PILOT HANDLING OF HIGHLY AUTOMATED AIRCRAFT
GAPAN WORKING GROUP REPORT

The Working Group was set up at the behest of the Chairmen of the Technical & Air Safety Committee and Education & Training Committee. It followed recognition that, although the introduction of highly automated aircraft has seen a significant improvement in safe and efficient operations, there remain areas of concern. The system design, the operating procedures and the training given can in some circumstances leave the crew unable to complete the task adequately and safely. The reasons for this are the subject of numerous previous and on going research projects.

The Working Group was requested to carry out a study into the pilot handling of highly automated aircraft with a view to deriving a position for the Guild. Consideration was to be given to:

1. A collation of incidents that have occurred to highly automated aircraft.
2. An appraisal of any common themes.
3. Suggestions to remedy the problems which have been encountered.
4. A review of how cockpit tasks and pilot skill requirements associated with operating highly automated aircraft have changed.
5. Proposals on how aptitude assessment and pilot selection might be adapted to take account of new skill requirements.
6. An assessment of how pilot training should be adapted to better prepare pilots for operating highly automated aircraft.
7. Any recommendations for further studies of the subject that could be funded by Trusts of the Guild.
8. A draft position statement for the Guild.

In view of the considerable amount of work elsewhere on the subject of handling of highly automated aircraft it was felt appropriate to review this at the beginning of the study.

It is not in question that the major technological advances in aviation have resulted in faster, more efficient and safer operations. This is part of a natural evolution which is to be encouraged and supported. Statistical evidence clearly shows that aviation on a mile for mile basis is the safest form of transport in the world today. Yet in spite of technology often specifically designed to assist the flight crew in the operation of the aircraft, avoidable incidents and accidents, caused or contributed to by flight deck error, still occur. Although the overall accident rate is improving, the ever increasing number of flights means that even with a reducing accident rate we still see too many events.

It is now recognised within the industry that some cockpit and system design is not user friendly. Much effort is now being made by manufacturers, regulatory authorities, operators and pilot associations to find solutions to the problems which have come to light. In particular a more human centred approach is seen to be the way forward and numerous research programmes are all paying appropriate attention to the vital Human Factors issues. Nevertheless the “Future Flight Deck” paper written some years ago by members of the Guild of Air Pilots and Air Navigators and the Royal Aeronautical Society, which highlighted many of the problems, remains as relevant today as when it was written. There is no doubt that design shortcomings contribute to pilot induced errors. However, aircraft in operation today will be with us well into the future and although we can expect design improvements we also need to find suitable ways of dealing with current deficiencies.

In taking a wide look at all the issues involved the Working Group found it useful to refer in some detail to the FAA Human Factors Team Report on the “Interfaces between Flightcrews and Modern Flight Deck Systems”. Other literature on the subject was also examined. It was apparent that in virtually all cases the conclusions followed a very similar pattern.

In the mid 1990s it was perceived that the introduction into service of new aircraft types with advanced flight deck systems had not brought about the anticipated reduction in the fatal accident rate for air transport category aircraft. Following investigations into several air transport accidents and serious incidents, in which the flight crew’s level of understanding and operation of flight deck automation was cited as either the principal or a significant contributory causal factor the Federal Aviation Administration sponsored a study by a joint FAA/NASA/JAA Human Factors Team, which also included a number of specialist technical advisors. The Team was tasked with evaluating system design, flight crew training and flight operations for potential safety deficiencies and to make recommendations for improvements. In the subsequent report one of the key findings was as follows:

> “From the evidence the Team identified issues that show vulnerabilities in **flightcrew management of automation and situation awareness.** These vulnerabilities appear to exist in varying degrees across the current fleet of transport category aircraft regardless of the manufacturer, the operator or whether accidents had occurred in a particular aeroplane type. Although the Team found specific issues

associated with particular design, operating and training philosophies, we consider the general issues and vulnerabilities to be a larger threat to safety, and the most important and most difficult to address. It is this larger pattern that serves as a barrier to needed improvements to the current level of safety and could threaten the current safety record in the future aviation environment"

It was concluded that these vulnerabilities exist because of a number of interrelated deficiencies including:

- Insufficient communication and coordination.
- Processes used for design, training and regulatory functions inadequately address **human performance** issues.
- Insufficient criteria, methods and tools for design, training and evaluation.
- Insufficient knowledge and skills, yet at the same time **"investments in necessary levels of human expertise are being reduced in response to economic pressures when two- thirds to three-quarters of all accidents have flightcrew error cited as a major factor".**
- Insufficient understanding and consideration of cultural differences in design, training, operations and evaluation.

