element towards intermodal travel. This evolution may completely change the practice the user has of an urban or larger area, his dwelling and travel patterns, as well as his time patterns. Privacy protection concerns may also rise, because the ticketing system potentially allows those who have access to data from smart cards to trace the whole travel pattern of an individual. Another side-effect is reluctance by some people to use a blind payment method, with which they can not check if the right amount has been deduced from their account.

The integration of public transportation into a common operating environment brings tremendous organisational implications. Apart from the modification of the organisation of each transport company, because of the implementation of some elements of especially new information and communication technologies, there is a potential need for common institutions to be created that are responsible for the collection of information from the different public companies, for the data processing, and for the integration of information, and for presenting relevant information in real time to the public (i.e. travellers and/or passengers) at the right time and the right place. Other organisational tasks are harmonisation of timetables, integration of pricing policy, protection of the privacy of passengers who use smart cards, etc.

New transport technology in the area of passenger information and electronic ticketing offers a possibility for integration in the public transportation area being one of the first steps toward a Citizens' network (CEC, 1996; European Commission 1998). It is not probable that public transport companies will build the necessary organisational background for an — at least from the user's point of view — integrated travel services. Sustainable mobility, on the other hand, demands a bigger share of public transport means to be used for the transportation of people. It is, therefore, an important policy issue for the next period to build and support an organisational base for the use of new technical possibilities in the area of the collection, processing, and communication of information to support the use of public transport means.

As a first step the transport process (mode-related) must be improved and harmonised, and as a consequence the passenger "workload" in the production of the transport can be reduced. At the same time the travel process (mode-independent) must be made more flexible (and perhaps automatic), and as a consequence transport demands can be captured "at the source" (but often at the loss of some integrity). Transport services must be the responsibility of actors within every single transport mode while travel services must be responsibility of authorities and policy makers involved in transportation of people. The final solution must incorporate a combination of mode-independent and mode-related features (also in relation to the necessary actions to be performed) and can be seen as the first steps towards "true intermodality".

The basis for such an approach is an information and communication platform based on an open architecture. The necessary technology does already exist, but still not many applications have been implemented – an application-pull situation exists. Apparently there is still no business case to be found in the area of "intermodal solutions" and the high dependency on the necessary infrastructure (related to high investment costs) makes the area of "intermodal services" the responsibility of "society". However, an opening might be found in different approaches to public/private partnership, but then mainly in a local or regional context.

# 3. CURRENT MANAGEMENT OF TECHNOLOGY

## 3.1 INTRODUCTION

It is in the management of the introduction of new technologies that the *organisational* issues, as opposed to the purely *human* issues, come to the fore. The problems arising from the introduction of new technologies may be human, but the solutions will have to be organisational, through new procedures, improved training and regulation. In his book "Managing the Risks of Organizational Accidents", James Reason writes:

> In aviation and elsewhere, human error is one of a long-established list of 'causes' [of accidents] used by the press and accident investigators. But human error is a consequence not a cause. Errors…are shaped and provoked by upstream workplace and organizational factors. Identifying an error is merely the beginning of the search for causes, not the end. The error, just as much as the disaster that may follow it, is something that requires an explanation. Only by understanding the context that provoked the error can we hope to limit its recurrence. (Reason, 1997, p. 126)

The task being faced in the introduction of new technologies in transport, is to manage the process in such a way that human factors problems and errors are minimised in the first place. In order to ascertain whether changes are needed in current situation, we first need to understand how the introduction of new technologies is handled in the various modes.

As revealed in the previous chapter, the issues and problems of the various modes have a great deal in common — perhaps not surprising since the same new technology tends to be applied in more than one mode. But in terms of the way it is currently managed, each mode is very different, with the road mode being the extreme in that overall the process of the introduction of new technologies is hardly managed at all, whereas in the air mode for example, there is an international management process, but one which is not entirely problem-free.

It is also notable that the air domain has tended to lead in the introduction of new technologies (automated flight, the glass cockpit and headup displays are examples), with the other modes then adopting those same technologies somewhat later. The experience of the air mode is therefore very informative, both in terms of successful processes and procedures and in terms of problems that have arisen and issues that have not been fully addressed.

## 3.2 AIR

### *3.2.1 Regulation and certification*

In the air domain there is a significant infrastructure for the management and certification of airframes, airborne and ground based systems, and personnel to ensure safe and efficient air travel. This infrastructure is at the organisational level — manufacturers, operators; or at a national level — certification and regulatory authorities for both flight deck and air traffic control, and at an international level via agreements that cover operations across the globe. These agreements are not always legislative and are often voluntary.

The regulation and certification of new aerospace systems is a fraught task. Questions yet to be answered include: what to certify, what measures to use, where to draw the line for *acceptability,* who to use to assess it and so on. This is particularly true for the certification of systems for which there is no precedent. It is also very difficult to certify conceptual elements like the adaptability to the new system that might be required from the pilot, what degree of Situation Awareness might be required, will the workload level be acceptable (all of the time, some of the time?), how might the standard operating procedures (SOPs) change as a result of the new technology, how does the fuzzy logic work, and, even more importantly, how can the artificial intelligence be certified.

The 1994 human factors review initiated by the Federal Aviation Administration (FAA) concluded that "except for flight crew workload, the existing regulations and advisory material do not provide the regulatory authorities with the criteria and methods they need to conduct an evaluation of human performance issues associated with the design." It is interesting to note that the introduction of a Human Factors expert to a Joint Aviation Authority[3] (JAA) certification team is happening in the UK for the first time this year (1999).

The potential for regulatory and certificatory involvement covers the whole gamut of aerospace contributors and the whole system lifecycle from concept to design to commissioning to maintenance covering all the SHEL (software, hardware, environment and liveware) elements.

### 3.2.2 Existing strategies

There are several strategies published by different organisations laying out how that organisation will cope with increasing air traffic whilst maintaining a current or better safety record and improving air traffic services generally. They also set out objectives and goals and describe the ways in which they hope to achieve those goals. The following sections discuss the degree to which the human implications for new emerging technologies are being considered.

The strategies so far identified are:

1. ICAO (International Civil Aviation Organisation): Strategy Guiding International Civil Aviation into the 21st century
2. FAA strategic plan
3. FAA report: Challenge 2000
4. Technology Foresight
5. IFATCA (International Federation of Air Traffic Controllers Associations): Towards the 21st Century: A Vision Document

There have also been workshops trying to identify the way forward for human factors in the certification process, and one such was organised by the UK DTI in March 1997.[4]

[3] See section 3.2.3.
[4] European Workshop to develop human factors guidelines for flight deck certification. DTI/ Cornfield College of Aeronautics/EUREKA Conference, March 1997

### 3.2.3 European Aviation Authorities

In the UK, the Civil Aviation Authority plays a leading role in the development of the aviation industry through the safety and economic regulation of British aviation and by providing air traffic services in UK airspace. Its specific responsibilities include:

- Air Safety
- Economic Regulation
- Air Traffic Services

In addition the CAA advises the Government on aviation issues, represents consumer interests, conducts economic and scientific research, produces statistical data and provides specialist services. Other European countries also have bodies with similar roles nationally.

The Joint Aviation Authority[5] (JAA ) is a European co-operative of 29 National Civil aviation authorities, but has no real legal constitution. It has rulemaking, standardisation and implementation functions in the areas of regulation, certification, maintenance, operations, and licensing. The objectives are to maintain a high and consistent level of aviation safety, maintain a cost-effective safety system so as to contribute to an efficient Aviation Industry, to contribute to fair and equal competition and to promote JAA worldwide.

The JAR (Joint Air Requirements) committees have been set up to assist in the regulatory needs of the NAAs (National Aviation Authorities) and also the practical needs of the industry. The JAR relating to large aeroplanes is number 25 and it spells out in detail the requirements for all aspects of the aircraft, including display design. It also includes recommendations that specific human factors issues are addressed in the design of flight deck interfaces such as:

1. Ease of operation;
2. Error tolerant design, including provision for detection and recovery from human errors;
3. Appropriate levels of workload, distributed between crew members during normal and abnormal operation;
4. Adequacy of system-to-human feedback, including clear and unambiguous information on system status, failures, unacceptable crew actions and any compensatory action taken by the system which if prolonged might adversely affect aircraft safety.

The JAA must be satisfied that these conditions are met before issuing compliance certification. Appendix 6 gives a short excerpt illustrating the level of detail within the requirements. JAR-25 receives a significant amount of attention, and it may be time to address other areas of aircraft traffic in more detail, particularly as pilots can now acquire pieces of equipment such as hand-held GPS systems which may or may not have completely up to date databases, and may therefore cause problems for the wider aircraft community and for air traffic control.

The JAA also has research guidance role and Project Advisory Groups (PAGs) have been set up to advise on the sort of research that is required in both the short and the long term. Since 1995, JAA's PAG for Human Factors has aimed to establish research needs, and to recommend topics for research to the European Commission. The ten most important research topics were identified by the PAG as follows:

1. Validation of crew resource management concepts
2. Integration of crew resource management to include other than just the cockpit crew
3. Cabin training against unruly behaviour

[5] Joint Air Authorities consist of the Aviation Authorities of Austria, Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland., Ireland, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom. Joint Aviation Requirements (JAR) are adopted after joint work with industry, Operators and other interested organisations of theses countries.

4. Crew co-operation and national culture
5. Crew resource management for maintenance personnel
6. Impact of new technologies (in operational contexts) — here there is research on incidents involving Flight Management Systems
7. Certification and design methodology
8. Predictive capability of the pilot (to aid decision making and early warnings)
9. Merging of airlines (impact on safety)
10. Long term fatigue (over several days to weeks)

### 3.2.4 The International Civil Aviation Organisation (ICAO)

The ICAO is a specialised agency of the United Nations and was formed in 1944 at the convention on International Civil Aviation. The ICAO has published a strategy called "Guiding international civil aviation into the 21st century". This document has 8 objectives and within these has the requirement for human factors input within the areas of:

- Flight safety and human factors
- Controlled flight into terrain programme
- Safety shortcomings in the air navigation field

Strategic objective E is a key one for human factors since it explicitly states the importance of the human factors role in three areas, namely:

1. The introduction of new technologies,
2. The increased use of automation, and
3. The implementation of new concepts such as the ICAO satellite-based Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) systems.

