TRAINING NOTES

ON

CREW RESOURCE MANAGEMENT

GOVERNMENT OF INDIA
CIVIL AVIATION DEPARTMENT

OFFICE OF THE
DIRECTOR GENERAL OF CIVIL AVIATION
OPP. SAFDARJUNG AIRPORT, NEW DELHI – 110 003

TELEPHONE: 091-011-4635261
4644768
FAX: 091-011-4644764

TELEX: 31-74127
TELEGRAMS: AIRCIVIL

भारत सरकार
नागर विमानन विभाग
महानिदेशक नागर विमानन का कार्यालय
सफदरजंग एयरपोर्ट के सामने
नई दिल्ली - ११० ००३

Reference: No.: संख्या : AV.22024/3/2007-FID
Dated: दिनांक : 26 March 2009

ADVISORY CIRCULAR 8 of 2009
FOR AIR OPERATORS

Subject: CREW RESOURCE MANAGEMENT TRAINING

1. PURPOSE

This advisory circular (AC) presents guidelines for developing, implementing, reinforcing, and assessing Crew Resource Management (CRM) training programs for flight crew members and other personnel essential to flight safety. These programs are designed to become an integral part of training and operations. This AC presents one way, but not necessarily the only way, that CRM training may be addressed. CRM training focuses on situation awareness, communication skills, teamwork, task allocation, and decision making within a comprehensive framework of standard operating procedures (SOP's). Crew Monitoring and Cross-Checking, emphasizes the critical role of the pilot-not-flying (PNF) as a *monitor*. Monitoring is always essential, and particularly so during approach and landing when controlled flight into terrain (CFIT) accidents are most common. Accordingly, references to PNF have been changed to pilot monitoring (PM), in accordance with government and industry preference. In **appendix 3**, attempted hijack has been included as the most serious level of passenger interference requiring effective crew response, and has been identified as an appropriate CRM training topic.

2. DEFINITIONS

The human factors safety challenge and the CRM training response may be defined as follows.

a. Human Factors. Human factors is a multidisciplinary field devoted to optimizing human performance and reducing human error. It incorporates the methods and principles of the behavioural and social sciences, engineering, and physiology. Human factors is the applied science that studies people working together in concert with machines. Human factors embrace variables that influence individual performance and variables that influence team or crew performance. It is recognized that inadequate system design or inadequate operator training can contribute to individual human error that leads to system performance degradation. Further, it is recognized that inadequate design and management of crew tasks can contribute to group errors that lead to system performance degradation.

b. Crew Resource Management (CRM) Training. The application of team management concepts in the flight deck environment was initially known as Cockpit Resource Management. As CRM training programs evolved to include cabin crews, maintenance personnel and others, the phrase Crew Resource Management has been adopted.

(1) As used in this AC, CRM refers to the effective use of all available resources: human resources, hardware, and information. Other groups routinely working with the cockpit crew, who are involved in decisions required to operate a flight safely, are also essential participants in an effective CRM process. These groups include but are not limited to:

(a) Aircraft dispatchers.
(b) Cabin crews.
(c) Maintenance personnel.
(d) Air traffic controllers.

This AC, however, does not address issues of CRM training for aircraft dispatchers, maintenance personnel and air traffic controllers.

(2) CRM training is one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities. These activities include team building and maintenance, information transfer, problem solving, decision making, maintaining situation awareness, and dealing with automated systems. CRM training is comprised of three components: initial indoctrination/awareness, recurrent practice and feedback, and continual reinforcement.

3. RELATED REGULATIONS: RESERVED

4. RELATED READING MATERIAL

a. DGCA, AC: Standard Operating Procedures.

b. DGCA, AC: Communication and Coordination between Flight Crew members and Cabin crews.

c. DGCA, AC: Line Operational Simulations: Line- Oriented Flight Training, Special Purpose Operational Training.

d. Controlled Flight into Terrain, ALAR Education and Training Aid, Flight Safety Foundation and International Civil Aviation Organization (ICAO).

e. ICAO Human Factors Training Manual, Document 9683, Part 2 Chapter 2, Crew Resource Management (CRM) Training.

5. BACKGROUND

Investigations into the causes of air operator accidents have shown that human error is a contributing factor in 60 to 80 percent of all air operator incidents and accidents. Long term research has demonstrated that these events share common characteristics. Many problems encountered by flight crews have very little to do with the technical aspects of operating in a multi-person cockpit. Instead, problems are associated with poor group decision-making, ineffective communication, inadequate leadership, and poor task or resource management. Pilot training programs historically focused almost exclusively on the technical aspects of flying and on an individual pilot's performance; they did not effectively address crew management issues that are also fundamental to safe flight.

a. SOP's have been identified as a persistent element in these problems, which sometimes have led to accidents. SOP's define the shared mental model upon which good crew performance depends. Too often well-established SOP's have been unconsciously ignored by pilots and others; in other cases they have been consciously ignored. In still other cases SOP's have been inadequately developed by the operator for use by its pilots or cabin crews, or a significant SOP has been omitted altogether from an operator's training program. Initiatives to improve SOP's and adherence to those SOP's are among the top-priority safety initiatives now being implemented.

b. Industry and DGCA have come to consensus that training programs should place emphasis on the factors that influence crew coordination and the management of crew resources. The need for additional training in communication between cockpit crewmembers and cabin crews has been specifically identified.

c. Coordinated efforts by representatives from the aviation community have produced valuable recommendations for CRM training programs. While compliance with this AC is not mandatory, the recommendations that it contains provide a useful reference for understanding and applying the critical elements of CRM training.

d**.** Continuing impact of CRM training show that after initial indoctrination, significant improvements in behaviour occur regarding crew coordination and flight deck management. In programs that also provide recurrent training and practice in CRM concepts, significant changes have been recorded in flight crew performance during Line Oriented Flight Training (LOFT) and during actual flight. CRM-trained crews operate more effectively as teams and cope more effectively with non-routine situations.

e**.** Research also shows that when there is no effective reinforcement of CRM concepts by way of recurrent training, improvements in behaviours observed after initial indoctrination tend to disappear, and individuals' behaviours tend to revert to former levels.

6. THE MISSION OF CRM TRAINING

CRM training has been conceived to prevent aviation accidents by improving crew performance through better crew coordination.

7. BASIC CONCEPTS OF CRM

CRM training is based on awareness that a high degree of technical proficiency is essential for safe and efficient operations. Demonstrated mastery of CRM concepts cannot overcome a lack of proficiency. Similarly, high technical proficiency cannot guarantee safe operations in the absence of effective crew coordination.

a. Experience has shown that lasting behaviour changes in any environment cannot be achieved in a short time, even if the training is very well designed. Trainees need awareness, practice and feedback, and continuing reinforcement: in brief, time to learn behaviours that will endure. In order to be effective, CRM concepts must be permanently integrated into all aspects of training and operations.

b. While there are various useful methods in use in CRM training today, certain essentials are universal:

(1) CRM training is most effective within a training program centered on clear, comprehensive standard operating procedures.

(2) CRM training should focus on the functioning of crewmembers as teams, not as a collection of technically competent individuals.

(3) CRM training should instruct crewmembers how to behave in ways that foster crew effectiveness.

(4) CRM training should provide opportunities for crewmembers to practice the skills necessary to be effective team leaders and team members.

(5) CRM training exercises should include all crewmembers functioning in the same roles (e.g., captain, first officer, and/or flight engineer, cabin crews) that they normally perform in flight.

(6) CRM training should include effective team behaviours during normal, routine operations.

c. Good training for routine operations can have a strong positive effect on how well individuals function during times of high workload or high stress. During emergency situations, it is highly unlikely (and probably undesirable) that any crewmember would take the time to reflect upon his or her CRM training in order to choose the appropriate behaviour. But practice of desirable behaviours during times of low stress increases the likelihood that emergencies will be handled effectively.

d. Effective CRM has the following characteristics:

(1) CRM is a comprehensive system of applying human factors concepts to improve crew performance.

(2) CRM embraces all operational personnel.

(3) CRM can be blended into all forms of aircrew training.

(4) CRM concentrates on crewmembers' attitudes and behaviours and their impact on safety.

(5) CRM uses the crew as the unit of training.

(6) CRM is training that requires the active participation of all crewmembers. It provides an opportunity for individuals and crews to examine their own behaviour, and to make decisions on how to improve cockpit teamwork.

(a) LOFT sessions provide an extremely effective means of practicing CRM skills and receiving reinforcement.

(b) Audiovisual (taped) feedback during debriefing of LOFT and other training is an excellent way for flight crewmembers to assess their skills as individuals and as team members. Bulk erasure of taped sessions is

suggested to encourage candor among participants while assuring their privacy.

(c) In cases where simulators are not available, crewmembers can participate in group problem-solving activities designed to exercise CRM skills. Through taped feedback during debriefing, they can then assess the positive and negative behaviours of all crewmembers.

(d) Crew members may also participate in role-playing exercises. Such exercises permit practice in developing strategies for dealing with events or event sets, and enable analysis of behaviours shown while dealing with them. Again, taping the role-playing exercises is useful for assessment and feedback during debriefing. Crewmembers' abilities can be clearly observed in such areas as adherence to SOP's, decision-making, teamwork, and leadership.

(e) Attitude and/or personality measures can also be used to provide feedback to participants, allowing them to assess their own strengths and weaknesses.

(7) Success of a CRM training program depends upon check pilot, instructors, and Examiners who are highly qualified in the operator's SOP's and specially trained in CRM.

8. FUNDAMENTALS OF CRM TRAINING IMPLEMENTATION

Documented research programs and airline operational experience suggest that the greatest benefits be achieved by adhering to the following practices:

a. Assess the Status of the Organization before Implementation. It is important to know how widely CRM concepts are understood and practiced before designing specific training. Surveys of crewmembers, management, training, and standards personnel, observation of crews in line observations, and analysis of incident/accident reports can provide essential data for program designers.

b. Get Commitment from All Managers, Starting with Senior Managers. Operations personnel receive CRM programs much more positively when senior managers, flight operations managers, and flight standards officers conspicuously support CRM concepts and provide the necessary resources for training. Flight operations manuals and training manuals should embrace CRM concepts by providing crews with necessary policy and procedures guidance centered on clear, comprehensive SOP's. A central CRM concept is communication. It is essential that every level of management support a safety culture in which communication is promoted by encouraging appropriate questioning. It should be made perfectly clear in pilots' manuals, and in every phase of pilot training, that appropriate

questioning is encouraged and that there will be no negative repercussions for appropriate questioning of one pilot's decision or action by another pilot.

c. Customize the Training to Reflect the Nature and Needs of the Organization. Using knowledge of the state of the organization, priorities should be established for topics to be covered including special issues, such as the effects of mergers or the introduction of advanced technology aircraft. Other special issues might include topics specific to the particular type of operation, such as the specific characteristics that exist in commuter operations, in long-haul international operations or night operations. This approach increases the relevance of training for crewmembers.

d. Define the Scope of the Program and an Implementation Plan. Institute special CRM training for key personnel including check pilots instructors and Examiners. It is highly beneficial to provide training for these groups before beginning training for crewmembers. CRM training may be expanded to combine pilots, flight attendants, and aircraft dispatchers. It may also be expanded to include maintenance personnel and other company team members, as appropriate. It is also helpful to develop a long-term strategy for program implementation in other departments.

e. Communicate the Nature and Scope of the Program Before Startup. Training departments should provide crews, managers, training, and standards personnel with a preview of what the training will involve together with plans for initial and continuing training. These steps can prevent misunderstandings about the focus of the training or any aspect of its implementation.

f. Institute Quality Control Procedures. It has proved helpful to monitor the delivery of training and to determine areas where training can be strengthened. Monitoring can be initiated by providing special training to program instructors (often called facilitators) in using surveys to collect systematic feedback from participants in the training.

9. COMPONENTS OF CRM TRAINING

The topics outlined below have been identified as critical components of effective CRM training. They do not represent a fixed sequence of phases, each with a beginning and an end. Ideally, each component is continually renewed at every stage of training.

a. Initial Indoctrination/Awareness.

(1) Indoctrination/awareness typically consists of classroom presentations and focuses on communications and decision making, interpersonal relations, crew coordination, leadership, and adherence to SOP's, among others. In this

component of CRM training, the concepts are developed, defined, and related to the safety of line operations. This component also provides a common conceptual framework and a common vocabulary for identifying crew coordination problems.

(2) Indoctrination/awareness can be accomplished by a combination of training methods. Lectures, audiovisual presentations, discussion groups, role-playing exercises, computer-based instruction, and videotaped examples of good and poor team behaviour are commonly used methods.

(3) Initiating indoctrination/awareness training requires the development of a curriculum that addresses CRM skills that have been demonstrated to influence crew performance. To be most effective, the curriculum should define the concepts involved and relate them directly to operational issues that crews encounter. Many organizations have found it useful to survey crewmembers. Survey data have helped identify embedded attitudes regarding crew coordination and cockpit management. The data have also helped to identify operational problems and to prioritize training issues.

(4) Effective indoctrination/awareness training increases understanding of CRM concepts. That understanding, in turn, often influences individual behaviour favorably regarding human factors issues. Often the training also suggests more effective communication practices.

(5) It is important to recognize that classroom instruction alone does not fundamentally alter crewmember attitudes over the long term. The indoctrination/awareness training should be regarded as a necessary first step towards effective crew performance training.

b. Recurrent Practice and Feedback.

(1) CRM training must be included as a regular part of the recurrent training requirement. Recurrent CRM training should include classroom or briefing room refresher training to review and amplify CRM components, followed by practice and feedback exercises such as LOFT, preferably with taped feedback; or a suitable substitute such as role-playing in a flight training device and taped feedback. It is recommended that these recurrent CRM exercises take place with a full crew, each member operating in his or her normal crew position. A complete crew should always be scheduled, and every attempt should be made to maintain crew integrity. Recurrent training LOFT that includes CRM should be conducted with current line crews, and preferably not with instructors or check pilot as stand-ins.

(2) Recurrent training with performance feedback allows participants to practice newly improved CRM skills and to receive feedback on their effectiveness. Feedback has its greatest impact when it comes from self-critique and from peers, together with guidance from a facilitator with special training in assessment and debriefing techniques.

(3) The most effective feedback refers to the coordination concepts identified in Indoctrination/ Awareness training or in recurrent training. Effective feedback relates to specific behaviours. Practice and feedback are best accomplished through the use of simulators or training devices and videotape. Taped feedback, with the guidance of a facilitator, is particularly effective because it allows participants to view themselves from a third person perspective. This view is especially compelling in that strengths and weaknesses are captured on tape and vividly displayed. Stop action, replay, and slow motion are some of the playback features available during debriefing. Behavioural patterns and individual work styles are easily seen, and appropriate adjustments are often self-evident.

c. Continuing Reinforcement.

(1) No matter how effective each curriculum segment is (the classroom, the role-playing exercises, the LOFT, or the feedback); one-time exposures are simply not sufficient. The attitudes and norms that contribute to ineffective crew coordination may have developed over a crewmember's lifetime. It is unrealistic to expect a short training program to reverse years of habits. To be maximally effective, CRM should be embedded in every stage of training, and CRM concepts should be stressed in line operations as well.

(2) CRM should become an inseparable part of the organization's culture.

(3) There is a common tendency to think of CRM as training only for captains. This notion misses the essence of the CRM training mission: the prevention of crew-related accidents. CRM training works best in the context of the entire crew. Training exercises are most effective if all crewmembers work together and learn together. In the past, much of the flight crew training has been segmented by crew position. This segmentation has been effective for meeting certain training needs such as seat dependent technical training and upgrade training, but segmentation is not appropriate for most CRM training.