The Team concluded: **Based on our investigations and examination of the evidence, our concerns represent more than a series of individual problems with individual, independent solutions. These concerns are highly interrelated and are evidence of aviation system problems, not just isolated human or machine errors. Therefore, we need system solutions, not just point solutions to individual problems. To treat one issue (or underlying cause) in isolation will ultimately fail to fundamentally increase the safety of aeroplane operations, and may even decrease safety.**

Recommendations for improvement covered a number of areas but came with a caution that changes should be made carefully to avoid detracting from existing safety practices. Areas for improvement were:

- Investments in people (designers, users, evaluators and researchers) – for example rebalancing flight crew training to ensure appropriate coverage of automation.
- Processes – improve how design, training, operations and certification are accomplished.
- Tools and Methods – development of new and existing tools and methods to improve the ability of aeroplane manufacturers, airworthiness authorities and operators to detect and eliminate design characteristics (or features) that create predictable errors.
- Regulatory Standards – improve certification and operating standards to match current technology and knowledge about human performance.

US/JAA CAST Initiative/CAA (SRG) Fatal Accident Review

Following publication of the Human Factors Team report two other safety related initiatives were undertaken to seek to address the principal causal factors and contributory factors in air transport accidents. The FAA formed the Commercial Aircraft Safety Team (CAST) to conduct a detailed analysis of fatal air transport accidents to identify the principal causal factors and develop a safety strategy for improvement. A parallel activity was established by the Joint Aviation Authorities (JAA), the Future Aviation Safety Team (FAST) with similar objectives. Both studies identified Controlled Flight into Terrain and Loss of Control as the two dominant groups in air transport fatal accidents up to that time, with a loss of situational awareness as a common major contributory cause. The results of these studies encouraged research into technical solutions and methods by which human system performance might be improved. The principal initiatives arising from this research have included the following:

Enhanced Ground Proximity Warning System (EGPWS) – The development of a more sophisticated EGPWS providing crews with improved early warning of a loss of separation with the ground.

Vertical Situation Displays – The development of Navigation Displays to permit the presentation of vertical situation information using GPS derived position information, combined with a topographical database providing crews with a clearer picture of the aircraft's vertical profile in relation to ground obstacles.

Flight Data Monitoring Systems (FDMS) – The evidence from British Airways, who had pioneered the use of recorded flight data to monitor flight crew performance, was that the system provided significant additional safety benefit by providing evidence that aircraft performance and flight profile conformed with Standard Operating Procedures during the more critical phases of flight such as take off and climb and approach and landing. Where predetermined performance gates were exceeded a process was available to permit the reason for these exceedances to be ascertained and appropriate follow up action taken. The development of quick access recorders and analytical tools permitted other operators to adopt similar systems with relative ease.

Crew Resource Management (CRM) and Line Orientated Flight Training (LOFT) - An important contributory factor to a loss of situational awareness has been identified as a break down of communication between crew members in difficult and stressful situations. The development of CRM and LOFT training was designed to improve pilots' awareness of the importance of managing crew resources effectively both in normal operations and particularly in the execution of recovery from emergency/non-normal situations. LOFT simulator training provided crews with the opportunity to implement CRM "best practice" in a line-operations scenario and for their performance to be evaluated and debriefed.

Line Operations Safety Audits (LOSA) – The concept of auditing line operations using a trained neutral observer was developed by the University of Texas. LOSAs were designed to identify objectively the way flight crew actually carried out the operation including non-conformance with SOPs and procedure "work-arounds". The aim was to identify reasons for such actions and to assess the possible outcomes where they might impinge on safety and to enable appropriate corrective measures to be put in place.

THE CURRENT SITUATION

Current evidence would suggest that the introduction of new technology in the form of EGPWS and Vertical Situation Monitoring has led to an improvement in flight crew situational awareness in a number of areas. This, combined with the development and adoption of continuous descent profiles for non-precision approaches, and improved crew awareness of the importance of accurately flown stabilised approaches, in some measure as a result of FDMS, would appear to have been successful in reducing the number of Controlled Flight Into Terrain type accidents.