The fact that the new technologies are creating new challenges for both flight and ground crews due to the complexity of the new systems is appreciated. The ICAO strategic objectives are given in more detail in Appendix 2.

### 3.2.5 U.S. regulatory bodies

**Federal Aviation Authority (FAA)**

The FAA published an updated strategic plan in 1996. It has been driven by current congestion levels and the increasing demand for air services, system flexibility to accommodate a variety of aircraft types and even more importantly the airlines' requirements for cost-effective routings, the impacts of new technologies on flying capabilities — e.g. separation, navigation accuracy and so on, and the increasing requirement to reconsider the current ageing air traffic management infrastructure.

Within the goals and objectives of the FAA 1996 Strategic plan, human factors is an explicit requirement. Its role in the reduction of accidents is recognised and the discipline features explicitly in 4 of the 10 stated goals. The FAA have planned for human factors activities to be carried out over the next 5 years and these are detailed in Appendix 3. The aviation goals where human factors has the greatest influence are those relating to "System Safety, security and human factors" and also to system "Capacity". The aim is to achieve zero accidents relating to system safety, security and human factors as causal factors.

**Challenge 2000**

A further initiative called Challenge 2000 is a comprehensive review of the FAA regulatory and certification capabilities. The review also addresses the "broader process of utilising new technologies, additional administrative techniques and other means of improving aviation safety." Key recommendations from the report include:

- Technology advances such as "new types of advanced sensors for reliable manufacturing, for providing intimate data on the state of equipment and aircraft and *for new techniques of extending pilot capabilities*" should continue to be emphasised;
- Every opportunity should be taken to use computer-based training for staff within the FAA as well as encouraging its use in the aviation community to disseminate critical Human Factors lessons with a view to avoiding potential accidents.

Within this review there is a section discussing "the impact of new technologies on systems and disciplines" and this describes the human factors role as well as using examples from the Boeing flight deck design philosophy to highlight the point. Examples of issues in safety and human factors highlighted by the Challenge 2000 review are:

- The right level of autonomy for free flight.
- What information and controls does the pilot require?
- How will ATC and the aircraft operate in both old and new ways during the transition to free flight?
- Future uses of TCAS (not presently anticipated) are highly likely.
- Predictive wind shear systems and their relationships to reactive systems.
- The difficulties of assigning probabilities to human error.
- Suppliers selling equipment to airlines under Supplemental-type certification processes that do not fit the original flight deck philosophy.

One area covered in detail concerns commercial off the shelf items (COTS) and non-development items (NDI) which are becoming increasingly common, particularly in the case of COTS software. Examples of such software are terrain databases and FMS updates which need to be documented so that the pilot knows the currency of the information, especially if that information conflicts with other information provided by a different system. COTS hardware is also available in much the same way as car drivers add-on after market systems such as in car entertainment, but in the air these 'add-ons' are more likely to be handheld GPS systems and PC versions of approach plates.

A concern that has been voiced is that the COTS component may behave in unanticipated ways or may interact with other components in an unanticipated way yet each may not violate their individual specifications. Monitoring of development processes may be difficult so quality assurance and configuration management procedures are particularly important if a high degree of confidence is to be achieved in the system. Lessons may be learned with respect to human factors in the design cycle from this approach to COTS certification in terms of documentation in the areas of description of interfaces, control and data flow and error detection.

### *3.2.6 Lobbying bodies representing interested parties*

There are several agencies which represent the user view and parties interested in aviation safety generally who commission research, publish reports and are active in lobbying for human factors and flight safety.

**Air Traffic Control Associations**

Air traffic controllers have a significant interest in developing technologies and are very anxious to ensure that the ATCo role is understood and considered when new technology and procedures are proposed. They are represented by organisations such as The International Federation of Air Traffic Controllers' Associations (IFATCA) and National Air Traffic Controllers Association (NATCA) in the U.S. Appendix 5 gives the IFATCA view and voices its concerns about the transition to new operating methods as a result of the CNS/ATM concept.

**Flight Safety Foundation**

The Flight Safety Foundation carries out safety audits when requested by member organisations. This audit experience, gathered over many years, is published in a non-attributable form so that lessons learned can be available to all. Particular issues identified in these audits relate to contract training where the organisation outsources training and there are few or no links between operational problems and the training given. They have also identified the problem of observance of Standard operating procedures where crews may modify or ignore SOPS. This is concerning because of the increasing complexity of modern flightdeck systems where the role of the procedure is even more important because of crew changes and language difficulties. This issue is extended to the pilot perception of their management's view towards compliance with documented limits and procedures. If deviations are condoned by management, safety margins may be compromised as well as undermining professional standards. The FSF has also commissioned the ICARUS report which looks at risk management and airline safety as well as a consolidated approach to human factors in aviation (Pinet and Enders, 1994).

**RCTA Certification Task Force**

In February 1998, the FAA requested the RTCA (Radio and Technical Commission for Aeronautics, which was founded in 1935) to form a Task Force to address the problems of certification. There are 4 working groups covering current system performance; human performance in CNS; standards, criteria and policy; and delivery of certification services. Government and industry representatives are involved as well as international representatives from, amongst others, the JAA and CAA.

### *3.2.7 Company level strategies*

There are also strategies at a manufacturing level dealing with design issues and with the introduction of automated systems. For example:

1. Airbus and Boeing automation strategies (see Salusjarvi et al, Information and the operator, HINT Deliverable 6, 1998).
2. NASA crew centred flight deck design philosophy for high-speed civil transport (HSCT) Aircraft (Palmer et al, 1995).

The latter report includes issues of use by multi-national and multi-cultural airlines. Some of the differences between countries are highlighted, not only those to do with language but also to do with colour stereotypes and switch position stereotypes and norms.

### *3.2.8 Initiatives*

There are several initiatives which are trying to improve safety by tackling the design process in an attempt to ensure that human factors principles are observed from the outset of the project lifecycle and that user requirements are central to the design. Some of these are discussed in the following sections.

**Crew Resource Management (CRM)**

This is an operational philosophy and is defined by ICAO as "the effective use of all available resources, i.e. equipment, procedures, and people to achieve safe and efficient flight operations." The FAA has added: "CRM training has been conceived to prevent aviation accidents by improving crew performance through better crew co-ordination".

This is a framework for taking into account human factors by formalising the approach in a SHEL mode (Edwards, 1988, and Shappell and Wiegman, 1997), where S is software, H is hardware, E is environment and L is liveware. Any element of human factors and CRM can be considered by a combination of these 4 factors — including teams (L-L), procedures (S-L) and the working environment (E-L). The framework emphasizes the flying task as a *crew* function rather than simply a pilot function, and that accidents only happen when any of the SHEL components fail, or when an interaction between components fails.

**Human Factors Integration**

Integration of Human Factors into multidisciplinary teams is an important aspect of progress towards user centred design. There are projects like ENHANCE which are trying to set up an infrastructure for the easy transfer of data between different disciplines — for example aerodynamics code, computational physics and human factors databases. The infrastructure aims to provide a framework for evaluating options and auditing design decisions whilst providing translators and common analysis tools. It is imperative that human factors is included in these initiatives, not only to deal with the human-computer interfaces but also to provide human factors data in the same place as other engineering data so that it can be directly accessed rather than having to search or look in another information system.

If the designer access to a bigger picture — not only the current engineering solution, but what that solution might mean to other parts of the system — the designer will have a better understanding of why and how other design decisions may have an impact on the chosen design solution. But there are problems of terminology, concept definition, and technical appreciation of problems within each discipline.

In multidisciplinary teams it is sometimes difficult to speak in common terms, understand each other's goals, and to deal with a potential overload of information to understand technical implications. Some cross training between disciplines may be beneficial to create an understanding of terms and objectives. There are also huge benefits to be had in multidisciplinary teams due to the aiding role — where solutions may be gleaned from other disciplines.

**Human Engineering Programme Plans (HEPP)**

As part of the AFDT II project, a template has been developed for the production of a human engineering programme plan. This initiative is an attempt to integrate human factors into the design cycle, documented in a formalised and traceable way. The aim of such a plan is to ensure that the design of the system or subsystem is carried out in such a way that due account is taken of the human requirements, capabilities and limitations, such that the resulting product can be operated and maintained safely, effectively and efficiently. The HEPP would draw on reference standards and would be tailored to meet the specific requirements of the technologies involved and the relevant design/development stage.

The HEPP demonstrates how human centred requirements associated with the system will be identified and analysed and how compliance with these requirements will be achieved and demonstrated. It also describes the process by which the Authority (e.g. the CAA) will be provided with visibility of the development process, the results of analyses performed and the outcome or user evaluations. It describes the organisation of the human engineering function within the wider design and development team and demonstrates how nominated human factors specialists will influence design and development activities to ensure that the final product is compatible with a human centred design philosophy.

**MANPRINT**

The MANPRINT programme was developed within the military procurement organisation as a result of some examples of products with very poor systems design which produced toxic fumes and required the operator to hold his breath for an unacceptable length of time to ensure safety. It stands for MANpower and PeRsonnel INTegration and the programme is a comprehensive management and technical initiative to enhance human operational performance and reliability. The programme delineates areas where contractors must take into account the man, the equipment and the environment in which he is operating. The MANPRINT domains are Human Factors Engineering; Manpower; Personnel; Training; System Safety; and Health Hazard Assessment. More details can be found in Booher (1995).

### *3.2.9 How to enhance the safety process*

**Accident statistics**

The role of accident statistics and safety audits in safety management is growing. There are a number of significant accident databases which have been used to identify where technology may be able to reduce the number of accidents, where training is needed and where organisational issues need addressing.

The NASA Aviation Safety Reporting System (ASRS) was established in 1975 under a Memorandum of Agreement between the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA). Pilots, air traffic controllers, flight attendants, mechanics, ground personnel, and others involved in aviation operations, voluntarily submit reports to the ASRS when they are involved in, or observe an incident or situation in which aviation safety was compromised. To date, more than 300,000 reports have been submitted.

Such databases have been used to develop taxonomies of error and failure types so that this information can be used to target design problems or to develop new pieces of equipment to aid the pilot in critical situations (e.g. TCAS), to enhance information quality and timeliness (eg datalink and satellite navigation) or to reduce human errors in high workload situations by automating appropriately (e.g. autoland).