(4) Reinforcement can be accomplished in many areas. Training such as joint cabin and cockpit crew training in security can deal with many human factors issues. . Joint training with aircraft dispatchers, maintenance personnel, and gate agents can also reinforce CRM concepts, and is recommended.

10. SUGGESTED CURRICULUM TOPICS

The topics outlined below have been included in many current CRM programs. Specific content of training and organization of topics should reflect an organization's unique culture and specific needs. **Appendix 1** offers a set of behavioural markers fitting

subtopics within each topic cluster. Sometimes overlapping, these markers may be helpful in curriculum development and in LOFT design. **Appendix 3** gives additional CRM training topics.

a. Communications Processes and Decision Behaviour. This topic includes internal and external influences on interpersonal communications. External factors include communication barriers such as rank, age, gender, and organizational culture, including the identification of inadequate SOP's. Internal factors include speaking skills, listening skills and decision-making skills, conflict resolution techniques, and the use of appropriate assertiveness and advocacy. The importance of clear and unambiguous communication must be stressed in all training activities involving pilots and cabin crews. The greater one's concern in flight-related matters, the greater is the need for clear communication. More specific subtopics include the following:

(1) Briefings. Training in addressing both operational and interpersonal issues, and training in establishing and maintaining open communications. Briefings should reaffirm established SOP's and should address the most threatening safety and security situations.

(2) Inquiry/Advocacy/Assertion. Training in the potential benefits of crewmembers advocating the course of action that they feel is best, even though it may involve conflict with others.

(3) Crew Self-Critique (Decisions and Actions). Illustrating the value of review, feedback, and critique focusing on the process and the people involved. One of the best techniques for reinforcing effective human factors practices is careful debriefing of activities, highlighting the processes that were followed. Additionally, it is essential that each crewmember be able to recognize good and bad communications, and effective and ineffective team behaviour.

(4) Conflict Resolution. Demonstrating effective techniques of resolving disagreements among crewmembers in interpreting information or in proposing courses of action. Demonstrating effective techniques for maintaining open communication while dealing with conflict.

(5) Communications and Decision-making. Demonstrating effective techniques of seeking and evaluating information. Showing the influence of biases and other cognitive factors on decision quality. There are benefits in providing crews with operational models of this group decision process. Crews may refer to these models to make good choices in situations when information is incomplete or contradictory.

b. Team Building and Maintenance. This topic includes interpersonal relationships and practices. Effective leadership/follower-ship and interpersonal relationships

are key concepts to be stressed. Curricula can also include recognizing and dealing with diverse personalities and operating styles. Subtopics include:

(1) Leadership/Follower-ship/Concern for Task. Showing the benefits of the practice of effective leadership through coordinating activities and maintaining proper balance between respecting authority and practicing assertiveness. Staying centered on the goals of safe and efficient operations.

(2) Interpersonal Relationships/Group Climate. Demonstrating the usefulness of showing sensitivity to other crewmembers' personalities and styles. Emphasizing the value of maintaining a friendly, relaxed, and supportive yet task oriented tone in the cockpit and aircraft cabin. The importance of recognizing symptoms of fatigue and stress, and taking appropriate action.

(3) Workload Management and Situation Awareness. Stressing the importance of maintaining awareness of the operational environment and anticipating contingencies. Instruction may address practices (for example, vigilance, planning and time management, prioritizing tasks, and avoiding distractions) that result in higher levels of situation awareness. The following operational practices may be included:

(a) Preparation/Planning/Vigilance. Issues include methods to improve monitoring and accomplishing required tasks, asking for and responding to new information, and preparing in advance for required activities.

(b) Workload Distribution/Distraction Avoidance. Issues involve proper allocation of tasks to individuals, avoidance of work overloads in self and in others, prioritization of tasks during periods of high workload, and preventing nonessential factors from distracting attention from adherence to SOP's, particularly those relating to critical tasks.

(4) Individual Factors/Stress Reduction. Training in this area may include describing and demonstrating individual characteristics that can influence crew effectiveness. Research has shown that many crewmembers are unfamiliar with the negative effects of stress and fatigue on individual cognitive functions and team performance. Training may include a review of scientific evidence on fatigue and stress and their effects on performance. The content may include specific effects of fatigue and stress in potential emergency situations. The effects of personal and interpersonal problems and the increased importance of effective interpersonal communications under stressful conditions may also be addressed. Training may also include familiarization with various countermeasures for coping with stressors. Additional curriculum topics may include examination of personality and motivation characteristics, self-assessment of personal style, and identifying cognitive factors that influence perception and decision-making.

11. SPECIALIZED TRAINING IN CRM CONCEPTS

As CRM programs have matured, some organizations have found it beneficial to develop and implement additional courses dealing with issues specific to their operations.

a. After all current crewmembers have completed the Initial Indoctrination/Awareness component of CRM training; arrangements are needed to provide newly hired crew members with the same material. A number of organizations have modified their CRM initial courses for inclusion as part of the initial training and qualification for new hire crewmembers.

b. Training for upgrading to captain provides an opportunity for specialized training that deals with the human factors aspects of command. Such training can be incorporated in the upgrade process.

c. Training involving communications and the use of automation can be developed for crews operating aircraft with advanced technology cockpits, or for crews transitioning into them.

12. ASSESSMENT OF CRM TRAINING PROGRAMS

It is vital that each program be assessed to determine if it is achieving its goals. Each organization should have a systematic assessment program. Assessment should track the effects of the training program so that critical topics for recurrent training may be identified and continuous improvements may be made in all other respects. Assessment of the training program should include observation of the training process by program administrators and self-reports by participants using standard survey methods.

a. The emphasis in this assessment process should be on crew performance. The essential areas of CRM-related assessment include communications processes, decision-making, team building and maintenance, workload management, and situation awareness, always in balance with traditional technical proficiency. An additional function of such assessment is to determine the impact of CRM training and organization-wide trends in crew performance.

b. For optimal assessment, data on corporate management and crewmembers' behaviour should be collected before CRM indoctrination and again at intervals after the last component of CRM training, to determine both initial and enduring effects of the program. The goal should be to obtain an accurate picture of the organization's significant corporate personality traits before formal adoption of CRM training, and to continue to monitor those traits after implementation.

c. Reinforcement and feedback are essential to effective CRM training programs. Crewmembers must receive continual reinforcement to sustain CRM concepts. Effective reinforcement depends upon usable feedback to crewmembers on their CRM practices and on their technical performance.

d. Usable feedback requires consistent assessment. Crewmembers and those involved in training and evaluation should be able to recognize effective and ineffective CRM behaviours. CRM concepts should be critiqued during briefing/debriefing phases of all training and checking events.

e. To summarize, the assessment program should:

(1) Measure and track the organization's corporate culture as it is reflected in attitudes and norms.

(2) Identify topics needing emphasis within the CRM program.

(3) Ensure that all check pilot, supervisors, and instructors are well prepared and standardized.

13. THE CRITICAL ROLE OF CHECK PILOT AND INSTRUCTORS

a. The success of any CRM training program ultimately depends on the skills of the people who administer the training and measure its effects. CRM instructors, check pilots, supervisors, and course designers must be skilled in all areas related to the practice and assessment of CRM. These skills comprise an additional level to those associated with traditional flight instruction and checking.

b. Gaining proficiency and confidence in CRM instruction, observation, and measurement requires special training for instructors, supervisors, and check pilots in many CRM training processes. Among those processes are role-playing simulations, systematic crew-centered observation, administering LOFT programs, and providing usable feedback to crews.

c. Instructors, supervisors, and check pilots also require special training in order to calibrate and standardize their own skills.

d. Instructors, supervisors, and check pilot should use every available opportunity to emphasize the importance of crew coordination skills. The best results occur when the crews examine their own behaviour with the assistance of a trained instructor who can point out both positive and negative CRM performance. Whenever highly effective examples of crew coordination are observed, it is vital that these positive behaviours be discussed and reinforced. Debriefing and critiquing skills are important tools for instructors, supervisors, and check pilots. (Behavioural markers of effective LOFT debriefings are shown in **Appendix 2**.)

e. Feedback from instructors, supervisors, and check pilot is most effective when it refers to the concepts that are covered in the initial indoctrination/awareness training. The best feedback refers to instances of specific behaviour, rather than behaviour in general.

14. EVOLVING CONCEPTS OF CRM

a. Crew Monitoring and Cross-Checking. Several studies of crew performance, incidents, and accidents have identified inadequate flight crew monitoring and cross-checking as a problem for aviation safety. Therefore, to ensure the highest levels of safety, each flight crewmember must carefully monitor the aircraft's flight path and systems and actively cross-check the actions of other crewmembers. Effective monitoring and cross-checking can be the last line of defense that prevents an accident because detecting an error or unsafe situation may break the chain of events leading to an accident. This monitoring function is always essential, and particularly so during approach and landing when controlled flight into terrain (CFIT) accidents are most common.

b. Joint CRM Training. More and more carriers are discovering the value of revising CRM training to reach various employee groups, and sometimes to combine those groups during training. Their objective is to improve the effectiveness and safety of the entire operations team as a working system.

(1) Terrorist activities have caused many restrictions on flight deck access. Among those affected are air traffic controllers, for whom revised access procedures are being studied. Pilots may observe operations in air traffic facilities under certain conditions, and are encouraged to do so. Using real air traffic controllers during LOFT sessions has also proven beneficial to pilots and participating controllers.
(2) Aircraft dispatchers have functioned jointly with flight captains for years. They have been allowed, indeed encouraged to observe cockpit operations from the cockpit jumpseat as part of their initial and recurrent qualification. Some carriers have included day trips to their aircraft dispatchers' offices to provide the pilot insight into the other side of the joint function scheme. Those trips have commonly been part of the special training offered to first-time captains. Now, internationally, real-life aircraft dispatchers are increasingly being used in LOFT sessions. The training experience gained by the pilot and the dispatcher during LOFT is considered the logical extension of earlier training methods, providing interactivity where CRM (and DRM, see Advisory Circular) principles are applied and discussed.
(3) Training of first-time captains has often included day trips to line maintainence offices where a pilot and a maintainence engineers can meet face to face. Some carriers have included maintenance personnel in LOFT sessions. Dedicated CRM training courses for maintenance personnel have also been found extremely useful.
(4) Even broader cross-pollination of CRM concepts has been considered, using other groups such as passenger service agents, mid- and upper-level managers, and special crisis teams like hijack and bomb-threat teams
(5) Cabin crew are probably the most obvious of the groups other than pilots who may profit from CRM training. Joint CRM training for pilots and cabin crews has been practiced for years. One fruitful activity in joint training has been that each group learns of the other group's training in shared issues. The joint training has revealed inconsistencies between training for one group and training on the same topic for another group. Examples of shared issues include delays, the use of

personal electronic devices in the cabin, and evacuation and ditching. When inconsistencies are identified between the contents of pilots' manuals and cabin crews' manuals, for instance, or between widely held ideas or attitudes in those two populations, those inconsistencies are brought out into the open and often resolved. Other specific topics for joint training include:

(a) Pre-flight briefings.

(b) Post incident/accident procedures.

(c) Sterile cockpit procedures.

(d) Notification procedures pre-takeoff and pre-landing.

(e) Procedures for turbulence and other weather.

(f) Security procedures.

(g) Passenger-handling procedures.

(h) In-flight medical problems.

(i) Smoke/fire procedures.

(j) Passenger-related regulations such as those relating to smoking, exit row seating, and carry-on baggage.

(k) Authority of the pilot in command.

(2) CRM principles are made more relevant for pilots and cabin crews by treating those principles in a familiar job-related context. Furthermore, each group should benefit from concurrent training in CRM that is complemented by usable knowledge of the other's job.

(3) Communication and coordination problems between cockpit crewmembers and cabin crew continue to challenge air operators and the DGCA. Other measures with positive CRM training value for flight crews are being considered, such as:

(a) Requiring cockpit observation flights for all new-hire cabin crews.

(b) Providing experienced flight crewmembers to teach new-hire cabin crew orientation classes.

b. Error Management. It is now understood that pilot errors cannot be entirely eliminated. It is important, therefore, that pilots develop

appropriate error management skills and procedures. It is certainly desirable to prevent as many errors as possible, but since they cannot all be prevented, detection and recovery from errors should be addressed in training. Evaluation of pilots should also consider error management (error prevention, detection, and recovery). Evaluation should recognize that since not all errors can be prevented, it is important that errors be managed properly.

c. Advanced Crew Resource Management. CRM performance requirements or procedures need to be integrated into the SOP's of air operators. Specific callouts, checks, and guidance need to be included in normal checklists, quick-reference handbooks, abnormal/emergency procedures, manuals, and job aids. This integration captures CRM principles into explicit procedures used by flight crews.

d. Culture Issues. While individuals and even teams of individuals may perform well under many conditions, they are subject to the influence of at least three cultures - the professional cultures of the individuals themselves, the cultures of their organizations, and the national cultures surrounding the individuals and their organizations. If not recognized and addressed, factors related to culture may degrade crew performance. Hence, effective CRM training must address culture issues as appropriate in each training population.

15. SUMMARY

Effective Crew Resource Management begins in initial training; it is strengthened by recurrent practice and feedback; and it is sustained by continuing reinforcement that is part of the corporate culture and embedded in every stage of training.

Sd/-
Capt A. Kathpalia
Flight Operations Inspector

APPENDIX 1

CREW PERFORMANCE MARKER CLUSTERS

Italicized Markers apply to Advanced Technology Flight Decks. These behavioural markers are provided to assist organizations in program and curriculum development and to serve as guidelines for feedback. They are not presented as a checklist for evaluating individual crewmembers.

1. COMMUNICATIONS PROCESSES AND DECISION BEHAVIOUR CLUSTER

a. Briefings. An effective briefing is interesting and thorough. It addresses coordination, planning, and problems. Although briefings are primarily a captain's responsibility, other crewmembers may add significantly to planning and should be encouraged to do so.

Behavioural Markers.

(1) The Captain's briefing establishes an environment for open/interactive communications (for example, the captain calls for questions or comments, answers questions directly, listens with patience, does not interrupt or "talk over," does not rush through the briefing, and makes eye contact as appropriate).

(2) The briefing is interactive and emphasizes the importance of questions, critique, and the offering of information.

(3) The briefing establishes a "team concept" (for example, the captain uses "we" language, encourages all to participate and to help with the flight).

(4) The briefing covers pertinent safety and operational issues.

(5) The briefing identifies potential problems such as weather, delays, and abnormal system operations.

(6) The briefing provides guidelines for crew actions centered on SOP's; division of labor and crew workload is addressed.

(7) The briefing includes the cabin crew as part of the team.

(8) The briefing sets expectations for handling deviations from standard operating procedures.

(9) The briefing establishes guidelines for the operation of automated systems (for example, when systems will be disabled; which programming actions must be verbalized and acknowledged).

(10) The briefing specifies pilot flying and pilot not flying duties and responsibilities with regard to automated systems.

b. Inquiry/Advocacy/Assertion. These behaviours relate to crewmembers' promoting the course of action that they feel is best, even when it involves conflict with others.

Behavioural Markers.

(1) Crew members speak up and state their information with appropriate persistence until there is some clear resolution.

(2) "Challenge and response" environment is developed.

(3) Questions are encouraged and are answered openly and non-defensively.

(4) Crew members are encouraged to question the actions and decisions of others.

