ECOTTRIS

European Collaboration On Transition Training Research for Improved Safety

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I Executive Summary

ECOTTRIS (European Collaboration On Transition Training Research for Increased Safety) is a two year project (1996-1998), initiated and sponsored by the European Commission / Directorate General for Transport. The research has been centred around the transitions of pilots from conventional to more advanced cockpits in terms of automation, the so called "glass" cockpit. The main objective of ECOTTRIS is to improve existing transition training procedures. The research tools to fulfil this objective were the analysis of flight deck designs, tasks, required skills and knowledge, and comparing the findings with existing training practices, and results of accident and incident review to identify problems as well as recommendations to improve pilot performance and safety.

Within the ECOTTRIS programme the major type of transition proved to be the acquisition of new or alternative knowledge and skills on glass-cockpit specific items. For the project a fully glass cockpit was defined as one having EFIS (Electronic Flight Instrument System) displays on which data are represented in a computer-generated integrated manner, an FMS and facilities for systems management that at least diagnoses system failures. As many aircraft were found to be semi-automated, either early glass cockpits or retrofitted conventional ones, a group of hybrid aircraft were also identified. On the basis of analysis of types and numbers of aircraft at airlines in Europe, the major transitions from conventional/hybrid to glass cockpit aircraft in the future were clearly highlighted, namely from the older B737 and B747 aircraft to Airbus 320 family. Transitions from glass to glass cockpit aircraft were also expected which would likely involved transfer between Airbus 320 family and the B747-400, B757/767/777 types and vice versa.

There will be a number of conventional aircraft in operation in the foreseeable future, but the actual number of pilot transitions is estimated to be small. Our findings thus far point us to the firm conclusion that glass-cockpits will have an increasing monopoly on transitions and that conventional designs in all sectors of the industry will gradually disappear. However, our findings indicate that a substantial number of transitions will occur from one manufacturer's type to another manufacturer.

The differences in design philosophies of various aircraft manufacturers were investigated by means of available aircraft documentation (Aircraft manuals, Aircraft Operations Manuals (AOM), etc.). This resulted in a categorisation or classification of possible approaches in cockpit design as well as the identification of inconsistencies within one cockpit.

The operational philosophies of the airlines that operate various aircraft were investigated by means of questionnaires distributed to line pilots. Pilots were asked about their airlines' philosophy and procedures with respect to the operational use of various automation parts.

It was confirmed that a large percentage of flight deck functions have been extensively automated over the past years. This is especially true for the functions: steering, navigation and system management. The investigation of the available designs showed a striking lack of standardisation

of the automated functions. Manufacturers employ different design philosophies and sometimes even use different philosophies for different types of their own aircraft. Such flightdeck automation issues are also often stated in other research (FAA, 1996, Owen and Funk, 1997). These variations in automation design will lead to problems with transition training, as WP1 of ECOTTRIS identified that many transitions will take place between different manufacturers.

Another issue found was that airlines use different Standard Operating Procedures. Some prescribe the use of automatic systems whereas other leave it to the discretion of the crew. The overall trend is to use the automatic systems. This strategy is fuelled by the fact that automatic systems allow more economic flight handling. The reliability and performance of these systems is also an important consideration. An example is the increase of the prescriptive nature of auto pilot usage in non-normal and/or emergency conditions. However, 34% of the pilots also reported that the use of some auto pilot modes were prohibited by their airline, again indicating that airlines use the aircraft differently than initially designed for and make a selective use of the original design capabilities.

In order to identify what kinds of problems occur in automated aircraft, a review of accident and incident reports from a number of European and US sources was completed. Reports were selected on the basis of keyword searches for terms relating to human factors, training and automation, and were then classified using a taxonomy developed in ECOTTRIS to identify various operational, behavioural, design contributory and general automation factors. Analysis of frequency of factors and linkages between factors was carried out and yielded the following results: deficiency in CRM was a contributory factor in incidents and accidents (identified in 39% of all reports) and this could be linked with incorrect settings, monitoring and vigilance, inadequate knowledge of aircraft systems, experience and flight handling. Furthermore, complacency was found in 13% of reports and improper use of systems occurred in 15% of reports. In this part of the study, mode awareness was identified as a factor in only 6% of reports.

To identify skills that are critical for operating the glass cockpit, the importance and need-for-training for seven different skills-groups was investigated (skill-groups were based on Rasmussen's behavioural categories, extended with CRM-skills). The analysis indicated inter alia the relative importance of different skill-groups for coping with difficult situations in the glass cockpit. A ranking of those skill-groups is provided in table 1a.

Over the full range of skills that were investigated, a substantial percentage of the investigated pilot population expressed a need for extra training. A ranking of those skill-groups, starting with the skill-group for which the highest percentages of pilots expressed a need for more training, is also represented in table 1b.

Table 1a: ranking of seven different skill groups with respect to *importance*

rank	*Importance*
1	knowledge of automation/ decision making
2	Crew Resource Management
3	manual flying/ determination of appropriate SOP's/ knowledge of SOP's
4	standard cockpit handling

Table 1b: ranking of seven different skill groups with respect to *need/priority for extra training*

rank	*need for training*
1	knowledge of automation
2	decision making
3	Crew Resource Management
4	manual flying
5	determination of appropriate SOP's
6	standard cockpit handling
7	knowledge of SOP's.

Following the incident/accident- and skill-analysis a training activity analysis was undertaken at Airbus Industry, British Airways and Lufthansa in order to assess current practices. Transition courses form the major part of the training effort at all three. Innovative training tools were investigated, ranging from the CBT concept through Zero Flight Time simulation, equivalence training and beyond. Low-fidelity tools such as PC-based briefing and debriefing stations have begun to show their merits and are particularly favoured by the Airbus Training Centre at Toulouse. LOFT (Line Oriented Flight Training) construction using actual events from incident databases such as AIRS (Airbus Incident Reporting System) has been beneficial to give added insights into operational problems as encountered during line flying. Lufthansa's Integrated Type Rating and BA's B777 programme are evidence of an attempt to specifically address glass issues during transition. Integration of automation management into LOFT and other training scenarios is now becoming common on the most advanced fleets.

Further issues that have been analysed and discussed under the heading of training activity analysis are: maintenance of manual flying skills, training for adequate mental models of automation, the provision of SOP's for interaction within the automation, glass cockpit specific CRM training and the use of low-cost PC-based simulation in transition training.

Fifty eight structured interviews were conducted at a number of European airlines to enable pilots and training instructors to comment on current transition training practices, to give levels of understanding of various automated systems and express their views on automation and related issues. The results suggested inter alia. that specific pre-course preparation is not common, often pilots finish flying their old aircraft, only days before the course starts, limiting their time for preparation. The interviews also suggested that the courses spent very little time on highlighting the differences and similarities between old and new aircraft. Ensuring that pilots are aware of differences, improves the pilots' knowledge and understanding both during and after the course and reduces risks for negative transfer of habits or strategies.

Pilots attitudes towards the automation were generally positive. Surprises caused by the automation tended to occur especially early after training, as did human errors due to negative transfer. In cases where pilots were surprised, they admitted that it did influence their trust in the aircraft. Comments suggested that a higher level of understanding of systems, better problem solving skills and prioritisation rules to avoid excessive head-down time, could mitigate negative effects of difficult situations.
Comments regarding the documentation (manuals) were often negative regarding: content, style of presentation and/or language. Each factor created hurdles for accessing the information or reduced general pilot confidence in operating the systems.
Given the current focus on computer based training, pilots were asked how they would appreciate more PC-based training opportunities for auto-flight systems. The suggestion was well received, particularly for the FMS, where the packages could be self paced and used out of normal hours for extra practice. Certainly the high level of complexity of the FMS and its computer interface makes it a candidate for such practise - as long as the same software version as that on the current aircraft is used.

For the FMS in particular, several pilots who rated their level of understanding and knowledge as high, still admitted having problems. Therefore, enhanced/additional training was considered a good idea. Pilots requested more practice and some suggested that a fully functional FMS model with free-play facilities would be very beneficial. For the auto pilot more simulator time with a better explanation/ exploration of the modes was requested; more time for mode changes and more opportunities to practise in the simulator and on CBT. The comments made, suggest a need for extra time on an easily accessible simulation(s) that would allow pilots to investigate and explore the features of each system and especially how they interact with each other.

From this research and other reports (FAA, 1996), it became clear that no single best solution can be provided to solve the problems pilots face when converting to a glass cockpit aircraft. Therefore, a "battery" of recommendations to enhance transition training has been suggested. The ECOTTRIS strategy was to develop and validate potential enhancements that could be used.

In the final stage of the field-oriented data collection, two enhancements, one for CRM skills and one for knowledge of automation, were successfully validated, including an informal user consultation process at an airline training department.

A booklet of glass cockpit CRM training scenarios was developed that focused on five main glass cockpit CRM areas identified from further analysis of the accident/incident reports. These areas were: prioritisation, situational awareness, crew communication, automation and information processing. The scenarios highlighted the relevant issues in each scenarios, showing how problems with CRM are closely linked with operational aspects of flying the aircraft and how, if not properly handled, could lead to serious problems. The glass cockpit CRM booklet received a positive assessment from the validation. While the booklet was designed particularly to address the elements of CRM related to interaction with the glass cockpit, use of the booklet was strongly supported for other types of training. The most popular use for the glass cockpit CRM booklet seemed to be an inclusion in the regular simulator scenarios.

The second enhancement validated in ECOTTRIS was for operationalising the actual knowledge level of automation. Providing extra technical knowledge would be one solution, but without hands-on practice it is difficult for pilots to gain a good understanding of systems operation and interaction. Therefore, suggested enhancements for training knowledge of automation, looked at low-cost PC simulation for practising FMS and auto pilot skills together with full interaction with other cockpit systems using pre-planned flight scenarios. For the purposes of this research, the system selected to evaluate this enhancement was PS1™. This, PC based, 747-400 simulation was well received both as a training tool and as an effective simulation (important for pilot acceptance and for preventing any negative transfer effects), and was thought to be beneficial for operationalising knowledge of automation and skills. It was found to be much more flexible than conventional CBT and was thought to play an invaluable role in transition training. Free play was considered useful for testing the aircraft systems and seeing what happens under different circumstances/configurations. It was also suggested that PS1™-type training could be used with an instructor available to provide guidance and help with problems and could be used to re-play situations useful for simulator debriefing and problem solving. In this way, such training could be used to bridge the gap between technical ground school and simulator sessions. Pilots want to practice programming the FMS, learn the different auto-flight mode transitions and their annunciations, learn the interactions between the different other cockpit systems and generally want to flex their knowledge.

Therefore, it is clear that both enhancements in the validation were viewed positively in the aviation community and could become important additions to training for pilots moving to glass cockpit aircraft. Particularly important is that such enhancement are inexpensive and not difficult to implement and easily adapted to individual airline requirements.

Other enhancements are still possible, and indeed manual flying skills remains to be addressed. However, if these two initial suggestions could be implemented, the process of conversion from conventional to glass cockpit could become easier and safer without too much additional cost and more full motion simulation time could be freed for manual flying time.

On the basis of the research, the following conclusions and recommendations were formulated:

- The reliability and safety record of glass cockpit aircraft has improved in relation to older conventional aircraft.

- However, as stated so many times, the safety of civil aviation needs further improvements to keep the absolute numbers of accident and incident at an acceptable level, due to an ever increasing growth in flight movements.

With respect to *transition training* for the glass cockpit, the following was concluded:

- A trend towards reducing transition course lengths was observed, while pilots expressed a need for more training. Many pilots indicate a need for a higher level of expertise, especially in coping with difficult situations.
- Due to increased reliability of systems, the exposure to malfunctions in glass cockpits is an order of magnitude lower than with “steam gauge” aircraft. However, because of to increased system integration, the consequences of malfunctions may be more aggressive and more difficult to understand. Further, due to the lower exposure to malfunctions, skills involved will not be retained or even never be experienced by either of the crew members in an operational situation.
- Inherent to the glass cockpit is the gap between performance requirements during normal operation and non-normal operation. Non-normal operation may require a reversion from a “strategic mindset” to a “tactical mindset”, including aborting strategic tasks and decision making in favour of more tactical tasks and decision making.
- The way of communication changes from conventional to glass cockpits: the conversation and allocution as means of information exchange/communication has become poorer and more artificial, while registration (of instructions) and consultation (of flight information) has become more sophisticated, more precise, but also artificial and tiresome in terms of interfacing.
- Transition training could be more effective if individual data (e.g. computer literacy) were taken into account and if the training programme would address transient needs of the trainee by monitoring the learning process rather than training to pass an exam.
- Transition training could be more effective if innovative training media would be used that could cater for a wider range of training activities and related training objectives.
- In transition training for pilots transitioning from a conventional type to a glass cockpit type aircraft, very little time is spent highlighting the differences and similarities between the conventional type and the glass cockpit type.
- CRM for glass cockpits was not found to be widely taught although CRM was identified as being an important skill and a factor in glass cockpit accidents/incidents.

On this basis recommendations were formulated concerning:

- *training objectives:* what knowledge, skills or attitudes need to be mastered?
- What kind of *training methods* may be used to achieve the training objectives?
- What kind of *training media* could be used?
- What *feedback* is given to the trainee during and after an exercise?
- How is the achievement of training objectives *assessed*?

An example transition training programme has been outlined in order to illustrate the implementation of the aforementioned recommendations. The basic scheme of the training programme is fairly traditional when it is compared to training offered at airlines. The scheme is based on phases, starting with an ‘initial phase’, followed by an ‘advanced phase’, which is primarily training on a fixed base or full flight simulator and subsequently training on the aircraft (‘aircraft/operational phase’). Finally, recurrent/refresher training is considered as an integral part of the transition training.

Furthermore, a trainee-centred approach has been taken in the sense that *training objectives* are based on the needs of the (individual) trainee or target group, given the operational requirements of the airline.
Each phase consists of several training modules with increasingly ambitious training objectives. For example, after a initial phase module that familiarises the trainee with systems in isolation, a module follows to learn the interaction between systems, such as the components of the auto-flight system. On the basis of background data of the trainee (logged hours, particular glass experience, etc.) specific training modules have to be followed and others are skipped. The trainee-centred approach is further enhanced by allowing some flexibility in the order and duration of training modules. Where possible training is made available at a time, place and pace to suit the needs of the individual.

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1. Introduction

1.1 What is ECOTTRIS?

ECOTTRIS (European Collaboration On Transition Training Research for Improved Safety) is a two year project (1996-1998), initiated and sponsored by the European Commission / Directorate General for Transport, within the scope of the Fourth Framework. The work was executed by an international consortium consisting of a major airline, a flight deck manufacturer, two aeronautical research establishments and a simulator manufacturer. ECOTTRIS concerns Human Factors research in the field of training. The research has been centred around the transition of pilots from one cockpit to another. In particular, the transition to a more 'advanced' cockpit in terms of automation, the so called ‘glass’ cockpit. The main objective of ECOTTRIS is to improve existing transition training procedures. The research tools to eventually fulfil this objective are the analysis of flight decks, tasks, skills, knowledge and existing training practices as well as the analysis of difficult situations, incidents and accidents.

1.2 Why ECOTTRIS?

The introduction of technology, such as multi-function displays and flight management systems, into the modern cockpit has led to a change of the crews' roles. The increase of automated tasks in an airline cockpit has changed the role of the crew from an active one, controlling all kinds of parameters, into an apparently more passive one, supervising and managing automated systems. Many believe that this fundamental change in role has not received enough attention and that it may have led to crews not being adequately trained to perform their new supervisory and management tasks, where an in depth knowledge of the systems themselves and their status is required. Some examples of incidents and accidents where better understanding of the systems’ functionality would have possibly prevented them from happening are listed below (Source: Aviation Week & Space Technology, Jan. 30 1995):

Date	*Location*	*Type*	*Operator*	*Factor*
1976	**(anon.)**	**DC-10**	**(anon.)**	**Mode understanding**
Pilot forgot he was using control wheel steering on approach causing tail strike.				
8/6/89	**Boston**	**B767**	**(anon.)**	**Mode understanding**
On Autopilot ILS approach, aircraft overshot the localise. Captain switched from approach to heading select mode to regain the localiser, disengaged the Autopilot, and used the Flight Director. Since the Glide Slope had not been captured, the Flight Director was in Vertical Speed mode commanding 1800 feet per minute descent instead of staying on Glide Slope. Alert from the Ground Proximity Warning and tower caused a go-around from about 500 feet.				
14/2/90	**Bangalore**	**A320**	**Indian Airl.**	**Mode understanding**
Inadvertent altitude acquisition and open descent modes resulted in a crash of the aircraft.				
Various	**various**	**A320**	**various**	**Mode understanding**
Aircraft was set to a V/S of x000 fpm instead of x deg flight path angle.				

These accidents and incidents are but a few of those reported where the cause of the problem was attributed to lack of mode awareness. Mode awareness indicates the amount of knowledge the crew has of the systems and in particular status and activity of the auto-flight systems; the term is most often used in relation to glass cockpit aircraft. By now it appears that modern glass cockpit aircraft have an inherent risk of the crew not being fully mode aware. Part of this problem might be solved by better design and could be prevented in future aircraft, but one has to realise that present aircraft will be flying for some decades before they are replaced. Equipment can be updated in the form of retrofit systems, but it is not likely that this would solve the problem completely. Therefore, solutions should be found through different approaches. One of the most likely candidates to solve (part of) the problems could be more effective (transition) training and/or crew procedures.

1.3 ECOTTRIS Objectives

The objectives of ECOTTRIS are:

- To produce an accident and incident analysis (from real flight as well as from training sessions) in relation to transition training factors from which operational and/or training factors can be derived which lead to possible safety risks.
- To produce a skill and training analysis based upon which training requirements and recommendations can be derived which would lead to more effective transition training to compensate for the above mentioned risks.
- To recommend where applicable, e.g. where more effective procedures and/or training is not expected to be adequate to solve the problem, cockpit changes based on human factors standards. These recommendation will include retrofit items.

1.4 ECOTTRIS Research Plan

The research within ECOTTRIS has been subdivided into 5 work packages, which will be described hereafter. The work packages were carried out sequentially with the exception of the work packages WP2A and WP2B which were carried out in parallel.

- WP1 which started in June 1996 was lead by British Airways;
- WP2A and WP2B were carried out in parallel during late 1996 and 1997, WP2A was lead by NLR and WP2B was lead by DERA;
- WP3 was lead by DERA from Autumn 1997 until Summer 1998;
- WP4 was lead by NLR and was carried out in the second half of 1998;
- Project co-ordination of ECOTTRIS was carried out by NLR.

Work Package 1

WP1 had the following objectives:

1. To define the transition concept in terms accessible to the lay reader.
2. To provide a taxonomy of current and possible future transitions.
3. To provide a glossary of terms related to those transitions.

Methods employed in WP1:

- The transition concept was defined by way of reference to various sources;
- The taxonomy of current and future transitions has been derived from a survey of a number of airlines chosen for their present and potential fleet mix;
- To predict future transitions, a numerical/statistical analysis has been conducted.

Work Package 2A

WP2A had the following objectives:

1. To make an inventory of design philosophies employed by aircraft manufacturers.
2. To make an inventory of philosophies for aircraft operations employed by airlines.
3. To investigate similarities and differences in above mentioned philosophies.
4. To produce a skill list based upon which training requirements and recommendations can be derived which could lead to more effective transition training.

Methods employed in WP2A:

- To investigate whether airlines automation philosophies are compatible with the automation as applied in aircraft, an inventory of automation of “glass aircraft” has been created. This has been done in co-operation with airline pilots with experience on the considered glass cockpits and by search in the literature such as flight manuals.
- A questionnaire, distributed among “glass cockpit” pilots, was used to investigate to what extent airlines prescribe pilots to use this automation. Emphasis has been put on the differences of cockpits in the way the crew has to fulfil flying tasks.
- The same questionnaire was used to investigate the abilities that glass cockpit pilots currently require and whether they consider their ability level sufficient to fly glass aircraft under difficult situations.

Work Package 2B

WP2B had the following objectives:

1. Identify factors in aircraft accidents and incidents related to automation/glass cockpit technology.
2. Identify factors in aircraft accidents and incidents that arise from poor transition training.
3. Identify training issues in transitioning to new aircraft types.

Methods employed in WP2B:

- To identify any causal factors related to transition and training, incident and accident reports compiled through aviation and research institute databases (including CAA MORS, CHIRP, AAIB Reports, NASA ASRS, WAAS and other non-identifiable sources) were reviewed;
- To identify glass cockpit issues in the data collected, a classification scheme has been devised;
- To identify the effects of transition training a structured interview was developed and conducted with pilots who have recently had transition training and are now back on the line. The interviews have been conducted with pilots from a number of cultures, both national and organisational, and follow a structured format that asks a variety of questions about the training they received.

Work Package 3

WP3 had the following objectives:

1. Identification of theoretical shortcomings of transition training.
2. Assessment of user opinions on the potential shortcomings of training.
3. Validation of enhancement to transitions training.

Methods employed in WP3:

- Training Activity Analysis: collection of information on training programmes from a number of sources.
- User Consultation: continuation of interviews with line pilots and training pilots from European airlines using the structured interview format developed in WP2B. The data from the interviews were transcribed into a interview database, ready for analysis.
- Validation of enhanced transition training.

Work Package 4

The objectives of WP4 are to discuss the results of the research such that:

- recommendations can be made directed to relevant areas such as civil aviation authorities, flight deck manufacturers, airlines and training centres, research centres, and
- conclusions can be drawn regarding: current training practices, transition problems, benefits of measures taken following from the research, expected safety benefits; expected economical and social benefits.

WP4 results are described in this report.

1.5 Report Structure

The remainder of this report starts with an overview in Ch. 2 of the scope, methodology and results of the most important tasks in the research, i.e. definition of the transition concept, design philosophies, analysis of incidents and accidents, analysis of glass cockpit skills, analysis of current training activities at operators, consultation of users with respect to training and validation of training enhancements.

Ch. 3 is the discussion chapter. For purposes of a coherent discussion, a distinction has been made between discussions of ‘pilot training and performance’, ‘glass cockpit operation’, and ‘flight deck design’. Obviously, the research focused on pilot training and performance. In this section a ‘historical perspective’ is given with respect to developments in transition duration, reliability of aircraft systems and the changing nature of aircraft systems. Further the individual training needs of the pilot and the use of training media is discussed and the implications for pilot training and performance.

In Ch. 4 and 5 conclusions and recommendation are listed, following the same basic structure as in Ch. 3 (pilot training and performance, glass cockpit operations and flight deck design).

Recommendations with respect to pilot training and performance have been specified with respect to training content (training objectives, what need to be trained?), training method (how will it be trained?) and the employment of training media during transition training.

Some of those recommendations have been implemented in a ‘future transition training example’ that is described in appendix A.

Ch. 7 offers a comprehensive list of terms to assist in the understanding of the structure and content of transition training. Finally Ch. 8 provides a list of abbreviations and acronyms.

2. Scope, Methodology and Results

2.1 The transition concept

Research goals and methodology
The initial assignment of the ECOTTRIS project was to define the *transition concept and* to classify *current and future transitions.* The data derived from the study provided a reference for later stages of the project and provided an insight into the future levels of transitions in our geographical area.

The definition of the transition concept has been extracted from various sources and is applicable to all of the aircraft operators within the EC. It is a broad brush picture of what is required by the regulatory bodies throughout the world. The taxonomy of current and future transitions has been derived from a survey of a number of Airlines chosen for their present and potential fleet mix.

Aircraft transition as defined for ECOTTRIS
A pilot who flies a civil airliner on a commercial basis must hold a valid pilot's licence which must include a Type Rating for that particular aircraft. This Type Rating includes knowledge and skills on flight deck layout, systems operation, normal, abnormal and emergency operations and performance and handling. When a pilot wants to convert to another aircraft, he/she will enter a transition training programme to acquire the knowledge and skills of the new aircraft. Within the ECOTTRIS programme the acquisition of knowledge and skills on glass-cockpit specific items has been investigated. Glass-cockpit items are EFIS display formats (PFD, NAV, Engine and Systems information), FMS operations and functionality, MCP operations and flight mode annunciation, Digital Support Systems operations and functionality. This included primarily the transition from traditional steam gauge type aircraft to new glass cockpit aircraft. The reason to include only this transition is described below.

Taxonomy of current and possible future transitions
For the ECOTTRIS project a *fully glass* cockpit was defined as one having EFIS (Electronic Flight Instrument System) displays on which data are presented in a computer-generated integrated manner, an FMS and systems management that at least diagnoses system failures (EICAS, ECAM, etc.).

With this definition some conventional types would not fall neatly within our terms of reference. Therefore, a *hybrid* category which encompasses aircraft that contain some glass characteristics was created. Examples of fully glass types, hybrid types and conventional types are given in table 2.

Table 2: Examples of fully glass types, hybrid types and conventional types

fully glass	***hybrid***	***conventional***
Airbus 320 Family	Airbus 310	Airbus 300
Boeing 747-400	ATR 42/72	Boeing 737 100/200
Boeing 757/767	Boeing 737 300-500	Boeing 747 100-300
Boeing 777	Fokker 50	DC9
Fokker 70/100	MD80 family*	DC10
MD11		Fokker 28
		MD80 Family*

*As there are many modification states of these types they fall into both categories

Current and future transitions - Airline survey

The survey targeted 39 airlines of varying sizes within the broader European area, chosen for their fleet mix and growth potential. The scope of the airline survey was limited to a four-year band (viz. 1994-97). The airlines were chosen using a number of parameters; fleet size and mix as well as geographical spread over the area were considered.

The actual number of transitions appeared to have been relatively constant over the last three years. Although there are large variations within the smaller companies, for example during re-equipment programmes or on initial start-up, the global figure within the survey group has changed little since 1994. The figures for transitions to glass-cockpit aircraft also include those movements from one glass type to another.

The situation is further complicated by the fact that many airlines now operate both conventional and hybrid variants of the same type and have introduced a dual rating, enabling pilots to fly, for example, B737-200 and -400, having completed an initial transition onto one or the other aircraft followed by a short differences course. This facility is presently under review by the JAA and their decision will have a considerable impact on the planning strategies of the airlines concerned, probably hastening the decline of conventional aircraft within the larger operators' fleets.

The majority of responding operators did not anticipate any significant training programmes onto conventional types alone, indeed many reporting none whatsoever.

Current and future transitions - theoretical prediction

The theoretical prediction targeted 47 airlines of varying sizes in the European Union, which contain either only glass aircraft or have a mixed fleet, that is non-glass (conventional/hybrid) and fully glass aircraft.

To calculate the maximum theoretical number of pilot transitions, two formulae were developed, one for the transition from conventional to glass aircraft and one for the transition from glass to glass aircraft. Furthermore, a selection was made of aircraft types, of which more than 40 aircraft are flown in the airlines of the European Union. The analysis was based on actual fleet compositions (situation 1996). The results of this analysis is depicted in tables 3 and 4.

Table 3: Maximum possible pilot transitions non-glass to fully glass in the EU

To glass Non-glass	A320 Family	B747 400	B757/767	B777	MD11	Fokker 70/100
A300	621	55	90	0	66	15
A310	301	78	33	0	19	31
ATR 42/72	43	14	9	0	0	297
B737 100/200	541	206	265	49	0	61
B737 300-500	1158	455	678	51	72	226
B747 100-300	523	278	341	44	77	25
DC9	134	0	218	0	66	22
DC10	241	36	134	10	50	3
MD 80 Family	466	0	326	0	132	110
Fokker 28	46	5	188	3	0	187
Fokker 50	18	0	176	0	0	191

Table 4: Maximum possible pilot transitions fully glass to fully glass in the EU

Glass Glass	A320 Family	B747 400	B757/767	B777	MD11	Fokker 70/100
A320 Family		990	1254	220	264	242
B747 400			1078	352	220	176
B757/767				352	484	198
B777					0	44
MD11						132
Fokker 70/100						

The major theoretical transitions from conventional/hybrid to glass cockpit aircraft were clearly highlighted, namely to Airbus 320 family and from the older B737 and B747 aircraft. The major theoretical transitions from glass to glass were clearly highlighted, namely between Airbus 320 family and the B747-400, B757/767/777 types.

Main conclusions

All the data gathered thus far points towards a gradual disappearance of the conventional flight-deck within the transition system and a growing reliance on pure glass technology. There will obviously be a residual number of conventional aircraft operated for the foreseeable future but the actual number of pilot transitions will remain very small. The size of the conventional fleet world-wide will also be influenced by the outcome of other ostensibly unrelated issues, such as noise, environmental considerations and commercial pressures.