TRACr is a framework for developing a taxonomy of errors in an environment where if things go wrong it is usually attributable to a human error at some level. The model will be used to derive error reduction measures for ATM (Air Traffic Management) (Shorrock and Kirwan, 1998) .

There are also incident reporting systems at a company level which can be quite sophisticated in terms of the information held. An example of this is the British Airways SESMA database which also stores black box information relating to incidents reported by pilots.

New technologies and automation aid the pilot, and potentially reduce high workload situations. Unfortunately, the technologies are so powerful that they also introduce greater functionality, which gives rise to completely new ways of flying, greater autonomy for the systems and can actually increase workload for the pilot (Parasuraman, 1997). The design is then driven by the adage ‘we can provide this functionality so we will’ rather than looking at pilot requirements. The functionality is manifested by many different flying modes, all requiring to be understood by the pilot and all increasing cognitive load and introducing mode awareness problems. These results in a situation where 20% of functionality is used 95% of the time, and modes that are rarely used their capability and effects on other systems will be less well understood.

The technology allows reduction in separation distances to alleviate high density airspace, but in the process the adaptability of the pilot is being pushed to the limit. This is fine in ‘normal’ conditions, but compounds the risk in an abnormal situation. Training is one type of solution to this problem, but not the only one. Human centred design should address these types of issues long before any incidents occur. Therefore the loop between incident and accident reporting needs to continue to be linked to the design process.

**Bluecoat forum**

The Bluecoat forum on the Internet is a very useful source of current pilot and air traffic controller experiences. Individuals can relate experiences on occurrences in the air and share them with colleagues. There is the facility to make non-attributable comments but generally the author of the contribution is given so that there can be dialogue. Very varied topics are covered — map shifts, procedures, landing in crosswinds, understanding how the FMS works and so on. This type of forum gives invaluable information to a wide targeted audience about ‘what do you do if…’ type issues or ‘it happened to me, it might happen to you’ information. There is encouragement at the moment for airline engineers to join the forum to give an engineering view.

### *3.2.10 Conclusions: air*

The Human Factors area needs regulatory support to ensure that it is not just lip service that is paid to the needs of pilots and air traffic controllers. It is short-sighted not to consider the impact of a new system on the operators of that system, considering the fact that the human link is so critical to the safe functioning of the system.

It is still necessary to address the way in which human factors is integrated into the design programme in an auditable way. It is only by integrating human factors principles into the design lifecycle from the very beginning that human centred design will be possible.

The following key areas of concern have been identified:

- There is a need for an organisational and cultural approach, as outlined by Abbott et al (1996) and Reason (1997). This would deal with error, attitudes to automation, and safety culture.
- There are important design issues. There is a need to change the assumption that selection and training will deal with all the issues that design cannot deal with.
- There is a need for the integration of human factors into design process — from requirements capture to design to evaluation
- A standard system development life cycle is needed that is auditable and accountable. Regulatory support is needed to achieve this.
- There needs to be consideration of the links between systems:

  - links between different factors affecting a single systems: e.g. design, maintenance, selection, training, COTS, configuration control, operating procedures, safety culture, organisational culture, attitudes to automation, crew experience level
  - links between different systems such as FMS and ATC so that, for example, both the pilot and the ATCo know what the FMS does.
  - links between human factors specialists and multidisciplinary design teams

- Harmonisation of goals — manufacturers, regulatory bodies, operators, training establishments
- Pay master issues — in the military aircraft domain there is a common paymaster. In the civil domain paymasters are various, all with different agendas and the requirement to satisfy shareholders and to make a profit.
- Certification is not the end of the line. In-service performance must be monitored and events and incidents fed back to both the organisation and the manufacturer so that potentially safety-critical flaws do not persist in service.

## 3.3 MARITIME

### *3.3.1 Organisations*

Like aviation, operational and safety standards for maritime transport are largely set on an international level. The International Maritime Organization (IMO) is the forum in which seafaring nations (member states) are united. Its recommendations have the virtual power of law in participating nations. In the safety arena, there is cooperation with the International Labour Organization (ILO).

Apart from IMO/ILO there is, on the European level, an ongoing 'Concerted Action on Casualty Analysis' (CAC), within the CEC Fourth Framework Transport Research Programme. Although this group has no formal relation to IMO, the persons taking part in it are almost without exception involved in IMO activities. It is serving more or less as a think tank to prepare recommendations that will also be considered by IMO. In addition there are some other relevant waterborne Concerted Actions in the Transport Research Programme: VTMIS (Vessel Traffic Management and Information Systems) and FSEA (Formal Safety and Environment Assessment). These Concerted Actions will end with the Fourth Framework Programme.

### *3.3.2 Functioning of IMO*

**Entry into force of IMO Conventions**

The adoption of a convention marks the conclusion of only the first stage of a long process. Before the convention comes into force — that is, before it becomes binding upon Governments which have ratified it — it has to be accepted formally by individual Governments. Each convention includes appropriate provisions stipulating conditions which have to be met before it enters into force. These conditions vary but, generally speaking, the more important and more complex the document, the more stringent are the conditions for its entry into force. For example, the International Convention for the Safety of Life at Sea, 1974, provided that entry into force requires acceptance by 25 States whose merchant fleets comprise not less than 50 per cent of the world's gross tonnage; for the International Convention on Tonnage Measurement of Ships, 1969, the requirement was acceptance by 25 States whose combined merchant fleets represent not less than 65 per cent of world tonnage. When the appropriate conditions have been fulfilled, the convention enters into force for the States which have accepted - generally after a period of grace intended to enable all the States to take the necessary measures for implementation.

For the important technical conventions, it is necessary that they be accepted and applied by a large section of the shipping community. It is therefore essential that these should, upon entry into force, be applicable to as many of the maritime states as possible. Otherwise they would tend to confuse, rather than clarify, shipping practice since their provisions would not apply to a significant proportion of the ship they were intended to deal with. Accepting a convention does not merely involve the deposit of a formal instrument.

A Government's acceptance of a convention necessarily places on it the obligation to take the measures required by the convention. Often national law has to be enacted or changed to enforce the provisions of the convention; in some case, special facilities may have to be provided; an inspectorate may have to be appointed or trained to carry out functions under the convention; and adequate notice must be given to shipowners, shipbuilders and other interested parties so they must take account of the provisions of the convention in their future acts and plans. At present IMO conventions enter into force within an average of five years after adoption. The majority of these instruments are now in force or are on the verge of fulfilling requirements for entry into force.

**Enforcement of IMO Conventions**

The enforcement of IMO conventions depends upon the Governments of Member Parties. The Organization has no powers in this respect. Contracting Governments enforce the provisions of IMO conventions as far as their own ships are concerned and also set the penalties for infringements, where these are applicable.

They may also have certain limited powers in respect of the ships of other Governments. In some conventions, certificates are required to be carried on board ship to show that they have been inspected and have met the required standards. These certificates are normally accepted as proof by authorities from other States that the vessel concerned has reached the required standard, but in some cases further action can be taken.

The 1974 SOLAS Convention, for example, states that "the officer carrying out the control shall take such steps as will ensure that the ship shall not sail until it can proceed to sea without danger to the passengers or the crew". This can be done if "there are clear grounds for believing that the condition of the ship and its equipment does not correspond substantially with the particulars of that certificate". An inspection of this nature would, of course, take place within the jurisdiction of the port State. But when an offence occurs in international waters the responsibility for imposing a penalty rests with the flag State. Should an offence occur within the jurisdiction of another State, however, that State can either cause proceedings to be taken in accordance with its own law or give details of the offence to the flag State so that the latter can take appropriate action.

Under the terms of the 1969 Convention Relating to Intervention on the High Seas, Contracting States are empowered to act against ships of other countries which have been involved in an accident or have been damaged on the high seas if there is a grave risk of oil pollution occurring as a result. The way in which these powers may be used are very carefully defined, and in most conventions the flag State is primarily responsible for enforcing conventions as far as its own ships and their personnel are concerned. The majority of conventions adopted under the auspices of IMO or for which the Organization is otherwise responsible fall into three main categories.

The first group is concerned with maritime safety; the second with the prevention of marine pollution; and the third with liability and compensation, especially in relation to damage caused by pollution. Outside these major groupings are a number of other conventions dealing with facilitation, tonnage measurement, unlawful acts against shipping and salvage.

**How does IMO implement legislation?**

IMO does not implement legislation; it was established to adopt legislation. Governments are responsible for implementing it. When a Government accepts an IMO Convention it agrees to make it part of its own national law and to enforce it just like any other law. The problem is that some countries lack the expertise, experience and resources necessary to do this properly. Others perhaps put enforcement fairly low down their list of priorities.

With 156 Governments as Members IMO has plenty of teeth but some of them don't bite. The result is that serious casualty rates — probably the best way of seeing how effective Governments are at implementing legislation — vary enormously from flag to flag. The worst fleets have casualty rates that are a hundred times worse than those of the best.

IMO is concerned about this problem and in recent years has set up a special Sub-Committee on Flag State Implementation to improve the performance of Governments. Another way of raising standards is through port State control. The most important IMO conventions contain provisions for Governments to inspect foreign ships that visit their ports to ensure that they meet IMO standards. If they do not they can be detained until repairs are carried out. Experience has shown that this works best if countries join together to form regional port State control organisations.

IMO has encouraged this process and agreements have been signed covering Europe and the north Atlantic; Asia and the Pacific; Latin America: and the Wider Caribbean. IMO also has an extensive technical co-operation programme which concentrates on improving the ability of developing countries to help themselves. It concentrates on developing human resources through maritime training and similar activities.

### *3.3.3 Approach to human factors issues*

Historically, the international maritime community has a predominantly technical perspective. Conventional wisdom has been to apply engineering and technological solutions to promote safety and minimize the consequences of marine casualties and incidents. Accordingly, safety as well as operational standards have primarily addressed ship design and equipment requirements. This perspective is slowly changing, however, in that more emphasis is gradually being put on the human factors associated with the introduction of new technologies and its consequences, both with respect to everyday operation and safety.