(5) Crew members seek help from others when necessary.

(6) Crew members question status and programming of automated systems to

confirm situation awareness.

c. Crew Self-Critique Regarding Decisions and Actions. These behaviours relate to the effectiveness of a group and/or an individual crewmember in critique and debriefing. Areas covered should include the product, the process, and the people involved. Critique may occur during an activity, and/or after completing it.

Behavioural Markers.

(1) Critique occurs at appropriate times, which may be times of low or high workload.

(2) Critique deals with positive as well as negative aspects of crew performance.

(3) Critique involves the whole crew interactively.

(4) Critique makes a positive learning experience. Feedback is specific, objective, usable, and constructively given.

(5) Critique is accepted objectively and non-defensively.

d. Communications/Decisions. These behaviours relate to free and open communication. They reflect the extent to which crewmembers provide necessary information at the appropriate time (for example, initiating checklists and alerting others to developing problems). Active participation in the decision making process is encouraged. Decisions are clearly communicated and acknowledged. Questioning of actions and decisions is considered routine.

Behavioural Markers.

(1) Operational decisions are clearly stated to other crewmembers.

(2) Crew members acknowledge their understanding of decisions.

(3) "Bottom lines" for safety are established and communicated.

(4) The "big picture" and the game plan are shared within the team, including cabin crews and others as appropriate.

(5) Crew members are encouraged to state their own ideas, opinions, and recommendations.

(6) Efforts are made to provide an atmosphere that invites open and free communications.

(7) Initial entries and changed entries to automated systems are verbalized and

acknowledged.

2. TEAM BUILDING AND MAINTENANCE CLUSTER

a. Leadership Follower-ship/Concern for Tasks. These behaviours relate to appropriate leadership and follower-ship. They reflect the extent to which the crew is concerned with the effective accomplishment of tasks.

Behavioural Markers.

(1) All available resources are used to accomplish the job at hand.

(2) Flight deck activities are coordinated to establish an acceptable balance between respect for authority and the appropriate practice of assertiveness.

(3) Actions are decisive when the situation requires.

(4) A desire to achieve the most effective operation possible is clearly demonstrated.

(5) The need to adhere to standard operating practices is recognized.

(6) Group climate appropriate to the operational situation is continually monitored and adjusted (for example, social conversation may occur during low workload, but not high).

(7) Effects of stress and fatigue on performance are recognized.

(8) Time available for the task is well managed.

(9) Demands on resources posed by operation of automated systems are recognized and managed.

(10) When programming demands could reduce situation awareness or create work overloads, levels of automation are reduced appropriately.

b. Interpersonal Relationships/Group Climate. These behaviours relate to the quality of interpersonal relationships and the pervasive climate of the flight deck.

Behavioural Markers.

(1) Crew members remain calm under stressful conditions.

(2) Crew members show sensitivity and ability to adapt to the personalities of others.

(3) Crew members recognize symptoms of psychological stress and fatigue in self and in others (for example, recognizes when he/she is experiencing "tunnel vision" and seeks help from the team; or notes when a crew member is not communicating and draws him/her back into the team).

(4) "Tone" in the cockpit is friendly, relaxed, and supportive.

(5) During times of low communication, crewmembers check in with others to see how they are doing.

3. WORKLOAD MANAGEMENT AND SITUATION AWARENESS CLUSTER

a. Preparation/Planning/Vigilance. These behaviours relate to crews' anticipating contingencies and the various actions that may be required. Excellent crews are always "ahead of the curve" and generally seem relaxed. They devote appropriate attention to required tasks and respond without undue delay to new developments.

(They may engage in casual social conversation during periods of low workload and not necessarily diminish their vigilance.)

Behavioural Markers.

(1) Demonstrating and expressing situation awareness; for example, the “model” of what is happening is shared within the crew.

(2) Active monitoring of all instruments and communications and sharing relevant information with the rest of the crew.

(3) Monitoring weather and traffic and sharing relevant information with the rest of the crew.

(4) Avoiding “tunnel vision” caused by stress; for example, stating or asking for the “big picture.”

(5) Being aware of factors such as stress that can degrade vigilance and watching for performance degradation in other crewmembers.

(6) Staying “ahead of the curve” in preparing for planned situations or contingencies, so that situation awareness and adherence to SOP's are assured.

(7) Ensuring that cockpit and cabin crewmembers are aware of plans.

(8) Including all appropriate crewmembers in the planning process.

(9) Allowing enough time before maneuvers for programming of the flight management computer.

(10) Ensuring that all crewmembers are aware of initial entries and changed entries in the flight management system.

b. Workload Distributed/Distractions Avoided. These behaviours relate to time and workload management. They reflect how well the crew manages to prioritize tasks, share the workload, and avoid being distracted from essential activities.

Behavioural Markers.

(1) Crew members speak up when they recognize work overloads in themselves or in others.

(2) Tasks are distributed in ways that maximize efficiency.

(3) Workload distribution is clearly communicated and acknowledged.

(4) Non operational factors such as social interaction are not allowed to interfere with duties.

(5) Task priorities are clearly communicated.

(6) Secondary operational tasks (for example, dealing with passenger needs and communications with the company) are prioritized so as to allow sufficient resources for primary flight duties.

(7) Potential distractions posed by automated systems are anticipated, and appropriate preventive action is taken, including reducing or disengaging automated features as appropriate.

APPENDIX 2. LOFT DEBRIEFING PERFORMANCE INDICATORS

The effective line-oriented flight training (LOFT) facilitator leads the flight crew through a self-critique of their own behavior and of their crew performance during the simulation. The debriefing and crew analysis include both technical and crew resource management (CRM) discussion topics. Positive points of crew performance are discussed as well as those needing improvement. At the conclusion of the session, key learning points are summarized covering all participants, including the instructor. A strong sense of training accomplishment and learning is taken away from the session.

The following performance markers may be used to evaluate the LOFT facilitator's performance in the debrief/critique phase of LOFT.

a. Actively states the debriefing and critique agenda and solicits topics from the crew on items that they would like to cover; sets time limits.

b. Asks the crew for their appraisal of the mission overall.

c. States his/her own perceptions of the LOFT while guarding against making the crew defensive. Comments are as objective as possible and focus on performance.

d. Shows appropriate incidents using videotape of the LOFT session, including examples of technical and CRM performance, and selects tape segments for discussion illustrating behaviors that feature the crew performance markers.

e. Effectively blends technical and CRM feedback in the debriefing; does not preach to the crew, but does not omit items worthy of crew discussion.

f. Is patient, and is constructive in probing into key areas where improvement is needed.

g. Ensures that all crewmembers participate in the discussion, and effectively draws out quiet or hostile crewmembers.

h. Provides a clear summary of key learning points.

i. Asks the crew for specific feedback on his/her performance.

j. Is effective in both technical and CRM debriefing.

APPENDIX 3

APPROPRIATE CRM TRAINING TOPICS

1. BACKGROUND INFORMATION

a. Findings coming from accident investigations have consistently pointed to the fact that human errors contribute to most aviation accidents.

b. Research findings suggest that CRM training can result in significant improvements in flight crew performance. CRM training is seen as an effective approach to reducing human errors and increasing aviation safety.

c. Aviation safety information is readily available through the World Wide Web. Many websites contain valuable source materials and reference materials that may be helpful in developing CRM training. Websites commonly link to other websites containing related material. Some of the aviation related websites are included in the following:

(1) International Civil Aviation Organization (ICAO)
http://www.icao.org

(2) National Aeronautics and Space Administration (NASA),
http://www.nasa.gov

(3) National Transportation Safety Board (NTSB),
http://www.ntsb.gov

(4) Federal Aviation Administration (FAA),
http://www.faa.gov.

(5) Civil Aviation Safety Authority of Australia (CASA)
http://www.casa.gov.au

(6) Transport Canada
http://www.tc.gc.ca/en.menu.htm

2. TRAINING TOPICS, PRINCIPLES, AND TECHNIQUES

It is recommended that CRM training include the curriculum topics described in paragraph 10 of this advisory circular (AC) and the following topics, principles, and techniques:

a. Theory and practice in using communication, decision-making, and team building techniques and skills.

b. Theory and practice in using proper supervision techniques, i.e., captains working with first officers.

c. Theory and practice in selecting and using interventions needed to correct flying errors made by either pilot, especially during critical phases of flight. These interventions may include, but not be limited to, communication, assertion, decision-making, risk assessment, and situation awareness skills.

d. During Line Operational Simulation training, information, and practice of non flying pilot functions, i.e., monitoring and challenging pilot functions, and monitoring and challenging errors made by other crew members for flight engineers, first officers, and captains. Training will alert flight crews of hazards caused by tactical decision errors, which are actually errors of omission. Practice in monitoring, challenging, and mitigating errors, especially during taxi operations, should be included. These skills are important to minimize procedural errors that may occur as a result of inadequately performed checklists.

e. Training for check pilot in methods that can be used to enhance the monitoring and challenging functions of both captains and first officers. The check pilot training should include the message that appropriate questioning among pilots is a desirable CRM behaviour and part of the corporate safety culture; further, that such questioning is encouraged, and that there will be no negative repercussions for appropriate questioning of one pilot's decision or action by another pilot.

f. Training for new first officers in performing the pilot not flying duties in monitoring and challenging of errors made by the pilot flying. Training should stress that appropriate questioning is encouraged as a desirable CRM behaviour, and that there will be no negative repercussions for appropriate questioning of one pilot's decision or action by another pilot.

g. Training for captains in giving and receiving challenges of errors. Training should stress that appropriate questioning is encouraged as a desirable CRM behaviour, and that there will be no negative repercussions for appropriate questioning of one pilot's decision or action by another pilot.

h. Factual information about the detrimental effects of fatigue and strategies for avoiding and countering its effects.

i. Training for crewmembers, which identify conditions in which additional vigilance is required, such as holding in icing or near convective activity. Training should emphasize the need for maximum situation awareness and the appropriateness of sterile cockpit discipline, regardless of altitude.

j. Training that identifies appropriate levels of automation to promote situation awareness and effective management of workload.

k. Training for crewmembers in appropriate responses when passengers intimidate, abuse, or interfere with crewmember performance of safety duties. Training should address crew coordination and actions, which might defuse the situation.

l. Line-oriented flight training (LOFT) or special purpose operational training (SPOT) for cockpit crewmembers, which addresses appropriate responses to the effects of pitot-static system anomalies, such as a blocked pitot tube. Emphasis should be on situation awareness, inquiry/advocacy/assertion, and crew coordination, when flight instruments act abnormally.

n. LOFT or SPOT (Special Purpose Operational Training) for cockpit crew members that contain a controlled flight into terrain scenario. Emphasis should be on prevention through effective communication and decision behaviour. The importance of immediate, decisive, and correct response to a ground proximity warning should also be addressed.

o. Training for pilots in recognizing cues that indicate lack or loss of situation awareness in themselves and in others, and training in countermeasures to restore that awareness. Training should emphasize the importance of recognizing each pilot's relative experience level, experience in specific duty positions, preparation level, planning level, normal communication style and level, overload state, and fatigue state. Pilots should assess these characteristics actively and continuously, in their fellow crewmembers and in themselves. Training should also emphasize the importance that improper procedures, adverse weather, and abnormal or malfunctioning equipment may have in reducing situation awareness.

p. Training in communication of time management information among flight crew and cabin crewmembers during an emergency. Training should stress that the senior or lead cabin crew can effectively brief other cabin crews and passengers and prepare the cabin only if the time available in the emergency is clearly communicated by the flight crew. Other information elements that are vital in effective time management are the nature of the emergency and any special instructions relating to the planned course of action.

3. APPROPRIATE TRAINING INTERVENTIONS

a. The most effective CRM training involves active participation of all crewmembers. LOFT sessions give each crewmember opportunities to practice CRM skills through interactions with other crewmembers. If the training is videotaped, feedback based on crewmembers' actual behaviour, during the LOFT, provides valuable documentation for the LOFT debrief.

b. CRM training can be presented using a combination of the following training interventions:

(1) Operator in-house courses.
(2) Training center courses.
(3) Special Purpose Operational Training.
(4) LOFT sessions.
(5) Computer Based Training courses.

APPENDIX 3

LOFT DEBRIEFING PERFORMANCE INDICATORS

The effective Line-Oriented Flight Training (LOFT) facilitator leads the flight crew through a self-critique of their own behaviour and of their crew performance during the simulation. The debriefing and crew analysis include both technical and CRM discussion topics. Positive points of crew performance are discussed, as well as those needing improvement. At the conclusion of the session, key learning points are summarized covering all participants, including the instructor. A strong sense of training accomplishment and learning is taken away from the session.

1. The following performance markers may be used to evaluate the LOFT facilitator's performance in the debrief/critique phase of LOFT.

a. Actively states the debriefing and critique agenda and solicits topics from the crew on items that they would like to cover; sets time limits.

b. Asks the crew for their appraisal of the mission overall.

c. States his/her own perceptions of the LOFT while guarding against making the crew defensive. Comments are as objective as possible and focus on performance.

d. Shows appropriate incidents using videotape of the LOFT session, including examples of technical and CRM performance, and selects tape segments for discussion illustrating behaviours that feature the crew performance markers.

e. Effectively blends technical and CRM feedback in the debriefing; does not preach to the crew, but does not omit items worthy of crew discussion.

f. Is patient and is constructive in probing into key areas where improvement is needed.

g. Ensures that all crewmembers participate in the discussion, and effectively draws out quiet or hostile crewmembers.

h. Provides a clear summary of key learning points.

i. Asks the crew for specific feedback on his/her performance.

j. Is effective in both technical and CRM debriefing.

Crew Resource Management

CRM is a management system that makes optimum use of all available resources - equipment, procedures and people – to promote safety and enhance the efficiency of flight operations.

Back ground

Having found that the primary cause of the majority of aviation accidents was human error, and that the main problems were Failures of interpersonal communication, Leadership, and Decision making in the cockpit, a training pattern called CRM was evolved, to put together cohesively all the above to prevent such errors. CRM or Crew Resource Management or Cockpit Resource Management training is focused on improving flight safety.

The CRM thus evolved was found effective and so, different types of industries & organisations have successfully adapted to a variety of CRM models, all based on the same basic concepts and principles.

Overview

CRM training encompasses a wide range of

1. Knowledge,
2. Skills and
3. Attitudes including
    - Communications,
    - Situational awareness,
    - Problem solving,
    - Decision making, and
    - Teamwork; together with the entire attendant sub-disciplines which each of these areas entails.
    -

CRM is concerned not so much with the technical knowledge and skills required to fly and operate an aircraft but rather with the cognitive and interpersonal skills needed to manage the flight within an organised aviation system.

In this context,

1. Cognitive skills are defined as the mental processes used
   - for gaining and maintaining situational awareness,
   - for solving problems and
   - for taking decisions.
2. Interpersonal skills are regarded as communications and a range of behavioural activities associated with teamwork.
3. In aviation, as in other walks of life, these skill areas often overlap with each other, and they also overlap with the required technical skills.

Furthermore, they are not confined to multi-crew aircraft, but also relate to single pilot operations, which invariably need to interface with other aircraft and with various ground support agencies in order to complete their missions successfully.

CRM training for crew has been introduced and developed by aviation organisations including major airlines and military aviation worldwide.

CRM training is now a mandated requirement for commercial pilots working under most regulatory bodies worldwide, including the FAA (U.S.), JAA (Europe) and DGCA (India).

Communication

CRM fosters a climate or culture where the freedom to respectfully question authority is encouraged.