Our findings thus far point us firmly to the conclusion that glass-cockpit technology will have an increasing monopoly on the transitions and that conventional designs in all sectors of the industry will gradually disappear. Furthermore our findings indicate that transitions are very often from one manufacturer’s type to another manufacturer.

2.2 Design philosophies

Research goals and methodology

This task was aimed at the comparison between the intended use by the flightdeck manufacturer of the provided automation, as described by the design philosophies of the various aircraft manufacturers, and its actual use as described by the operational philosophies of airlines.

The design philosophies of various aircraft manufacturers were investigated by consulting literature that is available about the working of aircraft (Aircraft manuals, Aircraft Operations Manuals (AOM), etc.). This resulted in categorisation or classification of approaches in cockpit design as well as the identification of dissimilar approaches within one cockpit. The operational philosophies were investigated by means of distributed questionnaires directed to pilots. Pilots were asked about their airlines' philosophy and procedures with respect to the use of different automation parts.

Design Philosophies employed by manufacturers

Design philosophies are described by indicating to what extent automation has taken over the following flying functions: steering, navigation, system management, communication and look-out (Abbink,1989). These functions were defined as follows:

- *Steering* implies controlling the aircraft to required parameters values of attitude, heading, altitude, track and speed.
- *Navigation* implies guidance of the aircraft along a predefined trajectory towards its destination. The navigation task consists of determining the present position, the optimal flight parameter values for altitude, heading, speed to arrive at the destination given the present position and by taking into account aircraft performance, cost index and meteorological information.
- *Systems management* implies control and monitoring of all aircraft systems, such as hydraulics, electrics, pneumatics and engines.
- *Communication* implies extracting and providing information from other players in the air system, such as air traffic control, airline operations centre, other aircraft and cabin staff.
- *Lookout* implies extracting information visually (through windows and/or instruments) of the outside world such as other aircraft, terrain, thunderstorms, runway location etc.

Steering

With regards to the steering function the investigation showed not only that automation has matured dramatically for this function, but also that the different manufacturers have employed various implementations for the different functions of the autopilot. All glass-cockpit aircraft can (and are expected to) be flown automatically from take-off to landing. Through inclusion of electronics in the manual control loop, aircraft designers could even obtain similar aircraft behaviour from different aircraft types. Another application of the use of electronics was the introduction of flight envelope protection zones, which is indicated for different aircraft types in table 5.

Table 5: Flight envelope protections when the aircraft is steered by the automation (AP)

	Aircraft Types					
	A-310	***F-100***	***A-320***	***B-747 400***	***MD-11***	***B-777***
AOA (stall protection)	*	*	*	-	*	*
Pitch	-	-	*	-	*	-
High speed	*	*	*	*	*	*
Low speed	-	*	-	*	*	-
Bank	-	-	*	*	*	*

* =present, **-** =not present

The auto-pilot and the auto-throttle have evolved into an elaborate auto-flight system, making it possible to perform many more functions compared to the traditional auto-pilot functions such as heading hold and attitude hold. It is now possible to perform altitude hold, level change, vertical speed climb/descent and automatic approach and landing (the latter using the ILS signals, localiser and glide slope). Using the auto-throttle system the functions above can be coupled to a desired speed. Finally, the auto-flight and auto-throttle system were also connected to the FMS, which allowed the FMS to guide the auto-flight and auto-throttle system, making automatic course changes, descent and climb profiles possible. Due to operational demands and developments of electronics, the number of flight modes has grown significantly. The result of the different flight modes are similar, but the results are achieved in a different fashion. Furthermore, the flight control automation became more complex because particular flight modes were coupled. The modes of the auto-throttle system were coupled to the vertical control modes of the auto-pilot.

Next to the complexity, the non-standardisation of the autoflight system between the manufacturers was found to be an issue. This is best demonstrated by table 6 which shows the different flight mode annunciators of the different aircraft considered.

Table 6: Differences in flight mode annunciation

	Aircraft					
	A-310	***F-100***	***A-320***	***B-747 400***	***MD-11***	***B-777***
Type	CRT	CRT	CRT	CRT	CRT	CRT
Box	Mode change	FMS mode	Mode Change	Mode change	Auto flight available	Mode change
Column division	Control parameter	Controlled parameter	Controlled parameter	Control parameter	Controlled parameter	Control parameter
Top row	Active	Active	Active	Active	-	Active
Bottom row	Armed	Armed	Armed	Armed	-	Armed
Green	Active	Active	Active	Active	Dual auto-land	Active
Cyan	Armed	Armed	Armed	Armed	-	-
White	-	AP,AT,FD annunciation	-	AP normal	Available (AP, ATS)	Armed
Amber	-	Manual thrust	-	-	Not available (AP, ATS)	-
Magenta	-	Cause parameter	-	-	Active FMS mode	-
Flashing	-	Not possible to control	-	-	Not possible to control	-
Flashing amber	-	Failure	-	-	-	-
Triangle (5 sec.)	-	Capture	-	-	-	-
Asterisk	-	-	Capture	-	-	
Text "armed"	-	-	-	-	Armed	-

Navigation
Navigation in its most basic form consists of the following tasks:
1. Determining the aircraft's position.
2. Determining direction and distance to the destination or next way-point.
3. Optimising heading, altitude and speed with respect to safety and costs.

Glass cockpit aircraft contain Flight Management Systems (FMS) that perform all three tasks. Besides lateral guidance and steering, the FMS also provides vertical guidance and steering. Furthermore, the FMS computes an optimal speed on basis of gross weight, altitude, temperature cost index and wind conditions. Performance functions of engines, the aircraft's navigation is performed by the automation in a increasingly complex way, taking into account more and more flight parameters.

While earlier navigational systems only accounted for inputs from inertial systems and radio beacons, the FMS performs navigational computations taking into account performance data such as fuel flow and fuel remaining, etc. External factors such as fuel cost and wind profiles can be entered by the pilot, and databases of airports, airways, navigation aids etc. were also added to be able to fly the most efficient flight, in terms of time and fuel consumption. Again, each manufacturer uses different systems, with different page and menu layouts.

Systems management
System management consists of the monitoring and control of aircraft systems like electrics, hydraulics, pneumatics and engines. In large-wing conventional aircraft, flight engineers are still present for systems management. The flight engineer controls and monitors aircraft systems, calculates optimal altitudes and remaining fuel quantities at the destination and looks-up procedures and checklists. By means of simplification of aircraft systems and use of automation, the flight engineer was made redundant in the “glass” cockpit. Different manufacturer’s concepts are shown in table 7.

Table 7: System management concepts (* = present, **-** = not present)

	Aircraft Type					
	A-310	***F-100***	***A-320***	***B-747 400***	***MD-11***	***B-777***
Warning/caution inhibition	*	*	*	*	*	*
Diagnoses	*	*	*	*	*	*
Electronic Normal checklists	-	-	*	-	-	*
Electronic Abnormal checklists	-	*	-	-	-	-
Electronic Emergency checklists	-	*	-	-	-	*
Automatic reconfiguration	-	*	*	-	*	-
Monitoring of pilot’s actions	-	-	*	*	-	-

Communication
Little has changed for the communication function with regards to automation. The developments are primarily focused towards the introduction of datalink included in packages such as the Future Air Navigation System (FANS).

Look out

Systems which are presently available for the lookout function are the Ground Proximity Warning System (GPWS) and the Enhanced Ground Proximity Warning System (EGPWS) which alert the crew for terrain. Next to be mentioned is the Traffic Collision and Avoidance System (TCAS), which alerts the crew for the proximity of other aircraft, based on transponder signals. Weather radar information would typically be depicted on separate displays located in the central forward pedestal area as a retrofit item. In glass cockpit aircraft the weather radar information is integrated with the navigation display, so that the pilot does not have to integrate the weather information with the navigational data by matching the positions on both displays. Wind Shear Advisory Systems (WSAS) have been developed to warn pilots about wind shear, which is especially useful in take-off and approach phases. However, these systems are reactive and only warn once the aircraft is within the wind shear.

No further investigation of the lookout and communication functions have been pursued within ECOTTRIS because all the above mentioned systems are fitted in an equal manner in the various aircraft and none of these systems are actually taking over control of the aircraft.

Operational philosophies employed by airlines

In this section some results will be discussed with respect to the functions steering, navigation and system monitoring. The results are obtained from the data of 100 pilots.

According to 59% of the pilots, operational philosophy tells the pilot to continue to fly with the autopilot when a mode change occurs due to a flight envelope limitation. Nineteen percent of the pilots are told to disconnect the autoflight system. Another interesting result was that 34% of the pilots were prohibited to use certain auto-pilot modes. Striking was also that the prescription to use the autopilot increased with non-normal and emergency situations from 64% to 82%. Finally the use of electronic checklists and especially the automatic reconfiguration was encouraged by the majority of the airlines involved in the questionnaire. Some reservations were made with the use of the checklists because they would often deviate from the checklists of the airline.

Main conclusions

The previous paragraphs have shown that a large percentage of flight deck functions have been automated over the past years. This is especially true for the functions steering, navigation and system management. The investigation of the design issues showed a striking lack of standardisation of the automated functions. Different manufacturers employ different design philosophies, sometimes even with regards to their own aircraft. This has often been stated in other research (FAA, 1996, Owen and Funk, 1997). This issue could lead to problems with transition training, for as found within WP1 of ECOTTRIS, many transitions are and will take place between different manufacturers.

Another issue found was that different airline Standard Operating Procedures are used. Some will prescribe the use of automatic systems whereas other will leave it more to the discretion of the crew. However, the primary tendency is to make use of the automatic systems. This could be fuelled by the belief that using automatic systems will lead to more economic flight handling, but also because of the reliability and performance of these systems. This is very clearly demonstrated by the increase of the prescriptive nature of AP usage with non-normal and emergency conditions. The fact that 34% of the pilots reported that the use of some autopilot modes were prohibited by their airline also indicates that airlines use the aircraft differently that initially designed for. The literature confirms this belief (Owen and Funk, 1997) by stating that the interface of the automatic system is very often found to be incompatible with the task environment (e.g. ATC commands).

All in all the main findings are:

- Lack of standardisation with regards to automatic functions between the different aircraft manufacturers.
- Different usage of the automatic functions between the airlines but also with regards to design of the manufacturer.

2.3 Incident And Accident Review

Identification of training/automation problems through incidents and accidents research
One of the main methods for identifying issues related to automation is to review reported accidents and incidents. The FAA Human Factors Team Report (1996) used both accident/incident reports and reports from the confidential NASA Air Safety Reporting System to provide insight into the issues that affect safety while other studies have focused on particular problems and examined the type and numbers of reports relating to them. Unfortunately, because of the variable nature of the information and its content, classifying and analysing such data can be difficult and caution needs to be taken when inferring causality. However, although there are problems inherent in using accident and incident data, the value of the information, if used with other evidence as in ECOTTRIS, can be great.

Research goals, methodology, taxonomy, database
The aim of the accident and incident review was to identify factors in aircraft accidents and incidents related to automation/glass cockpit technology and to poor transition training. The methodology was to search accident/incident databases held by aviation authorities, airlines and research centres, etc. using an extensive set of keywords. The keywords were selected because they related to specific aircraft systems, training and human factors, and because they appeared in the literature where other researchers had identified them as being relevant. The same keywords were used for each search although in some cases the words had to be exchanged for appropriate lexicon terms. Once all databases had been searched the reports were sifted to remove reports that were not relevant to the ECOTTRIS project. To ensure that the results of the accident/incident analysis were useful for making transition training recommendations, a classification taxonomy was developed. The categories used in the classification were suggested by terms regularly cited in incident reports and their database descriptions; the taxonomy developed by Funk, Lyall and Riley (1996); and the calculations and explanatory HF guidance provided by ICAO (1993) for accident and incident investigators.

The taxonomy had six areas:
- Top level contributory factors (CRM, workload, SA, distractions, weather).
- Behavioural factors: such as problems relating to how cockpit information is perceived or the impact of over-complacent behaviour.
- Operational factors: these included the level of experience; transition training; insufficient knowledge to operate a system; inadequate supervision of aircraft; problems related to manual handling; inadequate monitoring of the situation; and insufficient knowledge of procedures.
- Equipment design factors: problems with display and control design; misreading of instruments; and lack of cockpit standardisation.
- General automation issues: highlighting areas such as poor mode awareness; improper use of the system.
- Result of the incident: this was a separate category to highlight the end-result of the incident/accident.

Each report was independently classified twice and then any differences were discussed to achieve a single classification for each report. Once classified the reports were entered in an MS Access™ database where they could be easily analysed to identify common problems and themes.

Results

Contributory factors

CRM was found to be the most commonly occurring factor in all incidents (identified in 39% of reports). Further analysis (discussed later) found it to be linked with incorrect setting, monitoring and vigilance, inadequate knowledge of aircraft systems, experience and flight handling. Distractions were found to be contributory in 21% of incidents/accidents, workload was a factor in 14% of reports, while situational awareness was found only in 7% of reports. Where SA was a factor, further analysis found it was linked to incorrect setting.

Behavioural factors

The behavioural factors, flight crew perception and complacency were not found to be among the most common factors in aircraft accidents and incidents. Complacency was found in 13% of reports and was more often a non-primary cause than a primary one. Not easy to identify in incident reports, it is perhaps a sub-factor of CRM related to poor crew communication and monitoring behaviour. Flight crew perception was more equally used as a primary or non-primary cause but only occurred in 5% of all reports.

Operational factors

The operational factors were found to be the most relevant for ECOTTRIS in that in that, apart from CRM, they can be more easily addressed by transition training than other factors. In this area, monitoring and vigilance was the most common factor being identified in 28% of reports, usually as a non-primary factor and often related to incorrect setting and inadequate knowledge of aircraft systems. Later analysis also showed it as being closely linked with CRM. Inadequate knowledge of aircraft systems was found to be a factor in 18% of reports as both a primary and non-primary cause. Flight handling was found in 21% of reports more often as a primary cause and was found to be linked to experience and flight supervision. As factors, transition training and experience were both found in 11% of reports. The section on further analysis describes more linkages for these factors.

Equipment design factors

After training, one of the aims of ECOTTRIS was to consider the influence of design factors in accidents and incidents. However, these were only identified in about one fifth of reports; perhaps because the identification of design factors from accident/incident reports can be quite difficult as information is often minimal. The most commonly found design factor was inadvertent operation of switches which was identified in 9% of reports usually as a primary factor. Design/location of instruments was found in 7% of reports, misreading or misinterpreting instruments in 2% of reports and lack of cockpit standardisation was only considered an issue in one report in the database.

General automation issues

This category of the taxonomy was related to the influence of general automation on behaviour and received fairly high ratings. Incorrect settings accounted for 28% of all reports and in three quarters of these it was a primary factor. Incorrect setting can be related to inadequate interface design, poor understanding of the system and genuine error. In terms of the incident/accident reports, it was found to be strongly related to monitoring and vigilance where perhaps an unnoticed erroneous input resulted in more serious problems later. Improper use of systems occurred in 15% of reports and could result from poor understanding of systems and not using procedures correctly. Lack of mode awareness was identified as a factor in 6% of reports and was related to experience and inadequate knowledge of aircraft system as well as monitoring/vigilance and incorrect setting items. This factor was not as commonly occurring as perhaps might have been expected perhaps because it is difficult to report what one is not aware of, when describing a situation for an accident/incident report.

Further analysis

Further analysis of the data was carried out to identify the linkages between taxonomy items commonly rated together as primary and non-primary factors in the classified reports. This analysis showed:

- Where experience was a primary factor, contributing non-primary factors included: inadequate knowledge of procedures; transition training; and CRM.
- There were no obvious links between transition training as a primary factor and other non-primary factors. However, when experience, CRM and inadequate knowledge of systems were primary factors, transition training was a non-primary causal factor.
- Inadequate knowledge of aircraft systems was often cited in reports both as a primary and non-primary factor. In the former case, it was linked to transition training, flight handling, knowledge of procedures, CRM and improper use of the system. Further, when rated as a non-primary cause, an associated primary factor was crew experience. This factor was also linked to monitoring/vigilance, workload and distractions.
- Flight supervision was a non-primary cause when flight handling, incorrect setting, workload, CRM and distractions were selected as primary causes. It was rarely cited as a primary cause.
- When flight handling was a primary cause, flight supervision, monitoring and knowledge of procedures were non-primary related causes; CRM was another key factor. As a non-primary factor, flight handling was linked to experience and inadequate knowledge of systems.
- One of the strongest links identified was between incorrect setting as a primary factor and monitoring/vigilance as a non-primary factor. Similarly there were strong links between incorrect setting and SA, workload, CRM and distractions.
- When knowledge of procedures was selected as a non-primary cause it was associated with flight handling as a primary factor and lack of mode awareness and improper use of the system as non-primary factors.
- The incorrect setting of a system as a primary factor was linked to all four contributory factors (SA, workload, CRM and distractions) with CRM being cited the most.
- There was no clear pattern between lack of mode awareness and the other factors, but it was linked to CRM as a non-primary factor.

- There was evidence of a weak link between the improper use of a system and inadequate knowledge of a system when both were non-primary factors. As before CRM was a key contributory factor.

Main conclusions

In terms of training related factors, the key finding was that CRM in glass cockpits was a major problem. What causes this is unknown and reports which included this factor will be analysed in more detail in the next phase. It may be that CRM covers a multitude of issues which need to be clarified further for glass-cockpit operations. Training for specific communication procedures in glass cockpits may be a requirement, in addition to training for general CRM skills, such as leadership. The key CRM aspect in glass cockpits is the maintenance of crew shared mental models, both between the crew and with ATC. This requirement for high levels of current and historical knowledge may need to be emphasised further in training awareness programmes.

The main areas identified from the accident/incident review to be further examined in later stages of the project included:

- The appropriateness of CRM training for glass cockpits.
- Methods by which manual flying skills can be maintained.
- Training for adequate mental models of automated system operations.
- Development of standard operating procedures (SOP's) specific to interactions within the computerised glass cockpit.
- Development of enhanced training scenarios appropriate for maintenance of the glass cockpit skills.

2.4 Glass Cockpit Skills

Research goals and methodology

Seven different skill-groups were selected for in-depth investigation in the context of the transition to the glass cockpit. Six of those skill-groups relate to individual skills that were derived from the three types of individual behaviour distinguished by Rasmussen (1983), i.e. knowledge-based behaviour, rule-based behaviour and skill-based behaviour.

Knowledge-based behaviour occurs in situations which are new to the pilot and determination of the appropriate action is based on reasoning with knowledge, either acquired through on-the-job experience or through formal training. In the case of *rule-based behaviour*, the situation has been dealt with before by the pilot and the pilot can determine an action on the basis of (logical) rules. If a particular type of rule-based behaviour is performed frequently the reaction to the stimulus can become *skill-based*, i.e. automatic. The pilot does not have to pay attention to his/her skill-based actions.

Two skill-groups that were addressed in this research, knowledge of automation and decision making, are based on Rasmussen's knowledge-based behaviour. Two other skill-groups, i.e. knowledge of Standard Operating Procedures and selection of the appropriate Standard Operating Procedure, are based on Rasmussen's rule-based behaviour. Further, two skill-groups, i.e. standard cockpit handling and manual flying, are based on Rasmussen's skill-based behaviour. The seventh skill-group concerned Crew Resource Management skills, such as leadership, social and communication skills.

For this purpose, a questionnaire was designed in which these different skill-groups were addressed. This questionnaire was directed to glass cockpit pilots in Europe and focused on situations in which EFIS, FMS, ECAM/EICAS or other automation did not behave as expected and made a situation more complex or difficult to handle.

The idea behind the questionnaire was to let the pilot describe a difficult situation he/she had encountered in a glass cockpit, including all relevant data at the time of this situation, such as phase of flight, aircraft type involved, experience on the aircraft type at the time of the situation, etc. Following this description of the difficult situation, the pilot had to indicate by way of a series of closed questions, how important a specific skill was in order to cope with the described situation, whether or not he/she needed more training for the specific skill and the preferred type of training for this type of skill. The results will be briefly discussed in the following sections.

Response rate and quality of response

In total, European pilot unions returned 152 questionnaires. Of these, 134 pilots reported their aircraft type. Only a distinction between Airbus and Boeing could be made since other manufacturers were relatively under-represented in the sample. For Airbus, the A340 (n=30), the A320 (n=24) and the A321 (n=15) were most frequently reported, while for Boeing the 747-400 (n=20) was most frequently encountered. The question of their position in the aircraft was completed by 130 pilots. Sixty of them were Captains (with a mean age of 45.2 years), the other 70 were First Officer (with a mean age of 33.5 years). Twenty four of the pilots responded that they had never encountered a difficult situation in a glass cockpit. The data in table 8 summarises the experience (in hours) of the pilots.

Table 8. Number of respondents by categories of hours of experience.

Total flying experience			**Glass-experience**			**Experience on type**		
<1000	1000-5000	>5000	<500	500-2500	>2500	<250	250-1250	>1250
1	45	82	21	73	35	18	64	43

Most respondents came from the United Kingdom (n=52) or Austria (n=24). Other well-represented countries were Italy (n=15), Portugal (n=14) and France (n=11). The remaining pilots originated from Belgium and Holland (both n=8), Germany and Ireland (both n=5), Luxembourg (n=3) and South-Africa (n=1).

Results

In general, all seven skill-groups were rated (on average) between important and extremely important by the pilots. Statistical tests revealed that that pilots rated the skill-groups knowledge of automation and decision making as significantly more important than all other skill-groups. Also, pilots rated Crew Resource Management skills as significantly more important than determination of appropriate SOP’s and standard cockpit handling. Thus, the skill-groups that are related to knowledge-based behaviour (i.e. knowledge of automation and decision making) are rated significantly more important than those related to rule- and skill-based behaviour.

Pilots rated the need for training of knowledge of automation as significantly higher than the need for training for any other skill-group. Furthermore, a majority of the pilots were of the opinion that more training is needed for CRM, decision making and manual flying. No differences were found between younger and older pilots in the need for training of a specific skill-group. For all skill-groups, the percentage of Airbus pilots that indicated to have a preference for more training is higher than the percentage Boeing pilots.

In general, training in a full motion simulator is the most preferred type of training for all seven skill-groups. Depending on the skill-group either training in the aircraft (manual flying) or other training environments, like computer based training in teams, training in the classroom and self study, were also suggested. Individual computer based training is a less preferred type of training, except for training of standard cockpit handling. The pilots also suggested having sessions for discussion and giving more attention to the actual experience of the different abilities.

Crew Resource Management (CRM)

This skill-group related to work-attitude, management, co-operation and leadership for the described difficult situation. On average CRM was rated very important (mean of 4.0) on the scale of importance (ranging from 1-5). Forty five percent of the pilots were of the opinion that their current training for CRM was sufficient. Fifty five percent of the pilots would need more CRM-training. A wide mix of training media was suggested for CRM. Approximately 60% of the respondents would prefer to train CRM in a high fidelity environment, i.e. in a full flight simulator or in the real aircraft, where the other half of the respondents suggest lower fidelity means or a classroom situation for CRM training.

Knowledge of Automation

Knowledge of automation was defined as having good knowledge of the aircraft automation involved in the described difficult situation (knowledge with respect to function, malfunctioning and interaction with the automation). The pilots rated this skill-group as very important (mean of 4.2 on the scale of importance ranging from 1-5). The pilots with less than 1900 hours of glass cockpit experience rated the skill-group significantly as more important than the pilots with over 1900 hours of glass cockpit experience. Over 75% of the pilots would like more training on this skill-group. Not surprisingly, pilots with 1900 or less hours of glass experience rated the need for training on Knowledge of Automation significantly as more needed than pilots with over 1900 hours of glass cockpit experience.

Of the 264 comments that were received on the question of the most appropriate type of training for Knowledge of Automation, 42% concerned training in a simulator (71% in favour of full motion) and 22% concerned training in the aircraft (57% in favour of route instruction, 29% of cockpit familiarisation and 14% of another type of training in the aircraft). 36% of the comments concerned other training environments. Of these, 44% were in favour of computer based training in teams with the possible assistance of an instructor followed by training in the classroom (28%). In 17% of the comments self study was also suggested as an alternative for training Knowledge of Automation. Individual computer based training (CBT solo) was suggested as the least favourable type of training for the Knowledge of Automation-skill-group, by the respondents.

Decision making

Decision making was defined as the capability to timely choose the optimal alternative for action in the described situation. Like knowledge of automation, the pilots also rated this skill-group as very important (mean importance rating for this skill-group was 4.2); 60% of the respondents were of the opinion that more training is needed in this area. Seventy percent of the respondents would prefer a full flight/motion context in order to train decision making in difficult situations.

Knowledge of Standard Operating Procedures

This skill-group related to knowledge of SOP's in the described difficult situation. SOP's define: what the task is, when the task is conducted, by whom it is conducted, how the task is done, what the sequence of actions is and what type of feedback is required. Mean importance rating was 3.8 (on the scale of importance ranging from 1-5). First Officers rated this skill-group as significantly more important than Captains.

Obviously correlated to the latter finding, pilots with 7500 or less hours of total flying experience rated the skill-group of Knowledge of Standard Operating Procedures as significantly more important than pilots with over 7500 hours of total flying experience. For this skill-group, 36% of the respondents were of the opinion that more training is needed. Likewise, First Officers rated the need for training on Knowledge of Standard Operating Procedures as greater than Captains, although this difference is only marginal significant.

Sixty seven percent of the respondents would prefer a full flight/motion context in order to train knowledge of SOP's in difficult situations.

Determination of the appropriate SOP:

This skill-group relates to determining the appropriate standard operating procedure for the described difficult situation. Mean importance rating was 3.8 (on the scale of importance ranging from 1-5). Most pilots (over 60%) rated the current training as sufficient. Sixty three percent of the comments received indicated a preference for a full flight/motion context in order to train this type of skills.

Further analysis revealed that younger pilots (below 30 years of age) rated the importance for Determination of appropriate SOP as more important than pilots in each of the other age-categories (30-40 years, 40-50 years, 50-60 years).

Standard cockpit handling

Standard cockpit handling included such actions as frequency selection, mode control panel settings, overhead panel settings and instrument reading and interpreting in the described difficult situation. This skill-group was rated with a mean of 3.7 for importance. Pilots who flew Boeing aircraft rated the skill-group Standard Cockpit Handling significantly as more important than pilots who flew Airbus aircraft. More training was thought to be needed by 37% of all pilots. Most pilots (over 60%) rated the current training on this skill-group as sufficient. Fifty-two percent of the respondents would prefer a full flight/motion context in order to train standard cockpit handling.

Manual flying

Mean importance rating for this skill group was 3.8. Fifty seven percent of the respondents were of the opinion that more training is needed in this area. Pilots with over 1200 hours of experience on type rated the need for training on Manual Flying as significantly greater than pilots with less experience on type. Over 80% of the respondents were of the opinion that manual flying is best trained in a full flight/motion environment.

Further analysis of the difficult situations

In order to identify issues that are important for glass cockpit training pilots were asked to describe a more difficult situation they had encountered with glass cockpit aircraft. These results (derived from both questionnaires) were analysed using the incident/accident taxonomy developed by DERA. From that analysis it was apparent that when pilots have to report a difficult situation themselves, they usually attribute the primary cause of the situation towards a “problem with the system” and to a lesser extent to “knowledge of the aircraft system”. Other factors, for example, equipment design, behavioural factors and general automation issues, were hardly ever mentioned. The reason for this might be that pilots were asked to describe a difficult situation, which in most cases did not result in an incident or accident. The point of view of pilots, involved in a difficult situation might differ from the point of view of investigators of incidents and accidents. The pilots encountered a problem with the system without relating this to the design of the equipment, to general automation issues or to their own behaviour. The same reason applied to the contributory factors. Thus pilots described a difficult situation they had encountered which did not result in an incident or accident. Contributory factors, such as (effective) CRM might have been of help to deal with this situation, and, therefore, were not perceived by the pilots as cause of the difficult situation or contributing to it.

Main conclusions

The analysis indicated the relative importance of different skill-groups in difficult situations with the glass cockpit. Ranking those skill-groups, starting with the skill-groups rated as most important and with decreasing importance, yields (1) knowledge of automation /decision making (2) Crew Resource Management (3) manual flying/determination of appropriate SOP’s/ knowledge of SOP’s and (4) standard cockpit handling. See table 9a.

