Crew Resource Management, Threat and Error Management and Assessment of CRM skills – current situation and development of knowledge, methods and practice

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Report for the Swedish Civil Aviation Authority

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Current situation and development of knowledge, methods and practices

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Introduction

Human Factors is a scientific field that focuses on the interaction between people, technology and organization so that goods or services can be produced safely and effectively. Human Factors is an interdisciplinary field that encompasses, among other things, psychology, technology and engineering, as well as sociology and organizational theory. Human Factors can concern everything from fundamental ergonomic questions regarding suitable working postures, to complex associations between the ways management expresses goals and how this affects day-to-day work in an organization. EUROCONTROL has summarized its interpretation of the field of Human Factors in an overview figure:

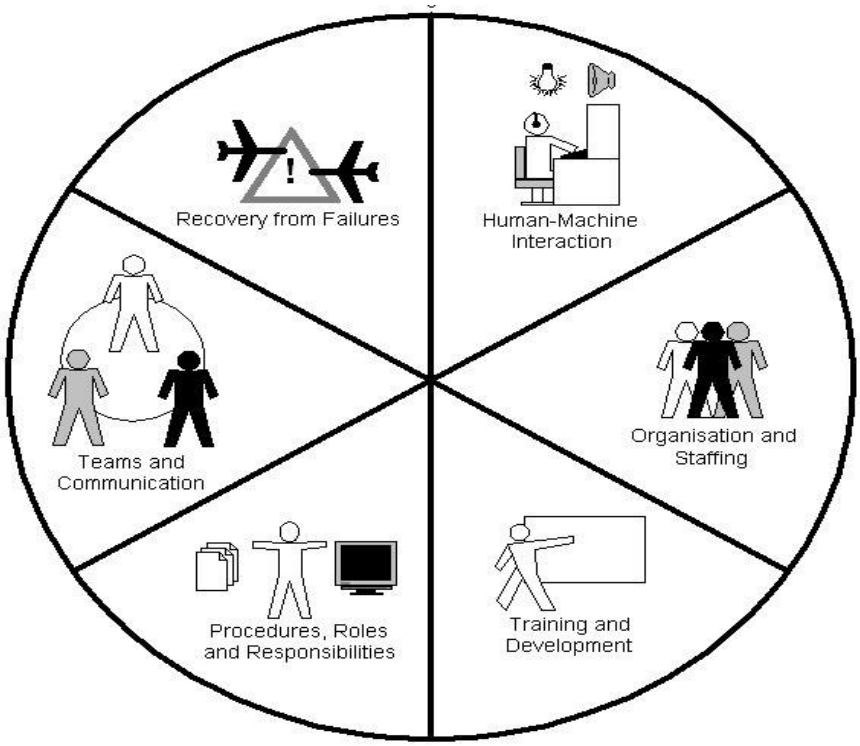


Figure. EUROCONTROL interpretation of the field of Human Factors
(http://www.eurocontrol.int/eec/public/standard_page/human_factors_case.html)

CRM (Crew Resource Management) can be considered as Human Factors in an applied form, primarily in the aviation industry. CRM has proven to be an important tool for improving safety and has been adopted in an increasing number of fields in which safety is of high priority, such as in sea and rail transportation, in chemical and nuclear industry and in medicine.

The intent of this report was to contribute to further development of CRM in Sweden, which in turn then can contribute to further development of flight safety in Sweden. The underlying thought is that increased attention to and knowledge of CRM can be an important tool for long-term improvement of flight safety in Sweden. The report focuses on CRM in flight operations, meaning primarily CRM for pilots and to a certain extent for cabin crew, while Human Factors training for technical personnel has received limited attention. The reason to focus on these groups, is that for them there are explicit regulatory requirements in regards to CRM or Human Factors training, which should be performed periodically as well

as in relation other events (such as in conjunction with changes of operators or aircraft types). The report, however, also includes information of value for other aviation and non-aviation occupational categories in which there may be a desire to use CRM as a tool for increasing operational safety.