It recognizes that a discrepancy between what is happening and what should be happening is often the first indicator that an error is occurring. This is a delicate subject for many organisations, especially ones with traditional hierarchies, so appropriate communication techniques must be taught to supervisors and their subordinates, so that supervisors understand that the questioning of authority need not be threatening, and subordinates understand the correct way to question orders.

Cockpit voice recordings of various air disasters tragically reveal first officers and flight engineers attempting to bring critical information to the captain's attention in an indirect and ineffective way. By the time the captain understood what was being said, it was too late to avert the disaster. A CRM expert named Todd Bishop developed a five-step assertive statement process that encompasses inquiry and advocacy steps:

Opening or attention getter –

Address the individual. "Hey Chief," or "Captain Smith," or "Bob," or whatever name or title will get the person's attention.

State your concern –

State what you see in a direct manner while owning your emotions about it. "We're low on fuel," or "I think we might have fire extension into the roof structure."

State the problem as you see it –

"I don't think we have enough fuel to fly around this storm system," or "This building has a lightweight steel truss roof. I'm worried that it might collapse."

State a solution –

"Let's divert to another airport and refuel," or "I think we should pull some tiles and take a look with the thermal imaging camera before we commit crews inside."

Obtain agreement (or buy-in) –

"Does that sound good to you, Captain?"

There are difficult skills to master, as they require a chance in interpersonal dynamics and organisational culture.

NB: - The term **cognition** is used in different ways by different disciplines.

In psychology, it refers to an information processing in view of an individual's psychological functions.

The meaning of cognition also link it to the development of

- concepts;
- individual minds,
- groups,
- Organisations, and even larger coalitions of entities, can be modelled as societies which cooperate to form concepts.

The autonomous elements of each 'society' would have the opportunity to demonstrate emergent behaviour in the face of some crisis or opportunity.

Cognition can also be interpreted as "understanding and trying to make sense of the world"

cognitive

1: of, relating to, being, or involving conscious intellectual activity (as thinking, reasoning, or remembering) <*cognitive* impairment>

cog·ni·tive·ly *adverb*

2: based on or capable of being reduced to empirical factual knowledge —

CRM Trg in Commercial Aviation

Changes in the nature of CRM training in commercial aviation

1. **Its shift from Cockpit to Crew Resource Management.**
2. **Validation of the impact of CRM.**
3. **Limitations of CRM, including lack of cross-cultural generality.**
4. **An overarching framework that stresses *error management* to increase acceptance of CRM concepts.**

Since the NASA meeting, the focus of CRM training has changed to reflect this evolution and on the problems that have been encountered in changing the attitudes and behaviour of flight crews.

The term 'evolution' is used in describing the changes in CRM over the last two decades. Evolution, as formally defined refers to the process of growth and development, a description that aptly fits CRM. Similarly, the very different content and foci of programmes called CRM justifies defining them in terms of generations (although temporally a CRM generation is closer to that of the Drosophila than the human). The focus is on the most recent approaches to CRM training.

1st GENERATION COCKPIT RESOURCE MANAGEMENT

The first comprehensive U.S. CRM program was initiated by United Airlines in 1981. The training was developed with the aid of consultants who had developed training programs for corporations trying to enhance managerial effectiveness. The United program was modelled closely on a form of training called the 'Managerial Grid' developed by psychologists Robert Blake and Jane Mouton (Blake & Mouton, 1964). The training was conducted in an intensive seminar setting and included participants' diagnoses of their own managerial style. Other airline programs in this era also drew heavily on management training approaches. These programs emphasized changing

individual styles and correcting deficiencies in individual behaviour such as a lack of assertiveness by juniors and authoritarian behaviour by captains. Supporting this emphasis, the National Transportation Safety Board (NTSB, 1979) had singled out the captain's failure to accept input from junior crewmembers (a characteristic sometimes referred to as the "Wrong Stuff") and a lack of assertiveness by the flight engineer as causal factors in a United Airlines crash in 1978. First generation courses were psychological in nature, with a heavy focus on psychological testing and general concepts such as leadership. They advocated general strategies of interpersonal behaviour without providing clear definitions of appropriate behaviour in the cockpit. Many employed games and exercises unrelated to aviation to illustrate concepts. It was also recognized that CRM training should not be a single experience in a pilot's career and annual recurrent training in CRM became part of the program. In addition to classroom training, some programs also included full mission simulator training *(Line Oriented Flight Training)* where crews could practice interpersonal skills without jeopardy. However, despite overall acceptance, many of these courses encountered resistance from some pilots, who denounced them as "charm school" or attempts to manipulate their personalities.

2nd GENERATION *CREW* RESOURCE MANAGEMENT

NASA held another workshop for the industry in 1986. By this time a growing number of airlines in the U.S. and around the world had initiated CRM training and many reported on their programmes. One of the conclusions drawn by working groups at the meeting was that explicit (or stand alone) CRM training would ultimately disappear as a separate component of training when it became imbedded in the fabric of flight training and flight operations.

At the same time, a new generation of CRM courses was beginning to emerge. Accompanying a change in the emphasis of training to focus on cockpit group dynamics was a change in name from *Cockpit* to *Crew Resource Management.* The new courses, typified by the program developed by Delta Airlines dealt with more specific aviation concepts related to flight operations and became more modular as well as more team oriented in nature. Basic training conducted in intensive seminars included concepts such as team building, briefing strategies, situation awareness and stress management. Specific modules addressed decision making strategies and breaking the chain of errors that can result in catastrophe. Many of the courses still relied on exercises unrelated to aviation to

demonstrate concepts. Participant acceptance of these courses was generally greater than that of the first generation, but criticisms that the training was heavily laced with "psycho-babble" continued (for example, the notion of 'synergy' in group dynamics was often condemned by participants as representative of irrelevant jargon). Second generation courses continue to be used in the U.S. and other parts of the world.

3rd GENERATION CRM - BROADENING THE SCOPE

In the early 1990s, CRM training began to proceed down multiple paths. Training began to reflect characteristics of the aviation system in which crews must function, including the multiple input factors such as organizational culture that determine safety. At the same time, efforts began to integrate CRM with technical training and to focus on specific skills and behaviours that pilots could use to function more effectively. Several airlines began to include modules addressing CRM issues in the use of flightdeck automation. Programmes also began to address the recognition and assessment of human factors issues. Accompanying this was the initiation of advanced training in CRM for check airmen and others responsible for training, reinforcement, and evaluation of technical and human factors.

Accompanying this greater specificity in training for flight crews, CRM began to be extended to other groups within airlines such as flight attendants, dispatchers & maintenance personnel. Many airlines began to conduct joint cockpit-cabin CRM training. A number of carriers also developed specialized CRM training for new captains to focus on the leadership role that accompanies command.

While third generation courses filled a recognized need to extend the concept of the flight *crew,* they may also have had the unintended consequence of diluting the original focus on the reduction of human error.

4th GENERATION CRM – INTEGRATION AND PROCEDURALISATION

The Federal Aviation Administration introduced a major change in the training and qualification of flight crews in 1990 with the initiation of its *Advanced Qualification Program*. AQP is a voluntary program that allows air carriers to develop innovative training that fits the needs of the specific organization. In exchange for this greater flexibility in training, carriers are required to provide both CRM and LOFT for all flight

crews and to integrate CRM concepts into technical training. Most of the major U.S. airlines and several regional carriers are transitioning into AQP from the older model expressed in Federal Aviation Regulations, Parts 121 and 135. To complete the shift to AQP, carriers are required to complete detailed analyses of training requirements for each aircraft and to develop programs that address the human factors (CRM) issues in each aspect of training. In addition, special training for those charged with certification of crews and formal evaluation of crews in full mission simulation is required (*Line Operational Evaluation* or LOE).

As part of the integration of CRM, several airlines have begun to proceduralise the concepts involved by adding specific behaviours to their checklists. The goal is to ensure that decisions and actions are informed by consideration of "bottom lines" and that the basics of CRM are observed, particularly in non-standard situations.

On the surface, the fourth generation of CRM would seem to solve the problems of human error by making CRM an integral part of all flight training. It would also appear that the goal of making explicit CRM training "go away" is starting to be realized. Although empirical data are not yet available, there is general consensus among U.S. airlines that the AQP approach yields improvements in the training and qualification of flight crews. However, the situation is more complex and the resolution not so straightforward. Before considering the latest iteration of CRM, it may be valuable at this point to pause and examine what has been accomplished in the past two decades of CRM training. By assessment, we mean understanding how well specific behaviours are enacted, *not* formal evaluation of human factors skills.

SUCCESSES AND FAILURES OF CRM TRAINING

Validation of CRM.

The fundamental question of whether CRM training can fulfil its purposes of increasing the safety and efficiency of flight does not have a simple answer. The most obvious validation criterion, the accident rate per million flights, cannot be used. Because the overall accident rate is so low and training programs so variable, it will never be possible to draw strong conclusions about the impact of training during a finite period of time. In the absence of a single and sovereign criterion measure, investigators are forced to use surrogate criteria to draw inferences more indirectly Reports of incidents that do not result in accidents are another candidate criterion measure. However, incident reporting is

voluntary and one cannot know the true base rate of occurrences, which is necessary for validation. We will discuss new developments in incident reporting later.

The two most accessible and logical criteria are behaviour on the flightdeck and attitudes showing acceptance or rejection of CRM concepts. Formal evaluation during full mission simulation (LOE) is a start. However, the fact that crews can demonstrate effective crew coordination while being assessed under jeopardy conditions does not mean that they practice these concepts during normal line operations. We feel that the most useful data can be obtained from line audits where crews are observed under non-jeopardy conditions. Data from such audits has demonstrated that CRM training that includes LOFT and recurrent training does produce desired changes in. This finding is congruent with participant evaluations of training. Crews completing course evaluations report that it is effective and important training..

Attitudes are another indicator of effect as they reflect the *cognitive* aspects of the concepts espoused in training. While attitudes are not perfect predictors of behaviour, it is a truism that those whose attitudes show rejection of CRM are unlikely to follow its precepts behaviourally. The attitudes that have been measured to assess the impact of CRM were ones identified as playing a role in air accidents and incidents. Data from a number of organizations show that attitudes about flightdeck management also change in a positive direction.

<u>CRM does not reach everyone</u>.

From the earliest courses to the present, a small subset of pilots have rejected the concepts of CRM. These CRM failures are found in every airline and are known to their peers and to management. Any chief pilot can identify these individuals, who have come to be known by a variety of names – *Boomerangs, Cowboys*, and *Drongos* to mention a few. Efforts at remedial training for these pilots have not proved particularly effective.

While CRM is endorsed by the majority of pilots, not all of its precepts have moved from the classroom to the line. For example, a number of airlines have introduced CRM modules to address the use of cockpit automation. This training advocates verification and acknowledgment of programming changes and switching to manual flight rather than reprogramming Flight Management Computers in high workload situations or congested

airspace. However, a significant percentage of pilots observed in line operations fail to follow these precepts.

<u>Acceptance of basic concepts may decay over time</u>.

Survey of pilots in a number of organisations several years after they received initial CRM training has revealed a disturbing finding from this research is a slippage in acceptance of basic concepts, even with recurrent training. The reasons for the decay in attitudes are not immediately apparent, but it is possible to speculate about likely causes. One candidate is a lack of management support for CRM and a failure by evaluators such as line check airmen to reinforce its practice. Another is the broadening of training to include flight attendants and other personnel, because a program stretched to fit all groups may lack the specificity needed to change behaviour. As training has evolved from one generation to the next, the original, implicit goal of managing error may have become lost. Proceduralising CRM (that is, formally mandating the practice of CRM precepts) might also obscure the purpose of the behaviour. Support for this view comes from informal interviews of crews asked "What is CRM?" A typical response is "Training to make us work together better." While this is certainly true, it only represents part of the story. It seems that in the process of teaching people *how* to work together we may have lost sight of *why* working together well is important. The overarching rationale for CRM, reducing the frequency and severity of errors that are *crew-based* has been lost.

<u>CRM did not export well</u>.

As first and second generation CRM training programs began to proliferate, many airlines in the U.S. and around the world began to purchase courses from other airlines or training organizations. Even in the U.S., courses imported from other organizations had less impact than those that were developed to reflect the organizational culture and operational issues of the receiving carrier. The situation was much worse when training from the U.S. was delivered in other nations. In many cases, the concepts presented were incongruent with the national culture of the pilots.

There is a growing trend for carriers outside the U.S. to include national culture as part of CRM training and to customize their programs to achieve harmony with their own

culture. This is an important development that should enhance the impact of CRM in those organisations. Malaysian Airlines, for example, has made national culture a part of its programme. Considering both the observed limitations of CRM in the United States and the differing reactions to the training in other cultures, let us now turn to the fifth generation of CRM training --one which we believe addresses the shortcomings of earlier training approaches.

5th GENERATION CRM – SEARCH FOR A UNIVERSAL RATIONALE

We have been searching for a rationale for CRM training that could be endorsed by pilots of all nations--including the Drongos. Returning to the original concept of CRM as a way to avoid error, we concluded that the overarching justification for CRM should be *error management.* In reaching this position, we were much influenced by the work of Prof. James Reason. While human error was the original impetus for even the first generation of CRM, the realization and communication of this was imperfect. Even when the training advocated specific behaviours, the reason for utilizing them was not always explicit. What we advocate is a more sharply defined justification that is accompanied by proactive organizational support.

CRM as Error Management.

Underlying the fifth generation of CRM is the premise that human error is ubiquitous and inevitable--and a valuable source of information. If error is inevitable, CRM can be seen as a set of error countermeasures with three lines of defence. The first, naturally, is the avoidance of error. The second is trapping incipient errors before they are committed. The third and last is mitigating the consequences of those errors which occur and are not trapped. This error management *troika* is shown in Figure 2. The same set of CRM countermeasures apply to each situation, the difference being in the time of detection. For example, consider an advanced technology aircraft which experiences a controlled flight into terrain (CFIT) because an improper waypoint is entered into the Flight Management Computer (FMC). A careful briefing on approach procedures and possible pitfalls, combined with communication and verification of FMC entries would probably avoid the error. Cross-checking entries before execution and monitoring of position should trap erroneous entries. Finally, as the last defence, inquiry and monitoring of the position should result in mitigating the consequences of an erroneously executed command before CFIT.

To gain acceptance of the error management approach, organizations must communicate their formal understanding that errors will occur, and should adopt a non-punitive approach to error. (This does not imply that any organization should accept wilful violation of its rules or procedures.) In addition to normalizing error, organizations need to take steps to identify the nature and sources of error in their operations. The U.S. Federal Aviation Administration has announced a new initiative, Aviation Safety Action Programs, to encourage incident reporting within organizations to deal with safety issues proactively. For example, American Airlines is participating in the program with the cooperation of the pilots' union and the FAA. This confidential, non-jeopardy reporting system allows pilots to report safety concerns and errors. The program has proved to be a resounding success, with nearly six thousand reports received in a two year period. Data generated by this system allow the company to take steps to prevent or minimize the recurrence of incidents.

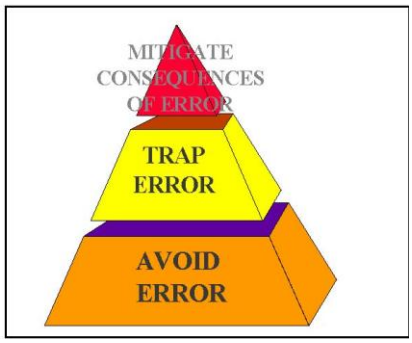


Fig2. The error *troika.*

<u>Considerations for fifth generation CRM</u>.