Table 9a: ranking of seven different skill groups with respect to *importance*

rank	*Importance*
1	knowledge of automation/ decision making
2	Crew Resource Management
3	manual flying/ determination of appropriate SOP’s/ knowledge of SOP’s
4	standard cockpit handling

Over the full range of skills that were investigated, a substantial percentage of the investigated pilot population expressed a need for extra training. Ranking those skill-groups, starting with the skill-group for which the highest percentages of pilots expressed a need for more training, yields (1) knowledge of automation (2) decision making (3) Crew Resource Management (4) manual flying (5) determination of appropriate SOP’s (6) standard cockpit handling and (7) knowledge of SOP’s. See table 9b.

Table 9b: ranking of seven different skill groups with respect to *need/priority for extra training*

rank	*need for training*
1	Knowledge of automation
2	decision making
3	Crew Resource Management
4	manual flying
5	Determination of appropriate SOP's
6	standard cockpit handling
7	Knowledge of SOP's.

The trends in "importance-ranking" and the "need-for-training-ranking" are similar, although differences between skill-groups in the need for more training are clearer than differences in importance.

From the research it becomes obvious that pilots flying glass cockpit aircraft, have an increased need for training of knowledge-based behaviour such as inductive reasoning with knowledge of automation and decision making in new and difficult situations. Different tendencies may account for this finding:

1. Aircraft systems have become more complex. In normal conditions, task constraints are relatively flexible, which means that multiple possible solutions or actions apply to such situations. In that case, flight crew behaviour can be rather flexible and rules of thumb can be used. However, in difficult situations task constraints are rather rigid, i.e. there are only a few possible solutions for automation settings to resolve the situation, given the timeframe. This requires the flight crew to reason with exact system knowledge and to extract appropriate information from the environment.
2. Interactions between ATC and other traffic.
3. Transition training durations shrinked from several months for traditional cockpits in the sixties to short courses of a few weeks for fully glass types in the eighties and nineties in which knowledge of systems is treated on a shallow need-to-know basis.
4. Aircraft and airport systems have become technically highly reliable over the years, resulting in increased air safety, but with, as a consequence, less exposure to malfunctioning equipment resulting in less operational experience with reasoning on the basis of knowledge of automation, less decision-making in difficult situations and less manual flying. The latter tendency is in line with the finding that pilots with more flight hours (1200 hours or more) with their current type of glass cockpit express a higher need for training of manual flying skills than pilots with fewer flight hours with their current type.

2.5 Current Training Activities at Operators

Research goals and methodology

- Current practices at a sample of European training providers were assessed, viz. Airbus Industry, British Airways and Lufthansa.
- Access was given by BA and Lufthansa to their training staff. Airbus Industry provided information, mainly through course literature and a visit to the Toulouse facility.

Results

- Transition courses formed the major part of the training effort at all three. The detailed content of a typical transition course has been discussed in WP1.
- Innovative training tools studied, ranged from the CBT concept, which is now widely used at Airbus, BA and Lufthansa, through Zero Flight Time simulation and Equivalence training and beyond. The CCQ concept designed at Airbus was discussed at some length in WP1 and WP3 and showed signs of gaining greater acceptance with airlines. Multiple or “common” type ratings are also in use with other than Airbus operators (e.g. B757/767). Low-fidelity tools such as PC-based briefing and debriefing stations have begun to show their worth and are particularly favoured by Airbus at Toulouse. LOFT construction using actual events from incident databases such as AIRS (Airbus Incident Reporting System) has been seen to give added insights into operational problems encountered during line flying. Lufthansa’s Integrated Type Rating and BA’s B777 programme are evidence of an attempt to address specifically glass issues during transition. Cabin Crew CRM programmes, which will soon become mandatory under JAR-OPS, at BA contain modules that aim to make cabin crew more aware of the computer-generated environment in which their pilot colleagues now find themselves.
- Integration of automation management into LOFT and training scenarios is now becoming common on the most advanced fleets.
- Continuation of training beyond minimum requirements is largely centred on the non-technical. Professional skills development and business awareness training are fostered by most enlightened airlines, often giving the Regulatory bodies impetus to expand on these initiatives and make them mandatory for other operators.
- Maintenance of manual flying skills during and post-transition is approached with differing levels of urgency, depending largely on the type of aircraft and its operating environment. During the transition phase itself much time is spent in manual flight especially on earlier types. Short-haul pilots, especially those flying hybrid or conventional equipment in multi-sector operations, do not experience the same handling practice deficiencies as their long-haul colleagues. Simulator flying is often allocated specifically for recency flying when pilots have not carried out the minimum number of take-offs and landings but this is clearly a very low base-line
- CRM specifically tailored to the glass cockpit is not widely practised in our group of training providers, although Airbus do have a CBT-based CRM programme at Toulouse.
- Training for adequate mental models of automatic system operation is not always of a high order. This is an area that has historically been undervalued and the results can be seen in many incident and accident reports.

Discussion points arising

- Maintenance of manual flying skills continues to be a thorny issue, although this is not primarily a transition problem. Handling skills will probably be at high level on completion of a move to a new type. However, this competence can quickly degrade if line experience is then limited. Exposure to very rare events such as GPWS or TCAS warnings at critical phases of flight can reveal dangerously low levels of manual skills. These skills could doubtless be improved by the allocation of more dedicated simulator time on high-fidelity equipment of a Zero Flight Time standard but this is unlikely to occur without intense pressure from groups without budgetary portfolios. PC-based tools, like the Aerowinx PS1™, have a potential role in underpinning the correct application of recovery techniques, required for example after TCAS and GPWS warnings.
- Training for adequate mental models of automation depends largely on the quality of the course material presented and the expertise of the instructors. The desire to achieve an advance in knowledge must also be demonstrated by the training establishment since extra effort and hence funds would need to be allocated.
- For obvious reasons, provision of SOP's for interaction within the glass cockpit across the range of current and future aircraft is not seen as an achievable goal in the near future, but in an ideal world this would be a useful step towards increasing safety levels during and immediately after transition. Some preparatory work is believed to have been undertaken by Boeing and Airbus in this area but it seems unlikely that substantial progress will be made, given the divergent philosophies of the two major players in the field.

2.6 Consultation of Users with respect to Training

Research goals and methodology

With the aim of investigating training issues for pilots converting to new aircraft types a structured interview format was developed to allow pilots and training instructors to be consulted about transition training, their views on automation and related issues, understanding of different aircraft systems, and thoughts on novel training techniques. A variety of questions were used, some with ratings scales and others allowing for free description. Interviews were conducted with fifty eight pilots from four geographical/cultural regions: Scandinavian, German, Anglo and Mediterranean. Background information was also collected from the pilots including flying history, age, time since training course and position in cockpit. All the interviews were conducted in English and followed the structured format. Once completed the contents of each interview were transcribed into an MS Access database for analysis.

Results

Preparation for transition course

The results suggested that specific pre-course preparation is not that common, often pilots finish flying their old aircraft just days before the course starts and so do not have time to study in advance. When pilots do investigate their new aircraft prior to the course this is usually through familiarisation flights or reading flight and operation manuals. Some airlines appeared to discourage advance preparation to avoid confusion. However, given that different individuals have different levels of experience and knowledge, up-to-date, representative, pre-course information should be available for those who do have the time and inclination to review it in advance. Pilots who have never flown glass cockpits before might feel more confident on their course with some background knowledge.

Negative transfer

The interviews suggested that very little time was spent on the course, highlighting the differences and similarities between old and new aircraft. While this can be difficult as the pilots in a class may have different experience, highlighting important and not necessarily obvious differences could prevent pilots making assumptions about how the new aircraft works based on knowledge of their previous type. The instance of negative transfer, in terms of operating the new aircraft as the old one, was considered to be fairly low and usually occurred soon after training. However, ensuring that pilots are aware of differences, that could cause problems if forgotten, would only improve the pilots' knowledge and understanding both during and after the course.

Attitudes to automation

Pilots attitudes towards the automation were generally positive. Most pilots had a healthy level of trust in the systems, acknowledging that the system and the operator could cause errors. Surprises caused by the automation were usually not serious and tended to occur early after training, as did errors due to negative transfer. In those cases when pilots had been surprised they admitted it did influence their trust in the aircraft. However, it was felt that greater experience with the aircraft would reduce surprises and that this could come partly from further training. Workload and situational awareness raised some concerns particularly problems with the system or late runway changes. While it was not felt SA could be improved with better training, comments clearly suggested that greater understanding of systems, improved problem solving skills and better prioritisation to avoid excessive head-down time could buffer the effect of difficult situations.

CRM for glass cockpits

Only a fifth of pilots had received training specifically for glass cockpit operation. Course content and length appeared to vary but generally syllabi covered: communication, workload, situational awareness, the importance of always flying the aircraft and not getting distracted by the automation or emergencies, allocation of tasks and glass cockpit problems, and the course was considered to have been helpful. Of the pilots who did not receive glass cockpit CRM, several explicitly said it would have been useful to cover issues relating to handling unusual situations, communication, task allocation, team working and reviewing accidents and incidents. Other pilots were less enthusiastic about the glass cockpit CRM although they may have had these issues discussed at the simulator stage of training.

Basic flying skills and manual reversion

Given the pilots interviewed fly automated aircraft they were asked how comfortable they felt with their basic flying skills. Most pilots were very or totally comfortable with their skills with only a few concerns expressed about lack of opportunity to practice on certain routes. A few pilots who were less comfortable with the level of their skill, commented that operational philosophy reduced exposure to manual flying but no pilots had a complete lack of confidence in their manual flying skills. In terms of being comfortable with the amount of manual reversion available the aircraft, almost all pilots were comfortable with the level of manual flying they could achieve; no one commented about not being able to turn off the fly-by wire technology.

Quality of training manuals

The comments regarding the manuals were often negative regarding the content, style of presentation or the language. Each of these created hurdles to the access of the information being sought or reduced the general confidence the pilot had in the operation of the systems.

Specific FMS, autopilot and autothrottle problems

As a way of identifying how familiar pilots were with various systems and how comfortable they were using them and solving problems, the interview asked how the pilots could solve a problem if there was a limited amount of time available. The systems were FMS, autothrottle and autopilot and the problem solving techniques were to reprogram the system, revert to manual flying or to change to a lower level of automation. The responses varied according to the system:

- For the autothrottle, about three-quarters of pilots opted to revert to manual flying as this would be the quickest way to recover from a problem.
- For the autopilot, two thirds would switch it off as they did not believe there was a lower level of automation available and disengaging the autopilot was the quickest and easiest solution.
- However, for the FMS the figures were different. Half the pilots said they would change to a lower level of automation and fly with the autopilot but using conventional navigation instruments and techniques.A quarter of pilots would turn the automation off altogether as

experience had taught them this was the easiest solution and they were confident in their flying skills. The remaining quarter would attempt to re-programme the FMS because the aircraft was designed to be flown on the automatics, it reduced workload and enabled the problem to be solved as soon as possible.

The differences in their responses may well be related to personal experience and preference, the type of aircraft being flown, and in a real situation the nature of the problem. Clearly there are advantages to each solution and pilot training needs to cover which is most appropriate in which circumstances.

PC-based training and distance learning over the Internet

Given the current focus on computer based training and ready availability of computers, the interview asked pilots how they would view training for the FMS, autopilot and autothrottle if it were provided on the Internet or via CD-ROM, perhaps even for home use. The suggestions were well received particularly so for the FMS, where the packages could be self paced and could be completed out of normal hours for extra practice. Support for the Internet was less because of concern that it would be very slow. Generally such training tools were thought to be slightly less useful for the autopilot and autothrottle. Certainly the high level of complexity and the fact that the FMS is a computer makes it a system that could be easily practised using a normal PC: so long as the simulation uses the same version of the software as that on the current aircraft.

System knowledge

One of the main parts of the interview focused on the pilot’s level of understanding of the different aircraft systems and displays: primary flight display, navigation display, EFIS, FMS, or EICAS/ECAM. For each of the systems pilots were asked to select a rating statement that best described their level of understanding of that system. The ratings scales ran from ‘I use the system as trained in standard operation procedures but do not understand how it operates’ to ‘ I use the system as trained in standard operational procedures and I have more than a basic understanding of how it operates, and would feel confident in solving a problem without a checklist’. The pilots were also asked about the appropriateness of their rating and if and how training could have been enhanced to improve their understanding. The majority of responses for each system were at the third level, where pilots would still need a checklist to solve problems. Some systems had high overall levels of uncertainty. A number of pilots felt they only had a basic understanding of the system but only one or two admitted not understanding how the system operated despite using it according to the standard operational procedures.

The primary flight display, the navigation display and the EFIS were generally well understood. However, the complexity of the systems was emphasised as was the need to use a checklist when solving problems. The responses relating to improving understanding through training varied between the systems. Generally experience in using the displays and information was found to have been beneficial, and was thought to be the best way to improve understanding, although for the PFD some pilots requested that training be more operational as opposed to being engineering/technology-based.

The FMS, autopilot and mode changes have been widely reported in the literature as systems where pilots may not have a full level of understanding. The interviewers found that while about

75% of pilots felt their understanding rated three or four (depending often on whether they considered it even appropriate to attempt to solve problems without a checklist) the complexity of these systems was acknowledged and the need for a thorough understanding was highlighted; many had obviously gained better understanding through experience. For the FMS particularly, several pilots who considered their understanding and knowledge to be high still admitted having problems. Enhanced training was definitely considered a good idea for all these systems, for the FMS pilots requested more practice and some thought a working FMS model with free-play facilities would be very beneficial. For the autopilot more simulator time with a better explanation of the modes was requested and for mode changes more time and greater opportunity to practice in the simulator and on CBT were seen as important enhancements. The comments for these systems seemed to suggest a need for extra time on an easily accessible simulation that would allow pilots to investigate the features of each system and how they interact with each other.

The autothrottle received generally high ratings, although there were some comments about learning to operate without feedback from Airbus pilots, and was thought to be fairly simple to understand and one where mastery could be achieved through use. The responses for EICAS/ECAM were a bit different. Pilots giving low rating felt more training time was needed and to support this, those with a complete understanding believed this to have come from experience, thus suggesting there was a lot they had learnt since finishing training. Half the pilots, while happy with their understanding, would not seek to solve a problem without a checklist. Again, where extra training was requested it was at the CBT/hands-on practising with the system level.

The system knowledge question sought to identify the levels of understanding pilots had of aircraft systems in their glass cockpit. Obviously the responses were subjective and do no provide evidence of actual understanding. However, as might be expected, pilots generally seem to have a high level of understanding although they would prefer, or are expected, to use a checklist when solving problems as this reduces the chance of error. Some pilots had more confidence in their ability to go it alone, which often seemed to be linked to greater experience. Irrespective of their level of understanding, pilots believed that for some systems training could be enhanced to improve their understanding. Furthermore they believed that training should focus on more information about the systems and their interaction. Training should also focus on the use of training tools and simulators to provide greater hands-on experience when learning how to operate the automation.

2.7 Validation of enhanced transition training

Research goals and methodology
From earlier research and reports (FAA, 1996), it became clear that no single solution can be taken to solve the problems pilots face when converting to a glass cockpit aircraft. Therefore, a battery of recommendations that could be used to enhance transition training has been suggested. The aim of this task was to develop and then validate potential enhancements that could be used to improve transition training for pilots converting from conventional to glass cockpit areas. From this and earlier work packages, three main enhancement areas were identified: knowledge of automated systems, glass cockpit CRM and manual flying; the latter was not addressed at this stage for practical reasons.

A consultative approach would be followed to provide validation on the different enhancements. This user consultation approach allowed experts from a number of different European airlines to be consulted with both pilots and their training instructors asked to provide comments on the knowledge and CRM enhancements. Pilots and instructors were asked to review and/or practice training scenarios and complete a short questionnaire asking about the enhancements. These findings were then used to refine the enhancements before making final recommendations.

Results - development of the enhancement for glass cockpit CRM
While many airlines are now working hard to improve their training in line with research recommendations, their focus tends to be on one particular aspect of the problem, such as complacency, and not the overall issue of flying skills for glass cockpit. In particular, CRM seems to be considered as a generic skill and is not always taught explicitly with reference to the glass cockpit. This work fully supports the effort airlines are making to improve non-technical skills. Indeed the aviation authorities may soon require assessment of these skills to ensure pilots are fully competent to fly in Europe’s increasingly busy skies and very demanding aviation environment. However, the findings from this research clearly identify the importance of linking CRM to glass cockpit activities to ensure the elements that make up good CRM are understood in an operational context and not just seen as ‘tick in box’ type training.

It was decided that the most useful tool for pilots would be a ‘CRM for glass cockpits’ booklet. This document would contain a set of scenarios derived from real incidents. Its aim would be to highlight the need for good CRM within the glass cockpit. Thus, it would form an integral part of a set of transition training enhancements currently being validated by pilots and training instructors for inclusion in the final ECOTTRIS recommendations.

The incidents were those that were considered to illustrate the most prevalent CRM related glass cockpit issues. Incident were presented in the form of a dis-identified description which allows a pilot to obtain a clear picture of the circumstances under which the incident happened. While the situations that have been described and the information associated with each may appear fairly basic, it is important to note that these events happened in normal flight operations with fully trained crew.

Each incident was evaluated in terms of the CRM issues using the British Airways team skills markers (WP3). These were used as they provided ease of access to a formalised structured scheme. It was found that the CRM issues fell into five categories: prioritisation, situational awareness, crew communication, automation and information processing. Within the booklet, each of these is defined in order that pilots all have a clear understanding of the meaning of these concepts.

As a result of the evaluation of the CRM aspects of each incident, potential training solutions were then suggested. These represent the suggested enhancements that should be made to the current training in order to avoid these situations happening again in the future. The aim is that both these and the CRM factors could be discussed either in the classroom or the cockpit. These scenarios are not intended to replace existing CRM training but rather to enhance it, helping to operationalise the CRM skills and show how they form a vital part of glass cockpit operation.

Results - validation of the enhancement for glass cockpit CRM

In order to evaluate the usefulness of the 'CRM for glass cockpits' booklet, pilots were asked to complete a questionnaire detailing their views.

In total, 14 pilots completed the questionnaire, most of whom were trainers. They all responded positively to the booklet, seeing it as a useful addition to a CRM training course, thus suggesting that it was a valid enhancement. Comments received stated that it meets a need and addresses the issues well. In addition, it was seen by some as beneficial that it was short and succinct. However, there were differing views as to when the booklet should be utilised. The following table, table 10, gives the frequency and percentage of the answers.

Table 10: responses when asked *when* the CRM booklet should be utilised

When should this booklet be utilised?	***Frequency***[1]	***Percentage***
Flying College, prior to entry	2	14.3%
Initial airline induction	9	64.3%
During transition training	7	50.0%
During recurrent training	10	71.4%
During instructor training	9	64.3%

Comments given would suggest that the booklet should be used with the benefit of instructor input but only when the crew has enough knowledge of the systems. Therefore, it would not be as beneficial prior to training. However, many stated that it was a useful, low cost addition which might be used during a training course to teach awareness of CRM concepts.

Pilots were asked how the information in the booklet could be best utilised. Table 11 represents a breakdown of the responses.

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[1] It should be noted here that multiple responses were made to this question, and the next, thus explaining why the overall frequency is greater than the number of pilots.

Table 11: responses when asked *how* the CRM booklet could best be utilised

How could the information be best utilised?	*Frequency*	*Percentage*
As part of role-play	7	50.0%
As part of a simulator scenario	9	64.3%
Isolated from other parts of the transition course	4	28.6%
Handed out and left to the student to assimilate	5	36%

It was mentioned that it could be used in the latter context to teach the pilots to 'aviate, navigate, communicate' and to highlight CRM concepts such as prioritisation of tasks and the 'big picture' concept. In contrast, only 29% of the pilots thought it would be beneficial to use the booklet in isolation from the other parts of the transition training course. The last option of using the booklet as a hand-out which the students could look over in their own time was chosen by 36%. Interestingly, those who did not see this as an option, often stressed the need for instructor input, either because the CRM issues were considered to be advanced or because the pilots being trained were still in the early stages of their flying career.

Fifty seven percent of pilots felt that more incidents should be included in the booklet. The number varied considerably as to what was thought appropriate, however, ranging from 20 to 100. The favoured amount appeared to be 20-30. The evaluation booklet currently contained six. Overall, therefore, the CRM for glass cockpits booklet seems to have been well received and to have generated interest. From the results of this validation, it may be possible to refine it to give the user what he/she wants. However, it should be stressed once again that this is not seen as a substitute for the current CRM courses but rather as an addition.

Results - development of enhancements for knowledge for automation

Means were investigated to provide pilots with comprehensive theoretical knowledge of the aircraft systems and an extra stage of training for operationalising this knowledge before reaching expensive, line-flying orientated simulator training. Such additional areas of practice could be provided to pilots for systems like the FMS and autopilot using a low-cost interactive training device.

A number of these computer based training programmes for aircraft sub-systems are now available as COTS (commercial off the shelf) software and can be run on a PC or a lap-top. As part of the ECOTTRIS training enhancements such a simulation system was chosen to evaluate the usefulness of additional FMS/autopilot practice for glass cockpit transition training. As an example of such a system, Aerowinx B747-400 PS1™ (CD-ROM Version 1.2) designed by Hardy Heinlin in Germany was used.

The evaluation centred around the programming of the FMS and the operation of a short flight sector (Manchester to London Heathrow) with a diversion to London Gatwick. The flight was carried out using autopilot LNAV and VNAV wherever possible and particular attention was paid to mode transitions and annunciations. No attempts were made to evaluate the manual handling characteristics. The volunteer pilots were given a briefing on the purely PC aspects of PS1™ and then asked to operate the flight as closely as possible to normal BA procedures, given the non-standard single-crew aspect of the simulation. The test sample pilots were from a varied background including some established and very experienced training Captains as well as some pilots currently undergoing transitions to the B747-400. Evaluation was carried out by means of a questionnaire giving subjective feedback. Nevertheless it was felt that the enthusiastic response from those who undertook the trial justifies optimism in the PS1™ concept.

Results - evaluation of the PS1™ simulator

In a similar fashion to that in the CRM booklet, both trainers and transition trainees were asked to complete a questionnaire to assess the usefulness of the PS1™ simulator software. Time and budgetary constraints meant it was only possible to carry out a small scale evaluation of this product. Thus, four trainers and three trainees assessed PS1™ as described previously. All of these completed the entire detail in real time.

It was found that:

- PS1™ simulator helped students understanding of certain operations and symbology, including the PFD, Navigation display, mode changes, FMS operation and autoflight component interactions through the use of the scenario.
- In addition it helped them to understand the same operations and symbology through their own investigation. This would suggest that they all found the software beneficial generally and not just for specific tasks. Instructors also indicated that it is applicable to all knowledge levels.

Instructors and students believed that PS1™could play a valuable role in the transition training of pilots to the B747-400, more specifically:

- would help the ground instructor;
- could be used to demonstrate the results of students' 'what if' questions;
- could replace/enhance FBS details;
- would be useful for free play and to re-play simulator details
- could be used as extra to existing CBT/AVT;
- could be used as a brief for self-study;
- would be very helpful for 'non-glass' students to become familiar with the PFD, ND and FMGC displays and the autopilot/flight director mode selections since the computer makes practice easily available.

However, it was felt by instructors that instructor guidance was needed, especially in the early stages. The results show that the majority of respondents believed simulator time could be saved by using PS1™ software. Most pilots believed that time on the CBT and simulators would be better utilised if students were also given access to a PS1™-type simulator during their transition course. One instructor did not think this was the case for CBT/technical training but did agree for simulator training. Overall, therefore, the evaluation of PS1™ and similar software appeared to be positive both from trainers and trainees. However, before it could be introduced into a formal training course, a larger scale validation would be necessary.

Main conclusions

Enhancements for CRM and knowledge of automation were successfully validated in an informal user consultation process.

A booklet of glass cockpit CRM training scenarios was developed from de-identified incidents to highlight the issues and to show how, if not properly handled, they could lead to serious problems. The glass cockpit CRM booklet received positive assessment from the validation and was considered by some pilots to meet a need in pilot training. While the booklet was designed particularly to address the elements of CRM related to interaction with and around the glass cockpit, use of the booklet was supported more strongly in other types of training than for transition training. The most popular use for the glass cockpit CRM booklet seemed to be as part of a simulator scenario, where perhaps the consequences of poor CRM can be easily demonstrated.

The second enhancement validated in ECOTTRIS was for operationalising knowledge of automation. Providing extra technical knowledge would be one solution, but without hands-on practice it is difficult for pilots to gain a good understanding of systems operation and interaction. Therefore, suggested enhancement for training knowledge of automation looked at low-cost PC simulation for practising FMS and autopilot skills using pre-planned flight scenarios. The system evaluated, PS1™, was well received both as a training tool and as an effective simulation (important for pilot acceptance and for preventing any negative transfer effects), and was thought to be beneficial for FMS type training and operationalising knowledge and skills. It was found to be much more flexible than conventional CBT and was thought to play an invaluable role in transition training. Free-play was considered useful for testing the aircraft systems and seeing what happens under different circumstances/configurations. It was also suggested that PS1™-type training could be used with an instructor available to provide guidance and help with problems and could be used to re-play situations which would be helpful for simulator debriefing and solving problems. In this way, such training could be used to bridge the gap between technical ground school and simulator sessions when pilots want to practice programming the FMS, need to learn the different mode transitions and their annunciations, and generally want to flex their knowledge.

Therefore, in conclusion to this section, it is clear that both enhancements in the validation were viewed positively in the aviation community and could become important additions to training for pilots moving to glass cockpit aircraft. Particularly important is that neither enhancement is expensive or difficult to implement and both could be easily adapted to meet individual airline requirements.

Other enhancements are possible, and indeed the use of manual flying skills still remains to be addressed, but even if these two initial suggestions could be implemented the process of conversion from conventional to glass cockpit could become easier and safer without too much additional cost.

3 Discussion

3.1 Pilot Training and Performance

Pilot errors leading to accidents (the 70-80% that is mentioned so often) have been diagnosed in the past (Besco et al., 1994) as the consequence of a breakdown in performance caused by:

1. Disregarding of knowledge of the risks and dangers in the current situation.
2. Unexercised or dormant skills needed by the pilot to counter the anomaly or the unexpected event.
3. Dysfunctional attitudes causing the pilot to be insensitive or unaware of the impending disaster.

In ECOTTRIS, the following pilot training and performance issues with respect to the glass cockpit were identified and elaborated upon:

3.1.1 Historical perspective - reduction in transition training duration

Over the last 30 years there has been a clear trend towards reducing transition course lengths. BOAC pilots moving to the B707 in the 1960's could anticipate some 4 months of ground school and simulator plus 7-10 days of base training on the aircraft prior to prolonged route training including many sectors as a trainee navigator. In contrast today's fledgling BA B777 pilot will receive under 2 *weeks* of CBT/FBS/FFS before venturing directly onto passenger carrying revenue flights.

This dramatic reduction in pilot off-line time has been brought about by a number of factors including:

- Commercial pressures.
- Changes in licensing requirements (e.g. by the CAA/JAA).
- Improvements in training techniques/equipment.
- Automation/computerisation/ increased reliability of aircraft systems.
- Communality of procedures and equipment.

Commercial pressure has only become a major factor in aviation with the advent of the privatisation of former state monopolies and the virtual removal of subsidies. In more gracious times pilot numbers and productivity were in the hands of pilot-managers and not accountants. Thus course lengths were determined by precedent and what was suitable for a piston-engined aircraft was carried across into the jet-age. Content was similarly biased towards what had been deemed essential on earlier types was imposed upon more modern equipment. The 1980's proved to be a watershed in the management of airline costs and thus training costs and productivity came under close scrutiny.

This new approach to running the airlines was the main driving force behind the restructuring of pilot and flight engineer training. The manufacturers also foresaw benefits to themselves if they prove that their particular aircraft types were more economical in terms of course length requirements and so they also participated in the move towards the streamlining of training.

Training techniques in the early jet-age had changed but little from the pre-war style of the 30's and 40's. "Chalk and talk" was still the order of the day, with rote learning of limitations and procedures. Systems were explored in intimate detail, occasionally using wooden models. Expanded diagrams of hydraulic and electrical layouts were hand-drawn and coloured by the students as "homework" exercises. There are probably many pilots who could still construct a B707 electrical schematic from memory! Full-size examples of engines and large components were used in the classroom to give close hands-on contact with the nuts and bolts of the aircraft. There were few other aids available to the instructors, other than the manuals and the blackboard. It was, therefore, not surprising that the course length for a B707 or VC10 in 1970 was over 5 months in ground school.