The report is oriented towards a reader who works at the Swedish Civil Aviation Authority, but it should be accessible to anyone who works with aviation in Sweden and who wants to increase his or her knowledge of CRM. In keeping with this orientation, it focuses on operations rather than training activities, meaning more on JAR-OPS than on JAR-FCL. (Consideration has also been taken to EU-OPS, which is of current interest but which to a far extent is JAR-OPS under a new name.) By presenting knowledge based on research and experience concerning CRM – with special focus on CRM Training, TEM (Threat and Error Management) and assessment of CRM skills – and guidelines for applying this knowledge, the intentions of applicable regulations for these fields may be further realized. With access to easily comprehensible information about these issues, the Swedish Civil Aviation Authority can more effectively support related operator development of them. This should subsequently contribute to increased flight safety.

It is important to emphasize that the report is not intended to be used use as a tool for formal regulatory audit of operative organizations. Where detailed issues concerning implementation of regulation by operators are covered, the purpose is to ensure that applicable regulations are applied so that they contribute to increased flight safety. The intention is to support development towards increased flight safety through effective CRM training – including application of TEM and assessments of CRM skills – by providing easily available information and support for all who work with the various aspects of flight safety.

A simple explanation for the report being prepared is that there is little material about CRM in Swedish, while for TEM and assessments of CRM skills, there is nothing at all. There is considerable interest in CRM among those who work with aviation in Sweden. But professionals of today normally are subjected to a substantial amount of information to digest in a limited time, and for Swedish Civil Aviation Authority personnel – as well as others who work with aviation in Sweden – this is especially true. Having access to scientific articles as well as the opportunity to set aside time for reading them is for many, not something that can be taken for granted, regardless of their level of interest in the subject. This report therefore attempts to present an overview of the current situation and developments in CRM.

For the reasons above, one objective in preparation of the report has been to make it easier to read than traditional scientific reports. Examples of this are the limited use of overly academic language and complicated abbreviations. There are no footnotes or references in the text, again to make the report easier to read. References to the literature that the report is based on, in the form of a list of recommended reading, is provided instead.

In closing, I would like to thank those who have helped with the report, especially my coauthors Jimisola Laursen and Johan Bergström. I would also like to thank the students at Lund University School of Aviation whom I have had the opportunity to assist in writing their theses over the years, especially Emelie Lundh and Magnus Nilsson, as well as Marcus Andreasson, Andreas Avedal and Anders Ludvigsson, whose efforts have significantly contributed to the report. I am also grateful to those at the Swedish Civil Aviation Authority and others who work with aviation who I have spoken with in to supplement my own experiences of the situation of CRM in Sweden. I am not mentioning these people by name, however, due to that the conversations have been informal in nature, rather than formal interviews. And last but not least, I would like to thank Bo Johansson at the Swedish Civil Aviation Authority for entrusting me to compile and write this report. I hope that it will be of use to as many as possible of those who work with aviation in Sweden.

Special introduction for the English version of the report

As can be clearly seen in the previous section of this introduction, this report was originally written in Swedish and intended for a Swedish readership. In particular, it was intended to provide a useful overview for Swedish Civil Aviation Authority personnel, as well as for operators and others working with CRM, Human Factors and aviation safety in Sweden.

That the report was deemed to be useful also outside of Sweden and translated into English was a pleasant surprise and again I have to express my gratitude to Bo Johansson and his colleagues at the Swedish Civil Aviation Authority for the cooperation, not only in producing this report but also in turning it into more widespread report than originally intended.

It should be noted that the report was translated by a non-aviation third party and this, together with the original text being specifically directed to a distinctly defined readership, means that in the text there are wordings which is not coherent with language normally used in the field of CRM, Human Factors and aviation safety. This is compounded by the fact that the text that was studied for the report was written in English and the translation to Swedish and back to English may have produced some unintended departures from the original texts.

Regardless of this, the report should be useful for anyone who is not already intimately familiar with the current regulatory and practical situation in regards to CRM, TEM and assessment of CRM skills. For comments or any other contact regarding the report you are welcome to contact me at nicklas.dahlstrom@tfhs.lu.se.