Recently IMO has introduced a safety management code, which takes into account the organisation of the whole company. This code is in force for certain types of vessels, including passenger vessels, Roros, tankers, and bulk carriers. General cargo vessels will follow in 2002.

**The ISM Code** establishes safety management objectives which are:

- to provide for safe practices in ship operation and a safe working environment;
- to establish safeguards against all identified risks;
- to continuously improve safety management skills of personnel, including preparing for emergencies.

The Code requires a safety management system (SMS) to be established by “the Company”, which is defined as the shipowner or any person who has assumed responsibility for operating the ship. This system is to be designed to ensure compliance with all mandatory regulations and to take into account all relevant codes, guidelines and standards recommended by IMO and others.

The SMS in turn should include a number of functional requirements:

- a safety and environmental protection policy;
- instructions and procedures to ensure safety and environmental protection;
- defined levels of authority and lines of communication between and amongst shore and shipboard personnel;
- procedures for reporting accidents, etc.;
- procedures for responding to emergencies;
- procedures for internal audits and management review.

The Company is then required to establish and implement a policy for achieving these objectives. This includes providing the necessary resources and shore-based support. Every company is expected “to designate a person or persons ashore having direct access to the highest level of management”.

The Code then goes on to outline the responsibility and authority of the master of the ship. It states that the SMS should make it clear that “the master has the overriding authority and the responsibility to make decisions…” The Code then deals with other seagoing personnel and emphasises the importance of training.

Companies are required to prepare plans and instructions for key shipboard operations and to make preparations for dealing with any emergencies which might arise. The importance of maintenance is stressed and companies are required to ensure that regular inspections are held and corrective measures taken where necessary.

Overall, although there is this growing awareness of the importance of human factors there is not presently, within IMO, a procedure that prescribes how an *a priori* assessment of the human factors aspects of new technologies should be performed. The emphasis is very much on the investigation of human factors within the context of *post hoc* accident investigation procedures. The results of these investigations should lead to the production of a database that lends itself, after a certain time, to forms of meaningful analysis.

### *3.3.4 Procedures for investigation*

The IMO/ILO ideas about how to investigate human factors issues are worth describing, even if they constitute an indirect way of assessing the effects of new technology.

IMO felt there was a need for guidance for accident investigators to assist them in identifying specific human factors which have contributed to marine accidents and incidents. Also, there was a need to provide practical information on techniques and procedures for the systematic collection and analysis of information on human factors during investigations. Therefore IMO proposed guidelines for the investigation procedure comprising the following steps:

1. Collect occurrence data. The first step is the collection of work-related information regarding the personnel, tasks, equipment and environmental conditions involved in the occurrence.

2. Determine occurrence sequence. This is developed by arranging the information regarding occurrence events and circumstances around five production elements, i.e. decision makers, line management, preconditions, productive activities, and defences.

3. Identify unsafe acts (decisions) and unsafe conditions. An unsafe act is defined as an error or violation committed in the presence of a hazard or potential unsafe condition.

4. Identify the error or violation type. Here the question is: "What is erroneous or wrong about the action or decision that eventually made it unsafe?"

5. Identify underlying factors. In this step the focus is on uncovering the underlying causes behind the act or decision.

6. Identify potential safety problems and develop safety actions.

It is expected that the guidelines will be approved and implemented by the end of 1998. They are then to be attached to IMO resolution A.849(20), which applies for all member states. However, within CAC certain objections have been raised to the validity and applicability of the analysis described above. CAC has also drawn attention to the fact that there should ultimately be developed pro-active forms of assessing the human factors implications of the introduction of new technologies.

## 3.4 RAIL

Compared to all other transport modes, railway systems are specific in that only vehicles owned by companies and driven by companies' employees are allowed to use infrastructure, which is physically impossible to access otherwise. Train drivers are professionally trained and qualified.

This closed-system propriety of railways made it possible, since the early days, to keep the system under heavy regulation, which covers not only safety matters, but several operational aspects as well (including seemingly unneeded details, such as the design of staff's uniforms and so on).

Railway regulations are issued by:
- some kind of state authority being in charge of railways; this may be the Ministry of Transport, or whichever institutions having the regulation authority on railways,
- the railway company itself, under the supervision of the state authority, or
- the railway company acting alone, for matters that are not covered by state regulation.

In several cases, regulations, issued by the main national railway operator, become eventually de facto standards at the national level. They are thus extended to all minor railway operators in a country.

In this highly regulated environment, monitoring of introduction of new technologies is almost always extensive and complete. Introduction of a new technology may never be the result of unnoticed individual decisions; it needs a clear decision at the company level. Occurring in a regulated environment, the decision to implement a new technology is always the source of explicit procedures, rules of "do and do not", which aim never to leave individual agents in ambiguous situations.[6]

On the other hand, profusion of regulations may be an impediment to innovation. Certification procedures may be long and complicated, especially at an international level, where conflicting national standards may be involved. This may result in important delays while attempting to introduce new technologies. Even at a local level, a single company may be forced to jettison innovation when faced with the tremendous effort needed to overcome existing regulations.

Management of new information and communication technologies is not different to that applied to other technologies (such as safety, rolling stock, traction, etc.). In most cases, introduction of a new technology is treated as a specific rather than as a general problem.

There are, however, some tendencies towards self-regulation. In the UK following privatisation and the establishment of numerous train operating companies, the Health and Safety Executive (HSE) which regulates rail safety has established a safety case regime as the key element in safety management (Evans and Horbury, 1999). Under this regime, each operator and Railtrack which owns the infrastructure is required to prepare a Railway Safety Case. In such a Safety Case, the operator describes his safety management procedures, arrangements for investigating accidents, particulars of safety procedures in the design and procurement of premises and equipment, arrangements for safety audit, and so on. New technologies would fall under the "design and procurement" rubric. The operator is also required to make a risk assessment as part of the Safety Case. This type of regime has been called "enforced self-regulation" (Ayres and Braithwaite, 1992).

## 3.5 ROAD

The situation in the road arena is far more complex than in aviation or waterborne transport. There are diverse actors — the EU, European and international standards bodies, national governments and national agencies — and it is frequently not clear where responsibilities lie. There has been no concerted attempt to ensure that *someone* is taking responsibility for a particular aspect of the human factors problems arising from road transport telematics. Who is responsible or who has provided guidance on human factors issues often depends on the type of system.

### *3.5.1 The vehicle*

Regulations covering vehicle manufacture are set at the international (UN ECE, i.e. Economic Commission for Europe) and EC level. ECE, through its Working Party on the Construction of Vehicles (Transport WP 29), sets safety and anti-pollution standards covering the major components of motor vehicles. These standards are essentially global, because most vehicle manufacturing countries participate. At the EC level, the EU has issued directives covering, for example, the frontal impact and side impact tests to be performed on new cars. An important avenue for ensuring conformity to standards for new cars and motorcycles sold in the EU is EC Whole Vehicle Type Approval (ECWVTA). Under ECWVTA, which became mandatory in 1996, manufacturers are responsible for compliance with the legal requirements on vehicle construction. The type approval authority verifies that their interpretation of the regulations has been satisfied. The manufacturer submits a representative sample vehicle to the type approval

[6] This situation, in turn, strongly restricts decision areas for the individual agent, and eventually impedes individual initiatives and creativity.

authority for compliance testing and approval. Manufacturers also have to certify ‘conformity of production’ and to issue a certificate of conformity with each vehicle sold. Any vehicle type granted ECWVTA can be sold anywhere in the Community without the need for further inspection or approval. Type approval covers areas such as braking, lighting and the fitment of equipment such as seatbelts.

An additional avenue for securing a responsible manufacturing community and an informed public is Euro NCAP, which was launched in 1997 and which exists to provide the public with independent, realistic and accurate information about the crash performance of individual car models. With support from the EU and from the Dutch, Swedish and UK governments, Euro NCAP carries out and publicises the results of crash tests on comparable cars. The programme is an interesting example of the promotion of safety by encouragement rather than regulation, with the market as the determining force.

Regulations on what can be done with originally fitted equipment, e.g modifications to brakes or the disabling of emissions equipment, are normally covered by national legislation. Generally, the laws and regulations have not been written to cover new technologies, so that a system such as Adaptive Cruise Control (ACC), which is now available on some upmarket cars, is not specifically covered in the regulatory framework. Therefore there is no verification of the ACC, although manufacturers of ACC-equipped vehicles could be required by current regulations to show that the fitment of ACC does not compromise braking performance. Instead ACC is currently covered by a draft standard from an ISO working group (International Organization for Standardization, 1998), and such standards even when final are recommendations rather than requirements.

As regards the *fitment* of additional systems within the vehicle, for example navigation systems, the only legal obligation in many EC countries is when the manufacturer fits them as original equipment. Then they are covered by the normal vehicle crash test procedures. In some countries, equipment fitted aftermarket has to be certain minimum standards, e.g. a TÜV approval in Germany, but elsewhere, when such systems are fitted to the vehicle after purchase, neither the manufacturer of the device nor the installer has any special obligations in this area beyond the normal obligations of consumer protection.

### 3.5.2 In-vehicle information systems

In the area of in-vehicle information systems, there are numerous guidelines and statements of principle both at the EU and the national levels. At a European level there are the ECMT Statement of Principles of Good Practice (ECMT, 1995) and, more recently, the European Statement of Principles on Human Machine Interface from the HMI Expert Task Force (European Commission DGXIII, 1998a). These codes provide advice on good and bad practice (e.g. not distracting the driver), but very little on how such good practice should be achieved and how it should be evaluated. The latest such document, the Expanded European Statement of Principles (European Commission DGXIII, 1998b), provides further detail and advice on what constitutes good and bad practice, but does not provide a test regime.

At a national level, there is further guidance along similar lines. In both the UK and Germany, codes of practice have been issued (Department of Transport, 1994; Wirtschaftsforum Verkehrstelematik, 1996). In addition the UK has established a licensing procedure that is required for private systems being deployed on national highways under the *Road Traffic (Driver Licensing and Information Systems) Act 1989*.