Instruction in the fifth generation has at its aim the *normalization* of error and the development of strategies for managing error. Its basis should be formal instruction in the limitations of human performance. This includes communicating the nature of cognitive errors and slips as well as empirical findings demonstrating the deleterious effects of stressors such as fatigue, work overload, and emergencies. These topics, of course, require formal instruction, indicating that CRM should continue to have its own place in initial and

recurrent training. These can be dramatically illustrated with examples from accidents and incidents where human error played a causal role. Indeed, the analysis of human performance is common to all generations of CRM training. We would argue, however, that even more powerful learning may result from the use of positive examples of how errors are detected and managed.

Pilots from all regions of the world have been found to hold unrealistic attitudes about the effects of stressors on their performance -- the majority feel, for example, that a truly professional pilot can leave personal problems behind while flying and that their decision making ability is the same in emergencies and normal operations. This attitude of personal invulnerability is a negative component of the professional culture of pilots and physicians. Training that demonstrates that these are erroneous or over-confident beliefs and that every individual is subject to stress can foster more realistic attitudes by reducing the onus attached to personal vulnerability. In turn, pilots who recognize the performance degradation associated with stress should more readily embrace CRM training as an essential countermeasure.

In theory, the error management approach should provide a more compelling justification for CRM and human factors training, but the impact remains to be evaluated empirically. Continental Airlines has refocused both the basic awareness and recurrent components of CRM as error management. As part of their commitment to this approach, all pilots were given the new basic course. Data on the outcomes of this program should help determine the effectiveness of the fifth generation approach. At the same time that error management became the primary focus of CRM training, Continental introduced a new program to train instructors and evaluators in the recognition and reinforcement of error management (Tullo, in press). This training stresses the fact that effective error management is the hallmark of effective crew performance and the well-managed errors are indicators of effective performance. There are many positive aspects of pilots' professional culture such as pride in job and motivation that contribute strongly to safety.

As part of our development of strategies for using the line audit as an organizational assessment strategy, we have modified the Line/LOS Checklist, which is used to measure team performance to include data on error types and error management. In preliminary observations at a U.S. airline, we found that observers could readily identify errors, their sources, and management strategies. Examples were found of errors avoided, errors trapped, and errors mitigated. Instances of errors never detected by crews and errors whose consequences were exacerbated by crew action were also found. We feel that a focus

on error management both in LOFT and in line checking can provide valuable feedback and reinforcement for crews.

HOW DOES ERROR MANAGEMENT CRM RELATE TO EARLIER GENERATIONS?

Fifth generation CRM is compatible with earlier generations. Special training in the use of automation and the leadership role of captains as highlighted in the third generation can be neatly subsumed under this model. The error management approach should strengthen the AQP approach to training by providing an all-important demonstration of the reasons for stressing CRM in all aspects of flight training. In the same vein, the integration of CRM into technical training and the proceduralisation of CRM also fit under this umbrella, and are likely to be better understood and accepted when the goals are clearly defined and organizationally endorsed. Pilots should also be better able to develop effective strategies for error management in situations where procedures are lacking and provide a focal point for CRM skills which are not amenable to proceduralisation.

Training modules such as situation awareness and the nature and importance of briefings can be seen as basic error management techniques.

Similarly, joint training of cabin and cockpit crews can be seen as extending the scope of error management to all employees in a safety culture. Finally, clarification of the basic goals of CRM training may be the best way to reach the Drongos who should find it difficult to deny the importance of error management.

CRM IN CONTEXT

CRM is not and never will be the mechanism to eliminate error and assure safety in a high risk endeavour such as aviation. Error is an inevitable result of the natural limitations of human performance and the function of complex systems. CRM is one of an array of tools that organizations can use to manage error.

The safety of operations is influenced by professional, organizational, and national cultures and safety requires focusing each of these toward an organizational *safety culture* that deals with errors non-punitively and proactively When CRM is viewed in the context of the aviation system, its contributions and limitations can be understood. What we do know is that the rationale for human factors training is as strong now as it was when the term CRM was first coined.

Human Error, Reliability and Error Management

Introduction

The science of Human Factors accepts the fact that human error is inevitable – what is important is to ensure that human error does not result in adverse events such as air accidents. This can be addressed in two ways: reducing errors in the first place, and controlling errors such that they, or their immediate effects, are detected early enough to allow remedial action. CRM addresses both types of mitigating strategies, but concentrates particularly on error detection, especially in the multi-crew situation.

Human reliability is the science which looks at the vulnerability of human beings to make errors (or less than perfect performance) under different circumstances. One could argue that it is more of an art than a science, since it is very difficult to predict, in quantifiable terms, human reliability in different situations, and from individual to individual. However, there are certain conditions under which humans are more likely to make errors (e.g. during circadian lows, when stressed, when overloaded, etc.), but these will be covered in other Appendices rather than under "human reliability" as such. If readers wish to find further information on the science of human reliability, a few references are included at the end of this Appendix.

Basic Theory

Introduction to Human Error

It has long been acknowledged that human performance is at times imperfect. Nearly two thousand years ago, the Roman philosopher Cicero cautioned “It is the nature of man to err”. It is an unequivocal fact that whenever men and women are involved in an activity, human error will occur at some point. In his book “Human Error”, Professor James Reason defines error as follows: “Error will be taken as a generic term to encompass all those occasions in which a

planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency".

Error Models and Theories

To appreciate the types of error that it is possible to make, researchers have looked at human error in a number of ways and proposed various models and theories. This attempt to capture the nature of the error and its characteristics. To illustrate this, the following models and theories will be briefly highlighted:

- design- versus operator-induced errors;
- variable versus constant errors;
- reversible versus irreversible errors;
- slips, lapses and mistakes;
- skill-, rule- and knowledge-based behaviours and associated errors;
- the 'Swiss Cheese Model'.

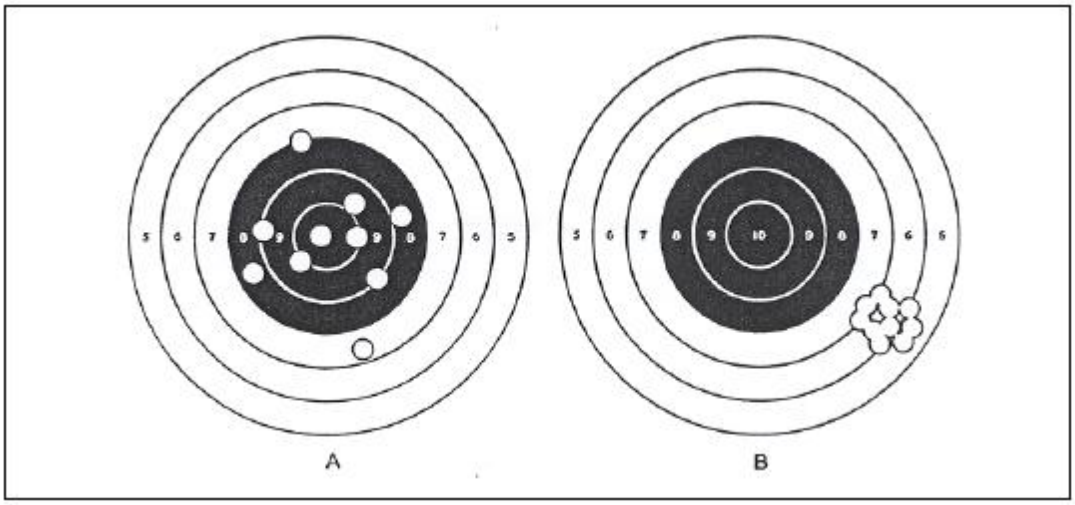
Design- Versus Operator-Induced Errors

In aviation, emphasis is often placed upon the error(s) of the front line operators, who may include flight crew, air traffic controllers and aircraft maintenance engineers. However, errors may have been made before an aircraft ever leaves the ground, by aircraft designers. This may mean that, even if an aircraft is maintained and flown as it is designed to be, a flaw in its original design may lead to operational safety being compromised. Alternatively, flawed procedures put in place by airline, maintenance organisation or air traffic control management may also lead to operational problems.

It is common to find when investigating an incident or accident that more than one error has been made and often by more than one person. The 'error chain' captures this concept. It may be that, only when a certain combination of errors arise and error " defences' breached (see the 'Swiss Cheese Model') will safety be compromised.

Variable versus Constant Errors

In his book "Human Error", Professor Reason discusses two types of human error: variable and constant errors. It can be seen in Figure 1 that variable errors in (A) are random in nature, whereas the constant errors in (B) follow some kind of consistent, systematic (yet erroneous) pattern. The implication is that constant errors may be predicted and therefore controlled, whereas variable errors cannot be predicted and are much harder to deal with. If we know enough about the nature of the task, the environment it is performed in, the mechanisms governing performance, and the nature of the individual, we have a greater chance of predicting an error.



Variable versus Constant Errors

Target patterns of 10 shots fired by two riflemen. Rifleman A's pattern exhibits no constant error, but large variable errors; rifleman B's pattern exhibits a large constant error but small variable errors. The latter would, potentially, be easier to predict and to correct (e.g. by correctly aligning the rifle sight).

However, it is rare to have enough information to permit accurate predictions; we can generally only predict along the lines of "fatigued pilots are more likely to make errors than alert pilots", or "The SOPs for task X on aircraft type Y is known as being ambiguous and likely to result in pilot error ". It is possible to refine these predictions with more information (e.g. The SOPs in Operator Z's QRH are known as being ambiguous), but there will always be random errors or elements which cannot be predicted.

Reversible Versus Irreversible Errors

Another way of categorizing errors is to determine whether they are reversible or irreversible. The former can be recovered from, whereas the latter typically cannot be. For example, if a pilot miscalculates the fuel he should carry, he may have to divert to a closer airfield, but if he accidentally dumps his fuel, he may not have many options open to him.

A well designed system or procedure should mean that errors made by flight crew are reversible. Thus, if a flight crew member incorrectly selects fuel feed which results in an imbalance, the aircraft systems should generate an appropriate alert.

Slips, Lapses, Mistakes and Violations

Professor Reason highlights the notion of 'intention' when considering the nature of error, asking the questions:

• Were the actions directed by some prior intention?
• Did the actions proceed as planned?
• Did they achieve their desired end?

Professor Reason suggests an error classification based upon the answers to these questions as shown in Figure 2.

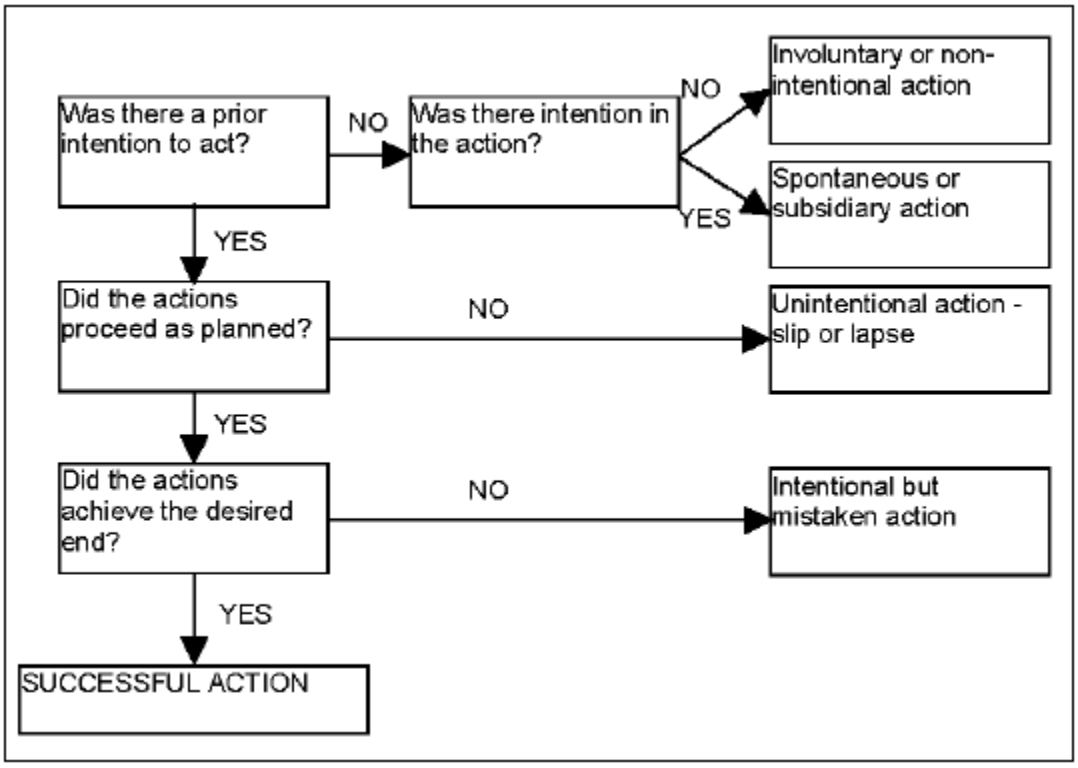
The most well-known of these are slips, lapses and mistakes.

Slips can be thought of as actions not carried out as intended or planned, e.g. 'finger trouble' when dialling in a frequency or 'Freudian slips' when saying something.

Lapses are missed actions and omissions, i.e. when somebody has failed to do something due to lapses of memory and/or attention or because they have forgotten something, e.g. forgetting to lower the undercarriage on landing. Mistakes are a specific type of error brought about by a faulty plan/intention, i.e. somebody did something believing it to be correct when it was, in fact, wrong, e.g. switching off the wrong engine.

Slips typically occur at the task execution stage, lapses at the storage (memory) stage and mistakes at the planning stage.

Violations sometimes appear to be human errors, but they differ from slips, lapses and mistakes because they are deliberate 'illegal' actions, i.e. somebody did something knowing it to be against the rules (e.g. deliberately failing to follow proper procedures). A pilot may consider that a violation is well-intentioned, e.g. electing not to climb in response to a TCAS RA, if he is certain that the other aircraft has already initiated avoiding action. There is great debate about whether flight crew should follow SOPs slavishly, or should elect to diverge from SOPs from time to time. Whatever the case, and however well-intentioned, this would still technically constitute a 'violation' rather than an error.

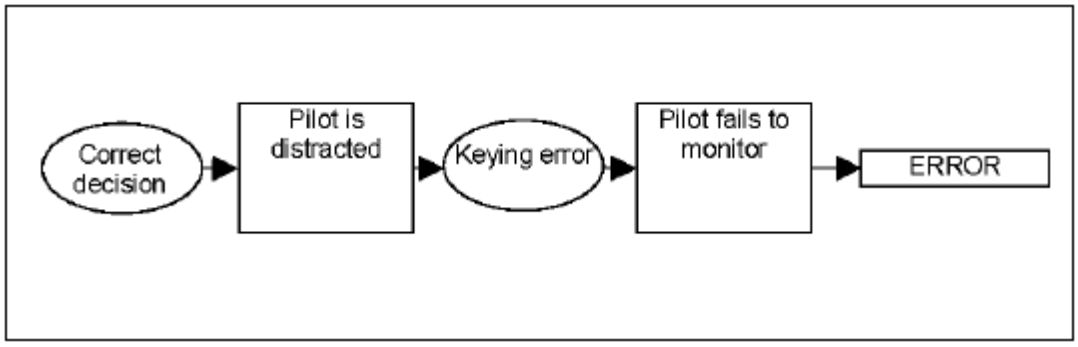


Error types base on intention. Source: Reason, 1990

Skill-, Rule- and Knowledge-Based Behaviours and Associated Errors

Human behaviour can generally be broken down into three distinct categories: skillbased, rule-based and knowledge-based behaviour. These are covered in greater detail in Professor James Reason's book "Human Error". Each of these behaviour types have specific errors associated with them.