1 Crew Resource Management (CRM)

1.1 Background information

Since the early years of aviation, flight safety has been a constant concern. Research and development regarding human performance and its limitations have, together with technological development, supported a continuous improvement of flight safety. Due to development of aircraft design and performance as well as of instrumentation, aircraft in general and cockpits in particular have evolved into the most advanced workspaces that most people ever encounter. Implementation and development of various types of technological aids, e.g. automation, have decreased pilot workload and thereby contributed to establishing a present level of flight safety that empowers people to travel to their destinations without being concerned about safety.

An important step in increasing flight safety was the phasing out of piston-engine aircraft in favor of jet engines, which dramatically reduced the number of accidents. The new and more reliable engines – along with other more reliable and safe technology in aircraft – lead to that from 1959 to 1979, the percentage of aviation accidents concluded to have been caused by technical problems declined to only about fifteen percent. A significantly larger portion, about two-thirds, was attributed to what is commonly referred to as “pilot error”.

The accident that resulted in the largest-ever number of fatalities occurred in 1977, when two Boeing 747s collided on the runway on the island of Tenerife. Along with other major accidents during the 1970s, this formed the beginning of a new era for flight safety. Flight safety no longer seemed to be primarily a matter of a pilot’s skills in handling their planes or even of technical reliability; pilots’ skills relating to interaction with other people were found to be at least as important.

Two years after the accident on Tenerife, the National Aeronautics and Space Administration (NASA) held a seminar covering the topic of “Resource Management on the Flight Deck”. At about the same time, analyses of accidents and incidents showed that the majority of them were not caused by inability to control the aircraft, but instead by deficiencies in information management, decision making, communication and leadership. NASA introduced the acronym CRM at the seminar, at this time meaning Cockpit Resource Management. Training programs aimed at improving information management, decision making, cooperation and leadership were recommended and a large number of the airlines that participated in the seminar began to gradually implement such training. CRM has since these events been further developed and the concept has successfully spread around the world, both within the field of aviation and beyond it.

When CRM training was first implemented, it was initially met with resistance from flight crews, who felt that it was overly oriented towards psychology (or even psychotherapy) and that the commander's authority could be undermined by the content. United Airlines was the first airline to implement CRM training as a consequence of NASA's seminar.

Since this time, CRM has continually evolved. From initially having been a voluntary element of pilot training used by some airlines, today it is in most parts of the world a mandatory part of initial, conversion and recurrent training. Even in other fields – such as shipping, chemical and nuclear industry, and medicine – training of this type is now performed. Within the aviation industry, the number of personnel categories that should undergo CRM training is constantly increasing. This is illustrated by the CRM abbreviation presently referring to all of the crew (C now stands for Crew instead of Cockpit) and that it is increasingly linked to the overall activities of a company (with C standing for Company).

Despite the aviation industry being largely convinced that CRM has been of great importance during the past decades in increasing flight safety, this is something that is

difficult to prove. Nonetheless, the conviction is sufficiently strong that over the years, several initiatives have been taken to promote the importance of CRM. The most prominent example of this may be the strengthened regulatory requirements, both regarding CRM trainers and assessment of CRM skills.

1.2 Present situation – Regulations and general recommendations

1.2.1 Introduction

Due to CRM and CRM training primarily being a concern for operations, relevant regulations for CRM can be found in sections focusing on operations (i.e. JAR-OPS and EU-OPS, hereafter reference will be made only to JAR-OPS). Subpart N contains regulations for flight crews and Subpart O, regulations for cabin crews. Each subpart stipulates who is to undergo CRM training and when training is to be performed. There are also requirements in regards to the qualifications of instructors for CRM training for pilots and cabin crews.

This report focuses on operations rather than training activities since CRM is primarily an operational matter. For basic flight training, CRM is normally first introduced in conjunction with the Multi-crew Cooperation course (MCC). This report therefore refers to JAR-FCL in only a few cases (see chapter 3). With implementation of the Multi-crew Pilot License (MPL), CRM and TEM have received a more prominent role in basic flight training, but since this is still a relatively new part of the regulations and it remains to be seen what this will in lead to in practice, CRM and TEM in conjunction with MPL have not been addressed in this report.