The UK Code of Practice does have an accompanying set of advice on evaluation procedures and checks in the form of the UK HMI Safety Checklist for in-vehicle information systems (Quimby et al., 1996a and 1996b) . This advice is echoed in the draft ISO standards for HMI (International Organization for Standardization, 1997a, 1997b, and 1997c). The UK checklist has 79 separate items, in the form of questions posed to the product designer. The difficulty here is not the thoroughness of the checklist. It is partly the sheer complexity of evaluating each of the items in the checklist, but also the confusion over *legal* requirements. It is not really sensible for individual EU countries to be passing their own legislation or establishing their own procedures. But at a European level, there are no mandated procedures.

The need for action has become all the more urgent in the last year with the rapid development of the "Office on Wheels" in the form of the Intel "Car PC" and Microsoft's "Auto PC" (ITS International, 1998). Such systems have the potential to allow the driver access to a very large number of functions that are not relevant to the driving task, including e-mail, office management and even, as has been proposed by one car manufacturer, home management (e.g. running lawn sprinklers).

### 3.5.3 Urban traffic management and control systems

In the UK there has been recent movement in this area too. A draft Code of Practice for Traffic Control and Information Systems has been prepared under Highways Agency auspices (Highways Agency, 1998). This document at least make allusions to the need for staff competence and training and requires a large number of quality assurance procedures in design, manufacture and deployment of new systems. It makes reference to the UK requirements for (traffic) Safety Audit of large highway schemes. There is little reference, however, to the important issues of human factors in the control centre itself (layout, teamwork, communications, etc.). However, here reference can be made to the first steps towards a "Human Factors Handbook/Guidelines for (Advanced) Traffic Management Center Design" performed by the Human Factors Department at Georgia Tech in Atlanta (Kelley, 1995; Folds, 1997) and supported by the Federal Highway Administration is the US.

An additional issue is that is not always clear where the responsibilities for ensuring compliance lie — they may end up falling between highway authorities, transport consultancies and system providers. Nevertheless, the UK code of practice constitutes an important recognition that problems arising from new technologies are not covered by existing procedures. Many of these issues are being addressed in the current UK Urban Traffic Management and Control project on Safety Issues (UTMC 22), which is preparing a "Framework for the Development and Assessment of Safety-Related UTMC Systems". There is a need for this work to be echoed at a European level.

### 3.5.4 Conclusions: road

Some progress has been made in identifying problems and even solutions. But there is a great need for a more systematic approach. Guidelines are often only advisory, vary between countries, and cover the potential new applications only partially.

# 4. STRATEGY AND RECOMMENDATIONS

## 4.1 INTRODUCTION

The HINT project work has revealed that there are many commonalities between the modes as regards the ways in which new technologies are affecting tasks, roles and organisations. A glance at the summary table in Appendix 1 will confirm this. However, the modes are managed in very different ways — air and waterborne transport mainly on an international basis, rail on a predominantly national basis, and road with numerous actors at the international, European, national, regional and local levels. In addition, the new technologies are permeating the modes at different rates. It is therefore not appropriate to propose an identical way of managing the problems for all the modes. It is, however, appropriate to propose a common approach for all the modes and then to tailor that approach to the needs of each mode.

Travel and transport services are qualitatively different from the purely mode-related traffic activities addressed in the work. This is especially true since societal needs (expressed as policy issues) are the dominating driving forces behind the development of travel and transport services. Consequently, an application-pull situation exists. The problems of the services require another and complementary approach to make possible the introduction of “true intermodal services” in the future.

## 4.2 PROPOSED GENERIC APPROACH

### *4.2.1 Strategic*

There is a need at the EU level for some kind of "technology watch" on a permanent or at least regular basis. The problem is that the technologies change very quickly and that they move from concept to market with extraordinary rapidity. An example is the "Car PC" or "Auto PC", which has gone from concept to market in less than a year. There is a real danger that market pressures and technology push prevent the authorities and the public from ensuring that the legitimate requirements for safety and other social considerations are met.

What is required, then, is a means to identify trends in technologies and in the applications using those technologies through a formalised Technology Watch. The purpose would be to:

- identify major new areas of applications
- identify how changing technologies might be altering existing applications
- review the applicability of existing guidelines and standards
- identify new areas in which concerted action, task forces or standards activities were required
- recommend actors to participate in those activities

**A SHORT HISTORY OF THE CAR PC**

The first information that both Microsoft and Intel were thinking about an on-board PC to be installed in the car with a link to the Internet and able to perform a variety of entertainment, office and home management tasks was released early in 1998. By the end of the year, the Clarion Auto PC, running Microsoft's Windows CE and able to link to a portable PC and thus to the World Wide Web, was on the market. As well as providing route guidance information, this unit can be linked to any of the normal office functions, including fax, email, etc. The product has not gone though any approval procedure and there is no publicly released information to indicate that it conforms to any guidelines or standards — except perhaps those of fitting into the DIN radio slot in the dashboard and of running a standard Microsoft operating system.


**Figure 2: The Clarion Auto PC**

Technology Watch could be effective in three areas:

1. Feeding into standards development
2. Informing the legislative processes
3. Influencing research

Of necessity, this activity would have to be one capable of rapid response. It would have to report to more than one directorate within the Commission, along the lines of the current High Level Group in Road Transport Telematics, which reports to both DG VII and DG XIII. But in contrast with the current HLG, it should consist mainly of experts drawn from the academic, research and industrial communities, i.e. of those with intimate knowledge of current developments. The group or groups should be multi-national and multi-disciplinary. In contrast with some current ISO groups, the Technology Watch should not be dominated by industry suppliers, yet at the same time an appropriate mechanism for their participation needs to be found in order to encourage them to be forthcoming with information about prospective system and service development.

Because so many of the issues and technologies are common, the group should be organised to be cross-modal — an application being developed or one mode is likely to be transferred or adapted to another mode. But there may well be a case for specialist sub-groups for each mode. A public report should be produced on a regular basis — perhaps every two to three years.

### 4.2.2 Tactical

At the application level, the major current problem is that often no entity has responsibility for identifying human and organisational issues and problems before an application comes to market. It is clearly not practical to make one single body, for example a standards authority, responsible for setting standards for new technologies in transport and enforcing them across all modes. Such an approach would be both very unwieldy and stifling of innovation. The alternative is for the authorities to identify overall obligations and responsibilities, and for systems integrators and suppliers to become responsible for the systems that they provide.

It is proposed that this approach be adopted to cover the human factors issues arising from the introduction of new technologies in transport. This would work as follows:

1. At an *international and EU* level, guidelines would be formulated on issues and procedures to be adopted in addressing those issues. The recent "European statement of principles on human machine interface for in-vehicle information and communication systems" (European Commission DGXIII, 1998a and 1998b) is an example of such guidance. However, in contrast with the current situation, there would be a legal obligation on system integrators and suppliers to conform, i.e. some kind of certification process, covering such areas as safety and suitability for purpose. It is recognised that manufacturers have a need for confidentiality in product development. Therefore certification will largely have to take the form of self-certification by manufacturers of compliance with current standards and guidelines. Such self-certification can be backed up by outside verification, as is normal with quality assurance (e.g. ISO 9001). Where there is currently a lack of tools and advice, the EU should ensure that the gap is addressed as soon as possible, through research (where the required knowledge does not yet exist) and through the standards bodies or task forces (where the knowledge does exist).

**AN ANALOGY: REGULATION OF VEHICLE DESIGN**

A system of regulation combined with self-certification and quality checks already operates in certifying that road vehicles conform to current standards for safety and the reduction of emissions. In that area, a number of actors operate to secure the public interest:

- The performance standards and test procedures are set at an international level by the UN ECE and at a European level by the EU;
- The vehicle manufacturers test their own vehicles and certify that they conform to the standards (self-certification);
- The vehicle manufacturers are subject to verification of their conformance by checks on a sample of their vehicles, carried out by recognised test houses;
- The national authorities have "Construction and Use" regulations which forbid unapproved aftermarket modifications of the vehicles.

2. At a *national* level, adherence to the recommended procedures should be encouraged and preferably enforced. The best way to do so would be to place on system suppliers and integrators the legal obligation to certify that their products and systems conformed to current best practice. Systems that lacked such certification should be banned from installation and use, along the lines of the Construction and Use regulations for road vehicles. This would address the problem of the use of unchecked and unverified equipment, particularly equipment added by the user such as COTS (commercial off-the-shelf systems) in aviation or

PDAs (personal digital assistants) in cars. The most effective way to secure compliance would be national legislation.

3. At the *regional and local* levels, compliance with best practice should be ensured through tendering procedures. Suppliers would need to show that they were qualified and would have to certify their conformance to current standards and procedures. Such an approach is already being proposed or followed in some countries in the area of Urban Traffic Management and Control (UTMC).

4. *Suppliers and system integrators* would have the obligation to certify their conformance and the onus would therefore be on them to produce and test their products to the recommended procedures and standards. Failure to do so would incur legal liability.

Overall, this approach combines ***regulation*** in the form of standards, procedures and guidelines with ***self-certification*** by suppliers and systems integrators and with ***enforcement*** by appropriate authorities (usually national). This approach appears to offer the best combination of some degree of control of the process of the introduction of new technologies with the flexibility required to allow for innovation and for adaptation to particular circumstances.

However, these overall procedures will have to be adapted to the current way in which each mode is managed and to special requirements resulting from the systems being introduced in each mode. For example, in aviation (1) the mode is managed mainly at an international level and (2) systems cut across boundaries between aircraft manufacturers, operators and air traffic control.

## 4.3 RESPONSIBILITIES

Currently, new systems are often introduced without clear identification of responsibilities, among manufacturer, installer, user, national government or even the EU. Statements in user manuals advising drivers always to pay proper attention to driving and use equipment properly can be argued to be an abdication of responsibility. It is true that there are indeed responsibilities for the vehicle driver, just as there are for professional operators — pilots, captains and train driver — but other have responsibilities too. It is proposed that the EU issue a formal statement of responsibility, covering product development and implementation from initial design to final use (and even perhaps decommissioning). Responsibilities among:

- equipment manufacturers
- vehicle manufacturers
- aftermarket suppliers
- purchasing agencies
- contractors
- installers, and
- users

should be covered.

The EU itself, national governments and regulatory agencies will have a role in policing the situation to ensure that all the actors carry out their responsibilities. The Railway Safety Case regime in the UK has shown that self-regulation can work, but only when backed by enforcement. The alternative to self-regulation is a presciptive regulatory regime, but this has severe drawbacks in terms of stifling innovation.