Examples of skill-based errors are action slips, environmental capture and reversion. Action slips as the name implies are the same as slips, i.e. an action not carried out as intended. The example given in Figure 3 may consist of a pilot intending to key in FL110 into the FMS but keying in FL100 by mistake, after having been distracted by a query from his co-pilot.



Example of an Action Slip

Reversion can occur once a certain pattern of behaviour has been established, primarily because it can be very difficult to abandon or unlearn it when it is no longer appropriate. Thus, a pilot may accidentally carry out a procedure that he has used for years, even though it has been recently revised. This is more likely to happen when people are not concentrating or when they are in a stressful situation. Reversion to originally learned behaviour is not uncommon under stress. Rule-based behaviour is generally fairly robust and this is why the use of procedures and rules is emphasised in aircraft maintenance. However, errors here are related to the use of the wrong rule or procedure. For example, a pilot may misdiagnose a fault and thus apply the wrong SOP, thus not clearing the fault. Errors here are also sometimes due to faulty recall of procedures. For instance, not remembering the correct sequence when performing a procedure. Errors at the knowledge-based performance level are related to incomplete or incorrect knowledge or interpreting the situation incorrectly. An example of this might be when a pilot makes an incorrect diagnosis of a situation without having a full understanding of how the aircraft systems work. Once he has made such a diagnosis, he may well look for information to confirm his (mis) understanding, while ignoring evidence to the contrary (known as confirmation bias).

Violations

It is a fact of life that violations occur in aviation operations. Most stem from a genuine desire to do a good job. Seldom are they acts of laziness or incompetence.

There are three types of violations:

- Routine violations;
- Situational violations;
- Optimising violations.

Routine violations are things which have become 'the normal way of doing something' within the person's work group (e.g. flight crew from one company base). They can become routine for a number of reasons: flight crew may believe that procedures may be over prescriptive and violate them to simplify a task (cutting corners), to save time and effort. This rarely happens in flight operations, since flying tasks are so proceduralised, but it is not unusual to see these type of violations in maintenance engineering.

Situational violations occur due to the particular factors that exist at the time, such as time pressure, high workload, unworkable procedures, poorly designed manmachine interface in the cockpit. These occur often when, in order to get the job done, pilots consider that a procedure cannot be followed.

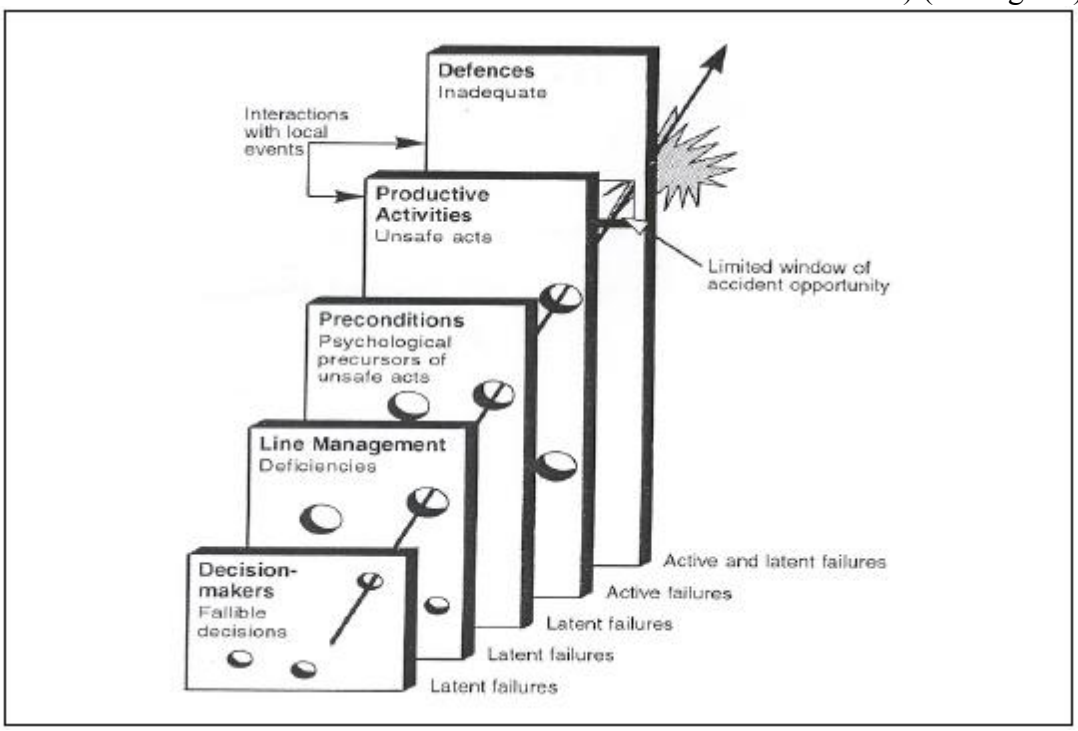
Optimising violations involve breaking the rules for 'kicks'. These are often quite unrelated to the actual task. The person just uses the opportunity to satisfy a personal need. Flying an illegal circuit over a friend's house might be an example. Time pressure and high workload increase the likelihood of all types of violations occurring. People weigh up the perceived risks against the perceived benefits, unfortunately the actual risks can be much higher.

Error Management

One of the key concepts associated with error management is that of "defences in depth", based on the premise that there are many stages in any system where errors can occur, and similarly many stages where defences can be built to prevent and trap errors. Professor James Reason covers error management in his book "Human Error".

Reason's 'Swiss Cheese Model'

In his research, Reason has highlighted the concept of 'defences' against human error within an organisation, and has coined the notion of 'defences in depth'. Examples of defences are pre-flight checks, automatic warnings, challenge-response procedures, etc., which help prevent to 'trap' human errors, reducing the likelihood of negative consequences. It is when these defences are weakened and breached that human errors can result in incidents or accidents. These defences have been portrayed diagrammatically, as several slices of Swiss cheese (and hence the model has become known as Professor Reason's "Swiss cheese" model) (see Figure).



Some failures are 'latent', meaning that they have been made at some point in the past and lay dormant. This may be introduced at the time an aircraft was designed or may be associated with a management decision. Errors made by front line personnel, such as flight crew, are 'active' failures. The more holes in a system's defences, the more likely it is that errors result in incidents or accidents, but it is only in certain circumstances, when all holes 'line up', that these occur. Usually, if an error has breached the design or engineering defences, it reaches the flight operations defences (e.g. in flight warning) and is detected and handled at this stage. However, occasionally in aviation, an error can breach all the defences (e.g. a pilot ignores an in flight warning, believing it to be a false alarm) and a catastrophic situation ensues.

Error Detection and Prevention

The concept of redundancy should be applied at all stages of the aviation system, never assuming that one single mechanism, especially if human, will detect and prevent an error. CRM provides a form of redundancy in that it emphasises the role of the second pilot to check what the first pilot has done. There is a potential danger with independent checks that the second person will trust the first person not to have done anything wrong, and therefore not to carry out the second check properly. CRM dual checking is one of the last lines of defence, especially if no automatic system checks and alerts are present, and pilots should always be alert for the possibility that their colleague may have made an error, when carrying running through SOPs which require challenge-response checks, no matter how much they might trust and respect the other pilot. Similarly, the pilot carrying out the first action should never become complacent and rely upon the other pilot detecting an error. (The same applies with pilot-ATC communications, and readbacks). It is essential to remember that we are all human therefore we all make mistakes from time to time, so assume the worst.

Practical Notes

It is important for both students and facilitators to accept the fact, from the outset, that human error is inevitable to some extent. Whilst CRM training should aim to reduce error as far as possible, it should also concentrate upon detecting and controlling error. As with HPL and information processing, teaching unrelated theory should be avoided; the emphasis should be upon practical guidance as to how to avoid and detect errors made by one and others. It may be useful to link in this module with information about the company's occurrence reporting scheme, stressing the importance of open and frank reporting of errors in order that lessons can be learned from them. However, this can be a sensitive area, and care should be taken not to jeopardise any confidentiality agreements, if using real examples of errors from the occurrence database.

Initial Training and Objectives

It is quite important to understand the theory of error, in particular the distinctions between slips, lapses, mistakes and violations, and their possible causes. It is also important for company managers to appreciate the concept of layers of defence, and what can be done to ensure that error provoking situations (e.g. poor procedures, poorly designed cockpits, undue commercial

pressure, bad rosters, etc.) are minimised, and that the pilot does not become the one and only layer of defence.

Recurrent Training and Objectives
LOFT exercise debriefs are probably the best way to learn from ones own errors and those of the crew, but care should be taken to ensure that errors are treated as learning exercises, and not as criticisms of personnel performance. For recurrent training carried out in a classroom environment, use of scenarios where errors have taken place is probably the most effective means of learning how to detect and prevent such errors in the future. Positive examples, as well as negative, can be useful.

Situation Awareness

Introduction
Situation Awareness (SA) is "knowing what is going on around you" and is fundamental to correct decision making and action. Information processing tends to be the term used for the psychological mechanism of receiving and analyzing information; situation awareness is a description of an individual's, or team's, understanding of the aircraft state and environment, based on perceived and processed information. SA is more than just perception - it is understanding the meaning of what you perceive, how it might change in the future, and the implications. Decision making is based on situation awareness, therefore if you have poor SA, you are likely to make poor decisions. SA has sometimes been referred to as "perception of reality" and it is quite possible for different crew members to have different perceptions of reality. The aim of SA training should be to ensure that all flight crew members have good SA and a common (and correct) perception of the state of the aircraft and environment. This can be achieved by good teamworking and communication. SA is, therefore, an important element of CRM.

Definitions
There are many definitions of Situation Awareness.
One definition of SA is:
"the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future"
(Endsley 1998).

Another definition is:
"Situation awareness relates to one’s ability to accurately perceive what is in the cockpit and outside the aircraft. It is also one’s ability to comprehend the meaning of different elements in the environment and the projection of their status in the near future"

A third definition (ICAO - HF Digest 2) is:
“Situation awareness refers to one's ability to accurately perceive what is going on in the cockpit and outside the aircraft. It further extends to the planning of several solutions for any emergency situation which could occur in the immediate future. Maintaining a state of awareness of one's situation is a complex process, greatly motivated by the understanding
that one's perception of reality sometimes differs from reality itself. This awareness promotes ongoing questioning, cross-checking, and refinement of one's perception. Constant, conscious monitoring of the situation is required. Note that the situation referred to here includes the human environment. The evaluation of oneself and others for partial or
total incapacitation is vital but often overlooked."
Team SA has been defined by Wagner and Simon as "The crew's understanding of flight factors that affect (or could affect) the crew and aircraft at any given time".

Basic Theory
The basic theory of SA is that of cognitive psychology, in particular, attention, perception, information processing, memory and decision making. Whilst the term "situation awareness" is usually used, in the context of flight operations, to describe awareness of all aspects of the whole flight, this can be broken down into specific elements, of which flight crew need to be aware to varying extents at certain times of the flight. For instance, a pilot needs very good SA concerning runway and taxiway assignments prior to take-off, but this information
ceases to be useful after departure. Information on the frequency concerning your own aircraft is more important than ATC instructions to other aircraft, but it may be useful to retain some SA of the latter 'party-line' information, in case ATC mistakenly clear another aircraft to your level. Table 1 distinguishes between geographical SA, SA of aircraft position and movement, aircraft system SA, environmental SA and, more for military aircraft, tactical SA.

Table 1 Types of SA (modified from Endsley)

Geographical SA	own aircraft other aircraft terrain features airports cities waypoints navigation fixes position relative to designated features path to desired location runway and taxiway assignments path to desired location climb/descent points
Spatial/Temporal SA	attitude altitude heading velocity vertical velocity flight path actual values relative to assigned projected flight path projected landing time
System SA	system status functioning and settings radio altimeter transponders flight modes and automation deviations from correct settings ATC communications present fuel impact of degrades and settings on performance time and distance available on fuel

Table 1 Types of SA (modified from Endsley)

Environmental SA	weather formations and movement temperature icing ceilings fog turbulence, winds sun visibility IFR/VFR conditions areas to avoid flight safety projected weather conditions

One could also argue that "People SA" should be included, but this is not one of the elements in Mica Endsley's model. Mica Endsley has categorised SA into three levels: perception, comprehension and projection. These are described further in Table 2

The more experienced and skilled a pilot, the better his SA at all three levels tends to be. Novice pilots tend to be competent at level 1 SA, but poor at levels 2 and 3. On the other hand, some skilled and experienced pilots may make errors at the level 2 stage, in that they may perceive the correct information but draw an incorrect conclusion based on previous experience of a similar event. Individual factors which can influence SA are those described already in the Appendix on information processing. Human beings have a limited information processing capability and cannot attend to all sources of information all the time. It is necessary to switch attention from one source to another, often in fairly rapid succession, and store the information in memory. Appropriate training can help pilots develop and practice good 'attention sampling' strategies, to ensure that one or more sources of information do not get neglected. A simple example of this is the instrument scanning pattern which many pilots learn at an early stage in their flying training,

in order not to miss a potentially important source of information.

Table 2 SA Error Taxonomy (Mica Endsley, 1995)

Level 1 SA: failure to correctly perceive the situation	A: Data not available B: Data difficult to detect/perceive C: Failure to scan or observe data 1. omission 2. attentional narrowing/distraction 3. high taskload D. Misperception of data E. Memory failure
Level 2 SA: Failure to comprehend situation	A: Lack of/poor mental model B: Use of incorrect mental model C: Over-reliance on default values in model D: Memory failure E: Other
Level 3 SA: Failure to project situation into the future	A: Lack of/poor mental model B: Other
General	Failure to maintain multiple goals Habitual schema

Working memory capacity is a limit on SA, since its capacity can soon be overwhelmed when used to store perceived information, comprehending the meaning of that information, combining it with existing knowledge to achieve a composite picture, and predict future outcomes whilst still maintaining a good appreciation of the current situation. The load on working memory and processing capabilities can be reduced as tasks become more and more automatic, with the development of skill. However, this very 'automaticity' can have a down side in that
it can lead to failure to perceive new stimuli (e.g. hearing what you expect to hear, or seeing what you expect to see). Stress can have an affect on SA, sometimes positive, but more usually negative. Stress can be physical (noise, vibration, heat, cold, fatigue, etc.) or social/ psychological (fear, anxiety, uncertainty, mental load, time pressure, perceived time pressure, consequences of events, etc.). High workload is a form of stress, either long term high workload (e.g. a short-haul flight through several sectors in busy airspace, with an inexperienced crew), or short term or even momentary high workload or overload (e.g. bad weather on approach). Depending on the individual, some degree of stress may improve performance in general, including SA. More often, however, stress results in reduced SA since it competes with SA for an individual's limited attention capacity, and may result in
attentional narrowing. Other consequences may include reduced working memory capacity, and reduced information intake. Aural inputs may be significantly reduced, with peripheral visual inputs suffering next. This is a strong argument for placing master warning lights in the central visual area in cockpits, rather than rely upon peripheral attention-getters or aural warnings.
Stress can also result in decisions being made without all the pertinent information having been considered (e.g. shutting down wrong engine without looking to see which one is on fire!), and

also with failing to take account of contradictory information once a decision has been made, attention being given only to information which supports the decision. Training can make people aware that this is a danger, help them to recognise the symptoms of stress and reduced SA, and train them to actively search for, and attend to, all pertinent sources of information before making a decision or acting upon a decision.