It is also worth noting that in JAR-OPS, most information about CRM is to be found in the text that covers Acceptable Means of Compliance (AMCs) in Section 2, not in Section 1 (Section 1, which contains the regulations, has been translated into Swedish, while Section 2 with the AMCs has not.) With only a few exceptions, this report will not address the difference in legal status that exists between the regulations in Section 1 and the AMCs in Section 2. Even if there naturally should be a difference between regulations and the recommendations represented by the AMCs, it is important to remember that this categorization is more a matter of purely legal aspects concerning what is possible to implement in law in certain countries (and thus becomes very difficult to change). Because of this, in JAR-OPS we have the differentiation between more widely formulated regulations and the more specific recommendations, as represented by the AMCs. In most cases, however, both of these categories are to be considered in practice as regulations (even if the AMCs probably could be challenged from a strictly legal perspective).

It can be generally said that CRM training is to be performed on the following occasions, regardless of whether it is directed to pilots or cabin crew:

- Initial CRM training is to be provided to those who have not previously undergone such training
- Type-specific CRM training is to be provided to personnel who change to a different aircraft type, as part of their conversion training
- Operator-specific CRM training is to be provided to personnel who change to a different operator
- CRM for a new operative role is to be provided in conjunction with commander or cabin manager training
- Recurrent training is to be regularly conducted and be scheduled to cover the content of the initial course over a three-year period

1.2.2 JAR-OPS 1, Subpart N – Regulations and possible interpretations

Some of the paragraphs in JAR-OPS 1 addressing CRM are presented below. For the following interpretations and comments, texts in appendices to the respective paragraphs and the associated recommendations (AMCs) have also been used. To be able to describe and discuss the regulations in a way that makes them easy to grasp only the main paragraphs have been provided as reference. In JAR-OPS though, all references to appendices and recommendations have been provided directly under the main paragraphs to make it easier for readers to locate and read the original texts from the regulations.

JAR-OPS 1.943 Initial operator training concerning CRM

Before a flight crew member ("pilot" will be used from this point forward) undergoes CRM training, he or she shall previously have received initial training in Human Factors. If this knowledge is insufficient, training corresponding to the basic course in Human Performance & Limitations shall be conducted (which can be combined with the CRM course). Most likely, this requirement is seldom applicable because most pilots have already undergone some form of Human Factors or CRM training. It cannot be precluded, however, that it may be applicable to those who begun working in commercial aviation late in their careers or who have been trained and worked outside of Sweden or other JAA states.

Pilots who will be working in commercial aviation must first complete an initial operator's CRM course, which shall be based on a detailed syllabus in the operations manual (JAR-OPS 1.943 and 1.945). Those employed by an operator may, however, have already completed such training with a previous operator or in conjunction with a Multi-crew Cooperation (MCC) course, or in conjunction with training for a specific aircraft type or even during their basic training. Initial training in CRM shall have been of at least one day in duration for a crew member in a single pilot operations or at least two days for crew members in all other types of operations. The course shall have been completed within one year of the date of employment and have been conducted by at least one CRM trainer who is acceptable to the authority, and who may be assisted by experts in certain subject areas. Recommendations concerning course content are presented in table 1.2.2.1, column b.

JAR-OPS 1.945 Conversion training and checking

In conjunction with aircraft type changes, CRM training adapted to this shall be a part of the conversion training. It shall focus on human error, automation, type-related differences and relevant case studies (see table 1.2.1.1, column c). In contrast to the initial course, the duration of this course is not stipulated in the regulations.

During conversion training in conjunction with changing operators, the CRM course shall focus on safety culture, procedures and organizational factors, as well as automation and case studies (see table 1.2.2.1, column d). Human error, communication and leadership shall also be covered on an overview level. Stipulations on course duration are not provided here either.

JAR-OPS 1.955 Appointment of commanders

CRM training shall be undergone in conjunction with the command course and with focus on all subjects covered in the initial course with the exception of human error, which can be covered more in the form of an overview (see table 1.2.2.1, column e). Time for this is not specified.