## 4.4 FEEDBACK

The mechanisms for identifying problems with new technologies, particularly safety problems and accidents, vary significantly by mode and indeed by country. A more detailed and consistent procedure for investigating failures and problems would help to guide better design and better implementation. There is role for the EU here in stimulating improved data collection and improved investigation.

## 4.5 VARIATIONS BY MODE

### *4.5.1 Air*

In some respects, the air mode already conforms to the proposed approach. However, current management of the air still has room for improvement. Both the ICAO and FAA strategies at the highest level explicitly include the requirement for Human Factors input to the flight safety programme to maintain and improve current levels of safety in the context of highly automated systems and increasing traffic density. The Human Factors community now has to meet the challenges presented by the air authorities. The FAA HF team has prepared a comprehensive list of issues and recommendations and the JAA has published their top ten list of research activities. There are, however, still problems with the management of air certification and the integration of human factors within the design process. One reason is that, although there is significant research in aviation human factors, the design engineers are not always aware of that research. The links between the different factors affecting a single system (e.g. maintenance, training, operating procedures, organisational culture and so on), the links between systems (e.g. the requirement for both pilots and air traffic controllers to understand the Flight Management System), and also the links between human factors and other disciplines are sometimes tenuous or non-existent. The FAA Human Factors team have clearly stated that "human factors engineering (should be) a core discipline of the flight deck system design activity".

There is also a multiplicity of authorities and agencies, with varying agendas and there is a critical need for coordination and for responsibility to be identifiable. Clearly the regulatory bodies are including human factors issues in the regulations themselves, and the human factors decisions through the design lifecycle should be traceable and auditable to ensure compliance with the regulation.

### *4.5.2 Maritime*

IMO, which has 156 governments as members, is the primary arena for regulatory efforts in the maritime mode. Relatively little of its attention, however, is devoted to the application of human factors principles in the context of the introduction of new technologies. Thus, regulatory efforts are of necessity fairly limited in this respect.

There is a joint IMO/ILO (International Labour Organisation) working group on the investigation of human factors in maritime accidents and incidents. This group has recently developed guidelines for such investigations, which are based on the integration of a modified SHEL model (Hawkins) and Reason's GEMS model. The results of the investigations will then be input in a database, which hopefully will reveal patterns in the role of human factors in shipping accidents over the years. However useful this approach may turn out to be in the long term, it is clear that this is not a proactive method to be applied when new technology presents itself.

Certain human factors aspects of new technologies for the maritime mode are covered by presently available standards and codes, which are mostly of a general ergonomic and safety management nature. There is also specific knowledge available about some technologies as a result of 'dedicated' research, which can be of help in the authorities' decision-making process. Within the EU, Concerted Actions on certain safety and operational aspects function on a temporary basis, and are a forum for an exchange of expert ideas. All in all, there is a growing awareness of the importance of human factors, but this has not yet found a definitive form.

### *4.5.3 Rail*

Based on existing evidence, one may conclude that until now railway companies have kept a reasonable control of the process of introducing new technologies. Although explicit standards on how to manage such introduction often did not exist, the closed-system nature of railways, and their heavily regulatory environment, have helped to keep the process under control, and to correct or to balance major human implications.

On the other hand, railways have already a large experience with standards on purely technical issues. Very often such standards have been developed on an international level (mainly managed by the UIC, the International Union of Railways), and have become de facto standards at the national level.

The "free access" policy promoted by the European Union, along with the formal separation of infrastructure and operation management of European railways, is creating a formidable challenge, which will also have implications on the need to extend the current standards, in order to ensure interoperability. Major efforts in this field are in progress, and many European research projects (ERTMS, Eirene, Morane, etc.) contribute or have contributed to setting common standards and specifications. Part of this effort is devoted to aspects related with human factors issues, such as cab displays, ergonomics issues, etc.

There is probably no massive need to create new standards to control the process of introduction of new technologies in railways in addition to the effort that is already being provided. Particular technologies may need their own standards for introduction, defining what, when and how to monitor, but this problem is mostly technology-dependent. Nevertheless, with the easing interchange of equipment between different rail companies, coordination at the European level will undoubtedly increase.

### *4.5.4 Road*

Road transport is the area where the highest number of independent actors are present, and which offers the biggest market for different system providers. While air, road, and maritime transport are mainly run by larger or smaller companies, transport companies represent a minority on the road network. Protection of user interests and regulation of new technology implementation and use can not, therefore, be promoted by bodies other than the European, national and local authorities mentioned above.

One area in road that requires special treatment is that of traffic management and control, both urban and inter-urban. The issue here is that of responsibility, i.e. who should have responsibility — governments that lay down standards (these are currently mainly national) such as type approval; consultancies who may provide an overall specification of a new system or a modification to an existing one; manufacturers who may supply part or all of a system; and highway authorities who are generally the customer for and operator of the systems.

One of the major problems here is that new technology is often grafted on to existing systems, or that an existing system is expanded to provide new capabilities. It is thus not practical merely to make the supplier responsible for certification, since the supplier (1) may only be providing a very small part of a complex system and (2) may not have detailed knowledge of a legacy system. Of course, suppliers' equipment needs to be in compliance with current standards (this is normally required by law). But the system operator, normally a highway authority, needs to be given ultimate responsibility for ensuring safe operation. This is not merely an equipment issue. It extends also to such areas as training, personnel management (e.g. procedures for handovers), control room design, safety at work, etc.

As regards in-vehicle equipment, if *some* equipment undergoes human factors certification, then *all* equipment should do so. This means that equipment, both original and after-market, should come with some kind of certificate of approval for use in the vehicle, while non-verified equipment should be banned from use while driving. This can only be achieved through legislation at the national level.

## 4.6 INTEGRATED TRAVEL AND TRANSPORT SERVICES

There are strong indications that transport policy-making on both the European and national levels promotes the development of sustainable transport solutions and the promotion of public means of passenger transport is one effect of the priorities given. The most promising solutions in this area rely heavily on improved travel and transport services for both travellers and passengers and, as a consequence, the need arises for an information and communication platform based on an open architecture.

The ultimate objective is the creation of intermodal passenger transportation. As transport services mainly are the responsibility of actors within every single transport mode, travel services (in principle being mode-independent) must be made the responsibility of authorities and policy-makers involved. A final solution must incorporate a combination of mode-independent and mode-related features (also in relation to the necessary actions to be performed) and can be seen as the first steps towards “true intermodality”.

The necessary technologies already exist, but not many applications have been implemented. Apparently an application-pull situation exists, and measures for stimulating investments and development of service applications have been introduced. However, as the business case of “intermodality” is not that evident, the introduction of “intermodal solutions” (or as a first step the introduction of “integrated approaches”) must be made the responsibility of “society”. However, an opening might be found in the future by exploring different approaches to public/private partnerships, mainly in local or regional contexts.

## 4.7 CONCLUSIONS

Two situations can be identified which have to be met with different kinds of actions. The first, that of travel and transport services, can be characterised as using an application-pull approach. There is a need for society to promote the introduction of necessary infrastructure platforms and to stimulate the development of new travel and transport services based on these platforms is evident. As a consequence, organisational changes must follow, and new entities combining travel and transport perspectives will become necessary (potentially as public/private partnerships on local or regional levels). Apart from the necessary funds for investment, resources must also be raised for the (rather high) running costs of high quality service operations.

The second and even more important situation can be characterised as being dominated by a technology-push situation. Here an urgent need for action has been identified, as the process of managing the introduction of new technologies is currently out of control, especially in the motion, traffic and transport processes. If anything, the pace of change is accelerating while the process of regulation is non-existent or extremely slow. An action plan at the EU level, co-ordinated with international bodies and national authorities is required.

Perhaps a fitting message to conclude is an endorsement by James Reason of the role of regulation and regulators in preventing major disasters:

> Societies, just like the operators of hazardous systems, put production before protection. …[S]afety legislation is enacted in the aftermath of disasters, not before them. There is little or no political kudos to be gained from bringing about a non-event, although, in the long run, meeting this challenge successfully is likely to be much more rewarding. Every society gets the disasters it deserves. Let's hope that, in the next millennium, the regulators are seen to deserve something better than has so far been the case. Then, perhaps, we will all be safer. (Reason, 1997, p. 188)

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# APPENDIX 1:
# SUMMARY OF RESULTS OF BROAD REVIEW

| ***Areas*** | ***Air*** | ***Maritime*** | ***Rail*** | ***Road*** |
|---|---|---|---|---|
| **Areas of human implications** | Flight deck and air traffic system automation. | Impacts on the operator of the sea vessel | Automation is the key issue, especially - but not only - for train operation. | Impacts on drivers and on traffic control centre personnel. |
| **Levels of intervention** | Several possible levels from direct manual control to autonomous operations. Reversion to manual not always possible. | New systems are expected to intervene in the operator task in many levels | All levels of intervention are concerned, from pure informational systems up to full automation. | New technology in road transport will provide information, advice/ guidance and/or control |
| **Situation awareness** | Awareness of automated system status, system intent, current actions and rationale for those actions are the main issues. Situation awareness - big picture development and maintenance. Particularly for high levels of automation and management by exception. Differences in style of air traffic control - focused or broad awareness. | Information provided to the operator may enhance knowledge, but not necessarily understanding and correct prediction. | Advances in technology will improve, at first, situation awareness in control centres, through better, more up to date and more accurate information. Eventually however, automation of standard procedures, may lead to deterioration, if operators are left with only task of handling exceptional situations. | Information systems may increase situation awareness by informing on aspects of the environment that machines can better perceive that the human eye. Problems with situation awareness may arise when control systems take over part of the driving task and the driver is not properly informed on the process and the actual situation. |
| **Communication** | Communication between flight deck systems and the ground without pilots being aware of it can be expected. Changes in communication procedures, in message formation, information availability, can be expected. | Communication between ships and to and from management/control centres will bring a shift from actual manoeuvring to communicative activities. | Requirements will sharply increase; this may increase communication failures (misses, misunderstandings, etc.). | Demand for communication between traffic control centres and from there to drivers will increase. Direct communication between drivers may be hindered by providing more and more information by in-car displays. |