Recognition of reduced SA is almost as important as subsequent retrieval of good SA. LOFT exercises and debriefs are a useful way to improve on recognising when SA is reduced, with regard to both individuals and the flight deck crew team. Mica Endsley advocates a training method whereby LOFT exercises are stopped midway through, in order to test individuals on their SA, and make them aware of their actual levels of SA, rather than their perceived levels, particularly at the end of an exercise.

Training can help flight crew manage their workload to avoid overload situations and the associated reduction in SA. Training can help flight crew recognise reduced SA when it happens. CRM training can help improve teamwork such that team members can have good team SA, as well as monitoring one another to ensure that individual team members are maintaining SA. One of the key benefits of training, however, is to train individuals and teams how to cope in a non-normal or emergency situation, and how to maintain SA under stress. Training aids and videos are available for specific situations, e.g. approach and landing, engine failure, CFIT, turbulence, etc., but generic training in how to maintain and improve SA is valuable to give flight crew a good understanding of the techniques available.

Communication, Teamwork, Leadership, Decision Making and Managerial Skills

Introduction

One of the basic underlying premises of CRM is that a team can, and should, perform better than two (or three) individuals in the cockpit. The aim of CRM is to ensure that 1+1>2, as opposed to 1+1<2 (in a two pilot cockpit), and that team performance takes precedence over individual performance. Good CRM is getting the balance right as a team, whilst recognising that the Captain has the final say and responsibility for the safety of the aircraft. In order to be effective, team members must be able to talk to each other, listen to each other, share information and be assertive when required. Commanders should take particular responsibility for ensuring that the crew function effectively as a team. Whilst the emphasis in CRM is primarily upon the cockpit crew, and how they work as a team, it is also important to look at wider team effectiveness, namely the whole flight crew. CRM principles may also extend to situations where ATC, maintenance, company experts, etc., are considered to be part of the team (especially in emergency

situations).

Communication

Good communication is important in every industry. In aircraft operations, it is vital. Communication, or more often a breakdown in communication, is often cited as a contributor to aviation incidents and accidents. Communication is defined in the Penguin Dictionary of Psychology as: "The transmission of something from one location to another. The 'thing' that is transmitted may be a message, a signal, a meaning, etc. In order to have communication both the transmitter and the receiver must share a common code, so that the meaning or information contained in the message may be interpreted without error".

Modes of Communication

We are communicating almost constantly, whether consciously or otherwise. We may need to communicate:

- information (e.g. "ATC have instructed us to...");
- feedback/challenger/response (e.g. "checked" or "set");
- ideas/proposals/counter-proposals (e.g. "I disagree. What about.XX instead?");
- feelings (e.g. "I'm not happy with....").

As the sender of a message, he will typically expect some kind of response from the person he is communicating with (the recipient), which could range from a simple acknowledgement that his message has been received (and hopefully understood), to a considered and detailed reply. The response constitutes feedback.

Verbal Communication

Verbal communication may be either social or functional/operational. Both serve a useful purpose, the former helping to built teamwork, and the latter being essential to the task of flying an aircraft.

For a spoken or written message to be understood, the sender has to make sure that the receiver:

- is using the same channel of communication;
- recognises and understands his language, including any subtleties;
- is able to make sense of the message's meaning.

The channel of communication is the medium used to convey the message. For spoken communication, this might be face-to-face, or via the radio or intercom. Written messages might be notes, information keyed in, or tone messages (e.g. between flight deck and cabin crew). Oral/aural communication is the primary mode of communication in an aircraft. Pilot-ATC communication is a very important area. However, it is not appropriate to go into too much detail in this document, other than to stress that CRM principles should also apply to pilot-ATC communications (within the restrictions of standard phraseology and air-ground

communications procedures) as well as face-to-face communications.

Non-verbal Communication

Non-verbal communication can accompany verbal communication, such as a smile during a face-to-face chat. It may constitute acknowledgement or feedback (e.g. a nod of the head). It can also be used when verbal communication is impossible, such as a thumbs-up in a noisy environment.

Body language can be very subtle, but often quite powerful. For example, the message "No" accompanied by a smile will be interpreted quite differently from the same word said whilst the sender scowls.

Non-verbal communication may also take the form of written information or notes, between pilots or flight deck and cabin crew.

Future ground-air communications are increasingly more likely to be non-verbal as data link technology and associated procedures gradually replaces oral/aural RTF communications between ATC and pilots. As mentioned above, this is not addressed in any detail in this document.

Non-verbal communication is the predominant manner by which systems communicate their status. For instance, most displays in the aircraft cockpit present their information graphically. However, man-machine interface issues are not covered in this document.

Communication Problems

There are two main ways in which communication can cause problems. These are lack of communication and poor communication. An example of the former is a young first officer who is very IT-literate, who is engrossed with programming the FMS but doesn't explain to the less-IT-literate Captain what he is doing. An example of the latter is a flight deck crew who advise the cabin crew that there will be a precautionary emergency landing, but fail to tell them not to evacuate the cabin. Both problems can lead to subsequent human error.

Communication also goes wrong when one of the parties involved makes some kind of assumption. The sender of a message may assume that the receiver understands the terms he has used. The receiver of a message may assume that the message means one thing when in fact he has misinterpreted it.

Problems with assumptions can be minimised if messages are unambiguous and proper feedback is given.

There are several hazards which reduce the quality of communications:

• failures during the transmitting process (e.g. the sending of unclear or ambiguous messages, language problems);

• difficulties caused by the medium of transmission (e.g. background noises or distortion of the information);

• failures during receiving (e.g. the expectation of another message, wrong interpretation of the arriving message or even its disregard);
• failures due to interference between the rational and emotional levels of communication (e.g. arguments); and
• physical problems in listening or speaking (e.g. impaired hearing or wearing of the oxygen mask).
It is the task of Human Factors training to prevent or minimise communication errors. This task includes the explanation of common communication problems as well as the reinforcement of a standard of language to ensure the error-free transmission of a message and its correct interpretation. Ambiguous, misleading, inappropriate or poorly constructed communication, combined with expectancy, have been listed as elements of many accidents, the most notorious one being the double 747 disaster in Tenerife.

Leadership/Followership
The following text has been adapted from ICAO HF Digest No. 1: Fundamental Human Factors Concepts. ICAO Circular 216-AN/131. A leader is a person whose ideas and actions influence the thought and the behavior of others. Through the use of example and persuasion, and an understanding of the goals and desires of the group, the leader becomes a means of change and influence. It is important to establish the difference between leadership, which is acquired, and authority, which is assigned. An optimal situation exists when the two are combined. Leadership involves teamwork, and the quality of a leader depends on the success of the leader's relationship with the team. Leadership skills should be developed for all through proper training; such training is essential in aircraft operations where junior crew members are sometimes called upon to adopt a leadership role throughout the normal performance of their duties. This may occur when the co-pilot must take over from an absent or incapacitated captain, or when a junior flight attendant must control the passengers in a particular cabin section.

Skilled leadership may be needed to understand and handle various situations. For instance, personality and attitude clashes within a crew complicate the task of a leader and can influence both safety and efficiency. Aircraft accident and incident investigations have demonstrated that personality differences influence the behaviour and performance of crew members. Other situations requiring skilled leadership may be rooted in the frustrations of first officers over slow promotions, or of pilots who are employed as flight engineers. Both leadership and followership are essentially skills which can be learnt. The skills are similar but in the case of the follower they should be exercised in a supporting role that does not attempt to undermine the leader. One upmanship would be a classic case of inappropriate behaviour both for the leader and the follower.

Teams
In most companies, flight crews do not comprise the same individuals on a regular basis. Teams, therefore, have little opportunity to grow and form over time, and must function effectively from

the moment they are formed, perhaps only an hour or so before the flight. It is important, therefore, to have a common understanding among team members as to how they will all be expected to work together as a team, from the outset. Company and operating procedures will cover the functions and actions, but CRM training is needed to show what behaviours and attitudes are expected and to help standardise across the company.

It is important for the team to establish openness from the outset, and for the commander, particularly, to demonstrate that he will welcome input from other team members, in particular the other flight deck crew. A glowering Captain who speaks to no one in the crew bus on the way to the aircraft is unlikely to set the appropriate atmosphere for the rest of the flight! Talking about a hypothetical situation on the way to the aircraft (e.g. what to do if a drunk and disruptive passenger boarded) may help to establish mutual expectations and encourage open communication.

There may be a large difference in age and experience between the various team members, with a younger, less experienced pilot being reluctant to challenge or query the Captain's actions in any way. Similarly, there may be a reluctance on the part of the cabin crew to 'bother' the flight crew with concerns. It is important to ensure that communication between team members is encouraged from the outset, even if that information often turns out to be non-relevant or not important, or a challenge by a copilot proves the Captain to be correct. Team members should not be afraid or embarassed to speak up.

Assertiveness training should help ensure that people speak out when appropriate, and using illustrations of incidents and accidents where team communication or functioning has been poor (or particularly good) helps reinforce the training.

Crew Co-ordination1

Crew co-ordination is the advantage of teamwork over a collection of highly skilled individuals. Its prominent benefits are:

• an increase in safety by redundancy to detect and remedy individual errors; and

• an increase in efficiency by the organised use of all existing resources, which improves the in-flight management.

The basic variables determining the extent of crew co-ordination are the attitudes, motivation and training of the team members. Especially under stress (physical, emotional or managerial), there is a high risk that crew co-ordination will break down.

The results are a decrease in communication (marginal or no exchange of information), an increase in errors (e.g. wrong decisions) and a lower probability of correcting deviations either from standard operating procedures or the desired flight path. Additionally, emotional conflicts in the cockpit may result. The high risks associated with a breakdown of crew co-ordination show the need for CRM training. This kind of training ensures that:

• the pilot has the maximum capacity for the primary task of flying the aircraft and making decisions;
• the workload is equally distributed among the crew members, so that excessive workload for any individual is avoided;
• co-ordinated co-operation – including the exchange of information;
• the support of fellow crew members and the monitoring of each others' performance – will be maintained under both normal and abnormal conditions.

Leadership and Managerial Skills

Effective leadership and managerial skills help to achieve joint task completion within a motivated, fully-functioning team through co-ordination and persuasiveness. Use of authority and assertiveness

The use of authority and assertiveness infers the ability to create a proper challenge and response atmosphere. The given command authority of the Captain should be adequately balanced by assertiveness and crew member participation. If a situation requires, decisive actions are expected.

Examples of poor practice:
• Hinders or withholds crew involvement;
• Passive, does not show initiative for decisions, own position not recognisable;
• Does not show appreciation for the crew, coaches very little or too much.

Examples of good practice:
• Advocates own position;
• Takes initiative to ensure involvement and task completion;
• Takes command if situation requires;
• Motivates crew by appreciation and coaches when necessary.

Providing and maintaining standards

Providing and maintaining standards refers to the compliance with essential standards (SOPs and others) for the task completion. Supervision and intervention in case of deviations from standards by other crew members is also part of this skill. If the situation requires, non-standard procedures might be necessary. Such deviations shall be discussed and announced.

Examples of poor practice:
• Does not comply to SOPs, does not monitor crew for SOP compliance;
• Does not intervene in case of deviations;
• Applies non-standard procedures without announcement or consultation of crew members.

Examples of good practice:
• Ensures SOP compliance;
• Intervenes if task completion deviates from standards;
• Having consulted the crew deviates from standard procedures if situation requires.

Planning and co-ordination
Planning and co-ordination refers to applying an appropriate concept for organized task-sharing and delegation in order to achieve top performance and to avoid workload peaks and dips. Communication of plans and intentions leads to coordinated activities within the whole crew.

Examples of poor practice:
• Plans only for self, does not involve crew;
• Intentions not stated or confirmed;
• Changes plan without informing crew or follows plans blindly.

Examples of good practice:
• Encourages crew participation in planning and task completion;
• Clearly states intentions and goals;
• Having consulted crew, changes plan if necessary.

Decision Making
Decision making is the process of reaching a judgement or choosing an option.

Problem definition and diagnosis
Problem definition and diagnosis is the ability to collect the information needed to define a problem and its causal factors.

Examples of poor practice:
• Nature of the problem not stated or failure to diagnose;
• No discussion of probable causes.

Examples of good practice:
• Gathers information and identifies problem;
• Reviews causal factors with other crew members.

Option generation
Option generation refers to the ability of a crew member to generate multiple responses to a problem.

Examples of poor practice:
• Does not search for information;
• Does not ask crew for alternatives.

Examples of good practice:
• States alternative courses of action;
• Asks crew members for options.

Risk assessment and option selection
Risk assessment and option selection refers to the ability of a crew member to successfully assess risks and benefits of different responses to a problem, and to select the best response. Both should be accomplished through discussion with other crew members.

Examples of poor practice:
• Inadequate discussion of limiting factors with crew;
• Failing to inform crew of decision path being taken.

Examples of good practice:
• Considers and shares risks of alternative courses of action;
• Talks about possible risks for course of action in terms of crew limitations;
• Confirms selected course of action.

Co-operation
Co-operation is the ability to work effectively in a crew.

Team-building and maintaining
Team-building and maintaining is about the ability to establish positive interpersonal relations between crew members and their active participation in fulfilling the tasks.

Examples of poor practice:
• Blocks open communication;
• Keeps barriers between crew members;
• Competes with others.

Examples of good practice:
• Establishes atmosphere for open communication and participation;
• Encourages inputs and feedback from others;
• Does not compete with others.

Consideration of others
Consideration of others involves the acceptance of others and understanding their personal condition.

Examples of poor practice:
• Ignores suggestions of other crew members;

• Does not take account of the condition of other crew members;
• Shows no reaction to other crew members' problems.

Examples of good practice:
• Takes notice of the suggestions of other crew members even if s/he does not agree;
• Takes condition of other crew members into account;
• Gives appropriate personal feedback.

Support of others
Support of others relates to giving help to other crew members when they need assistance.

Examples of poor practice:
• Hesitates to help other crew members in demanding situations;
• Does not offer assistance.

Examples of good practice:
• Helps other crew members in demanding situations;
• Offers assistance.

Conflict solving
Conflict solving is about the articulation of different interpersonal positions and giving suggestions for solutions.

Examples of poor practice:
• Overreacts in interpersonal conflicts, sticks to own position without considering a compromise;
• Accuses other crew members of making errors.

Examples of good practice:
• Keeps calm in conflicts;
• Suggests conflict solutions;
• Concentrates on what is right rather than who is right.

Initial Training and Objectives
To ensure that flight crew understand what is expected of them in their role.
To be aware of company procedures relating to the responsibilities of Captains and other flight crew members.
To be aware of what constitutes good and bad communication in the cockpit, and elsewhere.

Recurrent Training and Objectives

To improve upon own communication and team skills, based on feedback from a TRE, CRM instructor or colleagues.

Automation

Introduction

CRM in highly automated aircraft presents special challenges, in particular in terms of situation awareness of the status of the aircraft. Many researchers and practitioners have looked at training for modern automated aircraft, in particular Mica Endsley, in the context of situation awareness of automation modes. Thefollowing text has been adapted from ICAO Digest 05 (Automation) Chapter 3.