However, notwithstanding that many airlines have reviewed their proficiency training and have introduced/improved CRM/LOFT training, air transport accidents and serious incidents have continued to occur in which the primary causal factor or a major contributory factor was related to one or more aspects of human performance.

The evidence from more recent accidents and incidents tends to suggest that it is not possible to identify a common trend, except that in a number of cases the crews would appear to have maintained a goal-orientated approach. Examples of this are where the crew have elected to continue the approach and landing in spite of being positioned to land well past the normal touchdown zone in adverse weather. This may be either as a result of not considering the risk of an unsuccessful outcome or simply rejecting that possibility.

Such situations can arise from a form of human behaviour known as "confirmation bias", in which the individual elects to accept pieces of information that confirm an earlier decision, but rejects conflicting information even when this is compelling in isolation.

An added problem relates ironically to the success and reliability of the automated systems. By definition the highly automated flight deck relieves pilots of many of the tasks of operating an aircraft. This has made possible the operation of large, highly complex aircraft by just two pilots. However, there is a danger that, in reducing workload to such an extent, pilot arousal levels may fall below that required for satisfactory performance of the flying task. While this is less likely on short haul operations the risk increases on longer sectors. There have been serious incidents where this factor may well have been present and it is undoubtedly a significant threat. It follows that measures should be introduced to ensure that crews maintain an adequate level of arousal.

A further issue stemming from the reliability of modern automation is what might be termed computer complacency. Automation has now become so reliable that crews can succumb to a temptation to take computer derived data at face value, and there is evidence that this has played a major part in a number of accidents. It is important, therefore, that pilots are trained to carry out a common sense crosscheck of data before using computer generated information. In so doing they will be alerted to the type of gross error associated with mis-programming of the FMS and other flight deck computers. Such activity would help to keep the crew "in the loop" and enhance their situational awareness.

CRM/LOFT training can be useful in improving flight crew preparedness and situational awareness. Unfortunately the random nature of threats and the often subtle effects that arise from them make it difficult to prepare a crew fully for all such eventualities in advance. However, in those cases where such situations have been handled well, invariably the crew has considered all the available options, identified a course of action and reviewed progress and options regularly until a successful outcome is achieved.

DEFFENSIVE STRATEGIES

A suggested way of raising crew awareness to the inherent risk of continuing with an inappropriate course of action and of warning them of an impending dangerous situation would be to provide guidance in the form of a simple defensive strategy, which if followed would provide a means of mitigating the risk of some of the human error traps.

In looking at the available incident and accident data it is apparent that the causal factors relating to serious accidents are fairly random in nature and not dissimilar to what has been seen in the past. Such common themes as do exist centre around mishandling of the aircraft and/or systems and poor decision making. Such decisions should be made with a clear understanding of each pilot's individual limitations. For example a Captain, new to command and new on type, faced with a complex approach on a dark, wet and windy night into an unfamiliar airfield needs to know at what point it is appropriate to discontinue and divert. Clearly only he can make that decision.

Misunderstanding and misuse of the automation may certainly play a part but **just because the crew have lost the plot there is no need for them to lose the aircraft**. Use of a set of simple defensive strategies could help to avoid reaching the point where recovery is difficult or impossible. These strategies might include:

- Radio Altimeter awareness calls – defence against most CFIT and Approach and Landing Accidents. Operators would have a simple list of appropriate aircraft flight conditions for radio altimeter call outs. These call outs can now be made automatically on most aircraft and thus do not depend on a highly stressed crew remembering to call them, which is the weak link in some current procedures. Suggested checks would include:
  1000ft MUST be level or on an approach
  500ft MUST be on approach, approaching DH
  100ft MUST be in sight of threshold (except low vis procedures)
  50ft MUST NOT be still in sight of threshold OTHERWISE GO AROUND
- Understand significance of TDZ markings (defence against overruns)
  Touchdown MUST be within that zone.
- Recognise unusual control wheel positions (Defence against loss of control due to progressive using up of autopilot authority in e.g. undetected engine failure, excess ice accumulation or fuel imbalance).
  Type limits specified for control wheel angle under autopilot control.
  NOTE. It is appreciated that this will not apply to some current aircraft.
- Recognise inappropriate attitudes for the existing flight path (Defence against loss of control and some approach and landing incidents).
  Type specific limits for positive and negative pitch attitudes as well as the usual bank limits.
- Recognise appropriate vertical speeds for flight phase e.g. – for most aircraft a Rate of Descent of 1000 fpm at 100ft should be an absolute limit (even where high rates of descent are needed to maintain the glideslope they should be reduced at that height).
- Implement drills and procedures designed to provide protection against gross errors arising in critical areas, such as may occur as a result of low arousal levels, complacency or simply limited experience on a new type. Effective cross checking clearly has a part to play in this.