The changes brought about by the commercial structures already mentioned began to have their effect with the introduction of the L1011 Tristar and later the B737. The B747 also benefited from the modernisation of training techniques. Tape and slide presentations replaced blackboards and soon full-scale AVT (Audio Visual Training) equipment was introduced. Crews began to train in pairs or trios, thus allowing more flexibility in addressing specific topics. Full-axis simulators allowed all flight manoeuvres to be properly simulated and the requirement to replicate the whole simulation programme on the actual aircraft before a licence could be issued was gradually phased out. Computer-generated daylight visual presentations replaced crude rolling map/camera displays and the later dusk/night simulations. FBS (Fixed Base Simulators) and CBT (Computer Based Training) also began to make their mark, as did part-task trainers and PC-based tools for FMS and TCAS training.

Course length is obviously also determined by the actual content of the individual lessons. A more scientific analysis of the knowledge and skills required to undertake the various tasks on the flight deck allowed a considerable course shortening to be undertaken. It was decided that a detailed knowledge of every actuator and servo motor did little to improve pilot performance. "Nice to know" was replaced by "need to know," although the confidence factor which access to extra information can create was sometimes undervalued.

All types now "benefit" from this approach: many situations and procedures are no longer practised in detail in the simulator because it is felt that similarities with other flight deck activities are of such an order as to remove this requirement. The Airbus Equivalence programme (q.v.) advances this concept to its theoretical conclusion.

The fidelity of flight simulators has had a profound effect in terms of cost saving and in reducing the crews' exposure to potentially hazardous manoeuvres. Historically many more flight crew have been injured or killed whilst training to cope with difficult situations than handling them in actual operations.

The incentive for change was again cost driven and the extensive use of simulators today emphasises the importance of high quality simulation.

The remarkable progress from the wheezing Link Trainer of *ab-initio* days, through limited axis, non-visual machinery, valve and later analogue equipment to the fully digital Zero Flight Time simulators of the 90's is proof of the industry's confidence in simulation as the way forward.

The increasing reliance on automation on the flight deck has in very recent times had a dramatic effect on the amount of time a pilot must spend learning to operate his new aircraft type. When computerisation began to take a significant place in a pilot's life, the initial effect was to create a requirement for more things to be learned rather than less. Much of the equipment was of the bolt-on variety; mechanical actuators and sensors provided data for more advanced indicators and CRT displays. Highly complex auto land procedures were developed, such as those of the early B747, which involved extra school and simulator time. The fully integrated systems of the present day types like B777 and Airbus 340 allow a programme of up to half as many simulator details compared to the 14 of the B707 in 1970.

Aircraft systems, many of which are computer controlled, self-monitoring and almost autonomous, provide new challenges for the industry in terms of training requirements. If a particular piece of equipment is effectively inaccessible to the crew and cannot be manually controlled then little time need be spent on its operation other than identifying possible failure modes. MTBF rates of such state of the art technology are extremely hard to ascertain but anecdotal evidence would suggest that failures are very rare at present. Some might argue that more time should be spent on those very rare situations, remote though they might be. Our research in WP3 has shown that many pilots are not totally happy with their level of expertise in these areas.

Many of the larger airlines have rationalised their fleet structures so that a single manufacturer supplies all their needs, from short-haul through to long-haul types. This clearly brings with it benefits in the transition arena since much of the knowledge can be carried across and thus cut down training needs. The Airbus CCQ programme (q.v.) again is the industry leader in this field.
Licensing has historically followed a step behind the commercial interests of the airlines but with a greater awareness of the industry's needs the Regulators now seem to be accommodating many of the needs of the airlines. The current enlightened approach to Zero Flight Time training for example would have been scarcely thinkable two decades ago. Thus course lengths have been able to be reduced with the blessing of the authorities.

Table 12: Approximate length of transition courses at BA 1970-1998

Yr	*Type*	*Medium groundschool*	*Training on A/C*	*Duration and no. of sim. details*
1970	B707	Classroom	Base: 7-10 days	4 months + Simulator (14 details)
1975	L1011	Classroom/ Tape slide	Base: 7days	4 weeks + Simulator (12 details)
1980	B737	AVT	Base: 3 days	2 weeks + Simulator (10 details)
1998	A320	CBT	fly-out demo	12 days + Simulator (9 details)
1998	B777	CBT	0	10 days + Simulator (8 details)

Concluding, it must be remarked that today, it would be inconceivable to require from a trainee pilot to reproduce from memory the logic transition diagrams for the autoflight system of the B777 or the A320. The restricted duration of todays' transition courses does not allow for this kind of 'nice-to-know' exercises. However, if more attention could be paid to the understanding, principles and know-how of cockpit automation, this could partly solve the "permanent" drawbacks of automation: system opacity, system autonomy and system protection as listed by Amalberti (1995).

3.1.2 Historical perspective - increased reliability of systems

The safety virtues of increased reliability of systems are clear. However, paradoxically there are also some downsides of having highly reliable systems. These are addressed in this section.

Using a sports analogy, it could be said that one of the roles of the automation is to play defence and that one of the roles of the crew is to be the goal-keeper, necessary in case the defence is lacking. However, if the defence is good, the goal keeper will seldom get the opportunity to play. This is the paradox: how often will the crew actually be in the position to successfully cope with their team role in situations with failing systems? To answer this question, the system reliabilities of conventional (Fokker F28) and glass aircraft (Fokker F100) may be considered. This yields that a conventional indicator system in the F28, consisting of several separate electronic components, had a mean time between failures of 600 flight hours. Considering the functional counterpart in the glass cockpit, the fully integrated EFIS system in the F100, it was found that the mean time between failures of this system is actually 6200 hours. On the basis of this data we could conclude that crew on a F28 experienced a problem with a particular system several times during their respective careers on that type, while a crew flying on a F100 could have had only one of those experiences or none at all. What predictions can be made about the ability (skills) of the crew to cope with such situations on the basis of very infrequent exposure to difficult situations?

On-the-job-experience in glass cockpits

The process of learning complex skills is thought to develop through three stages: cognitive, associative and autonomous stages (Fitts, 1962). It must be noted that these stages are not strictly defined or visible in the learning curve of complex skills. Further, different parts of the complex skill are developed through the stages in different manners. Some parts of the complex skill, such as scanning of instruments and trouble-shooting will never be completely autonomous, and stay on the level of cognitive processing (or knowledge based behaviour, Rasmussen, 1983), while some human-machine interactions can often be completely autonomous.

It is clear that with infrequent exposure to difficult situations such as malfunctioning automation, development of critical skills, such as decision making in that particular situation, will never reach beyond the cognitive stage. At best, the relevant aspects of the difficult situation can be learned (by exposure to similar situations) and declarative knowledge needed to cope with the difficult situation maybe stored in memory.

During performance in abnormal situations there are heavy demands on working memory and attentional resources (not to forget the fear of dying); performance will be slow, inaccurate and effortful and will interfere with other mental activities (not to forget the fear of dying). A large amount of attention is given to cues, events and responses that are not critical to performance. There is a need for specific information in what is wrong and what is right and how to correct it (feedback). The characteristics of such behaviour is reflected in the numerous remarks that we got from European pilots with respect to their difficult situations, such as: "I was unsure of the various modes and how modes could default into other modes"; "That was something we were not prepared for because normally, a double emergency is not proposed in our simulator training sessions, and also the strange behaviour of the equipment was a little tricky to be thoroughly understood" and "I believed that the automation could not cope with a full [power] T/O with level off at 2000 ft".

Development of manual flying skills
Next to the problem of lack of sufficient knowledge of automation, the issue of manual flying skills was also raised. The reliability of automated systems in the glass cockpit combined with an operational philosophy of many airlines to fly on the autopilot as much as possible, also in non-normal situations, have lead to increased need for training of these skills, especially in long-haul fleets and especially with pilots who have extended experience on their current glass type. Thus, this is not primarily a transition problem. Handling skills will probably be at high level on completion of a move to a new type. However this competence will degrade if line experience is then limited. Fifty seven percent of the respondents of the ECOTTRIS questionnaire (mostly experienced glass cockpit pilots) were of the opinion that more training is needed in this area.

Exposure to very rare events such as GPWS or TCAS warnings at critical phases of flight can reveal dangerously low levels of manual skills. Some of the difficult situations described by glass cockpit pilots in the ECOTTRIS questionnaire often related to responses to GPWS and TCAS such as a ground proximity warning activation during a fast approach.

These skills could doubtless be improved by the allocation of more dedicated simulator time on high-fidelity equipment of a Zero Flight Time standard but this is unlikely to occur without intense pressure from groups without budgetary portfolios. A new training program at American Airlines underscores need for improved manual flying skills. This training programme calls for return to basic airmanship to help reduce accidents (Aviation Week and Space Technology, June 9, 1997)

Final remarks with respect to the reliability of systems

The principles of training for advanced technology cockpits are at least dissimilar to those of older cockpits in the basic fact that it must take into account the increased reliability of glass cockpit systems compared to conventional cockpits and the resulting lack of in-flight exposure to system malfunctions. With strongly increased mean-time-between-failures of various system the skills involved will not be retained or even never be experienced by either of the crew members in an operational situation.

We conclude with the remark that on-the-job-experience in glass cockpits does not allow for development of autonomous, skill-based behaviour in difficult situations with malfunctioning automation. This clearly does not justify the ‘need to know’ approach for knowledge of automation but calls for an approach to optimise knowledge-based behaviour in novel situations.

3.1.3 Historical perspective - changing nature of aircraft systems

Much has been published on how aircraft systems have been changed over the last decades. In ECOTTRIS, some of those changes have been dealt under the heading of design issues. In this section we focus on how those changes have affected task performance and how this could be addressed in transition training.

Table 13: Changing nature of aircraft systems

Conventional aircraft	***Glass cockpit aircraft***
Tactical – Short time span	Strategic – Long time span – programming
Direct feedback	Opaque feedback
All information on top	Information in layers deep in the system
Man-Machine interaction	Man-Machine Interaction + Man-Machine-Man dialogue
Most control direct by actions of crew	Control indirect through automatic control systems and programming (something invisible)

In WP2A (design philosophies) we have addressed the changes in systems in detail for the aircraft functions steering, navigation, look-out, systems management and communication. Taking a more general approach, the most salient changes are summarised in table 13.

Tactical vs. Strategic operating environment

Glass cockpit specific equipment such as the programmable and highly autonomous Flight Management System has turned the conventional tactical operating environment into a strategic operating environment. Short-to- medium term flight planning on a crude basis has been replaced with long term detailed flight planning. This long term flight planning is subject to a complex set of constraints such as those implied in company routes, fuel management and ATC-restrictions, which constraints have to be extracted from various sources of information. Herewith the consequences of errors have been shifted into the future and will be hard to relate to the planning/programming phase. Therefore, this planning process requires anticipation – realise in detail how the (remainder of) the operation is going to be fulfilled and conscientiousness – checking and bookkeeping. This will put cognitive demands on the crew in terms of memory and attention.

Communication by datalink will further abstract and sophisticate this process in future. Electronic clearances may be issued a long time ahead (30 minutes) and a fully automatic negotiation process between the ground ATC systems and the on-board flight management system, in which the role of the crew will be managing by consent. Since the crew has final responsibility in the operation, they will need to assess the validity of the outcomes of this process up to a certain extent and reach agreement with each other and consulting of other players (including automated air and ground systems). This involves hard thinking, inductive reasoning, concentration on verbal information (data, messages) and negotiation about the course of action to be taken on the basis of this information.

In non-normal situations and emergencies, though, glass cockpit crew has to “revert to the tactical mode”, to tactically intervene in the situation. This change of mindset can be difficult and from pilot reports, it is well known that the crew can be caught head-down in a critical flight phase, busy with strategic tasks, while full concentration should be with the tactical aspects of the situation. A particular example commonly report by pilots new to the glass cockpit is that there are instances when they cannot change the computer commands without disconnecting the automatic flight control system (e.g. Kabbani, 1997). This often happens during critical phases of flight or unanticipated phases of flight, for example, when an ATC command for a runway change is received after ILS localiser and glide slope capture. Problems like these could be resolved with extra training on low-cost simulation devices or FMS-trainers.

Direct vs. Opaque feedback, Information on top vs. Layers deep in the system

Automated systems often provide poor or little feedback about their current or future activities (Sarter and Woods, 1997). The opacity of automation tends to increase with progress in technology. The result is a poor mental representation of system functionality. Furthermore, ergonomic display designs that only provide the crew with top-layer information behind which the actual complexity (as a result of system integration) is hidden, maybe an large advantage for standard operations but can be a huge barrier in non-normal situations, as was already pointed out by Amalberti (1995). Here again, it is noted that cockpit automation results in a growing distance between performance requirements for normal and non-normal operation.

Training measures could be extra training for automation-naive pilots to improve the mental representation of the system functioning. An instructional principle to be used in simulations could be “c*ue augmentation”,* that is the use of (feedback) cues that are not present or have insufficient cueing effect in the real situation, but may have a positive effect when they are introduced or amplified in the training environment. This kind of augmented feedback could be gradually eliminated with performance improvement. Chappell and Mitchell (1995) suggested intelligent tutoring systems to support mode awareness in the cockpit

Under the same heading we would like to discuss the changed nature of information exchange in the cockpit. An important factor is the replacement of the flight engineer in the conventional cockpit with the automation in the glass cockpit. A large share of man-man and traditional man-machine interactions in the conventional cockpit has been replaced by autonomous actions of the automation and incidental dialogues with the automation. Those dialogues are characterised by one crew member *registrating* an item of information and the other crew member *consulting* the automation with respect to that same item of information, a process that could be called a man-machine-man dialogue.

In the conventional flightdeck, the flight engineer and pilots could spontaneously exchange thoughts, e.g. about their intentions, in a process called *conversation*. However, in the glass cockpit, individual crew-members communicate with the automation using *consulting*- and *registration* techniques for information exchange via keypads, annunciator panels and layered pages of information. Exchange of information by way of *allocution*, i.e. the simultaneous transfer of information from a central instance (person or device) to both crew members, is in the glass cockpit done by the automation in a crude, simple and verbal manner, sometimes quite silent (change of alphanumerical symbology to denote a flight mode change) and sometimes quite explicit (warnings beeps). If the four possible information exchange modes are considered, i.e. conversation, allocution, consultation and registration, we could say that with the introduction of automation and the disappearance of the flight engineer, conversation and allocution as means of information exchange became poorer (“impoverished”) and more artificial, while registration (of instructions) and consultation (flight information) became more sophisticated, more precise, but also artificial and tiresome in terms of interfacing.

The implications for those basic shifts in exchange of information are obviously in the area of Crew Resource Management, i.e. assigning tasks and responsibilities among crew members in an optimal way. This assignment process relates to work-attitude, management, co-operation and leadership, and it has been clearly identified in WP2B that CRM is a key factor in a large percentage (39.2%) of the glass cockpit incidents and accidents reviewed. The implications for training are diverse but not always clear. Many airlines installed so-called CRM-training but this training does seldom address the specific CRM problems of the glass cockpit in an integrated context, as has been outlined in WP3.

3.1.4 Tailor the training to the individual needs of the pilot

From our training activity analysis it became clear that individual differences within a group are taken into account at only a minimal level in transition training. In most transition training only previous FMS experience is taken into account and there is obviously little room to address specific needs and problems within the given time frame of the transition training of 10-12 days.

However, from research into the training of high performance tasks[2], it is well known that trainees can have very different demands in terms of training time for specific subjects and trials on specific tasks to reach equal levels of operational performance. This issue can become cloudy when pilots are trained to pass exams, such as in the case of training with a pre-programmed nature where anyone knows what to expect. Additionally, we already pointed out that there are large quantitative and qualitative differences between standard operation and non-normal situations in a glass cockpit: most accident scenario's are combinations of very unpredictable events.

Therefore, the training programme driven by the technical examination at the end can place the focus of learning in the wrong place. Since it is impossible to develop a standard operating procedure for every situation, pilots need practice with unexpected complex decision-making situations where there are not necessarily right or wrong answers (Amalberti, 1995). The training objective would be then that these pilots could generalise the experience and knowledge involved in those situations to novel situations, not encountered before

Some of findings on individual training needs to be taken into account are the following:

- Introducing computer naive pilots to automated aircraft and bringing pilots up to a nominal level of computer literacy is an under-emphasised or even unrecognised training need (Besco et al, 1994).
- In addition to selection for desirable personality characteristics, researchers might also consider the possibility that different training strategies for crew co-ordination may work more effectively with different personality profiles. Perhaps more personalised training approaches would make selection less critical. This would be extremely valuable in an area where recruits are relatively scarce and where careers are long, making population change a very long-term undertaking. (Chidester et al., 1991).

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[2] Tasks for which:
a. extensive practice is required,
b. substantial numbers of individuals fail to develop proficiency, and
c. performance of experts is qualitatively different from that of novices

3.1.5 Difference training

It was noted that currently transition training (particularly relevant for the ground-school part) does not often take into account differences between the previous type flown by the trainee and the new type (as far as was observed during the research, only generic FMS experience is taken into account in by training programmes). While the trainee has flown his previous aircraft for several years and up to a week before, he/she is asked to forget all about his/her old aircraft and start from scratch to learn everything about the new aircraft.

There are a few drawbacks to this current approach that decrease the effectiveness of transition training:

- Individual knowledge, skills and attitudes based on experience with the previous type are not taken into account. At best, the training programme takes into account the common denominator of knowledge, skills and attitudes, leading to a sub-optimal training programme for at least part of the trainees.
- Previous experience serves as a reference framework, which can make instruction more effective. Knowledge and insight in a particular system or principle is easier obtained and has better retention if reference is made to a similar and well-known system or principle. This could be as wide ranging as specific differences or similarities in operating the type, procedures, checklist items, the Mode Control Panel, Flight Mode Annunciation, differences in principles of the autoflight system, envelope protection, etc.
- Differences and similarities between the previous flightdeck and the new flight deck may give rise to specific problems, specific skills and de-skilling issues and should, therefore, be highlighted where needed. This is a safety issue.

Obviously, the introduction of difference training within transition training requires adaption of courseware, additional expertise of instructors (on the previous type flown by the trainee), etc. Such difference- training is more common in other area’s, e.g. the military (where transitions are more uniform, better defined target groups) and the software industry (there are MS-Word courses and courseware specifically for ex-Word Perfect users, etc.).

3.1.5 Use of training media

The increasing range of widely varying skills that have to be mastered in the glass cockpit will make it practically impossible to drill the pilot on all of those skills with traditional instructional strategies such as over-learning and on-the-job exercise. As a consequence it must be taken into account that a number of tasks will have to be performed on the basis of knowledge about the systems and its behaviour. Therefore, task-performance will depend less on automated behaviour.

In general, low-cost training devices now provide possibilities that in the past could only be achieved on expensive and complex systems. In addition to a quality improvement in low-cost simulation, there is also a quantitative advantage. A larger number of task relevant scenario's can nowadays be supported by relatively simple and inexpensive equipment. In fact, a number of tasks can already be trained with 'state of the art' PC's, providing the opportunity to procure a larger number of this type of training devices.

In our view, the term low-fidelity does not necessarily imply a sub-optimal training environment when compared to the real system or aircraft. A first condition for an effective low-fidelity device is the presence of identical elements that are critical to required task-performance, allowing the trainee to develop the proper response strategy. This characteristic of the training device to allow the development of a proper response is more important than having an exact replica of all cues involved (the stimulus). Secondly, the low-fidelity training device may provide some instructional strategies superior to those attainable in the on-the-job situation.

The goal is to meet operational training objectives in the most efficient way, by optimising the training environment and thus speeding up the learning process. A range of devices of lower fidelity could be used to support and shorten high fidelity training, provided that they are tailored to the different stages of the learning process. Ideally a wide range of training devices are used during the skill acquisition process, each of those training devices tailored to the temporary needs of the trainee. The deployment of training devices of increasing fidelity should not be seen as a serial chain in the training program since the training syllabus should allow and promote skipping, and stepping backwards and forwards between training devices.

The least sophisticated devices are interactive PC-based trainers with which knowledge and (part) skills are learned, but not necessarily through simulation. The learner is interactively involved in the learning process. The realism of the learning environment is relatively low and there is no task-specific hardware involved. The strength of the device lies in the integration of knowledge and basic skill components which is very valuable for the initial stage of skill acquisition. Important features are for example:

- Interaction.
- Performance monitoring.
- Immediate Feedback.
- Tests.
- Individual pace of learning.
- Guidance combined with the freedom to choose what to do next.
- Knowledge needed to perform a (part) skill is available while practising a skill.
- Use at any time and any place.

The more sophisticated devices for individual training focus on a realistic free-play simulation, operational scenarios and online performance scoring. In a PC-based simulation it is possible to gradually build up from part tasks to whole tasks (progressive part training), which is particularly important in learning complex skills. The learner can practice the tasks as in the real situation/context, based on scenarios. Where needed, task specific hardware, such as consoles, displays, controls, realistic seating and headsets are used. Additional features are for example:

- Use of instructional strategies such as progressive part training or adaptive training.
- Explicit feedback in de-briefing form, for example through knowledge of results followed by an explanation and demonstration of appropriate performance.
- Access to the learned knowledge (e.g. in on-line help).
- Provision of replay possibilities.

- *Cue augmentation,* that is the use of cues that are not present or have insufficient cueing effect in the real situation, but may have a positive effect when they are introduced or amplified in the training environment.
- Built-in coach.
- Use of original system (aircraft) components or software modules.

It is concluded that there is clearly a rational and scientific basis for low-cost training devices in glass cockpit transition training. Preliminary results show that PC-based training devices can be used to support the initial and advanced stages of training, thereby saving costly simulator and on-the-job time. Furthermore such devices are effective briefing tools and can significantly reduce instructor briefing time.

Also, "*providing pilots with increased access to free play training devices in a discretionary, non-jeopardy, informal setting may be an effective means of increasing proficiency with flight management systems. It may also prove to be an economical means of improving the quality of training and line performance, and in particular a useful tool in a fleet's conversion to AQP standards. However it should be noted that free-play should not and is not meant to replace certain aspects of the training experience such as formal FMS instruction. Rather, free-play should be viewed as a way to allow transitioning pilots to efficiently develop FMS familiarity, so that training (and especially simulator) time can be spent on operationally focused tasks such as emphasising the development of automation use judgement*." (Sherman and Helmreich, 1997). Finally it must be noted that embedded flight management system training has been under-emphasised or even unrecognised in current airline practices (Besco et al, 1994)

3.1.6 Final remarks on training and performance discussion

In summary, air crew have been, and presumably will be in future, the goal keepers in air safety and are, therefore, valuable personnel assets that must be provided with the best possible training. Valid training analysis is a critical step in this process.

Up to now, manufacturers and airlines have focused on minimising transition training duration and pilot off-line times while addressing minimum regulatory requirements. This rational cost-effective approach is reflected in an efficient but rather inflexible logistic planning of training resources (students, instructors, media, etc.) at airlines, streamlined CBT-activities that address automation training on a “need-to-know” basis and pre-programmed simulator details (also Foushee, 1990).

This approach ignores that after their transition to the new flightdeck aircrew may have to cope with a large variety of unpredictable and thus unexpected events (seemingly irrational automation anomalies and surprises, hampering information-exchange, etc.) in which the pressurised situation could turn the shallow “need-to-know” basis in an “ought-to-know” nightmare.

More time-consuming and flexible training strategies are currently avoided since operational effectiveness of in-depth knowledge of automation is not easily predicted and, therefore, difficult to justify in terms of operating costs. Moreover, regulatory requirements usually set common standards for training, rather than providing flexibility in the process.

The present research yielded that an important characteristic of the glass cockpit is the large distance between performance requirements for standard operations and training for non-normal and emergency situations. *Normal operation is relatively easy* while non-normal situations are increasingly complex. To cope with the latter, training contents and duration should be tailored to the individual pilot and should result in extended and practical applicable knowledge of automation in those situations. Suitable means could be through more flexible use of a wide range of training media.

3.2 Glass Cockpit Operation

3.2.1 General

In the previous paragraphs the flight deck design and the individual skills of the pilot have been discussed in relation with glass cockpits. This section will discuss the issues that relate to the glass cockpit operation as a whole. In other words the difference between operating within a conventional vs. a glass cockpit in relation with the (inter)actions of the air crew. As seen in previous sections, the main difference between conventional cockpits and glass cockpits is the level of automation. A modern glass cockpit has been automated to a very high level. As discussed previously, dealing with an automated cockpit depends on a high level of knowledge of the individual pilot, but also on the interaction of the crew, which will be discussed below. Because of the sub-optimal feedback given by the complex aircraft systems (see par 3.3) a crew has to *manage the automation* by optimally employing all of their resources.

3.2.2 Automation management

How does one manage automation? How does one keep “ahead of the aircraft”, especially when an aircraft is pre-programmed? In the old days the aircraft would not do anything unless an action was initiated by the crew. Nowadays the aircraft will fly for hours (even up to a landing if programmed in advance) without the crew touching one of the primary controls. It is, therefore, not a surprise that staying “ahead of the aircraft” requires a different strategy than before. The inherently more passive structure of today’s flying means more emphasis has to be put on *monitoring and vigilance* of the crew. Next to monitoring and vigilance effective *crew communication* has become vital in an modern cockpit to ensure that both crewmembers operate with the same expectations regarding the progress of the flight. If a crew allows itself to lag ‘behind’ the aircraft and when actions are required, especially when non-standard operations occur, the crew can be faced with a situation in which they are (over)loaded with information which they need to prioritise and integrate in such a way that a correct decision can be made regarding the actions to follow, hence the last section on *prioritisation and decision making in non-standard operations.*

Operational philosophies

WP2A showed that most operational philosophies prescribe the use of automation to a large extent. Obviously using the automation will reduce operating costs and is, therefore, prescribed by most airlines. Also the prescriptive nature increases regarding the use of autopilot and decreases regarding the use of FMS when abnormal events occurs. This indicates that operators have a high degree of trust in the autopilot and autothrust systems. However this also indicates that manual flying skills experience is reduced to a large extent to flight simulator time only.
The other conclusion was that pilots often deviate from these procedures. Obviously, this would imply that procedures are not always compatible with the human perspective of flight operations. Pilots will deviate from procedures because of individuality reasons or because they believe that

the situation calls for a deviation from the procedure. However deviations from procedures should be considered as sub-optimal situations. Reasons why deviations occur and possible improvements to operational procedures should be investigated.

Monitoring and vigilance

A glass cockpit aircraft has and will increasingly have automatic capabilities for monitoring and controlling operational parameters. Herewith, the crew is put into the outer loops of a set of complex control systems. In most phases of flight, the crew could then plan and manage-by-consent a few top-level desired values, while being vigilant and monitor the unwinding of the operation. However, continuous use of this capability to its full extent could make pilots susceptible to missing critical signals (which is a well known phenomena in supervisory behaviour in process control).

Flying a highly automated aircraft is, therefore, a demanding task regarding the effort needed to monitor all of the actions performed by the automatic systems. Ideally, this requires the crew to predict and check all of the automatic functions (expectancies). This in turn requires an almost perfect knowledge of how, when and why automatic systems do what they do. Within the ECOTTRIS project and other research (Moricot, 1997, Walley, 1995) the amount of knowledge of the automatic systems was found to be less then the described ideal above. Indeed a large percentage of pilots reported that they wanted more of that knowledge. Therefore, it can be assumed that the ideal situation will not normally occur. Next to the lack of perfect knowledge, another factor can play a role with respect to the monitoring and vigilance of the crew, which is the human aspect of complacency. In paragraph 3.1.2. the high reliability of modern avionics was discussed. Indeed many pilots reported with the questionnaires that they had never encountered a difficult situation in their career. It is well known that monitoring a system with little or no interaction often leads to complacency with human operators (Harris and Christhilf, 1980).