| *Areas* | *Air* | *Maritime* | *Rail* | *Road* |
|---|---|---|---|---|
| **Locus of responsibility** | The pilot is responsible for the safety of his aircraft and passengers. The Air Traffic Control operator is responsible for the safe transit of all aircraft in his sector and maintain the required separation.<br>Future control regimes<br>(free flight, 4D flight ) have responsibility issues attached- these are as yet unresolved. | Responsibility for the vessel will de jure remain on board, but in situations when a traffic control centre guides the vessel, it is better informed, and issues of responsibility have to be re-defined. | Automation of large components needs thorough planning, in order to avoid the case of "forgotten", seemingly secondary functions (i.e. functions that may be assigned to nobody and to nothing during periods of full automatic operation). | In theory the driver remains responsible for the safe operation of the vehicle, but in practice some control functions will be taken over by driver assistance systems and this may lead to uncertainties and shared responsibility between driver and system provider. |
| **Training** | Training for the future has to take into account the demands of new air-traffic management system, and the development of appropriate aviator skills to deal with highly automated flight decks.<br>Pilots as pilots rather than aeronautical engineers. | Training today is mainly based on On-the-Job training which definitely is not adequate when introducing new technology. | Training requirements will be high. All forms of training will be needed. Increased sophistication and innovation in automated devices will also require innovative training methods. | New systems should be part of the basic driver training. Some systems demand formal re-training, others provide user information themselves. |

| *Areas* | *Air* | *Maritime* | *Rail* | *Road* |
|---|---|---|---|---|
| **Human errors** | Emphasis in design has shifted from that of the error-free flight deck to the error tolerant flight deck. Errors cannot be accepted in Air Traffic Control. Predictive tools are being developed to prevent errors becoming conflicts. | Assistance systems aim at eliminating perceptual, motor and decision errors, but may generate other ones (“mode errors”, communication errors) | Errors in train operation will be reduced by automation. In system-wide automation that involve multiple functions, there is a real potential to induce new sources of errors. | Some systems aim at eliminating human errors, but they may create new errors as well. Some user groups may be prone of such errors, e.g. elderly drivers. Careful analysis is needed at every new system. |
| **System errors** | It will be necessary to develop highly redundant concepts of fail-safe automation, instead of reverting to manual control.<br>System errors may be more difficult to detect. | Sophisticated technology on board may create vulnerability because of lack of expertise to maintain or repair on board. | To avoid unnecessary fragility, it is paramount that safety functions be kept independent of the driving function. Risks of failure in co-operation between subsystems sharply increase with system complexity. | Lack of system integration and interference between add-on systems may be sources of system errors. Standards on system development and guidelines on combination of in-car systems are needed. |
| **Long-term behavioural adaptation** | Automation complacency and automation bias have been identified as potential problems. Skills in using raw data or integrating information sources need to be maintained to add redundancy and to cross check and highlight system errors. | The availability of very accurate position and other information may induce faster but riskier route choices or following established routes with smaller margins. | With automation drivers may lose the sense of responsibility, at least partially. | Delegation of responsibility on systems that take over some control task and dividing attention between driving and some other activity may be a dangerous behavioural adaptation effect. |

| ***Areas*** | ***Air*** | ***Maritime*** | ***Rail*** | ***Road*** |
|---|---|---|---|---|
| **De-skilling** | There is already considerable evidence of gradual erosion of pilots' hands-on flight path control skills, and further de-skilling can be expected in the future. Potential de-skilling of Air Traffic Control operators in terms of decision making and complex problem solving if the computer always generates the solutions. | De-skilling is going to be a severe problem. The loss of some skills is unavoidable, and skill maintenance has to be ensured for the case of automation failure. | Driving skills have to be maintained for cases when manual operation is still needed. Some human skills at the company level will be lost by automation. | Driver assistance and control systems may replace some driving skills which may be needed in situations when the system does not function |
| **Failure** | Communication and navigation failures may be problematic if they are invisible to the crew. Computer failure would be a significant problem. | Clear and immediate reporting of system failure to the operator is a must. | Reversion to manual operation in case of automation failure should always remain possible (currently, it is). | Drivers have to take over system functions in case of system failure, therefore they have to be informed on the failure, and a procedure to revert to manual mode has to be developed. |
| **Organisational issues** | Organisational issues such as company policy, the culture of the company, crew resource management, regulations, etc. are a central success factor. | An immediate consequence of several new technologies is a reduction of personnel. | All issues mentioned in the "Air" column apply also to rail. Moreover, need for disaster planning will increase. | Organisational structure for traffic information collection, processing and dissemination in an international level has to be developed. |

| ***Areas*** | ***Air*** | ***Maritime*** | ***Rail*** | ***Road*** |
|---|---|---|---|---|
| **Standards** | Standardisation of flight deck design is a topical issue. Standardisation in the sense of all flight decks from a certain aircraft manufacturer being ‘similar’. International standardisation of R/T - digital formats will also need to be standardised. | Standards, where they are available at present, are limited to interface proper. Standard on ‘Maritime navigation and radio-communication equipment and systems’ (IEC 61209) is under development. | Standards needed are under development. It is important to avoid proliferation of unneeded standards, that may inadvertently hamper innovation. | Developing standards for new systems, especially for in-car systems is inevitable, including the regulation of use of some technically available systems by drivers while driving. |
| **Policy issues** | Human factors certification initiatives should be encouraged and supported through to regulatory status. Rigorous testing of new flight procedures and Air Traffic Control operator workstations is necessary before implementation. Programmes should include human factors assessments and not just be technology demonstrators. | Safety as well as improving cost/benefit ratio need to be considered. | Automation involves policy issues because of job loss and reclassification, and drainage of financial resources to invest in automation. Unattended infrastructures raise issues such as passenger security and vandalism. | The aims and strategy of new transport technology development and implementation have to be clearly defined and consequently followed. Human impacts of emerging new technology needs to be further studied. |

# APPENDIX 2:
# INTERNATIONAL CIVIL AVIATION AUTHORITY STRATEGY

# ICAO STRATEGY: GUIDING INTERNATIONAL CIVIL AVIATION INTO THE 21ST CENTURY

## STRATEGIC OBJECTIVES:

The objectives of this Strategic Action Plan are to further the safety, security, and efficiency of international civil aviation, and to promote the principles enshrined in the Convention on International Civil Aviation. They will be achieved by developing the vision for harmonious development of inter-national civil aviation on a national and regional basis and reflecting this vision in global planning, by creating and fostering the implementation of common aviation standards and practices and by encouraging the economic design and operation of aircraft and aviation facilities while avoiding discrimination between Contracting States and optimizing the utilization of human, technical and financial resources. To this end, the International Civil Aviation Organization will:

A. Foster the implementation of ICAO Standards and Recommended Practices to the greatest extent possible worldwide
B. Develop and adopt new or amended Standards, Recommended Practices and associated documents in a timely manner to meet changing needs
C. Strengthen the legal framework governing international civil aviation by the development of new international air law instruments as required and by encouraging the ratification by States of existing instruments
D. Ensure the currency, co-ordination and implementation of Regional Air Navigation Plans and provide the framework for the efficient implementation of new air navigation systems
E. Respond on a timely basis to major challenges to the safe and efficient development and operation of civil aviation
F. Ensure that guidance and information on the economic regulation of international air transport is current and effective
G. Assist in the mobilization of human, technical and financial resources for civil aviation facilities and services
H. Ensure the greatest possible efficiency and effectiveness in the operations of the Organization, inter alia to meet the above objectives.

### *ICAO Strategic Objective E*

### *Key Activities: Flight Safety and Human Factors*

Objective:
To improve safety in aviation by making States more aware and responsive to the importance of human factors in civil aviation operations through the provision of practical human factors materials and measures, developed on the basis of experience in States, and by developing and recommending appropriate amendments to existing material in Annexes to the Convention on International Civil Aviation and other documents with regard to the role of human factors in the present and future operational environments.

Human Factors are a vital element in aviation safety. The growth in air traffic, the increased use of automation and the introduction of new technology and concepts such as the ICAO satellite-based Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) systems with their associated complexity in both flight and ground operations are creating new challenges for the personnel operating the aviation system. Through the programme ICAO is providing practical human factors materials and ensuring that the experience acquired in any part of the world benefits all ICAO Contracting States. The programme also ensures that all technical standards and guidance material developed by ICAO take into account human factors consideration from the early stage of development to its implementation.

ICAO contact: Chief, Personnel licensing and Training Section at ICAO Headquarters of local regional ICAO representative
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# APPENDIX 3: FAA PLANNED HUMAN FACTORS ACTIVITIES 1996–2001

# FAA PLANNED HUMAN FACTORS ACTIVITIES 1996 – 2001
## (FROM 1996 FAA STRATEGIC PLAN)

1. The results from FAA research initiatives, including those identified in 1995 accomplishments, emphasize the importance of human factors to aircraft (as well as other areas). Planned research products include those related to human factors design, integration, evaluation, and certification of: 1) air traffic control (ATC) systems, 2) aircraft flight deck displays and control systems, 3) computer/human interface (CHI) applications to the operation of ATC and aircraft, 4) maintenance systems, and 5) new technology applications. Human factors related to flight deck, aircraft maintenance, air traffic control, and airway facilities continue to play an increasingly important role in FAA functions and are an essential element of the FAA Strategic Plan.
2. FAA will also develop tools and reference information for improved performance-based controller selection, training, certification, and retention; criteria for work force selection based on emerging NAS requirements; prototypes and guidelines for improved training programs in crew resource management, aeronautical decision making, team situational awareness, and leadership/followership strategies.
3. FAA will develop analysis tools, standards, and guidelines for assessing/ predicting controller work activity and performance; reconstructing and mitigating operational errors and incidents; developing policies on data link architectures (frequencies, bandwidths, interfaces) and procedures (human factors, including impact on controller and pilot workload, are crucial); and revising aircrew medical criteria, standards, and assessment procedures.
4. FAA will develop prototypes, baselines, and enhancements for automated performance measurement of air crew and controllers; guidelines for factors affecting human performance as well as causative factors in aviation accidents and incidents; guidelines, models, and techniques for air carrier training, pilot/controller/aviation maintenance technician situational awareness, CHI requirements; and recommendations for fatigue countermeasures and work/rest schedules.
5. FAA will develop bioaeronautical guidelines, standards, and models for air cabin equipment, procedures, and environments as a base for regulatory action to enhance appropriate human performance; research data base information on pilot medical history, age, prior experience, airmanship history, and information on accidents and incidents to elucidate causes of accidents attributed to human factors; new medical standards and certification procedures to ensure full performance capability; and advanced documentation technology to provide rapid access to technical information.