These "defensive flying" strategies could no doubt be added to but the aim in principal is to add some rind on Professor James Reason's famous Emmenthal - in other words, action to break the chain of events leading to an accident.

APTITUDE ASSESSMENT AND PILOT SELECTION

It is considered that many of the traditional selection tools are still valid. Leadership and decision making skills remain very important; indeed it has been said that with the advent of CRM the problem of the autocratic Captain has been replaced by the problem of the indecisive Captain.

Aptitude testing in the Royal Air Force is under continuous review and in the light of changes in cockpit technology much work is being done to extend the breadth of the pilot aptitude test battery. Reasoning skills are expected to play a more important part in pilot training and situational awareness remains very important. Bearing in mind the increased multitasking requirement in highly automated cockpits we consider that improved testing for capacity would merit further consideration.

Most training organisations have now fully recognised the value of aptitude testing, though the tests they use do vary. It should be remembered that a validation programme for all testing is an important part of the process and that this takes time to show meaningful results.

While the modern computer generated aptitude tests can measure much of the skill potential required for success in pilot training for highly automated aircraft, it is still necessary to complete the process with an in depth interview. This must be carried out by highly competent interviewers who should be looking for evidence of potential in decision making, leadership, teamwork, common sense, stability and motivation.
Psychological tests exist which can help in this process and, if used, would of course precede the interview.

PILOT TRAINING

Training is a vital issue. There has been an assumption in some quarters that with the introduction of automation pilot training requirements could be reduced, whereas it is likely that the reverse is actually the case. There is positive evidence that some pilots are not being trained to a level that enables them to understand adequately not just how the automated systems work but how to use them to best advantage in all circumstances – and **when to discard the automatics and revert to manual control**. In some respects automated aircraft may require a higher standard of basic stick and rudder skills, if only because these skills are practiced less often and may be called upon in the most demanding emergency situations.

Regulatory authorities should keep under continuous review type rating and recurrent training requirements to assess their appropriateness in relation to changes in technology. It follows that operators must keep their own company requirements under review and be prepared to make changes where necessary.

FURTHER STUDIES

The Guild is already funding ongoing studies on the operation of highly automated aircraft through its contribution to the Flight Operations Research Centre of Excellence (FORCE) at Cranfield.
Studies which concentrate on the important Human Factors and Human Performance issues should be given priority.
Given the continuing human failings in two crew operations the safety of single pilot operations, which rely more and more on automated systems, would merit further study.

DRAFT GUILD POSITION STATEMENT

The Guild supports and encourages the continued development of automatic systems specifically designed to enhance safety and operating efficiency. Such systems must take account of all human performance issues.

The Guild recognises that equipment designers have done a great deal to address the way in which automated systems are operated by pilots. Nevertheless the Guild wishes to emphasise the need to ensure that future flight deck design must enable a competent crew to function adequately and without confusion throughout the operating regime, including abnormal conditions.

The Guild suggests that pilot selection methods be kept under constant review to accommodate the new skill requirements brought about by automation.

The Guild believes that sound and comprehensive pilot training in handling all aspects of the automated systems is vital to ensure safe and efficient operation.

The Guild is of the view that regulatory authorities and operators must remain constantly aware of continuing developments in automation and be prepared to legislate and operate accordingly.

The Guild suggests that a carefully thought out set of simple defensive strategies, such as those outlined in this paper could, even where mishandling has occurred, help crews to avoid reaching the point where recovery is difficult or impossible.

Capt. G.A.C. Gray

Working Group Members

Capt. Gil Gray
Capt. Peter Bugge
Capt. Tony Banfield
Capt. Alex Fisher
Mr. Peter Tait
Capt. Keith Wilson-Clark

November 2007