Training for Automation

Pilot training is very important and it is also very expensive. There is no argument regarding its importance, but there is not always agreement on the kind and amount of training required to enable pilots to operate new and different aircraft safely and efficiently. The controversy regarding the effect of automation on training is an entirely separate issue. Some claim that automation requires additional skills, while others propose that automation reduces training costs and also reduces the level of traditional flying skills required in older (conventional flight deck) aircraft; in contrast, others propose that one of the greatest misconceptions about automation is that it reduces training requirements. Notwithstanding these conflicting opinions, there is little doubt about the importance of training. The interface between transport aircraft and the pilots who operate them is of great importance, as are the interfaces between the pilot and the manufacturer, procedures, Standard Operating Procedures and company operating philosophies.

One controversial issue already mentioned has been the changing role of the flight crew in automated flight deck aircraft. It comprises at least two basic questions:

• Is the pilot a control operator, a systems manager, or both?

• If a difference exists, is it in the pilot's role, or in the elements of that role?

Analysis suggests that the primary role of the transport pilot has not changed at all: since the goal is (as it has always been) to complete the planned flight safely and efficiently and with a maximum of passenger comfort, the role is to achieve that goal to fly safely and efficiently from point A to point B. The functions still include monitoring, planning, and making decisions in reference to the operations, and the tasks are those traditionally performed (communicating, navigating and operating). The question is how best to train pilots for advanced technology aircraft. The consensus seems to indicate that, as a general approach, automation should take a greater role in maintaining basic stability and control of the aircraft. Higher-level functions, such as flight planning/pre-planning, system status management and decision-making, should be

performed primarily by humans with the help of automation. Training should reflect the increased emphasis on the pilot's decision-making, knowledge of systems, monitoring and crew co-ordination. One point is clear, however: automation has not reduced the need for the basic airmanship skills and knowledge which have always been required of airline pilots. The importance of those fundamentals should be emphasised in the early phases of training, and general aircraft instruction should always precede detailed instruction in automatic features. The training should be sensitive to the varying needs of a pilot population that differs widely in areas such as total flight experience, corporate experience, recency of last transition training, computer literacy, etc.

Assessment of training requirements

One of the lessons learned regarding advanced technology aircraft is that assessment of training requirements should be made when a new aircraft type is designed. Determination of the general training requirements needed to enable pilots to operate new equipment safely and efficiently should be considered an integral part of the design process. These requirements need not be - and probably should not be – very detailed. They should clearly indicate what the designer of the system believes the pilot should know in order to operate that system safely and efficiently. The next occasion to do this would be when the new type is introduced. This gives an opportunity to introduce operational changes, but any inefficient practices existing at the time of introduction will tend to endure. This is the time to appreciate and understand the manufacturers' design and operating intents, since they heavily influence training and operational issues. Those responsible for the introduction of

new types, or charged with the responsibility of training development, should possess more background information with regard to the basic design philosophy than was needed in the past. This is important since most of the existing training programmes for new technology aircraft were originally developed for conventional aircraft.

Adequacy of training requirements

Careful considerations should be given to the adequacy of the transition training programme. The complexity of many of the systems may require a higher level of initial understanding and operational skill than was required with previous aircraft. The basic question is: do pilots, after completing their transition training, have sufficient skills, knowledge and understanding to operate these aircraft safely and efficiently? Although some believe that the traditional high level of manual skills will be required to a lesser extent, greater demands are placed on intellectual or mental skills due to the complexity of the systems and the environment in which they are operated. There is also evidence that routine operation of automatic modes may not provide adequate training opportunities. Flight deck observations have shown that pilots use only a few of the features available to them, because of incomplete knowledge about how to use other features. This says much about the inadequacy of the training and the complexity of the systems and modes.

Depth of training

The depth of training should ensure that pilots thoroughly understand systems interdependencies. This understanding may no longer be intuitively obvious even to highly experienced pilots. Training must provide more specific information about systems than was previously required when systems interdependencies were much less pronounced.
operational understanding which may not be intuitive. Training time devoted to aircraft operation with the automated system(s) failed would increase pilot confidence in taking manual control early and effectively.

Value and applicability of part-task trainers
It must also be remembered that "surface" competence during the normal operation of a new system may well differ considerably from "real" competence which can withstand high stress and high workload. To withstand such pressures, skills need to be overlearned. This is basic knowledge which does not seem to be always applied in practice. In order to obtain the necessary intensive hands-on training, the value and applicability of part-task trainers has been recognised. These devices include a highfidelity simulation of a particular system (or even the actual piece of equipment) which allows the student to concentrate on it without the extra load and distractions which might be imposed by a full flight simulator. They are less elaborate, and can range from large photographs which emulate the flight deck around the simulated system, to sophisticated desk-top computer-assisted training (CAT) devices. Part-task trainers can be highly cost-effective in developing the skills required for efficient system operation. The major drawback of some of these devices - as presently designed -
appears to be a lack of functional realism (e.g. at a given point of any exercise, there may be only one allowed sequence of responses, whereas in the real system much more freedom is available).

The use of home computers to fulfil training requirements and for voluntary self instruction should be explored. There is potential for misuse here, but there is also a considerable potential for fulfilling the needs and desires of pilots, management and authorities. Although implementation may be a particular challenge, experience indicates that some basic computer literacy (i.e. being comfortable with an alphanumeric keyboard) will make transition to new technology flight decks easier.

Recency
The time elapsed since the last transition training is an important factor when considering pilots' needs. Flight guidance systems and other automated systems are certainly more complex than in previous aircraft, yet it has been noted that quite often some pilots making the transition to these aircraft had not been to ground school for periods as long as 15 years. This may have contributed to the difficulties of some of these pilots, for whom transition training to new technology may not always go smoothly and may involve higher than expected training costs. A lack of meaningful operating experience (which can be quite different than total flight time) should be expected for the period immediately following training. One way to solve this problem may be to expose the flight crews to highly realistic flight situations in high-fidelity simulators. In many

countries this is called LOFT (Line-Oriented Flight Training)1. Because of the sophisticated equipment, the variety of situations that can be simulated, and the highly technical training methods now available, it enables pilots to gain flight experience (in addition to training) that in some cases may be even better
than actual flight.

Specific training issues
Specific issues also related to transition training include the transition from electromechanical instruments to electronic flight instrument systems; training for the loss of all the electronic displays (the aircraft would be controlled on standby instruments which are essentially the same as those in previous generation aircraft, but the step down in data available is much greater); and the use of the autopilot, flight management system and mode control panel. The manner in which these systems allow the flight to be conducted enables the pilot to become detached from the immediate state of the aircraft (position, speed, height, etc.). Crew procedures and training methods must ensure that no automation complacency is fostered by this process, and that the pilot maintains a satisfactory level of situational awareness. The training should be hands-on and line-oriented, and should stress sound practices.

Guidelines on the use of automation
Guidelines on the use of automation should be provided. They should indicate to the crew when to use automation, and, more importantly, when not to use it. Even when guidelines are available (usually through company policy or standard operating procedures), they reflect preferred practices in the context of particular operational environments. The existence of such guidelines does not necessarily mean that they are universally applicable, nor is the purpose of this Appendix to provide them.

Use of accident/incident data
In line with the well established practice of programming wind-shear profiles as part of flight simulator training, it might be worthwhile to explore the benefits of replaying incidents or accidents where automation has been considered a factor. The flexibility of contemporary simulator-computer systems and the information available from safety reporting systems makes this possible. Similarly, some contend that there is a need to include and review problems and incidents encountered in day-to-day operations.

Need to monitor
The need to monitor should be constantly reinforced, both during training and proficiency checking. The vast literature on vigilance shows, however, that humans are not uniformly effective monitors, and frequently miss system faults or wrong setups. This trait is sometimes aggravated by operations in a low stimulus environment, such as that found in long-range, "back-of-the-clock" operations. The possibility of more or different training has been raised as a remedy, although it seems difficult to achieve consistent gains in this way. Some attention has

been directed to placing more emphasis on creating the sort of stimuli (displays, procedures, additional meaningful tasks) that enhance the pilot's ability to monitor them. It is also a fact that pilots can do specific kinds of monitoring very well - for example, monitoring pilot flying performance during an approach from outer marker to touchdown. Many believe, however, that the influence of systems design must be investigated as an
alternative to alleviate the problem.

Adequacy of differences training

The adequacy of "differences" training must be considered when a new aircraft is considered "common" with an older aircraft. It is not unusual for some operators to have not only several different flight deck configurations for the same basic airplane model, but also different computers and software. When such a situation is coupled with mergers and fleet integration, the pilots can be exposed to quite different flight deck arrangements in quick succession. Also, prolonged absence from advanced technology aircraft may result in a marked diminution of skill. This has been demonstrated to have a greater impact on piloting proficiency than a similar absence from the flight deck of an older technology aircraft. This loss of proficiency is directly related to the operation of the flight guidance system.

Requalification training

Requalification training, when a pilot is returning to a less automated aircraft, must be very thorough. A major training consideration should be deprogramming the pilot's expectations: for example, automatic altitude capture and level off, a common feature of automated flight decks, may not be available on older technology aircraft. Evidence from field studies in automation indicates that pilots are also concerned about the degradation in their cognitive (mental) skills due to the ease of navigation and maintenance of situational awareness using electronic maps. Management should be aware of the potential hazards of these reassignments.

Standardisation and simplification

The need for standardisation and simplification of all aspects of operation of two person crew automated aircraft should be given a high priority. Standardisation is one of the foundations of safety, and its importance has been accentuated by the appearance of aircraft leasing organisations, airline mergers, consolidations, etc. Flight crews may be faced with different names for the same item, different procedures to operate the same systems, different symbology to display the same information, and all of this often under demanding conditions. Such problems may also be due in part to the constant improvements in aircraft, their systems and flight deck symbology. Standardisation of symbology is receiving considerable and well deserved attention these days. Symbols should be intuitive and their meanings consistent from one system design to the next. Standardisation should be emphasised, and this emphasis should be extended to flight operations and equipment manuals, operating procedures and checklists.

Operational procedures and checklists

Operational procedures and checklists should be carefully examined with particular attention to the workload required to perform them. In their operation of two-person crew aircraft, many operators have not reflected the advances that have been made in flight deck technology and in the understanding of flight crew behaviour. Special training considerations should be given to flight crew members making the transition to automated two-person crew airplanes from a three-person crew airplane. The use of Line-Oriented Flight Training as a tool to demonstrate heavy workload conditions is proposed in the following paragraphs. More importantly, LOFT can be an ideal tool to identify workloads which are a product of inappropriate policies or procedures, as considerable flight crew workload can be created by having to perform nonoperational tasks at inappropriate times (calls for passenger connections, meal requirements, wheel chairs, etc.). This is not a new problem, but it is more critical in the automated environment and with the proliferation of high density operations. (Some aspects of this problem are being met on many of the new airplanes with
separate communication facilities for the cabin crew.)

Tailoring of CRM and LOFT training

It has previously been assumed that Crew Resource Management (CRM) training programmes are model-independent. However, there is increasing evidence that at least some aspects of crew co-ordination and communication in the automated flight decks are qualitatively different from the flight decks of older aircraft. Recent experiments suggest, for instance, that there is a trend towards less verbal inter-pilot communication as the degree of flight deck automation increases. If this hypothesis can be confirmed through research, then customised modules of CRM training programmes should be developed to deal with such differences. These customized modules should also take account of the nature and the needs (culture) of the organisation. The following areas of concern in CRM of automated aircraft are the result of observations during actual flights. They indicate that highly automated flight decks may require special scrutiny in the areas of crew co-ordination and resource management, both in the assignment of tasks and the standardisation of their
performance.

• Compared to traditional models, it is now physically difficult for one pilot to see what the other is doing. For example, in previous generation aircraft the autopilot mode control panel was easily observable by both pilots; in automated flight decks the selections are made in the control display unit (CDU), which is not visible to the other crew member unless the same CDU page is selected. Proper procedures and intra-cockpit communication appear to be the answers to this problem.

• It is more difficult for the captain to monitor the work of the first officer, and vice versa. New or revised procedures and intra-cockpit communication are again the apparent answer.

• Automation can induce a breakdown in the traditional roles of the controlling pilot and monitoring pilot, and there is a less clear demarcation of who does what. This is particularly relevant, since it has already been mentioned that standardisation is one of the foundations of safety. The answer to this problem might be found in procedures and standard operating procedures

• Automated flight decks can produce a redistribution of authority from the captain to the first officer. This is unintended, and is a product of an apparently greater proficiency of some first officers in CDU data entry compared to that of the captains, plus the delegation of these duties to the first officer. Particularly in times of high workload, the captain may surrender some responsibility to the first officer in order to accomplish the task. A somewhat shallower trans-authority gradient1 may be the result, although captains, recognizing the superior CDU skills of their first officers, may follow good CRM principles and use them to their advantage.

• There is a tendency of the crew to help each other with programming duties when workload increases, which can dissolve a clear demarcation of duties. This seems to be computer-induced behaviour, since no similar situation is observed in traditional aircraft.

Although little is known about the implications of automation for the design and conduct of Line-Oriented Flight Training, some particular issues can be highlighted.

The automated flight deck offers new opportunities for scenario design. In conventional flight decks it was necessary to introduce system failures to elevate the workload and stress of the crew in a realistic manner, but the automated flight deck has enough built-in stressors to do this job, especially in the area of ATC instructions.

The “glass cockpit” presents new opportunities for scenario design that do not require abnormal conditions or emergencies - difficult problems at the human automation interface will suffice. There now exists the opportunity to design scenarios that will address the problems and opportunities of working in automated flight decks, where their peculiar characteristics can be stressed and where CRM principles can be easily exercised. For example, an ATC instruction including an unexpected, non-depicted holding pattern over a fix defined by a radial/DME value, provides considerable opportunities to practice CRM principles without the necessity of introducing any system failure.

Aircraft manufacturers are giving more importance to human performance issues in automated flight decks. At least one of them has joined efforts with a training development company to integrate present and future training programmes in Cockpit Resource Management into the transition training courses for its aircraft. The manufacturer's instructor pilots will receive CRM training. Current training courses for pilots and maintenance technicians will also incorporate CRM programmes. This particular manufacturer claims that CRM courses to be developed will be airplane tailored, with a different CRM course for each specific model of aircraft in the production line. The justification for this decision is based on the need to align training with

longer-term behaviourial education, as well as to concentrate on the assigned duties and responsibilities of the flight crews. Most importantly, it is the tacit
recognition that Human Factors education is no longer an exclusive responsibility of the operators, but an integral part of present-day system operations.

Adequate instructor/check pilot training is necessary, and must be emphasised, since some instructors may have only a little more meaningful (i.e. operational) experience and knowledge than the students. A strong case can be made for practical experience input to instructor and student training. The need for more emphasis on behavioural issues (CRM and LOFT training) has also been suggested. Though the Human Factors profession has recognised the problem, the issue of instructor training in relation to automation has not yet been properly addressed, and training specialists have no source to consult for guidance on the question of training for automation. Instructor selection and training continues to be determined by the same time-honoured methods and criteria applied for conventional flight decks, although the training issues are quite different on automated flight decks.

Role of the regulator

The role of the regulatory authority in the development of training programmes and instructor training must not be overlooked. During the certification process, the regulatory authority evaluates information presented by the manufacturer. These certification data must be delivered to the operator, since it provides the foundation upon which to build the training programmes. By knowing, for example, the manufacturer's design intent, the operator can develop procedures in which tasks can be properly identified. The training programmes thus defined must then be validated based on the same sources of information, closing the manufacturer-regulatory authority-operator loop. Training should be part of the integral system design, and it must be contemplated as part of a systems engineering approach.

.