# APPENDIX 4:
# FAA STRATEGIC GOALS REQUIRING HUMAN FACTORS INPUT

# FAA STRATEGIC GOALS REQUIRING HUMAN FACTORS INPUT

**Goal 1** is to achieve zero accidents relating to **System Safety**. This means eliminating 'accidents and incidents in aviation and protect(ing) public safety and property in space transportation systems by targeting the most critical areas'.

The FAA aim to achieve this goal by regulation, inspection and certification. The strategy goes on to state exactly where the most critical areas are, namely where commercial aviation accidents are primarily attributed to flight crew error, poor maintenance, or equipment failure or where contributing factors are medical problems or human performance issues.

Specific objectives to achieve the safety goal include:

- Strengthening safety risk assessment and risk management throughout FAA by developing and implementing an agency wide policy supported by guidance, training, data resources, analytical tools, and other resources.
- Improving the effectiveness of FAA safety inspection resources through risk assessment and operational indicators.
- Addressing key safety issues, including ageing aircraft hazards, the safety of aircraft movements on the airport surface, and weather.
- Improving FAA oversight of industry performance based on shared use of safety-related data and development of trend indicators. Address the problem of data confidentiality in order to improve FAA oversight.

**Goal 2** is to achieve zero incidents relating to **security**. This means 'eliminating security incidents in the aviation system'.
Specific objectives to achieve the security goal include:

- Strengthening the baseline of security through better selection and training of screeners and other security personnel, improved procedures, and accelerated development and application by industry of new technologies.
- Reducing the risk of security incidents in international civil aviation by working with foreign governments and international bodies to address vulnerabilities and strengthen each country's baseline of security.

**Goal 3** aims to eliminate **human factors** as a causal factor in accidents and incidents.

The FAA has set the following human factors objectives:

1. To resolve the most critical equipment-related, design-induced human performance degradations in certification, regulation, and FAA acquisitions.
2. To correct the most critical training-related contributors to error by NAS operations and maintenance personnel.
3. Design procedures that enhance human performance in the most critical areas for NAS operations and maintainers.
4. Define Government and industry organizations and management methods that improve human performance.

**Goal 4 – System Capacity**

Meet the system capacity needs for air and space transportation safely and efficiently through near-term actions targeted at specific problems and a long-term comprehensive program of research, planning, and investment matching user needs.

The effort is focusing on four broad measures in addition to safety:

**(1)** Flexibility**, the ability of the system to meet users' changing needs. FAA will measure its success by how much it will:**

- Reduce the number of procedural restrictions in the system,
- Increase the number of user-preferred route requests,
- Reduce the deviation between the route requested and the route flown,
- Reduce the difference between published preferred-route distance and direct routing distance between city pairs at low altitude,
- Increase the peak acceptance rate of airports and/or airspace, and
- Increase the number of decisions involving pilot/controller collaboration.

**(2)** Predictability**, or variance in the system as experienced by the user. FAA will measure success by how much it will:**

- Reduce variation in system performance associated with changes in weather,
- Reduce the impact of system outages,
- Increase the timeliness and quality of data provided to the user on weather, traffic, and system status, and
- Increase the number of delay allocation decisions made with direct user input.

**(3)** Access**, the ability of users to enter the system and obtain services on demand. FAA will measure success by how much it can:**

- Increase the number of runways with approved approaches,
- Increase the number of airports with precision approach capability,
- Increase the number of runways and airports with Category II and III precision approach capabilities to reduce weather delays,
- Increase civilian utilization of Special Use Airspace (as measured by either hours available or number of civil flights using Special Use Airspace),
- Increase the availability and quality of VFR inflight services,
- Increase the availability of flight services to the system user, and
- Increase the coverage of air traffic control surveillance and communication.

**(4)** Delay**, the amount of time over the optimum that it takes to complete an operation. FAA will measure success by how much it can:**

- Reduce ground movement times at key airports during peak operations,
- Reduce the difference between estimated and average en route time, and
- Reduce the number, duration, and impact of ground delays imposed by the Air Traffic Control System Command Center.

**Objective 4G. Human Factors-Implement new decision support systems and associated functional improvements in a manner that fully accounts for the proper role of people in the system.**

# APPENDIX 5: TOWARDS 21$^{ST}$ CENTURY BY IFATCA

# TOWARDS 21ST CENTURY BY IFATCA

The IFATCA Mission Statement:
*"To protect and safeguard the interests of the air traffic control profession"*

## *1. The transition to CNS/ATM (The Current ATC System)*

1. IFATCA opposes the notion that the introduction of new technologies can, by definition, successfully replace the old and tried methods of control without a full detailed evaluation and validation. Failure to complete this evaluation represents a major threat to safety.
2. The experience of IFATCA is that current operational knowledge and judgement must be called upon from the inception of any major ATC project.

## *2. Benefits of the CNS/ATM concept*

1. IFATCA requires that the safety, integrity, and reliability of GNSS be guarantee before GNSS archives a "sole means" status of navigation.
2. While IFATCA supports the progress in advanced ATC technology, it remains particularly mindful of the major inadequacies of ATC in many of the less-developed countries.
3. IFATCA recognises that Free Flight may be feasible in certain airspace. There are, however, other airspace environments that are incompatible with the introduction of Free Flight. The implementation of Free Flight will also be dependent on the development and development of certain enabling technologies, such as datalink and conflict/resolution tools.

## *3. Transition Issues*

1. IFATCA's concern is directed at the potential impact of this transition on the ATC system and the controller.
2. IFATCA believes that financial concerns must not lead to any loss of safety benefits.
3. IFATCA does not accept that datalink communications can replace all voice communications.
4. IFATCA believes that direct controller-pilot voice communications must be available for all non-routine and emergency messages, and for all tactical separation messages in continental high density and TMA airspace.
5. IFATCA believes that controllers must have the appropriate ratings and training for an advanced, sophisticated ADS environment before transitioning from any other type of control environment.
6. IFATCA believes that separation standards using ADS must only be reduced below the present minima following an assessment of risk quantified by an approved ICAO method and supported by operational judgement to account for those factors that cannot be modelled.
7. IFATCA believes that until tail-safe procedures have been proven and installed, the removal of terrestrial navigational aids is neither feasible nor safe and would therefore be highly premature.
8. IFATCA believes that all controllers must be trained at approved instructional establishments to ICAO-recognised standards and, on successful completion of that training, should be licensed in accordance with ICAO regulations.
9. IFATCA acknowledges the requirement for the progressive introduction of automation.
10. IFATCA recognises the importance of all parties working together to achieve the common objective of increasing capacity without compromising safety standards.

## 4. Safety – The Priority Issue

1. IFATCA supports the ultimate objective of achieving global harmonisation in safety regulation.
2. IFATCA believes that the many diverse processes of implementation taking place globally demand independent safety regulation.
3. IFATCA believes that sufficient resources should be directed towards establishing robust and independent safety regulation at national, regional and global levels to encompass ATM equipment, procedures and personnel.
4. IFATCA believes that safety standards must be clearly defined at an international level (ICAO) and must be adopted on a regional basis.
5. IFATCA believes that the establishment of a safety standard is predicated on the successful completion of verification, evaluation, and validation procedures and processes.
6. IFATCA is concerned that new technologies may be deployed merely because they are available, rather than because they meet a valid operational need. Decisions on new equipment must be based on sound operational and safety-related needs, and not on mere availability or novelty of equipment.
7. IFATCA supports the CNS/ATM philosophy that the responsibility for separation remains with the ground-based organisation and that the human remains at the centre of the control loop.

## 5. The Future ATM System (The Controllers' View)

1. IFATCA is a major stakeholder in the ATM system and is committed to the inclusion of the controllers' viewpoint in all future developments of the ATM system.
2. The view of IFATCA is that there are so many variables in the development of the ATM system that it is extremely difficult to forecast the final version of the system.
3. IFATCA believes that the development of interim CNS systems must not deflect from the necessity for the establishment of a fully SARPS-compliant Aeronautical Telecommunications Network (ATN) which will be the bedrock of a seamless global ATM system.
4. IFATCA believes that system design must incorporate all elements of the airspace and ground infrastructure, and recognises the fact that future ATM operations must exist as a seamless total environment — in other words, the "gate-to-gate" principle.
5. IFATCA accepts that, in certain closely defined circumstances, separation may be delegated from the ground to an airborne responsibility for a specified period of time.
6. IFATCA believes that Safety is the absolute priority and that it takes precedence over every aspect of the current and future ATM system.

# APPENDIX 6:
# EXTRACT FROM JAR-25 FOR LARGE AIRCRAFT

# EXTRACT FROM JAR-25 (JOINT AIR REQUIREMENTS) FOR LARGE AIRCRAFT

| | | |
|---|---|---|
| examples | JAR 25. 1303(b)(5) | – Attitude display systems |
| | JAR 25. 1309 (c) | – Warning Information |
| | JAR 25. 1322 | – Warnings and cautions |

JAR = Joint Air Requirement — this is the mandatory requirement that an aircraft must meet.
ACJ = Acceptable means of compliance or interpretative material for the JAR
AMJ = Advisory material joint — this part of the regulation describes how you might achieve the JAR.

### *"ACJ 25.1303(b)(5)(continued)*

1.9 Sufficient pitch and bank angle graduations and markings should be provided to allow an acceptably accurate reading of attitude and to minimise the possibility of confusion at extreme attitudes.
1.10 A bank angle index and scale should be provided. The index may be on the fixed or moving part of the display.
1.11 The 'earth' and 'sky' areas of the display should be of contrasting colours or shades. The distinction should not be lost at any pitch or roll angle.
1.12 Any additional information (e.g. flight director commands) displayed on an attitude display should not obscure or significantly degrade the attitude information.
1.13 The display should be visible under all conditions of daylight and artificial lighting."