Therefore, a technique has to be developed with which a crew can show effective monitoring and vigilant behaviour taking into account the factors just described. The monitoring and vigilance not only affects the flight progress but also the programming and setting of the various systems. As shown in the accident and incident analysis the “incorrect setting” accounted for many mishaps. Monitoring and vigilance can be seen as individual tasks. However, because humans are not capable of showing individual vigilant behaviour for extended time-spans, the problem should be tackled from a crew resource perspective. Techniques must be developed and investigated with which acceptable monitoring and vigilance behaviour can be accomplished without extensive interaction with the system. These techniques should also be maintainable for extended time-periods. The use of checklists for FMS operations could be considered, whereby the crew is more actively forced to discuss and check the programming of the various FMS entries during and before flight. Some manufacturers suggest the use of a crew activity monitor (Airbus 1995), which checks the cockpit data-bus for inputs of the crew. If no input is detected for a predetermined time-span an alarm is triggered. Systems like that could be developed with more sophisticated crew monitoring techniques, such as using context knowledge given by the phase of flight or using non-intrusive eye/head scanning techniques.

Crew communication

Effective crew communication is required for optimally employing all the knowledge of the crew. Too many accidents and incidents could have been prevented, if one of the crew members would have spoken out and/or taken action because of knowledge of a situation which was not clear to the pilot in command. Examples such as the 1977 accident at Tenerife (Gero, 1996) are still very clear in our minds when discussing this subject. This subject clearly relates to the authority gradient. In the old days when the authority gradient was very high junior crew members would very seldomly dare to question an action of the captain. This has changed over the years with many airlines, because of accidents such as Tenerife. One other reason why this might have changed could also be the fact that nowadays the junior first officer often has a better understanding of the computerised automatic systems in the cockpit. The situation then arises that the crew uses a less steep gradient to optimally employ the knowledge of the automation of the first officer with the experience of the captain in their advantage. However, one can also imagine an authority gradient which is not steep enough or even inverse. This can also lead to dangerous situations or even accidents such as the 1994 A-300 accident near Komaki in Japan (Gero, 1996). Having only a two man crew with an authority gradient which is not steep enough will result in stalemates which can cripple the operation of the flight. The situation in which that captain becomes overly dependent on the skills of the first officer should, therefore, be avoided. Airlines should define and work to an optimal authority gradient specifically for the operation of the glass cockpit.

Communication with a computerised crew member in between (the autoflight system) (see par. 3.2.3) stresses that communication protocols should be developed and implemented for specific use within the glass cockpit environment. As an example, because the CDU pages are not easily readable for the other crew-member (unless the same page is selected) cross checking CDU entries can be hampered. This would require modified procedures with regards to crew communication.

Prioritisation and decision making in non-standard operations

Again using the sports analogy, the pilot/crew is the ultimate goal-keeper of the system. This means that if "all hell breaks lose" the crew would still have to deal with the situation such that the flight is brought to a survivable end. Unfortunately, because of the nature of automated aircraft the "Hell" scenarios are difficult to predict. The complex interactions of the different aircraft systems make it almost impossible to predict what kind of malfunctions will occur during the lifetime of an aircraft. Therefore, the crew can be faced with situations for which they have not been trained specifically and, as discussed before, for which they sometimes do not have enough knowledge. Dealing with situations like that require different strategies as compared to convential aircraft. In the old days having enough training time available and having less complex aircraft most of the malfunctions that could occur were predictable and applicable SOP's were trained/drilled so that the crew could perform the necessary action as required. In a never before encountered situation the crew has to develop its own course of actions based on the information and knowledge available. This requires action strategies which are different from the conventional "according to the book" actions. The aviation community should incorporate more time on how to develop those strategies as crews. Guidelines on how to use automation and specifically on when not to use it should be imbedded in the training programmes. Incidents that occur during the lifetime of an aircraft should be made known to all other pilots of that aircraft in a way which would strengthen this problem solving strategy. For example using an interactive PC avionics simulator (like PS1™) one could create specific scenario files with which the pilots or crews could interactively train their abilities to solve situations for which no SOP's exist.

3.2.3 Accident/ Incident Reporting Systems

The review of accident/ incident reporting systems in WP2B to identify problems with operation of glass cockpit aircraft highlighted a number of issues surrounding the use of this data for training research.

These areas related to:

- availability of data: there are a number of sources of accident and incident data which vary in their maturity; some systems have been running for a number of years and others are in their infancy.
- access to data: this can be difficult because of the very sensitivity of the reports, especially where confidentiality has been ensured to the reporter. It seems necessary that at some high level a de-identified, standard global source of reports is collated which can be used for accident and incident analysis by the aviation community.
- nature of reports: the sources utilised differed in a number of ways, hence, there was little standardisation between reports:
- cultural differences: the safety culture impacts on the accessibility of data, as well as organisational concerns regarding potential legal actions. At the national culture level, the spread of data across Europe was often uneven with availability ranging from no system to duplicate systems.
- training data: there is little formal gathering of training data for generalised investigations.

3.3 Flight Deck Design

3.3.1 General

Within the ECOTTRIS project, the design issues were to be considered as far as they were practically feasible. ECOTTRIS was primarily aimed at transition training, and so design issues were only taken into account if they showed up consistently within the project and if something could reasonably be done about them through legislation or retrofitting. Koehl and Linsenmaier (1998) shows an in depth consideration of design issues found within ECOTTRIS. The main findings of this work are summarised below.

3.3.2 Lack of Standardisation

WP2A clearly indicates that the way functions have been and are automated is by no means standardised. As shown by the various overview tables within WP2A, the autoflight functions, controls and annunciators differ in many ways. Naturally this will hinder transitions from one aircraft to another, because pilots who are used to a certain Stimulus – Response relationship will have to forget the old one and learn a new one. It is not uncommon that on transition courses that pilots are told to forget everything they know of the old aircraft they were flying. However, apart from the fact that new SR relationships have to be learnt, there remains the risk that “old habits die hard” and that these return during high stress situations, possibly leading to disaster.

It would therefore be tempting for ECOTTRIS to recommend the authorities to standardise the HMI of the various automatic systems on board of the aircraft. This would hold for systems like autopilots and autothrust systems, flight mode annunciators, warning and caution systems, display formats (e.g. PFD, NAV) and many other systems (Koehl and Linsenmaier, 1998). However, this might well prove to be impossible in the near future. First of all, all aircraft presently flying are certified and cannot be easily changed. Second, some aircraft manufacturers are starting to standardise their cockpit for purposes of Cross Cockpit Qualifications and some of the issues raised during ECOTTRIS are suggesting that a number of items within that standard are suboptimal. Third, any redesign of a cockpit is going to be extremely costly and will be opposed by not only the manufacturers, but also by the airlines themselves. Finally if a standard is adopted, it will almost certainly be different in some aircraft to the present HMI which again will lead (even if it is only once) to the problems discussed before. Therefore, programmes should be initiated to study a core set of automatic functions, which initially could allow the different manufacturers to build a standardised HMI shell around it, with which they could still pursue their own design philosophies. (see par. 3.3.3.)

This research did not focus on cockpit design per se and so we do not feel that there is enough evidence in ECOTTRIS to recommend comprehensive standardisation at this time. However, as a realistic, nearer term aim, it would be beneficial if standardisation occurred for safety critical systems and information which is most likely to be used in an emergency situation. Moreover, this is the time when reversion to previous training is more likely to occur. For example, standardisation of warnings and cautions or PFD symbology.

3.3.3 Avionics Design vs. Operational Task Mapping

The questionnaires of WP2A found that many airlines uses their aircraft in a different manner than originally anticipated by the manufacturer. Some airlines even prohibit the use of certain autoflight modes under certain circumstances. Also, it was found with the questionnaires that many pilots reported that certain ATC clearances were difficult to program within their Flight Management Systems. In fact ATC clearances can vary geographically and in time. The way ATC operates in the USA is in many ways different from the way they operate in Europe or in other parts of the world.

All in all this has led to the fact that the way the automation has to be programmed is sometimes vastly different from the way operations are carried out. In other words, the mapping of operational tasks vs. avionics design can be substantially different. This is for a large part to blame on the extensive certification process within the airline industry. Every software change will have to be certified which takes a considerable amount of time and costs both the airline and manufacturer a lot. However, research has shown that changing the top layer only of the CDU page structure (without changing the functional behaviour of the system itself) could almost double the acceptability of the HMI by the crew (van Gent, 1995). Other research has also shown that by mapping the interface to the task the performance of the crew is vastly improved (Riley and Parasuraman, 1997). The aviation authorities should, therefore, think of a way in which the top layer of interfaces could be changed without the extensive certification process of today, such that the mapping of the interface to the task can be performed whenever necessary. The definition of for example the page structure could be put in a database and could be changed just like the navigation databases are changed nowadays within the FMS.

3.3.3 Complexity vs. Simplistic Interface

The final design issue discussed in this paragraph is complexity of the system versus the simplistic interface. Many manufacturers will boast about the fact that their cockpit only has so many displays and so many switches, calling out numbers an order of magnitude less than the conventional cockpits would have. What is never mentioned at that time is the fact that the systems which are being controlled by such a few number of switches are capable of many more functions than the old systems which were controlled by more switches. The reason for this reduction of switches is that many of the ones left over are now *multi-function.* This means that a switch could now have a multitude of functions depending on the setting of some other switch or output of another system. This in turn means that in comparison with the old fashioned way where a pilot could set a switch to “on” and know that that system would go “on”, nowadays setting a switch to “on” could be overruled by another system which prohibits the “on” function because of some imbedded rule. Some very nice examples are given by some incidents and accidents whereby the “weight on wheels” switch was malfunctioning causing the automated aircraft to think that it was still flying whereby certain braking functions were inhibited. Many more examples are found in Koehl and Linsenmaier (1998) The Stimulus Response relationship

has turned from a one-on-one relationship to a many-on-one relationship, sometimes complicating matters for the pilot dramatically.
The same goes for the displays. A manufacturer will boast about the limited number of displays and warning lights in a cockpit. Again what is not said is that a lot more information is presented on those limited number of displays than in the old days. It is true however that the format with which information is presented now has vastly improved because of the use of CRT's or other imaging hardware. One only has to compare the navigation display of today to the navigational instruments of conventional aircraft to appreciate the use of EFIS instruments. However there is also a downside. A navigation display is so compelling that a navigational error of the FMS is sometimes not recognised because many pilots do not check the navigation calculation be comparing those to the indication of an ADF or VOR beacon, leading to offsets in positions (reported a number of times in the WP2A questionnaire).

Also the vast improvement of the format for lateral navigation is not present yet for the vertical flight path. Presently the pilot has to develop a picture of his vertical path by using his vertical speed, airspeed, his flight mode annunciators and is sometimes aided by an arc presented on the navigation display indicating where the aircraft will reach the altitude set in the MCP-altitude window. Accidents and incidents have shown that the vertical picture in the cockpit could (and should) be improved. Especially the large amount of autoflight mode annunciations have been the subject of many critical reactions. Not only are they not standardised (see par 3.3.2) but many people believe that there are too many and that the feedback provided by the FMA's is far from optimal. Examples are given that the difference between having an annunciation with or without a box drawn around could mean that an approach would or would not be flown correctly. Again, this could prove to work well under normal conditions, but under stress pilots could well (and have proven to) overlook such an indication. Other examples of suboptimal feedback are given in relation with the CDU. The fact that inputs into the CDU are not seen by the other pilot has often lead to criticism and adaptation of operating procedures. Also because of the layered page structure of the CDU, FMS status and changes hereof are difficult to see.

The Warning and Caution systems have sometimes attracted criticism as well. Older types where limited prioritisation and filtering were built in resulted in a lot of confusion with the pilots because too many alerts and messages were presented at the same time leading to an overload of information within a short time-span. Present warning and caution systems have much more elaborate filtering and prioritising logic built in, leading to far less complaints.

Finally comments were made regarding the non-moving throttles and the uncoupled side-sticks of the Airbus type of aircraft. Incidents (or/and difficult situations) were reported where the above mentioned items lead to confusion and on one occasion also to an over-rotation of the aircraft. Again the principle behind this is that good feedback to the pilot is essential for awareness of what is happening to the aircraft.

Therefore, ECOTTRIS recommends that within the scope leading to a future standardisation a lot of effort is devoted to defining optimal feedback for automated systems. Also retrofitting cockpit with items which could aid the feedback of flight status to the pilot should be encouraged and further developed. Many examples are given by Koehl and Linsenmaier (1998). Items which should be taken into consideration are inter alia:

- Vertical navigation displays/formats.
- Active controls, instead of non-moving throttles and passive side-sticks.
- Improved software employing prioritisation and filtering of messages.
- Improved presentation of Autoflight status.
- Addition of electronic support systems such as Cassy (Koehl and Linsenmaier, 1998).
- Pilot action vs. task context consistency checking systems which alert the crew when abnormal actions have been initiated by the crew. (Koehl and Linsenmaier, 1998).

4 Conclusions and Recommendations

4.1 Pilot Training and Performance

This section describes the conclusions with regards to pilot training and performance. From each conclusion, recommendations can be given for transition and/or recurrent training. The recommendations are categorised as follows:

- Training Content: the learning objectives of the training, closely related to the end result: the operational performance of the pilot. What does the pilot need to know and what skills does the pilot need to have?
- Training Methods: specific training methods to learn the knowledge and skills (e.g. simulation of incidents, cue augmentation, differences training, etc.).
- Training Media: the kind of media that are used for training, fitting to the kind of training task to be performed and the training method to be applied.

Appendix A includes a scheme for a possible transition training programme. It serves as an example which takes into account the improvements that have been proposed in the ECOTTRIS work packages and the recommendations in this section.

Conclusion-PTP-1
A trend towards reducing transition course lengths was observed, while pilots express a need for more training. Many pilots indicate a need for a higher level of expertise, especially in coping with difficult situations.

Recommendation-PTP-1
Training Content:

- Extend or at least maintain current transition course duration.
- In transition training, put emphasis on operational applicable knowledge of automation to partly overcome features of the automation (opacity, autonomy and system protection) that could impair formation of adequate mental models of system functioning . An adequate mental model would lead to better prediction of the system behaviour, which would stimulate more active monitoring and vigilance.
- Additionally, transition training should support adequate knowledge based behaviour to cope with difficult situations in the glass cockpit.

Conclusion-PTP-2
As a result of increased reliability of systems, the exposure to malfunctions in glass cockpits is an order of magnitude lower than with steam gauge aircraft. However, because of increased system integration, the consequences of malfunctions may be more aggressive and more difficult to understand. Furthermore, because of the lower exposure to malfunctions, skills involved will not be retained or even never be experienced by either of the crew members in an operational situation.

Recommendation-PTP-2

Training Content:

- Transition training and/or recurrent training should cater for the lack of exposure to malfunctions.
- Put emphasis on knowledge of automation and decision making to optimise knowledge-based behaviour in novel situations.

Training Method:

- Enable simulated replay of type-specific incidents and accidents during transition and/or recurrent training, such that knowledge of automation and decision-making in these situations can be learned and/or applied.
- More training scenarios should be dedicated to understanding malfunctions. This enhances knowledge based behaviour, which in turn is necessary in order to cope with novel situations.

Training Media:

- Relatively low-cost and type-specific PC-based simulations could be used for simulated replay of incidents and accidents.

Conclusion-PTP-3

Inherent to the glass cockpit is the gap between performance requirements during normal operation and non-normal operation. Non-normal operation may require a reversion from a “strategic mindset” to a “tactical mindset”, including the abortion of strategical tasks and decision making in favour of tactical tasks and decision making.

Recommendation-PTP-3

Training Content:

- Extra training is needed to improve the mental representation of the system functioning in both normal and non-normal operation. (To be able to cope with normal and non-normal operation, the pilot will have to have a sound understanding and awareness of the system functioning/mode)
- Implementation of CRM-training specific for the glass cockpit is recommended, emphasising differences in behavioural and performance aspects between normal and non-normal situations.

Training Method:

- Use cue augmentation[3] on the system functioning in simulations which is gradually eliminated with performance improvement.
- Include both normal and non-normal situations and emphasise the differences in system functioning and in crew behaviour and performance.

Training Media:

- It is recommended to provide a suitable simulation environment / operational context to support the CRM training.
- Intelligent tutoring systems and low-cost training devices can be used to develop mode awareness in the cockpit.

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[3] the use of (feedback) cues that are not present or have insufficient cueing effect in the real situation, but may have a positive effect when they are introduced or amplified in the training environment.

- CRM Booklet (see Appendix B).

Conclusion-PTP-4
The way of communication changes from conventional to glass cockpits: the conversation and allocution[4] as means of information exchange/communication has reduced and became more artificial, while registration (of instructions) and consultation (of flight information) has become more sophisticated, more precise, but also artificial and tiresome in terms of interfacing.

Recommendation-PTP-4
Training Content:
- Glass cockpit specific CRM training is needed in communication and the related change in assigned tasks and responsibilities within the crew with respect to the conventional cockpit.
- Furthermore the shifts in exchange of information between crew and automation, when transitioning from a conventional type, should be learned in a operational context.

Training Method:
- Train communication and information exchange with crew and system in both normal and non-normal situations and emphasise the differences between those situations.

Training Media:
- It is recommended to provide a suitable simulation environment / operational context to support this training.

Conclusion-PTP-5
Transition training could be more effective if individual data (experience/expertise, such as computer literacy) were taken into account and if the training programme would focus on the trainee's (transient) needs by monitoring the learning process rather than training to pass an exam.

Recommendation-PTP-5
Training Content:
- Before entering transition training, a profile of the trainee could be made, e.g. on the basis of computer experience, learning/cognitive style, etc. On that basis, initial individual training needs should be established.

Training Method:
- The transition training programme should then offer the flexibility and cater the needs of the individual pilots in terms of type and number of training activities, use and configuration of training media and instruction strategy (individualised instruction).
- Monitoring the learning process of the individual trainee and adapting training needs to this (e.g. feedback, more training, more explanation…) could further increase transition training effectiveness.

Training Media:
- Intelligent tutoring systems and low cost training devices with performance monitoring systems can be used to give individualised instruction.

Conclusion-PTP-6

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[4] the simultaneous transfer of information to both crew members

In transition training for pilots transitioning from a conventional type to a glass cockpit type aircraft, very little time is spent highlighting the differences and similarities between the conventional or previous glass type and the new glass cockpit type.

Recommendation-PTP-6

Training Content:

- Ensure that pilots are aware of differences between the previous type and next (glass cockpit) type that could cause problems if forgotten. This would improve the pilots' knowledge and understanding of the system.

Training Method:

- Highlighting important and not necessarily obvious differences and similarities between the previous type and the next glass cockpit type could prevent pilots making assumptions about how the new aircraft works based on knowledge of the previous type.
- When possible, adapt the differences and similarities to the specific transition the pilot has to make.

Training Media:

- Use low-cost training media which highlight the differences and similarities between the previous and next type. Differences and similarities between specific aircraft can be accessed by means of different aircraft databases. For example, a split screen could be used for easily comparison of the previous and next cockpit, with additional information explaining the differences and similarities on the bottom.

Conclusion-PTP-7

Transition training could be more effective if innovative training media would be used that could cater for a wider range of training activities and related training objectives.

Recommendation-PTP-7

Training Method:

- It is recommended to define training activities that fit instruction strategies such as free-play progressive part training, and intelligent tutoring.
- The training syllabus should allow and promote skipping, and stepping backwards and forwards between training devices.

Training Media:

- Use training devices, ranging from low-cost commercial-of-the-shelf devices to full flight simulators, that support those instruction strategies.
- Further, low-cost training devices can also be used as effective (de-)briefing tools in transition training, especially when linked to high fidelity simulators.

Conclusion-PTP-8
Manual flying skills are rated among the skills mostly needing extra training.

Recommendation-PTP-8
Training Content

- It is recommended to train manual flying skills more often for long haul crew members
- It is also recommended to train special manual flying skills including:
    - TCAS resolution manoeuvres
    - GPWS pull-up manoeuvres
    - Unusual attitude recoveries

4.2 Glass Cockpit Operation

This section describes the conclusions and recommendations with regards to glass-cockpit operations. Recommendations are issued along two lines: The first line is that research should be started to develop optimal guidelines for training and operations and the second line is that CRM training should take specific glass cockpit items into account.

The main conclusion is that operations should take ‘automation management’ into account. The following items are thought to play a major role with regards to this automation management, including (1) monitoring and vigilance (2) crew communication (3) prioritisation and decision making.

Conclusion-GCO-1 (monitoring and vigilance)

- With the increased reliability of aircraft systems and the increased possibility of pre-programming a large part of flight operations, crew tasks will increasingly shift towards monitoring and vigilance of the crew will become more critical.

Recommendation-GCO-1a (monitoring and vigilance)

- Recommendations for training: Techniques known to aid monitoring and vigilant behaviour should be trained and practised using CRM type of training sessions. Examples of such techniques are often found in procedures aimed at cross checking each other during operations and the incorporation of specific call-outs of automation action.

Recommendation-GCO-1b (monitoring and vigilance)

- Techniques should be investigated and developed with which acceptable monitoring and vigilance behaviour can be further improved for extended time periods. The possibility to use checklists for FMS operations should be investigated.

Conclusion-GCO-2 (crew communication)

- With the increased pre-programmed nature of flight operations and consequent silent changing of automation set-points, communication of various systems states between crewmembers becomes increasingly important for maintaining knowledge of aircraft present and future state.

Recommendation-GCO-2 (crew communication)

- See Recommendation-PTP-4.

Conclusion-GCO-3 (prioritisation and decision making)

- Sometimes situations occur which are not covered by the procedures. Subsequently crews are then forced into knowledge based behaviour.

Recommendation-GCO-3 (prioritisation and decision making)

- Recommendation for research: Improved knowledge based action strategies should be developed for dealing with situations not described by checklists and or procedures.

Based on the research, the following conclusion and recommendations with respect to operational philosophies as employed by the airline were derived

Conclusion-GCO-4 (operational philosophies)

- Glass cockpit operational philosophies use automation as default and where ever possible. Cases have been identified where this approach has led to negative consequences.

Recommendation-GCO-4a (operational philosophies)

- The operational philosophies of airlines and manufacturers philosophies with respect to the use of automation could be refined and brought in line with each other and attempts should be made to formulate a framework for the application of procedures and behaviour in normal and non-normal situations.

Recommendation-GCO-4b (operational philosophies)

- Sub-optimal combinations of automation levels and non-normal situations should be further analysed.

Recommendation-GCO-4c (operational philosophies)

- Operational procedures with respect to the use of automation should be reviewed in more detail than has been done in ECOTTRIS so far, taking into account why pilots sometimes deviate from procedures.

Operational performance and training effectiveness

As a final remark, it must be stated that for training departments of airlines and training centres of the manufacturers it is difficult to identify whether the operational performance standards are met and correspond to training objectives. At the moment this decision is merely based on instructor-judgement during training.

It is recommended to develop an objective method to (1) evaluate the operational effectiveness of transition training programs and innovations in training (2) identify the need for extra / recurrent training on the basis of operational experience.

Accident/Incident Reporting Systems

There is little standardisation in the accident/ incident reporting systems across Europe and regarding the use of human factors terms within the reports. Efforts should be made to increase standardisation of the type, nature, content and availability of reports to allow for information sharing at a de-identified level to allow for accident/ incident analysis in the broader aviation community. The use of more human factors terms should be encouraged and the development of a confidential trainer/trainee reporting scheme may be profitable increase understanding of current training issues and practices.

4.3 Flight Deck Design

This section describes the conclusions with regards to design issues. From each conclusion, recommendations are given with regards to future legislation and/or retrofit items to be considered by manufacturers.

Conclusion-FDD-1
The reliability and safety record of glass cockpit aircraft has improved in relation to older conventional aircraft.

Recommendation-FDD-1
However, as stated so many times, the safety of civil aviation should be improved to keep the absolute numbers of accident and incident at an acceptable level, due to an ever increasing number of flight movements.

Conclusion-FDD-2
The lack of standards with regards to the automatic cockpit systems in modern airliners could have a detrimental effect on safety when transitioning between different types of glass cockpits.

Recommendation-FDD-2
The authorities should study standardisation as a long term goal (realising that standardisation on a short term basis is probably an impossible task). Furthermore, research and development programmes could be initiated to define a core set of standardised functions, with which manufacturers could pursue their own design philosophies as a top layer shell.

Conclusion-FDD-3
The design of the Human Machine Interface (HMI) often does not correlate with the operational use, due to changing environments and operational procedures.

Recommendation-FDD-3
Having identified a core set of functions within an avionics design, the authorities could consider a certification system whereby the certification rules of today apply for the core set of functions and whereby the HMI could be made flexible as a changeable top layer on the core functions.

Conclusion-FDD-4
The HMI often lacks effective feedback about the complex system with which it is connected.

Recommendation-FDD-4
Manufacturers should be urged to improve the feedback by every means economically and technically feasible. Special care should be given regarding the present (over)load of the visual senses of the crew and other modalities should be considered. Area's which are specifically in need of improvement of the feedback are:

- autoflight system behaviour.
    - in particular with regards to the vertical flight path

- incorrect or illogical data entry.
- message filtering and prioritisation under abnormal and/or emergency conditions (in particular with older/hybrid types).

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7 Glossary

A

Ability	Basic characteristic or quality that an individual brings to a situation with no special training or experience. It is the capacity or power to do something. Abilities can be cognitive (e.g. written comprehension, spatial orientation), psychomotor (e.g. reaction time, arm-hand steadiness) or sensory (e.g. vision, colour discrimination, hearing sensitivity).
Ab-initio training	First stage of pilot training before initial licence qualification
Accident	Any unplanned occurrence which results in damage to property or equipment, causes injury or illness to one or more persons, and/or adversely affects an ongoing activity or function.
Aircrew	the term aircrew is used to identify the flight crew (cockpit and cabin) responsible for the execution of the operation. Aircrew includes : Cockpit crew : air crew seated in the cockpit, Flight crew : air crew qualified for piloting the aircraft, Cabin crew : air crew with specific tasks to be performed in or out the cabin.
Aptitude	Personal characteristic, predictive for the ease of acquiring proficiency in specific tasks through training.
Assessment of training effectiveness.	A general term for the processes of determining to what extent training has enabled an individual to carry out his job satisfactorily.
Automation Management	Monitoring, vigilance, crew communication, prioritization and decision making processes involving automation.
Automation philosophy	A general term for a design approach as to how, and to what extent, automation is included in a system. It is, in effect, a strategy for allocation-of-functions. (also automation strategy or automation concept)

B

Basic training	The first stage of the training process for a given task, job, occupation or group of occupations, aimed at developing the fundamental attitude/knowledge/skill behaviour pattern to specified standards. Within conversion to type training, The term basic training is used to identify, the training required to perform general handling of the aircraft and normal / emergency procedures.
Behavioural factors	Type of factors used in the ECOTTRIS incident/accident analysis relating to problems how cockpit information is perceived or the impact of over-complacent behaviour
Behavioural objective	An unambiguous statement of what a learner is expected to be able to do as a result of training. The behaviour must be both observable and measurable.

C

Coach	A person monitoring the trainee in order to provide advice, guidance, help and encouragement towards the final achievement of the required goals or operational functions.
Coaching	Systematically increasing the ability and experience of the trainee by giving him planned tasks, coupled with continuous appraisal and counselling by the trainee's supervisor.
Cockpit procedure trainer	Early form of FBT/CBT (q.v.) where drills and procedures can be practised at low cost.
Cognitive skill	Thinking: decision making, problem solving, logical thinking etc.
Communication	See "Functions"/"Flying Functions"
Competence	Ability to perform a particular skill or range of skills to a prescribed standard.
Computer based examination	Use of the computer to give and assess examinations. Usually consisting of randomly selected multiple-choice or similar type questions.
Computer based training	Computer Based Training (CBT) is a generic term for the use of computers in any part of a training system. This can be categorised into: a. Computer Managed Training (CMT). The use of computers to support aspects of training in which the trainee is not directly involved, for instance in the generation of trainee profiles and the production of test statistics. b. Computer Assisted Learning/Training (CAL/CAT). A learning process whereby the trainee interacts directly with a computer which aids the learning by means of a combination of: (1) Drill and Practice. The rehearsal of previously acquired skills and procedure (2) Tutorial. The transfer of new knowledge on an individual basis. (3) Inquiry. The extraction of information from computer data files. (4) Simulation. The representation of real working conditions to enable a trainee to acquire and practise skills, knowledge and attitudes. (5) Modelling. The construction by the trainee of a computer model to illustrate a concept or system. (6) Gaming. The use of computer games to increase the motivation of the trainee during the learning process.
Continuation training	The term Continuation Training is used to identify the training required to maintain personnel proficiency and qualification at the desired level.
Continuous assessment	A method of assessment whereby the trainee is assessed whilst performing an extended series of exercises or tasks.
Contributory factors	Also called "top level overriding factors". General factors used in the ECOTTRIS incident/accident analysis which the raters could select as being influential in the incident/accident The contributory factors distinguished in ECOTTRIS are Situational Awareness, Workload, CRM, Distractions.
Conventional cockpit/aircraft	Aircraft having none of these characteristics are categorised as conventional

Conversion training/ conversion to type training	Training for pilots of knowledge and skills appropriate to a change between different aircraft types).See “transition”
Crew	The term crew is used to identify all the personnel required to operate the aircraft.
Crew resource management / Cockpit resource management	- Definition 1 (most general): The effective use of all available resources to achieve safe and efficient flight operations (Dr. John Lauber, University of Texas). - Definition 2 (used to explain CRM skills in WP2A questionnaire): Assigning tasks and responsibilities among crew members in an optimal way. This involves work-attitude, management, co-operation and leadership. - Definition 3 (glass cockpit context, used in WP3): Includes issues such as decision making, cross checking, prioritising and the allocation of tasks between crew members *including automatic systems*.
Critical task	A task which, if not accomplished in accordance with system requirements, will have adverse effects on cost, system reliability, efficiency, effectiveness, or safety.
Cross checking	Monitoring of other crew members activities as routine.
Cross crew qualification	Multi-rating concept introduced by Airbus Industrie involving structured training concepts producing potential of mixed fleet flying.(q.v)
Cue	Sensory stimulus that contains information on the task or the environment in which the task is performed and acts as a signal in guiding the operators’ (or trainees’) behaviour.
Curriculum	A curriculum is the combination of strategies and learning methods, human and material resources, assessment procedures and work schedule employed in an attempt to fulfil the objectives of an educational institution or training unit. A curriculum is concerned both with intentions and what actually transpires in consequence, in fact with every aspect of the life and work of the institution or unit concerned. (Compare Syllabus).

D

Decay of skill	The decrement in skill in the absence of training and experience relative to the level of skill at the end of the training (complementary to retention). Compare with forgetting.
Decision Making	Ability to evaluate information in order to timely choose the optimal course of action stet, does not include the initiation of standard procedures.
Deductive reasoning	Ability to reach a conclusion that follows logically from own facts or data.
Design Philosophy	See “Automation Philosophy” and “Flightdeck Philosophy”
Discovery Method	A method of learning, best suited to the development of comprehension, which is designed to enable the learner to formulate his own understanding of a subject through the solution of a carefully designed sequence of problems. Traditional expository methods usually tell the learner exactly what it is he has to understand. It usually proceeds by presenting principles first and examples later, whereas discovery method presents selected examples first and principles only when the learner has understood. (Compare Heuristic Method).

Distance Learning	Any form of learning in which the teachers and trainees are not together in the same place. (Compare Open Learning).
Drill	An orderly, repetitive training activity intended to instill a stable specific behaviour or overlearned knowledge. Also a procedure to achieve standardised handling of a/c systems esp. in emergency situations using paper or electronic checklists.

E

ECOTTRIS	European Collaboration On Transition Training Research for Improved Safety
ECOTTRIS Incident/Accident Taxonomy	Taxonomy used in the ECOTTRIS incident/accident analysis to distinguish primary, non-primary and contributory factors in incidents and accidents. The following six categories are distinguished: 1. top level overriding factors/contributory factors 2. behavioural factors 3. operational factors 4. equipment design factors: 5. general automation issues 5. result of the incident
Entry Level	The level of knowledge and skills at the start of training
Equipment Design Factors	Type of factors used in the ECOTTRIS incident/accident analysis relating to problems with display and control design; misreading of instruments; and lack of cockpit standardisation.
Error	See Human Error
Extrinsic cues/feedback	Extrinsic (as opposed to intrinsic) cues (or feedback) are added to the simulator environment to offer extra information, but are not available in an operational environment. Extrinsic cues can be added to improve performance, or to compensate for the lack of specific intrinsic cues. Extrinsic cues that are added to the simulator environment in an attempt to enhance training effectiveness (i.e. as an instructional strategy as to attain specific training objectives) are sometimes referred to as augmenting cues.
Experiential Learning	A technique whereby active trainee involvement in the learning process exists. Through role-playing or other methods, trainees become involved in and experience the learning point in question. (Compare Discovery Method).

F

Feedback	Message to the trainee that contains information on his/her performance. Goal of feedback during training is to help the trainee to utilise a learning strategy that results in the desired changes in knowledge, skills, behaviour or attitude. To attain this goal, feedback has to be informative and motivating.
Fixed Base Simulator/Trainer	Type-specific simulator without motion or visual capability. Used in early stages of transition training.
Flight profile	A graphic vertical-plane portrayal of an aircraft flight path.

Flightdeck Philosophy	A general term for a design approach of the flightdeck. In ECOTTRIS the term "design philosophy" will often be used instead of flightdeck philosophy, to distinguish from the "operational philosophy", which is the approach taken by the airline in operating the flightdeck and its equipment.
Flight Mode	Setting of the auto-flight system. The auto-pilot has evolved into an auto-flight system, making it possible to perform many more functions compared to the traditional auto-pilot functions such as heading hold and attitude hold. Due to operational demands and developments of FMS and auto-throttle system, the number of flight modes has grown significantly. See FMA
Flight Supervision	Overall monitoring of a/c activities. Usually seen as a function of command.
Flying function	See "Functions"
Free-play	Opportunity for unstructured self-tuition using appropriate aids. See Heuristic Method, Instructive Demonstrator. Compare with Discovery Method. See also PS1™
Full Flight Simulator	Multi-axis, type-specific equipment with full visual attachment. See also "Zero Flight Time"
Functions	A set of goal directed actions that can either be executed by a human or a machine. The following flying functions are distinguished in ECOTTRIS: a. Steering implies controlling the aircraft to required parameters values of attitude, heading, altitude, track and speed. b. Navigation implies guidance of the aircraft along a predefined trajectory towards its destination. The navigation task consists of determining the present position, the optimal flight parameter values for altitude, heading, speed to arrive at the destination given the present position and by taking into account aircraft performance, cost index and meteorological information. c. Systems management implies control and monitoring of all aircraft systems, such as hydraulics, electrics, pneumatics and engines. d. Communication implies extracting and providing information from other players in the air system, such as air traffic control, airline operations centre, other aircraft and cabin staff. e. Lookout implies extracting information visually (through windows and/or instruments) of the outside world such as other aircraft, terrain, thunderstorms, runway location etc.

G

General Automation Issues	Type of factors used in the ECOTTRIS incident/accident analysis used to indicate areas such as poor mode awareness; improper use of the system.
Glass Cockpit	A "glass" cockpit is defined as having EFIS (Electronic Flight Instrument System) displays on which data are presented in a computer-generated integrated manner, an FMS and systems management that at least diagnoses system failures (EICAS, ECAM, etc.).
Glass Cockpit CRM	Crew Resource Management specifically tailored to the glass cockpit environment. See also CRM

Glass Cockpit CRM Training Scenarios	Incidents chosen from actual events for their relevance to CRM in the glass cockpit, having been de-identified and restructured with potential training solutions.

H

Head-Down Tasks	Flight deck activity requiring crew members to focus their attention away from primary tasks, such as lookout and flight path monitoring
Heuristic Method	An educational method, the principle of which is to arrange the work so that the pupil discovers laws and principles for himself, rather than learning them directly from the teacher. (See also Free-play, Instructive Demonstrator and Discovery Method).
High performance tasks	Tasks for which: a. extensive practice is required, b. substantial numbers of individuals fail to develop proficiency, and c. performance of experts is qualitatively different from that of novices.
Holistic Method	A method in which there is continual repetition of instruction or practice on the entire operation to be learnt until proficiency is reached.
Human Error	“Error is intimately bound up with the notion of intention. The term ‘error’ can only be meaningfully applied to planned actions that fail to achieve their desired consequences without the intervention of some chance or unforeseeable agency. Two basic error types were identified: slips (and lapses), where the actions do not go according to plan, and mistakes, where the plan itself is inadequate to achieve its objectives” James Reason in “Human Error” (First Published in 1990).
Hybrid Cockpit/Aircraft	Aircraft, having one or two of the following systems are categorised as hybrid: a. EFIS (Electronic Flight Instrument System) displays on which data are presented in a computer-generated integrated manner b. FMS c. systems management that at least diagnoses system failures (EICAS, ECAM, etc.) When an aircraft has all of those three systems it is defined as a (fully) “glass” cockpit”.

I

Incident	Any occurrence or near-occurrence of an (uncommon) event which is recorded.
Individual Coaching	A training method in which the instructor works directly with an individual trainee. It may involve demonstration, guided practice, questioning or any combination of these.
Inductive reasoning	Generation of an explanation for a set of specific data or instances, giving structure and meaning to the information.
Instruction Strategy	Plan/method of the instructor to achieve an instructional objective
Instructive Demonstrator	A device that replicates most of the functions of the actual equipment being trained for. Such a device allows a trainee to “play” with the various functions. See also Free-play and Heuristic Method
Interactive Exploration	A training method used in CBT where the trainee is allowed to follow his/her own path through the training material. There is extensive interaction between the trainee and the computer in the form of questions, feedback and participation.

Interactive Guided Learning	A training method used in CBT where the trainee has to follow a predetermined path through the training material. There is extensive interaction between the trainee and the computer in the form of questions, feedback and participation.
Instructional Material	The term instructional material is used to identify all items of material prepared, procured and used in a course or programmes as part of the training process.
Integrated Type Rating	Training regimen used by Lufthansa for A320 and A340 transitions.
Intelligent Tutoring System	A computer program that aims at providing knowledgeable, individualised instruction in a one-to-one interaction with a trainee.
Intrinsic cues/feedback	In simulation: cues or feedback that represent real aspects of the operational environment, allowing the operator to perceive the simulated environment in a way that approximates the operational environment.

J

Jet Orientation	Phase of training at flying college where specifically jet related topics are first addressed

K

Knowledge	Difficult to define, but generally the following building blocks are recognised: 1. Declarative knowledge: facts and concepts 2. Procedural knowledge: procedures and strategies 4. Conditional knowledge: principles and conditions

L

Lateral Navigation	also known as Area Navigation. Inertial or GPS-based equipment for determining and controlling aircraft position.
Learner Controlled Instruction	A learning/teaching system in which the learner is encouraged to make, within his capability limits, his own decisions about the method and pace at which he learns. This is also known as Learner Centred Instruction. (Compare Self-paced Learning).
Learning Environment	The setting in which learning takes place. This environment includes people, physical factors and ideas; the trainee interacts with these and any one may influence the way in which he learns.
Lecture	An informative talk or exposition to an audience, possibly using visual or other aids, but without group participation other than questions, usually at the conclusion.
Lesson	The term lesson is used to identify a segment of instruction that contains an objective, an information to be imparted to the trainee and an evaluation instrument (test). This is also a segment of instruction that covers a specific task, procedure or idea. This is also, finally, that element of a module that is designed to teach one or more training objectives. The lesson should not be confused with the lecture, which is a straight talk or exposition, but without group participation other than through questions at the conclusion.

Lesson Plan	A statement of the essential component parts of the lesson, laid out in logical, progressive and practical sequence, and indicating the techniques to be used. Also structured pre-programmed plan for simulator details.
Line Oriented Flight Training	Real-time simulator exercises carried out under simulated line-flying conditions.
Look-Out	See “Functions”/”Flying Functions”

M

Media	The term media is used to identify the delivery vehicle for presenting instructional material or the basic communication stimuli presented to a student to induce training. examples include : text, pictorial, tactile, aural, motion, colour, odor and taste.
Mental model	When people interact with the environment, other people or the artefacts of technology, they develop interpretative representations that drive their performance. These representations are mental models, relating the different parts of knowledge (declarative, procedural, conditional) and including the perceptions of task demands and task performances.
Mixed Fleet Flying	Strictly part of the Airbus Industrie CCQ concept (q.v.) where pilots operate more than one type on a routine basis but also used in WP1 and WP3 to denote dual-rating on glass and non-glass cockpits.
Mode Awareness	Awareness of the current and future status and behaviour of the automation
Monitoring	To monitor is to scan one or more displays to keep the pilot abreast of the status of both the automated and the non-automated systems. Such information is imperative for failure detection, fault diagnosis, and problem solving in general.
Multi-Sector Operations	Flights involving more than one take-off and landing

N

Navigation	See “Functions”/”Flying Functions”
Negative transfer	A condition in which previous experience causes interference with the learning of a new task, usually due to conflicting stimuli or response requirements.

O

On-the-job-Training (OJT)	Training given at the normal place of work in the attitudes, knowledge and skills appropriate to a task or job under the supervision of a coach in a live situation. It is an integral part of the overall training programme. Also known as On-job-Training.
Open Learning	The process of making training available at a time, place and pace to suit the needs of the individual.

Operational factors	Type of factors used in the ECOTTRIS incident/accident analysis relating to the effect of inexperience and power gradients in the cockpit; transition training; insufficient knowledge to operate a system; inadequate supervision of aircraft flight path; problems related to manual handling; inadequate monitoring of the situation; and insufficient knowledge of procedures.
Operational Philosophy	The approach taken by the operator (airline) in operating the flightdeck and its equipment.
Operational Training	Training given in the operational work situation and following institutional training. It comprises transition training, pre-OJT training and OJT training.

P

Part-task	A part that is part (constituent) of another task (the target task or whole task).
Part-task Training	A method in which the operation to be learnt is broken down into separate sections, each of which is taught and practised separately. When each part has been learnt, the parts are brought together and practised in appropriate combinations until the whole operation has been mastered. Not all material can be broken down in this way.
Part-task trainer	A training device which provides an individual or a group with the ability to learn only portions of the total task.
Part to whole Training	A term used to describe the approach to training whereby instruction in basic theory preceeds instruction on specific applications of the theory. (Compare Whole to Part Training). Example. A trainee technician will be expected to know the principles on which a piece of equipment works before he is taught how to repair it.
Planned Experience	Supervised practice and experience in the normal work situation, carefully planned as an integral part of the training programme to develop and consolidate the attitude/knowledge/skill behaviour pattern already acquired, on or off the job, or to provide the basis for further training in more specialised jobs.
Primary task	That task to which an individual should pay the greatest attention and which is of the most importance or the highest criticality.
Primary factor	The factor, used in ECOTTRIS incident/accident analysis, rated as being the most important.
Pre-structured Learning	A learning situation which: a. Is designed to meet clearly defined training objectives. b. Has specified entry conditions. c. By careful selection of method and treatment, is likely to satisfy the learning requirements of individual students. d. Incorporates carefully designed criteria by which the d. effectiveness of training can be reliably assessed in relation to the training objectives.
Prioritising	Ordering events in sequence

Procedure	A procedure defines what the task is, when the task is conducted, by whom it is conducted, how the task is done, what the sequence of actions is and what type of feedback is required.
PS1™ simulator	PC-based B747-400 simulation designed by H. Heinlin of Aerowinx Flight Simulations, Germany.

Q

Qualification	A formal document, or proof, which recognises that a person has completed a specialised course of study or has a particular skill.

R

Recurrent training	Regular refreshing and checking of pilot skills as defined by Regulatory bodies (e.g. JAA/CAA)
Reliability	The probability that an item will perform its intended function for a specified interval under stated conditions.
Refresher Training	Further training given in skills previously acquired but in which the individual may not currently be up to standard.
Re-learning time	The time required for a previous user to re-achieve a previous level of competence following a period of non-use of a skill or training.
Resolution Advisory	TCAS warning “RA” requiring immediate pilot action (cf. Traffic Advisory “TA”)
Result of the incident	A separate category of factors used in the ECOTTRIS incident/accident analysis to highlight the end-result of the incident/accident
Retention	The degree to which performance is maintained in the absence of training and experience relative to the performance at the end of the training (complementary to decay).
Retrofit	Addition of equipment to an a/c to update or replace existing equipment.
Role	The set of tasks performed by a human controller/operator which constitute his/her purpose in the system. Thus, recent descriptions of pilots as “system managers” or “supervisors” reflect their changing roles because of the introduction of certain types of automation.
Role Playing	A form of simulation in which trainees act out a working model of some real-world human situation. They are provided with background data and roles to play together with constraints which may change, due to outside intervention or change factors, as the simulation proceeds. Trainees work in interacting groups, experience a problem presented to them and try to solve it.
Route Training	Phase of transition training carried out on revenue flights (i.e. with passengers)Also known as IOE (Initial operating experience)

S

Scenario	Script describing a possible sequence of events and circumstances.

Self-paced Learning	A learning/teaching system whereby the learner is able to control the pace at which he works.
Seniority-based bidding system	Method of work distribution and earnings potential determined by length of service
Short-haul flying	Typically sectors of under 5hours involving a return to home base.
Situation Awareness	Integration of up-to-date information from various sources in the system into the mental model, including the sharing of mental models (primarily the significance of events) between workers in a team.
Skill	(1) A goal-directed, well-organised behaviour that is acquired through practice and performed with economy of effort (2) An organised and co-ordinated pattern of mental and/or physical activity. It is built up gradually in the course of repeated training or other experience. Skills my be described as motor, manual, intellectual etc. according to the context or the most important aspect of the skill pattern.
Skill Analysis	A detailed and systematic study of the skills needed to perform a particular task, which can lead to the formulation of a training programme. It can also refer to the determination of the cues, responses, and decision making functions involved in performing a skill.
Standard Cockpit Handling	Includes frequency selection, mode control panel setting, overhead panel settings and instrument reading and interpreting.
Standard Operating Procedures	Standard Operating Procedures (SOP's) define what the task is, when the task is conducted, by whom it is conducted, how the task is done, what the sequence action is and what type of feedback is required.
Steering	See "Functions"/"Flying Functions".
Supervisory control	Monitoring allows the exercising of supervisory control via an intelligent mediator which can be a computer or another human. There are three meta-characteristics of supervisory control: 1. The roles of the human supervisor (in time-sequential steps operating at different time scales), of which five key areas are: planning, teaching (programming the automation equipment), monitoring, intervening (taking control), learning from past experience; 2. The loci of function for each above role comprising three separate sources: sensory functions (perceiving), cognitive functions (decision making), response functions (actions); 4. The levels of behaviour for supervisory activities: in terms of Rasmussens' trichotomy these are either skill-based, rule-based or knowledge based activities.
Syllabus	In its simplest form, a syllabus is a written statement of the subjects included in a course of study. In the training field, syllabuses are often written in objective terms which specify the skills, knowledge and attitudes to be acquired by the trainees. Syllabuses might also detail the resources required for the implementation of training, the methods to be employed and the timetable to be adopted; in this form, the document somewhat resembles a description of the intended curriculum. (See also Curriculum).

Systems Management	See “Functions”/”Flying Functions”

T

Target Group	A specific group of people identified as requiring the same training.
Traffic Advisory	TCAS warning that advises crew of traffic that may become conflicting but requiring no action at present (see also Resolution Advisory).
Training	Any activity of a trainee intended to enhance/induce learning.
Training Aids	The term training aids is used to identify any item developed, procured and / or fabricated for the purpose of assisting in the conduct of training and the process of learning (models, mock-ups, interactive courseware, audio-visual aids, displays, slides, books, pictures, etc...).
Training Devices	The term training devices is used to identify hardware and software designed or modified exclusively for training purposes, involving simulation and / or stimulation in its construction or operation to demonstrate or illustrate a concept or simulate an operational circumstance or environment.
Training Effectiveness	The term training effectiveness is used to identify a measure of the quality of training defined by a training device's ability to either present or support the events of instruction. The quality of training refers to whether or not trainees achieve the training objectives.
Training Manual	A personalised manual issued to all people requiring training and containing the details of their training route map, trainee training notes and other relevant documentation.
Training Objectives	Statement of the behaviour or performance expected of a trainee as a result of a training experience, expressed in terms of the behaviour, the conditions under which it is to be exhibited, and the standards to which it will be performed or demonstrated in a predetermined quality. A training objective may be broken down into a set of lower level objectives (enabling objectives), the attainment of which implies the attainment of the training objective. (Training objectives and the procedures for assessing their attainment will usually include a subjective element, for example in the assessment of attitudes and the performance of complex skills).
Training Records	The written evidence maintained to assist in the management and validation of training.
Transfer	The change in performance of a task as a result of previous learning. Transfer may be positive, negative or absent (zero).
Transition	Conversion or movement from one aircraft type to another.
Transition Training	See Conversion Training.
Tutoring.	The act of giving additional knowledge and guidance to an individual or small group of trainees in an off-the-job, informal training situation.

Type Rating	Aircraft-type specific equipment/system related knowledge and skills leading to recognised competency. Includes knowledge and skills on flight-deck layout, systems operation, normal, abnormal and emergency operations in addition to performance and aircraft handling

U

V

Validation (of Training)	The collection and processing of information regarding the effectiveness of training so that appropriate corrective action may be taken. Validation may be subdivided into: a. Internal Validation. The process of determining whether the training has enabled the trainees to achieve the objectives specified. b. External Validation. The process of determining whether the training objectives are realistically based on current requirements of the job.
Verbal Assessment	A method of assessment whereby the trainee is verbally questioned on his/her knowledge.
Whole to Part Training	A term used to describe the approach to training whereby basic principles and theory are taught within the context of the overall function of a piece of equipment or system. Whole to Part Training is largely synonymous with Top-down Training. (Compare Part to Whole Training).

X

Y

Z

Zero Flight Time	Pilot training utilising an appropriately certificated simulator, removing requirement for trainees to fly non-revenue flights (i.e. without passengers) before commencing commercial line operations.

8 Abbreviations and Acronyms

A

A/C	Aircraft
A/S	Airspeed
A/T	Autothrottle
AAIB	Air Accidents Investigation Branch (UK)
ACARS	ARINC Communications Addressing and Reporting Systems
AD	Airworthiness Directive
ADF	Automatic Direction Finder
ADI	Attitude Director Indicator
ADREP	Aviation Data Reporting Program (ICAO)
AFCS	Automatic Flight Control System
AFDS	Autopilot Flight Director System
AFS	Automatic Flight System
AIAA	American Institute of Aeronautics and Astronautics (US)
AIP	Aeronautical Information Publication
AIREP	Air Report
ALRT	Alert
ALT	Altitude
ALT HOLD	Altitude Hold
ALT/S	Altitude Select
AOA	Angle of Attack
AOM	Aircraft Operations Manual
A/P	Auto Pilot
APU	Auxiliary Power Unit
ARINC	Aeronautical Radio Incorporated
ASC	Automatic Systems Controller (MD-11)
ASRS	Aviation Safety Reporting System
AST	Avionics System Trainer
ASTP	Advanced Simulation Training Program
A/T	Auto Throttle
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Auto Thrust System
AVT	Audio-visual Trainer (Tape and slide based training aid)

B

BALPA	British Airline Pilots' Association
BASIS	British Airways Safety Information System
BEA	British European Airways- forerunner of British Airways
BOAC	British Overseas Airways Corporation-forerunner of BA

C

CAA	Civil Aviation Authority (UK)
CAI	Computer Assisted Instruction
CAPT	Captain
CBT	Computer Based Training.
CCPT	Cabin Crew Procedures Trainer

CCQ	Cross Crew Qualification.
CDU	Control Display Unit
CFIT	Controlled Flight Into Terrain
CHIRP	Confidential Human Factors Incident Reporting Programme
COTS	Commercial-Off-The-Shelf
CPT	Cockpit Procedures Trainer
CPT	Crew Professionality Training (working group)
CRM	Crew Resource Management.
CVR	Cockpit Voice Recorder

D

DASA	Daimler-Benz Aerospace
DERA	Defence Evaluation and Research Agency
DFDR	Digital Flight Data Recorder
DLR	Deutsche Forschungsanstalt fuer Luft und Raumfahrt

E

e.g.	(exempli gratia) for example
EC	European Community
ECA	European Cockpit Association
ECAM	Electronic Centralised Aircraft Monitoring (Airbus)
ECOTTRIS	European Collaboration On Transition Training Research for Improved Safety
EFCS	Electronic Flight Control System
EFIS	Electronic Flight Instrument System
EGPWS	Enhanced Ground Proximity Warning System
EICAS	Engine Indication and Caution Advisory System (Boeing)
ERA	European Regional Airlines Association
ETOPS	Extended-Range Twin Engine Operations
EU	European Union
EUCARE	European Confidential Aviation Safety Reporting Network
EUROCAE	European Organization for Civil Aviation Electronics

F

F/C	Flight Crew
F/O	First Officer
FAA	Federal Aviation Administration (US)
FANS	Future Air Navigation System
FAR	Federal Aviation Regulation (US)
FBS/FBT	Fixed Base Simulator/Trainer.
FBW	Fly-by-wire
FCL	Flight Crew Licensing. Regulatory group within the JAA
FCP	Flight Control Panel (McDonnell Douglas)
FCS	Flight Control System
FCU	Flight Control Unit (Airbus)
FDR	Flight Data Recorder
FFRATS	Full Flight Regime Autothrottle System
FFS	Full Flight Simulator
FMA	Flight Mode Annunciator
FMC	Flight Management Computer
FMGC	Flight Management Guidance Computer
FMP	Flight Mode Panel (Fokker)
FMS	Flight Management System
FOM	Flight Operations Manual

FOTM	Flight Operations Training Manual
FPL	Flight Plan
FSF	Flight Safety Foundation (US)
FTM	Flight Training Manual

G

G/A	Go Around
G/S	Glide Slope
GPS	Global Positioning System. Satellite-based navigation system.
GPWS	Ground Proximity Warning System
GS	Ground Speed

H

HDG	Heading
HDG/S	Heading Selected
HF	Human Factors
HMI	Human Machine Interface
HSI	Horizontal Situation Indicator
HUD	Head Up Display

I

i.e.	(id est) that is
IAS	Indicated Airspeed
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFALPA	International Federation of Airline Pilot Associations
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Reference System
ITS	Integrated Training System

J

JAA/PAG	Joint Aviation Authority/Project Advisory Group (Europe)
JAR	Joint Aviation Regulations (Europe)
JAR-FCL	JAA-Flight Crew Licensing
JAR-OPS	JAstet Requirements-Operations

K

L

LBA	Luftfahrt Bundesamt
LCD	Liquid Crystal Display
LDG	Landing
LNAV	Lateral Navigation
LOFT	Line Oriented Flight Training

M

MAN	Manual
MAX	Maximum
MAX CLB	Maximum Climb
MAX DES	Maximum Descent
MCP	Mode Control Panel
MD	McDonnell Douglas Aircraft Company
MEL	Minimum Equipment List

MFD	Multi Function Display
MLG	Main Landing Gear
MLS	Microwave Landing System
Mmo	Maximum Mach Operating Speed
MOD	Modification
MON	Monitor
MSA	Minimum Safe Altitude
MSG	Message
MTBF	Mean Time Between Failure
MTOW	Maximum Takeoff Weight

N

N/A	Not Applicable
NACA	National Advisory Committee for Aeronautics (US)
NASA	National Aeronautics and Space Administration (US)
NAV	Navigation
NAVAID	Navigation Aid
NB	Non-directional Radio Beacon
ND	Navigation Display
NLR	Nationaal Lucht-en Ruimtevaartlaboratorium
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board (US)

O

OM	Outer Marker

P

PAX	Passengers
PF	Pilot Flying
PFCS	Primary Flight Control System
PFD	Primary Flight Display
PIC	Pilot In Command
PLNG	Planning
PNF	Pilot Not Flying
PROF	Profile
PW	Pratt-Whitney
PWR	Power

Q

R

RLD	Rijksluchtvaartdienst
RNAV	Area Navigation
RNG	Range
RTE	Route
RTO	Rejected Takeoff
RVR	Runway Visual Range

S

SEP	Safety Equipment Procedures (Training)
SFI	Synthetic Flight Instructor
SID	Standard Instrument Departure
SIGMET	Significant Meteorological Advisory
SIM	Simulator

SOP	Standard Operating Procedures
SPD	Speed
SPD LIM	Speed Limit
SPDBRK	Speedbrake
STAB	Stabiliser
STAR	Standard Terminal Arrival Route
STD	Standard

T

t.b.d.	to be defined
T/O	Takeoff
T/R	Thrust Reverser
TRI	Type Rating Instructor
TA	Traffic Advisory
TACAN	Tactical Air Navigation
TAS	True Airspeed
TCAS	Traffic Collision Avoidance System
THR	Thrust
TMA	Terminal Manoeuvring Area
TOC	Top of Climb
TOD	Top of Descent
TOGA	Takeoff/Go Around
TT&S	Thomson Training and Simulation

U

UTC	Co-ordinated Universal Time

V

V/S	Vertical Speed
V1	Critical Engine Failure Speed
V2	Take Off Safety Speed
VASI	Vertical Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOLMET	Meteorological information for aircraft in flight
VOR	VHF Omnidirectional Range
VORTAC	VOR and TACAN Co-Located
Vr	Rotation Speed
VSI	Vertical Speed Indicator

W

WARN	Warning
WP	Work package (ECOTTRIS)
WSAS	Wind Shear Advisory System
WX	Weather
WXR	Weather Radar

X

X/WIND	Crosswind

Y

Z

ZFT	Zero Flight Time
ZFW	Zero Fuel Weight

Appendices

Appendix A: ECOTTRIS Future transition training example

1 Introduction

This section describes a scheme for a transition training programme. It serves as an example, with improvements based on the research in the ECOTTRIS work-packages and the recommendations with regards to training.
In order to realise this example, a number of assumptions have been made, the most important is that this transition training is for first officers that will eventually fly long haul operations on an Airbus A340. Furthermore, assumptions are made with respect to the previous experience of the individual trainees, i.e. their previous type and the number of logged hours.

The basic scheme of the training programme is fairly traditional when it is compared to training offered at airlines and centres such as Airbus Training in Toulouse. The scheme is based on phases, starting with an 'initial phase', followed by an 'advanced phase', which is primarily training on a fixed base or full flight simulator and subsequently training on the aircraft ('aircraft/operational phase'). Finally, recurrent/refresher[5] training is considered as an integral part of the transition training.

The innovation in this respect is that each phase can be flexibly configured to the needs of the trainee. A trainee-centred approach has been taken in the sense that the *training objectives* of the course are based on the needs of the (individual) trainee or target group, given the operational requirements of the airline. Each phase consists of several training modules with increasingly ambitious training objectives. For example, after a module in the initial phase that familiarises the trainee with systems in isolation, a module follows to learn the interaction between systems, such as the components of the auto-flight system. On the basis of trainee data (historical data such as logged hours, particular glass experience, etc., but also progress during the course) specific training modules have to be followed and others are skipped. Thus, flexibility is offered in the selection of training activities that suits the individual The trainee-centred approach is further enhanced by allowing some flexibility in the order and duration of training modules. Finally, where possible training is made available at a time, place and pace to suit the needs of the individual. Activities can initially be skipped and inserted in a later phase of training on an individual basis.

Each training module is functionally specified according to the following topics:
- What are the *training objectives* of the module? That is: what knowledge, skills or attitudes need to be mastered in the module?
- What kind of *training method* is used to achieve the training objective? E.g. is it based on an instructor? Does it contain a hands-on exercise?

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[5] Sometimes the term continuation training is used to identify the training required to maintain personnel proficiency and qualification at the desired level.

- What kind of *training media* could be used? E.g. could we use Computer Based Training? If yes, what kind of interactivity and functionality is needed?
- What *feedback* is given to the trainee during and after an exercise? E.g. knowledge of results? Additional explanation? Immediate feedback or during debriefing?
- How is *trainee error* dealt with? What is the attitude of the instructor towards errors and is the sort of error that may occur in operation also possible during the exercises?
- How is the achievement of training objectives *assessed*? Is that for example through self assessment, by the instructor or through a written test?

It must be emphasised that the training programme presented merely is an example of how transition training could be carried out. Numerous options in terms of course structure, utilisation of training media and instruction strategies are possible. It might be that other media and methods can be used as well. Not each module is innovative. For the appropriate modules it is explained how it relates to the ECOTTRIS findings/ recommendations. Furthermore, a detailed listing/description of technical topics to be covered in the course is outside the scope of this example.

Target group

Table 1 lists some of the characteristics of a possible target group. In our example, we assume that such a group of pilots will convert to F/O for the Airbus 340 and will eventually fly for one airline.

Table 1: A mixed group of pilots, coming from different backgrounds

Rank	***Previous type***	***Hrs on previous types***	***Age***
F/O	Boeing 737-200	1500	25
F/O	Boeing 747-400	3000	30
F/O	Airbus 300	1000	26
Ex-military	Fast jet	1600	35

Assumptions about pre-requisite courses

Prior to transition training it was assumed that the pilots were trained in the following topics:

- Basic Operating Procedures at the airline
- Flight safety, confidential reporting procedures (if any)
- Multi-crew co-operation course (according to JAR-FCL 1, Section 2, Subpart F)
  - Multi-crew co-operation training should be accomplished in several phases spread over a period.

These assumption have been made in order to be able to an example training that would cater for the training needs of this mix of trainees and the specific operational requirements of the airline.

Organisation of this example

The next paragraph describes the basic scheme of the transition training programme, i.e. on the basis of the four phases and the modules in each of those phases. Paragraph 3 outlines the method for the specification of each module. It primarily presents tables for the selection of training methods, training media, feedback methods, etc. Paragraph 4 contains the specification of each training module.

2 Overview Of The Transition Course

Table 2 depicts the four main phases of transition training. The first three phases fall within a relative short timeframe, approximately one month up to 6 weeks, the while recurrent/refresher training is done repeatedly on approximately a six-monthly basis.

Recurrent/refresher training must not be seen as a separate activity but must be considered as an integral part of transition training during which all elements of skill, knowledge and attitude may need to be brushed up and brought back to the necessary competence levels. The evidence and desire from pilots operating glass cockpit aircraft (especially those flying long haul) for an improved method of maintaining proficiency is overwhelming. Course contents and training methods and media for improved recurrent/refresher training has been investigated by Green (1998).

Table 2: Transition training subdivided in four phases.

Transition Training			
Initial phase	*Advanced Phase*	*Aircraft/ Operational Phase*	*Recurrent/Refresher Phase*

Table 3 describes in more detail the modules in each of the transition training phases. The shaded modules are obligatory, i.e. should be followed by all trainees. The remainder of the modules are taken on the basis of individual training need.

In the right hand column of table 3 indication for duration are given for each module. It should be noted that these figures are suggestions or rough estimates based on current practices. Those figures have not been validated in the research.

Moreover, the modules are preferably configured such that duration of each module can be adapted to individual training need.

The choice of which modules have to be followed by whom may be determined (e.g. by the chief instructor) on the basis of the background of the pilot and/or the pilots' progress during the course (such as the exercises done during A2, A3 or A4).

If for example, the pilot has some background in working with computers, either professional or at home, and is on this basis able to grasp some of the underlying concepts of automation in glass cockpits in a later stage in the course, then he/she will not need to take up module A2 'automation for computer naïve pilots'. If not, he/she will acquire the pre-requisite know-how with some exercises with simulated 'cockpit logic'.

Likewise, if the pilot has flown a fully glass cockpit before, he/she will not need to take up the module 'introduction glass cockpit', since he/she will already be proficient with basics of glass cockpit flying such as methods for monitoring mode information, indirect mode changes (mode reversions) and principles of communication in the glass cockpit.

In the next section, the basic ingredients for specification of the modules will be explained. It must be noted that actual development of training is a specialist process outside the scope of this example and, involves more detailed training needs analysis, training programme design and training media specification. This example must be seen as a first iteration of such an effort, based on the analysis done in ECOTTRIS. This example is, therefore, not an airline-specifc implementation of the recommendation resulting from the research, but a generic approach that could be detailed further by the training department.

Table 3: Training modules per phase, shaded modules are obligatory

	Initial phase	Indication for duration [days]
No.	**Module title**	
A1	Meta-training issues	0.5
A2	Automation for computer-naïve pilots	3
A3	Introduction glass-cockpit	0.5
A4	Supernumerary line flying	1
A5	A340 Systems and handling	5
A6	Systems in isolation	5
A7	Systems in interaction	2
A8	Manual flying	1
A9	Applications with shift of focus: - Technical skills and knowledge - Procedures and checklists - Crew interaction	3
A10	Safety Equipment Procedures	1
A11	Examination	0
	Advanced Phase	
No.	**Module title**	
B1	Introduction line flying	2
B2	Basic LOFT	3
B3	Advanced LOFT	3
B4	System refresher	0.5
B5	Procedures and checklist refresher	0.5
B6	Crew interaction refresher	0.5
B7	Fulfilment of licensing requirements	
	Aircraft/ Operational Phase	
No.	**Module title**	
C1	Base flying (and type rating, if applicable)	t.b.d.
C2	Double supervision line flying	1 (2 sectors minimum)
C3	Route/ Line training and qualification	10-40 sectors
	Recurrent/Refresher Phase	
No.	**Module title**	
D1	LOS-LOFT	2 / year
D2	LOS-LOFT special skills	2 / year
D3	System refresher	0.5 / year
D4	Procedures and checklist refresher	0.5 / year
D5	Crew interaction refresher	0.5 / year
D6	LOS-LOE	0.5 / year

3 Method used for specification of the training modules

The training modules were specified on the basis of 6 characteristics that supposedly are important for the transfer of training to operational task performance and the training effectiveness of the transition training course as a whole (see table 4).

Table 4: training modules are specified on the basis of 6 characteristic factors

	Specification category	*Specification subcategory*
1	Training objectives	-
2	Specification of the training method	- Teaching method - Training device based method - Method for sequencing/repetition of material - Heuristic methods
3	Training media, aids and devices	-
4	Specification of feedback	- Intrinsic feedback - Extrinsic feedback (training feedback, knowledge of results)
5	Way of dealing with trainee error	- Feedback on errors - Attitude towards errors
6	Assessment method	-

First of all *training objectives* are specified, i.e. the skills, knowledge and attitudes to be mastered. In principle, a progressive part-task approach has been followed. However, the trainee is confronted with whole-task performance in various settings in the early stage of training, i.e. through structured observation during supernumerary line flying and generic glass cockpit training in the introduction glass cockpit module. Thus, while a part-whole approach is maintained, the idea is to provide the trainee with the appropriate framework or scaffold for application of newly acquired knowledge and skills early in the process. The training objectives reflect this general idea, although these have not been formulated down to the lowest level of detail in this example.

3.1 Specification of the training method

A suggestion for the *training method* is given on the basis of the training objectives. No specific recipe is given for the selection of a training method, but general guidelines may be used to choose the most appropriate training method for the skills, knowledge and attitudes to be acquired.

Guiding principles could be:
- apply knowledge, skills and attitudes in an operational setting;
- convert newly acquired knowledge in know-how on a continuing basis, not just at the end of the day;
- minimize the amount of lectures, most pilots will be more motivated with hands-on type of training;

- don't try to be complete in the provided material. Provide the essential basics and let people find out laws and principles for themselves, where applicable;
- provide minimal paper training material such as cue-cards and check-lists, but invest in the preparation of this training material to make sure that these contain the essential basics in a structured and ready to use manner.

In table 5 the training method is further subdivided into four categories.

Table 5: five subcategories that specify the training method/ learning environment

I: teaching method (examples)
- Lecture
- Lesson
- Demonstration
- Exercise
- Tutoring
- Individual coaching
II: training device based method (examples)
- Guided learning
- Interactive guided learning
- Interactive exploration
- Line Oriented Flight Training
III: method for sequencing/repetition of material (examples)
- Part-task training
- Part-to-whole training
- Whole-task training
- Drill
IV: heuristic methods[6] (examples)
- Discovery method (presents selected examples first and principles only when the learner has understood)
- Experiential Learning (e.g. through role playing)
- Planned Experience (supervised practice and experience in the normal work situation)

The first category is the teaching method, which is relevant when a human is the primary mediator of the subject matter.

The second category is a training device based method, which is relevant when a training device is the primary means for learning.

Third, learning may be largely affected by the method for sequencing or repetition of material. For example, to learn manual flying, it is most effective to first repeat particular manoeuvres extensively in isolation (i.e. as part-tasks) and remove the line-oriented context, while specific decision-making skills can only be trained effectively in an operational context, in which all the aspects that could affect the decision making process are available.

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[6] Educational methods, the general principle of which is to arrange the work so that the trainee discovers laws and principles for himself, rather than learning them directly from the teacher.

Fourth, in the category of heuristic methods, a few examples of such methods are given. To master the principles of the automation in the glass-cockpit effectively in the restricted timeframe of a transition training, such methods could be more effective than the more traditional presentation of material. The hands-on nature of the exercise, the intellectual stimulation of discovering laws and principles for yourself and the elements and variability of the operational context are thought to contribute to retention.

3.2 Training media, aids and devices

In table 6, examples of training media are listed that could be used in transition training.

Without further specification of those devices the distinction between the different devices can be rather vague and their definition be dependent on state-of-the-art, manufacturer of the device or even local regulations. For example, different Computer Based Training (CBT) configurations on the market may cater for a wide range of training activities, such as those listed in table 6.

For reasons of definition it can also be useful to distinguish different CBT's in terms of interactivity. Siebert (1996) orders CBT at three levels. These are:

- level 1 Purposes: page-turner / video / animation / demonstration
- level 2 Purposes: programmed text / testing / controlled response
- level 3 Purposes: system simulation / performance verification

Further specification of training media that could be used during transition training is beyond the scope of this example.

Table 6: examples of training media to be used in the training modules

Training media, aids and devices (examples)	
Audio-visual aids	
Computer Based Training	Drill and Practice Tutorial Inquiry Simulation Modelling Gaming
Intelligent Tutoring System	
Instructive Demonstrator	
Cockpit Procedure Trainer	
Fixed Base Simulator/Trainer	
Full flight simulator	

3.3 Specification of feedback

Goal of feedback during training is to help the trainee to utilise a learning strategy that results in the desired changes in knowledge, skills, behaviour or attitude. To attain this goal, feedback has to be informative and motivating.

One way to classify feedback is according to intrinsic cues/feedback and extrinsic cues/feedback. Intrinsic cues (feedback) are cues that are naturally present in the operational task environment while extrinsic cues (feedback) have been added to the (training) environment for special purposes.

An example of extrinsic feedback is verbal information on task performance/ errors. A classification of this verbal information is listed in table 7.

Table 7: feedback information,/messages knowledge of results, extrinsic cues

Messages to the trainee that contains information on his/her performance		
Type of message	***Condensed Code***	***Type of skills to apply to:***
Knowledge of **I**ncorrect **R**esponses	KIR	Effective for training of basic psychomotor skills.
Knowledge of correct and incorrect **R**esponses	KR	Effective for learning lower level intellectual skills, knowledge of facts and labels
KR with the **C**orrect **R**esponse given	KR w/CR	Effective for learning verbal and structured information, more advanced psychomotor skills and attitudes.
KR with the **C**orrect **R**esponse and an **E**xplanation given	KR w/CR & E	Effective for intellectual skills on a high level, learning verbal and structured information, more advanced psychomotor skills, attitudes.
Knowledge of **C**onsequence	KC	Effective for training of cognitive strategies, more advanced psychomotor skills and attitudes.

3.4 Way of dealing with trainee error

This subject of trainee error is closely related to the specification of feedback and the assessment method (next paragraph).

This can be thorny subject, in the sense that in complex cognitive oriented tasks, especially in more advanced training stages, where the nature of error can be correspondingly complex.

It should be taken into account in training that people use error diagnosis and recovery circumstances as a means of searching and expanding the boundaries of their knowledge and competencies.

The factors that play a role in the origin of the error are not easily recognised (not by the trainee, often not by the instructor and certainly not by 'intelligence' in training devices yet on the market). In general it has been found that people are inadequate at recognising, diagnosing and recovering from errors they make. It is not always clear when an error has been made; even when the trainee (or experienced pilot) suspects something has gone wrong, it maybe difficult to understand just what went wrong and to determine how to address it.

Errors have a much broader role in skill development than just leading the trainee astray and frustrate him/her. Errors serve as a reference for further development of knowledge and know-how, and from a purely academic (behaviourism?) point of view, errors are necessary for developing the right skill at all.

However, to use errors to increase knowledge and know-how, trainees have to be aware when they have made an error. This allows them to be able to reason about the causal factors and how to recover from the error.

Table 8: categories and examples for dealing with error in training modules

Feedback on errors
- Provide immediate feedback to allow error recovery
- Make the trainee aware that an error occurred
- Delay/ do not give feedback and let error develop
Attitude towards errors
- Errors should be handled with tolerance (e.g. in briefings)
- A subset of errors should not occur or should be recovered from with competence
- Performance should be error free. In case of error, recovery should be smooth

Thus, errors in training, i.e. incorrect responses, can be dealt with in different ways in the assessment of performance (which can be done either by the trainer or through the use of intelligent training-devices in case of relatively simple observable processes, such as with standard cockpit handling).

The issue of how to deal with trainee error in specifying a training module is herewith not resolved. For the time being we provide the following categories for how to deal with error in the training modules (see table 8).

In an early stage of learning or skill-acquisition, basic errors (lapses, mistakes) in dealing with the new material are obviously natural and acceptable and should, therefore, be handled with tolerance. Obviously, the occurrence of such basic errors in later training stages could raise doubts about trainee progress.

3.5 Assessment method

Assessment of trainee progress with respect to the training objectives is an essential aspect of each course. In the current context, assessment is intended as a means to establish further training needs of the trainee, as a means of feedback to the trainee and to provide the trainer (developer) some data on which basis the course may be improved.

Although methods of assessment have not been subject of study in ECOTTRIS, some examples for specifation of the appropriate assessment method for each module are presented in table 9. Formal assessment (examination, proficiency checks) are outside the scope of this example.

Table 9: two dimensions of the assessment method and examples

Subject of assessment
- Assessment of the end product
- Assessment of the process
Assessment technique
- Assessment by instructor / teacher
- *Observation / demonstration / checklist*
- *Written test / interview*
- Peer assessment
- Self assessment
- Automatic assessment

4

Specification of training-modules

4.1 Specification of modules in the initial phase

Table 10: Training modules in the initial phase

No.	Module title
A1	Meta-training issues
A2	Automation for computer-naïve pilots
A3	Introduction glass-cockpit
A4	Supernumerary line flying
A5	A340 Systems and handling
A6	Systems in isolation
A7	Systems in interaction
A8	Manual flying
A9	Applications with shift of focus: - Technical skills and knowledge - Procedures and checklists - Crew interaction
A10	Safety Equipment Procedures
A11	Examination

A1: Meta-training issues

Table 11 presents training module A1 “meta-training issues”, i.e. a training module about the training and its effectiveness on long term. It is a 4-hour module (including exercise) which covers such topics as the training approach of the airline, the contents and structure of the transition training programme, how the trainee is assessed, etc.

The issue of long-term training effectiveness, i.e. retention and maintenance of skills, knowledge and attitude is addressed, e.g. to indicate how relevant training information and training media can be accessed and to explain the activities initiated by the airline for improving and maintaining operational skills and knowledge, feedback from line operations in general and feedback of operational information from the A340 (A320 family) fleet in particular.

This module should be followed by all trainees.

Table 11: specification of module A1: Meta-training issues

Training objectives	At the end of this module the trainee knows: - How he/she will receive transition training; - What will be expected from him during and after the training; - What training related information is available; - How operational information is fed back to relevant departments and how it is used.
Specification of the training method	- Classroom, visit to relevant departments - Lecture / discussion in small group - Demonstration of training programme/media - Exercise: Search relevant safety material available at airline and assess
Training media, aids and devices	- Orally presented material - Paper and pencil exercise
Specification of feedback	- Questions, discussion, feedback on exercise
Role of trainee error	- N/A
Assessment method	- Peer-assessment of end-product of exercise
Issue addressed by ECOTTRIS	- According to recommendation ‘operational performance and training effectiveness’

A2: Automation for computer-naïve pilots

Table 12 specifies module A2 (suggested duration 3 days): ‘automation for computer-naive pilots’. The module is aimed at those trainees that do not have a background in computers, neither from professional experience nor from home-computer use. The module is a mix of theory and hands-on training with basic automation concepts in an aviation context. Topics to be addressed could be analogue vs. digital signal processing, analogue-to-digital conversion of signals, data-storage and bus technology. In an exercise the trainee gets hands-on experience with some characteristics of cockpit automation to illustrate concept such as ‘system opacity’, ‘system autonomy’ and ‘system protection’.

Table 12: specification of module A2: Automation for computer-naïve pilots

Training objectives	At the end of the training, the pilot has gained insight in: - Digital technology (vs. analogue technology) - Interfacing: input and output devices - Different types of User Interfaces - Information ergonomics - FMS programming basics
Specification of the training method	- Classroom lecture - Demonstration of different User Interfaces - Exercise: Programmable Logic Control – Simulation of relevant cockpit logic, exercise in pairs
Training media, aids and devices	- Programmable Logic Control program- implemented on a PC (CBT/Simulation) – graphics output - Cue-cards to get started with the CBT - Orally presented material also available on paper
Specification of feedback	- Questions and Answers, feedback on exercise (KR w/CR &E)
Role of trainee error	- Provide immediate feedback to allow error recovery - All possible errors should be handled with tolerance - Technically allow only a subset of errors to occur
Assessment method	- Written test - Automatic/self-assessment of exercise result
Issue addressed by ECOTTRIS	- Recommendation PTP-2 (emphasis on knowledge of automation) - Recommendation PTP-5 (accounting for trainee profile)

A3: Introduction glass cockpit

This module with a suggested duration of half a day aims at providing non-glass cockpit pilots with a basic appreciation for the man-machine and crew interactions in the glass cockpit and how these differ from the traditional cockpit. Topics include the airlines' general operational philosophy for glass cockpits, coping with tactical and strategic tasks/ decision making (balance between head up and head down tasks, the danger of cognitive tunnelling, fixation).

Furthermore, an exercise ('Flight Mode Annunciation Training') is suggested in which the trainees have their first exposure (in pairs) to auto-flight systems which covers the basics of glass cockpit flying including the method for monitoring mode information, indirect mode changes (mode reversions) and principles of communication in the glass cockpit. The exercise could be carried out with simplified replica of a glass cockpit. Furthermore, the module/exercise should provide some insight in system reliability and trust in automation.

Table 13: specification of module A3: Introduction glass cockpit

Training objectives	- Basic glass cockpit flying
	  - The method for monitoring mode information
	  - Indirect mode changes (mode reversions)
	  - Degradation modes
	- Communication and resource management in glass cockpits (how does this differ from conventional cockpits?)
	- Principles of decision making in automated aircraft
	- Principles for coping with real time mission changes, software incompatibilities and anomalies in automated aircraft
	- Decision making processes (reversion techniques)

Specification of the training method	1. Lecture and demonstration. 2. Exercises and hands-on training in pairs. Instructor in the role of coach. Holistic method. Briefing – debriefing.
Training media, aids and devices	- Minimal paper material (checklists, cue-card) on the subject matter - Glass cockpit CRM booklet (see ECOTTRIS) - Hands-on training: low-fidelity cockpit mock-up with a real-time simulation of a generic (auto-)flight system (FMS/CDU, AP/MCP, FMA, PFD, ATS, Controls). - No realistic tactile cues required.

Specification of feedback	- During exercise:
	  - Augmented cueing
	  - KR w/CR
	- Debriefing (KC)

Role of trainee error	- Provide immediate feedback to allow error recovery - Errors should be handled with tolerance
Assessment method	- Peer-assessment of process - Assessment by coach (observation)
Issue addressed by ECOTTRIS	- Recommendation PTP-2 : emphasis on knowledge of automation and decision making - Recommendation PTP-3: improve mental representation in both normal and non-normal operations - Recommendation PTP-4: glass cockpit CRM

A4: Supernumerary line flying

This module provides the trainee with an overall picture of the operation, which will provide the context for the previous and further modules. Central to this module is the structured observation of task execution during the operation and the assessment of task execution afterwards.

Table 14: Specification of module A4: Supernumerary line flying

Training objectives	- Familiarization with the aircraft in an operational setting
Specification of the training method	- Learning through observation, example, demonstration - Exercise: structured observation and written report (preferably pre-defined format) on technical, procedural and CRM aspects
Training media, aids and devices	- Operational environment
Specification of feedback	- Additional information verbally communicated by crew on a flexible basis
Role of trainee error	- N/A
Assessment method	- Instructor assesses exercise (which could help to establish further training needs) - Exercises are assessed in group to exchange experience
Issue addressed by ECOTTRIS	- none

A5: A340 Systems and handling

This module, outlined in table 15, covers the standard syllabus of the A340, including the Airbus 340 operational philosophy as employed at the airline (and deviations from the design philosophy), topics according to JAR-FCL 1, Section 2, Subpart F: Aeroplane structures and equipment, normal operations of systems and malfunctions, limitations (General, Engine, System, Minimum Equipment List), performance, flight planning and monitoring. As well as:

- Load, balance and servicing;
- Application of procedures and checklists (AOM);
- Emergency Procedures;
- Airborne equipment, procedures and limitations.

An important characteristics of this module is the emphasis on the differences between the A340 and the previous type of aircraft flown by the trainee. Parts of this course may be done at home (home-work).

Table 15: Specification of module A5: A340 Systems and handling

Training objectives	- Understanding the Airbus 340 operational philosophy (and deviations from the design philosophy). - Technical knowledge, understanding, insight and know-how up to required standards (JAR-FCL).
Specification of the training method	- Either classroom lectures with audio-visual aids or individual CBT with instructor help (remotely) available. - Provide information on differences with other aircraft types where appropriate. - Individual paper-and-pencil exercises or CBT-exercises. - Feedback session with expert instructors on the application of procedures and checklist.
Training media, aids and devices	- Written material or low-interactivity CBT based on AOM (tutorial tailored to educational requirements). - Could be web-based or available for home-use on CD-ROM.
Specification of feedback	- Q&A sessions. - Feedback on exercises (KR w/CR). - Discussion with experts on problems with procedures and checklists during ‘feedback’ sessions.
Role of trainee error	- According to JAR-FLC standards.
Assessment method	- Test on technical knowledge (written, oral or computer based).
Issue addressed by ECOTTRIS	- Recommendation PTP-3. - Recommendation PTP-4.

A6: Functions and Systems in isolation

This module takes a part-task approach to make the trainee proficient with the following flying functions and the associated automated systems:

- Steering and navigation (see table 16);
- Systems management (see table 17);
- Look-out (see table 18)

Table 16: Steering and navigation functions and systems

'Steering and Navigation'	
Flight parameters	
Control parameters	
The EFIS	
'Manual'	***'Automatic'***
Mode Logic	Mode Logic
Flight Mode Annunciation	Flight Mode Annunciation
Fly-by-Wire System	MCP/ AP
Controls	FMS
Envelope protections	ATS

Table 17: Systems management functions and systems

'Systems management'[7]
EICAS
Warning/caution inhibition
Automatic diagnosis
Automatic reconfiguration
Monitoring of pilot actions

Table 18: Look-out functions and systems

'Look-out'
TCAS
GPWS
WSAS
Weather Radar

For each of those 'flying' functions the training objectives are outlined in table 19.
Learning is primarily based on hands-on training functions and systems in isolation.
The vehicle for transferring know-how to the trainee is Computer Based Training (Level 3), which is structured such that interactive guided learning is followed by exploratory learning on the basis of system simulation.

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[7] monitoring and control of aircraft systems like electrics, hydraulics, pneumatics and engines

The training objectives with respect to data-representation should also cover know-how about the management of data (normal indications, warnings, alert), more specifically the structure of information, finding information, understanding and interpreting of information, prioritisation and information redundancy.

Handling (e.g. FMS programming) covers such aspects as procedural aspects of handling, differences with respect to previous type, known system quirks, unsafe habits, the possibilities for fault recognition and actions to be performed upon computer failures.

Table 19: Specification of module A6: functions and systems in isolation

Training objectives	For each ‘flying’ function: - Knowledge of the enabling systems - Understanding principles of system operation, design and differences with respect to previous type - Main components (sum up) - Structure/hierarchy (reproduce block diagrams) - Understand logic (solve problem) - Functioning (predict problem/ malfunction) - Data-representation (find, understand, prioritise, ..) - System Integration - Handling (e.g. FMS programming) - Hands-on training functions and systems in isolation

Specification of the training method	- Device-based, self-contained lessons and exercises but instructor available when needed
	- Part-to-whole training
	- Lessons for each of the flying functions
	  - Interactive guided learning
	- Exercises for each of the flying functions
	  - Interactive exploration
	- Difference-training where appropriate
	  - Inquiry

Training media, aids and devices	- Paper material (minimal material per flying function, e.g. cue-cards); - PC-based simulation, other flying functions are blocked out; - Fully realistic and interactive in terms of functionality and dialogue but no realistic tactical cues required.
Specification of feedback	- Intrinsic feedback - KR w/C & E
Role of trainee error	- Provide immediate feedback to allow error recovery; - Errors should be handled with tolerance; - Progress must be shown.
Assessment method	- Assessment of exercise result; - Additionally (automatic) test on acquired knowledge.
Issue addressed by ECOTTRIS	- Recommendation PTP-3 - Recommendation PTP-6 - Recommendation PTP-7

A7: Interaction between functions and systems

The part-tasks that have been learnt in the previous modules are in this module, outlined in table 20, exercised in a whole-task context. PC-based simulation of the A340 could serve as the learning environment in which the systems are operated in interaction. Lessons could be directed at application of procedures and checklists (AOM) and operations with different levels of automation on the basis of the airlines' operational philosophy. The second and third stage (realistic scenarios with problems and free-play) may be considered as home-work.

Table 20: Specification of module A7: Interaction between functions and systems

Training objectives	- Practically operating the systems in interaction, including aspects of CRM - Application of procedures and checklists (AOM) - Operation with different levels of automation
Specification of the training method	1. Lesson structure / artificial scenarios. - Individual (not in pairs) guided learning - Instructor available for multiple students 2. Pre-defined realistic scenarios - Based on company routes - Problems (e.g. taken from the glass cockpit CRM booklet) embedded in the scenario. - Instructor available when needed 3. Interactive exploration (free-play) - PC-based simulation available at home when desired by the trainee - Instructor available on help desk basis
Training media, aids and devices	- PC-based simulation (type specific, full functional fidelity, low perceptual fidelity, sound) - Possibly enhanced with instructional features - Cue-cards from previous module - Minimal paper material to operate the simulation
Specification of feedback	- Intrinsic feedback - (automatic) debriefing (KC)
Role of trainee error	- Delay/ do not give extrinsic feedback and let error develop
Assessment method	- Self assessment, e.g. on the basis of checklists
Issue addressed by ECOTTRIS	- Recommendation PTP-2 - Recommendation PTP-3 - Recommendation PTP-6 - Recommendation PTP-7

A8: Manual flying

This module, outlined in table 21, is obligatory for all trainees, possibly split up in multiple shorter sessions with a total duration of 1 day. It is the first experience on a full flight simulator, purely ained at gaining manual flying proficiency with the A340 in various manoeuvres.

Table 21: Specification of module A8: Manual flying

Training objectives	- Achieve proficiency with A340 on manoeuvres: e.g.take-off, climb, climbing turn, level flight, level turn, stall recovery, N-1, descending turn, descend, landing, taxi.
Specification of the training method	- Instructor based - Instructor demonstration followed by: - Progressive part-task training from simple to complex manoeuvres (each manoeuvre is a part-task) - Subsequent part tasks are added when pre-defined technical proficiency criteria are fulfilled
Training media, aids and devices	- Full flight simulator
Specification of feedback	- KR w/CR (& E), fading feedback with increased proficiency level.
Role of trainee error	- Eventually trainee is able to fly all manoeuvres in a continuous and error free fashion (all pre-defined criteria fulfilled)
Assessment method	- Instructor observation on the basis of pre-defined criteria
Issue addressed by ECOTTRIS	- Rec. PTP-8

A9: Applications

This obligatory module, outlined in table 22, is the first module in which the trainee is able to apply crew skills. The module contains of three main parts: (1) exercises in which the emphasis is on application of technical skills and knowledge (2) exercises with emphasis on procedures and checklists and (3) exercises with emphasis on crew interaction. The context is operational, but highlights events and examples with the possibility of intervention and repetition rather than being line oriented, and takes place on a fixed based simulator under direct coaching of an instructor. The type of problems presented during the scenarios provide the basis for the shift of emphasis and the assessment of crew performance. Trainees rotate through the roles of F/O and Captain.

Table 22: Specification of module A9: Applications

Training objectives	- Building confidence in applying technical skills and knowledge, formation of routine skills; - Building confidence in applying procedures and checklists, formation of rule-based / procedure based behaviour; - Applying glass cockpit CRM processes and techniques, building confidence in problem solving through effective crew communication and sharing of mental models[8] of the systems, formation of knowledge based behaviour.
Specification of the training method	- Training in pairs (crew), flight preparation, briefing, debriefing; - Scenario-based exercise, supervision/coaching by instructor, room for discussion; - First, the presented problems (non-normals and emergencies) can be solved with predominantly technical skills. Subsequently, presented with application of procedures and checklists. Finally, embedded problems (e.g. automation surprises) could only be solved through effective crew communication and use of available resources.

Training media, aids and devices	- Cockpit Procedure Trainer, Flight Training Device or Fixed Based Simulator with functional and realistic tactile, audible and force feedback environment, realistic ATC environment, basic out-of-the-window view.
	- Tailored instructor facilities:
	  - Scenario definition/start/stop/replay/change, etc.
	  - Injection of malfunctions.

Specification of feedback	- Instructor feedback on errors during scenario - Debriefing sessions in which crew performance is initially evaluated with emphasis on the technical aspects. In further sessions crew performance is evaluated with emphasis on procedural aspects and CRM aspects
Role of trainee error	- Start by providing immediate feedback to allow error recovery, gradually only make the trainee aware that an error occurred, finally delay/ do not give feedback until debriefing
Assessment method	- Informal peer assessment - Structured observation by instructor (e.g. with forms)
Issue addressed by ECOTTRIS	- Rec. PTP-3, 4

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[8] When people interact with the environment, other people or the artefacts of technology, they develop interpretative representations that drive their performance. These representations are mental models, relating the different parts of *knowledge* (declarative, procedural, conditional) and including the *perceptions* of task demands and task performances.

4.2 Specification of modules in the advanced phase

Table 23: Training modules in the advanced phase

B1	Introduction line flying
B2	Basic LOFT
B3	Advanced LOFT
B4	System refresher
B5	Procedures and checklist refresher
B6	Crew interaction refresher
B7	Fulfilment of licensing requirements

B1: Introduction line flying

This module is a familiarisation with LOFT exercises.

Table 24: Specification of module B1: Introduction line flying

Training objectives	To become task-familiar in a LOFT environment with normal operation: - Automation management - Decision making - Situational Awareness - Workload Management - Problem Solving - Communication - Co-ordination and teamwork
Specification of the training method	- Exercise and coaching by instructor - Line Oriented Flight Training - Planned Experience (scenario based)
Training media, aids and devices	- Fixed Based Simulator, video recording and playback
Specification of feedback	- Knowledge of consequence - Crewmembers are encouraged to be self critical
Role of trainee error	- Make the trainee aware that an error occurred - All possible errors should be handled with tolerance - Technically allow all possible errors to occur
Assessment method	- Assessment of the process - Self assessment/ Peer assessment
Issue addressed by ECOTTRIS	- Rec. PTP-1-4, 8

B2: Basic LOFT

This module, outlined in table 25, is aimed at increasing operational proficiency with focus on normal and non-normal operation, except those aspects that require a full flight simulator. The latter are subject of the next module (B3).

Table 25: Specification of module B2: Basic LOFT

Training objectives	Increase operational proficiency with focus on normal and non-normal operation, except those aspects that require a full flight simulator: - Automation management - Decision making - Situational Awareness - Workload Management - Problem Solving - Communication - Co-ordination and teamwork
Specification of the training method	- Line Oriented Flight Training - Planned Experience
Training media, aids and devices	- Fixed Based Simulator, video recording and playback - Possibility to play back the LOFT session on an interactive PC-based simulation during debriefing
Specification of feedback	- Knowledge of consequence - Crewmembers are encouraged to be self critical
Role of trainee error	- Make the trainee aware that an error occurred - Errors should be handled with tolerance
Assessment method	- Assessment of the process - Self assessment/ Peer assessment
Issue addressed by ECOTTRIS	- Rec. PTP-3, 4

B3: Advanced LOFT

This module, outlined in table 26, is aimed at increasing operational proficiency with focus on those aspects that require a full flight simulator.

Table 26: Specification of module B3: Advanced LOFT

Training objectives	- Focus on operational aspects that require a full flight simulator - Advanced manual flying skills (e.g. GPWS recovery, N-1) - Automation management - Decision making - Situational Awareness - Workload Management - Problem Solving - Communication - Co-ordination and teamwork - During non-normals and emergency procedures
Specification of the training method	- Exercise and Individual coaching - Line Oriented Flight Training - Planned Experience
Training media, aids and devices	- Full Flight Simulator, video recording and playback - Possibility to play back the LOFT session on an interactive PC-based simulation during debriefing
Specification of feedback	- Knowledge of consequence - Crewmembers are encouraged to be self critical
Role of trainee error	- Make the trainee aware that an error occurred - Errors should be handled with tolerance
Assessment method	- Assessment of the process - Self assessment/ Peer assessment
Issue addressed by ECOTTRIS	- Rec. PTP-1-4, 8

B4: System refresher

This module, outlined in table 27, aims at refreshing system technical knowledge. Topics to be covered include flight controls and AP, navigation and FMS, systems (e.g. Hydraulics, Pneumatics, Electric), etc.

First part of the module is in pairs on a fixed base simulator, second part of the module is on the basis of free-play with PC-based simulation, possibly at home, with help-desk available.

Table 27: Specification of module B4: System refresher

Training objectives	- Knowledge of the systems - Understanding underlying principles and logic - Functioning - Data-representation - System Integration
Specification of the training method	1) Training in pairs: a) Pre-defined realistic scenarios, based on company routes; b) Problems based on fixed scenarios; c) Instructor available. 2) Individual interactive exploration (free-play): a) Pre-defined realistic scenarios, based on company routes; b) Problems based on reported incidents; c) Courseware available at home when desired by trainee; d) Instructor available on helpdesk basis.
Training media, aids and devices	- Fixed Base Simulator - PC based simulation (type specific, full functional fidelity, enhanced with instructional features)
Specification of feedback	- Intrinsic and Extrinsic feedback - (Automatic) debriefing (KC)
Role of trainee error	- Delay / do not give extrinsic feedback and let error develop - Technically allow all possible trainee errors to occur
Assessment method	- Informal peer assessment, based on outcome of scenario - Self assessment, based on outcome of scenario
Issue addressed by ECOTTRIS	- Rec. PTP-1, 2, 7

B5: Procedures and checklist refresher

The module is outlined in table 28.

Table 28: Specification of module B5: Procedures and checklist refresher

Training objectives	- Application of technical standard operating procedures and checklists (AOM)
Specification of the training method	- Lesson structure / standard scenario's - learning in pairs - Based on company routes - Problems based on reported incidents and fixed courseware - Instructor available
Training media, aids and devices	- Cockpit Procedure Trainer or Fixed Based Simulator (see A9)
Specification of feedback	- Extrinsic feedback - (Automatic) debriefing (KC)
Role of trainee error	- Provide immediate feedback to allow error recovery - Technically allow all possible trainee errors to occur
Assessment method	- Automatic assessment - Informal peer assessment
Issue addressed by ECOTTRIS	- Rec. PTP-1 - Rec. PTP-4

B6: Crew interaction refresher

The module is outlined in table 29.

Table 29: Specification of module B6: Crew interaction refresher

Training objectives	- Cf. A9
Specification of the training method	- Cf. A9
Training media, aids and devices	- Cf. A9
Specification of feedback	- Cf. A9
Role of trainee error	- Cf. A9
Assessment method	- Cf. A9

4.3 Specification of modules in in the aircraft/operational Phase

Table 29: modules in the Aircraft/Operational phase

C1	Base flying (and type rating, if applicable)
C2	Double supervision line flying
C3	Route/ Line training and qualification

C1: Base flying and type rating

This module (see table 30) is obligatory in case of non-Zero Flight Time Transitions. A type rating follows if applicable.

Table 30: Specification of module C1: Base flying and type rating

Training objectives	- To demonstrate a minimum level of competence in aircraft handling and achieve a specified number of take-offs and landings unaided by the instructor
Specification of the training method	- Instructor based - learning by doing
Training media, aids and devices	- Full flight simulator - ZFT-rated - Aircraft A340
Specification of feedback	- Intrinsic feedback - Instructor Feedback - KR w/CR & E - KC
Role of trainee error	- A subset of errors should not occur or should be recovered from with competence; eventually, performance should be error free. In case of error, recovery should be smooth
Assessment method	- Assessment by Type Rating Examiner according to legal requirements
Issue addressed by ECOTTRIS	- Rec. PTP-8

C2: Double supervision line flying

Obligatory module – no specific comments

Table 31: Specification of module C2: Double supervision line flying

Training objectives	- N.S. (according to legal requirements before start of route training, module C3)
Specification of the training method	- Supervision by line qualified crew
Training media, aids and devices	- A340
Specification of feedback	- Intrinsic FB
Role of trainee error	- Performance should be error free. In case of error, recovery should be smooth
Assessment method	- According to legal requirements
Issue addressed by ECOTTRIS	- none

C3: Route/ Line training and qualification

Obligatory module – no specific comments

Table 32: Specification of module C3: Route/ Line training and qualification

Training objectives	- To finally apply polish and finesse
Specification of the training method	- Route / Line training (10-40 sectors)
Training media, aids and devices	
Specification of feedback	- Intrinsic FB
Role of trainee error	- Performance should be error free. In case of error, recovery should be smooth
Assessment method	- According to legal requirements
Issue addressed by ECOTTRIS	- none

4.4 Specification of modules in the recurrent/refresher phase

Table 33: modules in the recurrent/refresher phase

D1	LOS-LOFT
D2	LOS-LOFT special skills
D3	System refresher
D4	Procedures and checklist refresher
D5	Crew interaction refresher
D6	LOS-LOE

D1: LOS-LOFT

Module D1 is outlined in table 34.

Table 34: Specification of module D1: LOS-LOFT

Training objectives	- Decision making - Situational Awareness - Workload Management - Problem Solving - Communication - Co-ordination and teamwork
Specification of the training method	- Exercise and Individual coaching - Line Oriented Flight Training - Planned Experience (scenario based)
Training media, aids and devices	- Fixed Based Simulator, video recording and playback
Specification of feedback	- Knowledge of Consequences - Crewmembers are encouraged to be self critical
Role of trainee error	- Make the trainee aware that an error occurred - Errors should be handled with tolerance
Assessment method	- Assessment of the process - Self assessment/ Peer assessment
Issue addressed by ECOTTRIS	- Rec. PTP-3, 4

D1: LOS-LOFT special & manual flying skills

Module is outlined in table 35.

Table 35: Specification of module D2: LOS-LOFT special & manual flying skills

Training objectives	- Manual flying skills
	    - e.g. GPWS recoveries
	- Decision making
	- Automation management
	    - e.g. Using the more advanced functions of the FMS (managed non-precision approaches)
	- Situational Awareness
	- Workload Management
	- Problem Solving
	- Communication
	- Co-ordination and teamwork
	    - During non-normals and emergency procedures

Specification of the training method	- Exercise and Individual coaching - Line Oriented Flight Training - Planned Experience
Training media, aids and devices	- Full Mission Simulator, video recording and playback
Specification of feedback	- Knowledge of consequence - Crewmembers are encouraged to be self critical
Role of trainee error	- Make the trainee aware that an error occurred - Errors should be handled with tolerance
Assessment method	- Assessment of the process - Self assessment/ Peer assessment
Issue addressed by ECOTTRIS	- Rec. PTP-1-4, 8

D3: System refresher

Module is outlined in table 36 and cover such topics as flight controls and AP, navigation and FMS, Systems e.g. Hydraulics, Pneumatics, Electrics etc. Learning based on interactive exploration (free play), possibly in the home environment.

Table 36: Specification of module D3: System refresher

Training objectives	- Knowledge of the systems - Understanding underlying principles and logic - Functioning - Data-representation - System Integration
Specification of the training method	- Interactive exploration (free-play) - Pre-defined realistic scenarios, based on company routes - Problems based on reported incidents - Courseware available at home when desired by trainee - Instructor available on helpdesk basis
Training media, aids and devices	- PC based simulation (type specific, full functional fidelity, enhanced with instructional features)
Specification of feedback	- Intrinsic feedback - (Automatic) debriefing (KC)
Role of trainee error	- Delay / do not give extrinsic feedback and let error develop - Technically allow all possible trainee errors to occur
Assessment method	- Self assessment, based on outcome of scenario
Issue addressed by ECOTTRIS	- Rec. PTP-1, 2, 7

D4: Technical Procedures refresher

Module is outlined in table 37. For this refresher of technical Standard Operating Procedures, the same concept is applied as for D3: interactive exploration , possibly at home.

Table 37: Specification of module D4: Technical Procedures refresher

Training objectives	- Application of technical standard operating procedures
Specification of the training method	- Lesson structure / standard scenario's - Individual learning - Based on comp routes - Problems based on reported incidents - Courseware available at home when desired by trainee - Instructor available on helpdesk basis
Training media, aids and devices	- PC based simulation (type specific, full functional fidelity, enhanced with instructional features)
Specification of feedback	- Extrinsic feedback - (Automatic) debriefing (KC)
Role of trainee error	- Provide immediate feedback to allow error recovery - Technically allow all possible trainee errors to occur
Assessment method	- Automatic assessment
Issue addressed by ECOTTRIS	- Rec. PTP-1, 7

D5: Crew interaction refresher

Module is outlined in table 34. The focus is on crew interaction. Crew training is provided in a fixed base simulator.

Table 38: Specification of module D5: Crew interaction refresher

Training objectives	- Application of SOP’s and checklists (AOM) - Building confidence in problem solving through effective crew communication and sharing of mental models of the aircraft systems
Specification of the training method	- Training in pairs (crew) - Flight preparation - Briefing debriefing - Scenario based exercise - Embedded problems from incident database specifically selected on communication grounds - Room for discussion - Supervision/coaching by instructor
Training media, aids and devices	- Cockpit Procedure Trainer of Fixed Based Simulator (see A9)
Specification of feedback	- KC during debriefing: crew performance is evaluated with emphasis on CRM aspects
Role of trainee error	- Delay and do not give feedback and let error develop
Assessment method	- Peer Assessment - Structured observation by instructor
Issue addressed by ECOTTRIS	- Rec. PTP-4

Appendix B: ECOTTRIS Training Enhancements - Glass Cockpit CRM

The aim of the ECOTTRIS project is to identify the issues arising when pilots convert from conventional to high technology ‘glass’ cockpit aircraft. In addition, recommendations for transition training will be provided to assist in resolving these issues.

Previous stages of the project identified Crew Resource Management (CRM) as one of the most common contributory factors in glass cockpit incidents. Particularly it was found that issues such as monitoring, prioritisation, management of automation and verbal communication all play a very integral part in effective resource management in the glass cockpit and a breakdown in any of these can lead to problems. However, while most airlines now provide generic CRM training to all pilots, relatively few provide CRM training specifically for the glass cockpit.

This document contains a set of scenarios derived from real incidents. It aims to highlight the need for good CRM within the glass cockpit and, thus, forms an integral part of a set of transition training enhancements currently being validated by pilots and training instructors for inclusion in the final ECOTTRIS recommendations.

The incidents used in this document were selected from an extensive database which was originally compiled for an earlier phase of the ECOTTRIS project. They are considered to illustrate the most prevalent CRM related glass cockpit issues. While the situations which have been described and the information associated with each may appear fairly basic, it is important to note that these events happened in normal flight operations with fully trained crew. These scenarios are not intended to replace existing CRM training but rather to enhance it, helping to operationalise the CRM skills and show how they form a vital part of glass cockpit operation.

For pilots/training instructors:

We would be pleased if you could review this document, focusing on the identified CRM factors and potential training solutions that would be discussed in the classroom or cockpit, and then complete a questionnaire in order to let us know your views about this as an enhancement to transition training.

Your assistance and expertise are greatly appreciated.

The selected incidents have been categorised under the following headings:

Prioritisation: the organisation of tasks by their importance and urgency.

- Coping with distractions whilst still concentrating on the primary task tends to be the most frequently occurring issue in this area.

Relevant incidents: B, C, D

Situational Awareness: a knowledge of the current situation and the ability to project its status into the future, enabling decisions to be made in a timely fashion.

- Commonly, a loss of situational awareness tends to result from a breakdown in communication between the crew.

Relevant incidents: A, B, C, D, E and F

Crew communication: an open challenge and response environment and the verbalisation of system changes which result in effective monitoring and cross-checking.

- Often, it is found that crews neglect to call out their actions at critical phases of flight.

Relevant incidents: A, B, D, E and F

Automation: this encompasses the management and operation of all automated systems including the FMS.

- Crews tend to have a deficit of knowledge about both the operation and performance limitations of these systems which can lead to issues such as lack of mode awareness.

Relevant incidents: B, C and D

Information processing: the management of information, coping with its complexity, ambiguity and abundance within the glass cockpit and the selection of appropriate information.

- A typical problem occurs when trying to resolve the conflict between the information displayed on glass and conventional instrumentation.

Relevant incidents: C and F

The incidents and CRM issues highlighted in this document should not be considered as a definite solution but rather represent examples of how scenarios and courses could be constructed in enhanced glass cockpit training. Other scenarios and CRM elements could be used as appropriate for an particular training session or transition type.

Incident A

Whilst manually flying the planned departure route, the F/O was given an early turn to intercept the departure radial of the SID. The Captain attempted to reprogram the FMS to achieve this but entered the incorrect radial. The F/O was surprised that the Captain felt it necessary to reprogram the route as it had been entered prior to departure. He failed to notice the mistake. The Captain then tried to correct his mistake as he had seen the original track shift but just repeated the same error. Now, seeing that the magenta and projected white track lines were overlaid, he assumed it to be correct. Meanwhile, the F/O, having seen him input a second time, looked at his own HSI. He also saw both track lines overlaid and assumed the Captain had corrected his mistake. They both now had independently confirmed that the aircraft was on course. However, it was actually flying an incorrect route. A TCAS RA warning ensued.

Situational awareness
Both crew members made an incorrect assessment of the situation and, although confused, did not question their understanding

Crew communication
The Captain failed to state his intentions
Neither crew member cross-checked the system status

Information processing
The Captain reprogrammed the FMS at a critical flight stage instead of using raw data which was available to complete the manoeuvre

Potential training solutions

- **The need for a challenge and response environment should be emphasised to counter any possible loss of situational awareness**
- **The crews should be reminded to protect themselves against compounded errors by careful cross-checking**
- **Crew should be reminded to consider the use of raw data as an alternative to reprogramming the FMS**

Incident B

During descent, the Captain attempted to fly whilst also dealing with passenger problems. The F/O was handling VHF comms and checklists. An FMS arrival route was received and entered into FMC by the Captain. This entry caused all the previous height restrictions to drop out and, on selection of VNAV mode, the aircraft continued to descend below the cleared altitude, to the surprise of the distracted Captain. This was the first time he had attempted an FMS transition.

Prioritisation
The Captain concentrated on communicating with the company rather than flying the aircraft
The F/O was engrossed in his non-handling duties and did not notice the deviation from the intended flightpath

Situational awareness
The Captain was not aware that the previous height restrictions would drop out on entry of new arrival route
The Captain was surprised when the aircraft descended below the cleared altitude
The F/O was out of the loop

Crew communication
The Captain failed to inform F/O of the changes made to the arrival routing in the FMC
The F/O did not monitor the Captain's actions

Automation
The Captain was too reliant on the automated system

Potential training solutions

- **It must be emphasised that the handling of the aircraft has to take priority at all times**
- **Crew should be trained not to be over-reliant on automated systems**
- **Examples of FMS transitions should be practised in the simulator environment**
- **Crews should share a common understanding of the situation/systems which can be achieved by cross-monitoring in a challenge and response environment**

Incident C

The aircraft departed with the A/T inoperative. On the initial climb, with a speed restriction of 250 kts, a further climb clearance was given. Flight Level Change was selected by Captain and climb power manually applied. An ECAM message briefly distracted the crew and when the Captain returned to scan his instruments he noticed the speed was 290 kts and accelerating. He immediately disengaged the A/P, raised the nose, reduced power and regained 250 kts. The Captain stated later that he was not confident with his knowledge of the basic manual power settings.

Prioritisation
The crew allowed themselves to be distracted from the task of flying the aircraft by an ECAM message

Situational awareness
Captain did not notice the speed increasing as he was distracted by an ECAM message

Automation
Crew failed to appreciate the problem caused by manually applying full climb power in Flight Level Change
The Captain was not fully familiar with the basic manual power settings

Information processing
Captain did not brief adequately on the significance of the auto-throttle being inoperative

Potential training solutions

- **Examples of potential distractions should be demonstrated in the simulator and their effect on the prioritisation of tasks**
- **Crews should be reminded of the ramifications of system inoperability**
- **Knowledge of basic manual power settings should be regularly refreshed**

Incident D

A recently converted Captain was flying an FMS descent. Approaching a crossing restriction, the rate of descent was increased by the FMS at the last minute. The more experienced F/O stated that he did not think the aircraft would level off and suggested disconnecting the autopilot but the Captain still tried to rectify the situation by reprogramming the FMS profile. A minor altitude bust required subsequent manual recovery by the Captain.

Prioritisation
Captain should have reverted to manual flight at an earlier stage instead of attempting to reprogram the FMS

Situational awareness
Captain allowed himself to fall behind the aircraft due to lack of familiarity with the new systems

Crew communication
The F/O, who was more experienced on type, should have intervened sooner when the newly converted Captain began to lose control of the situation.

Automation
Captain was not fully conversant with the limitations of the FMS and autoflight system

Potential training solutions

- **Crews should be trained to always concentrate on flying the aircraft first**
- **More exposure to FMS programming should be given during transition training**
- **Crews should be encouraged to take more supportive roles**

Incident E

The Captain, who was handling the aircraft, was cleared for a visual approach at 20miles/ 250 kts. The A/P was disconnected, A/T disengaged and F/D switched off as the aircraft slowed towards the flap lowering speed. The Captain noticed that the A/T had re-engaged. He then disconnected it again and selected flaps and speed brakes. During this period, the F/O and Captain were not communicating with each other and it appears that the F/O was attempting to help by selecting altitudes and modes without consultation. The A/T became active once more causing the aircraft to be high on the profile. With the assistance of ATC the correct approach path was regained and a normal landing ensued.

Situational awareness
Captain was not aware of the system status
Both crew members were working independently and neither sought to find out what the other was doing

Crew communication
The Captain failed to emphasise his intention to make a fully manual approach
No communication was attempted between the crew
The F/O did not inform Captain of the mode changes he was making in his attempt to be helpful

Potential training solutions

- **The importance of communication and cross-monitoring should be emphasised**
- **Strict adherence to SOPs in relation to mode selections could be regularly restated**

Incident F

On a daylight approach to an airfield with parallel runways, with the F/O handling, the aircraft was radar positioned onto the base leg for 10 mile finals. The Captain's approach briefing had been interrupted several times by ATC. When passing 2500 feet, the aircraft was cleared for approach onto the left runway. The Captain set the go-around altitude (4500 feet) in the AFDS. It was then noticed that the autothrottles were adding power because Flight Level Change was still selected. The autothrottles were disconnected and at the same time it was noticed that the aircraft was lined up to the right of the LNAV track on the HSI, even though the crew had received a ILS localiser capture indication. The autopilot was disconnected and the F/O initiated a left turn. Seeing what appeared to be excessively steep glideslope indications, the Captain switched the flight director off and then on and re-selected Approach and Vertical Speed in an attempt to recapture the glideslope. At this point, the crew became visual and at 1000 feet realised that they were well below the correct profile for the left runway. The correct approach path was gained and the gear and flaps were selected. An uneventful landing was made. A NOTAM existed which clearly stated the possibilities of capture of the wrong ILS when approaching this runway.

Situational awareness
The crew failed to share a common understanding of the situation/system and this was accentuated by the conflicting information given by the raw versus glass data
The crew members had not self briefed about relevant NOTAMs
Neither pilot used all the resources available and thus suffered a loss of awareness

Crew communication
The F/O was not aware of the changes made to flight director modes by the Captain
The crew did not make attempts to communicate their own understanding of the situation

Information processing
The conflict between the information on the glass and traditional instruments was not addressed in a timely fashion
The briefing was carried out at an inopportune moment

Potential training solutions

- **The consequences of not clearly verbalising system changes should be emphasised to the crew members**
- **The importance of thorough briefings at unfamiliar airfields should be emphasised**
- **It should be stressed that conflicts in the information displayed must be resolved at the earliest opportunity**