JAR-OPS 1.945 Recurrent training and checking

For recurrent training it is stipulated (JAR-OPS 1.965) that during a period that may not exceed three years, all topics covered during the initial operator CRM training shall be covered by the recurrent training (see table 1.2.2.1, column f). There is no time stipulated for this. For several Swedish airlines, times for annual recurrent CRM training vary from four to eight hours of instruction.

Despite the lack of support in the regulations for specific course durations, a possible interpretation is that since the time for the complete initial operators CRM training is specified as two days (except for single pilot operations), and that all subjects are to be covered within a three-year span, a timeframe of one-third of two days may be a logical assumption for annual recurrent CRM training, i.e. about five hours of instruction.

It is also emphasized in the regulations that CRM shall be integrated in all parts of recurrent training of and by all personnel who participate in conducting it, and that all personnel consequently shall have competence in CRM to ensure that this is achieved.

Other regulations concerning CRM

There are recommendations in the regulations stating that work concerning CRM training and execution of it should be coordinated between pilots and cabin crew whenever possible. (This will be covered later in this report.)

In three paragraphs under [ACJ] OPS [(IEM)] 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e) Crew Resource Management (CRM), there are additional guidelines for CRM training. It is emphasized here that CRM training shall reflect the operator's culture (a term that may be difficult to interpret) and that it can be conducted in the form of classroom training and practical exercises, such as group discussions, and analyses of accidents and serious incidents, to illuminate communications problems or deficiencies in information management and crew interaction.

In the second of these three paragraphs, it is stated that whenever possible, consideration should be given as to whether CRM training can be conduced in a simulated environment to reproduce a realistic and interactive environment, such as in conjunction with line-oriented flight training (LOFT).

In the last of these three paragraphs, there is an ambiguous recommendation calling for initial CRM training to be conducted "outside of company premises" so that the participants are removed from the "pressures of their usual working environment". What is odd about this is that if it is an initial CRM course that is actually referred to in the paragraph, the participants have just begun their careers with an operator (because the need for an initial CRM course indicates that they have not undergone such training previously) and subsequently, no problems with the "usual working environment" have probably yet been encountered.

(a)	Initial CRM Training (b)	Operator's conversion course when changing type (c)	Operator's conversion course when changing operator (d)	Command course (e)	Recurrent training (f)
Human error and reliability, error chain, error prevention and detection	In depth	In depth	Overview	Overview	Overview
Company safety culture, SOPs, organisational factors		Not required	In depth	In depth	
Stress, stress management, fatique & vigilance			Not required		
Information acquisition and processing situation awareness, workload management		Overview			
Decision making					
Communication and co-ordination inside and outside the cockpit			Overview		
Leadership and team behaviour synergy					
Automation, philosophy of the use of automation (if relevant to the type)	As required	In depth	In depth	Not required	Not required
Specific type-related differences			Not required		
Case based studies	In depth	In depth	In depth	In depth	In depth

Table 1.2.2.1. Overview of CRM course content for flight crews
(AMC OPS 1.945(a)(9)/1.955(b)(6)/1.965(e) Crew Resource Management (CRM) Training)

It can sometimes be difficult to draw distinct lines between CRM as a general subject concerning human behavior, focused on individuals and group interaction, and the more "technical" aspects of aviation. In this context, it is worth noting that in table 1.2.2.1, it is specified that in CRM training, standard operating procedures are to be covered in CRM training, as well as automation philosophy and the use of automation. In AMC OPS 1.945 (a)(9) Crew Resource Management – Use of Automation, it is also emphasized for conversion training that the application of the operations policy concerning the use of automation as stated in the operations manual is to be covered, as well as human limitations of relevance to this. This accentuates the wide area available in CRM for focusing both on general principles of human behavior as well as how it interacts with procedures and technologies on a much more detailed and technical level.

1.2.3 JAR-OPS 1 Subpart O – CRM training for cabin crew

The paragraphs in the regulations concerning CRM for cabin crew are somewhat differently formulated in comparison to those for pilots, but in most cases, the implications of them are similar. For cabin crew, there is text stipulating that CRM shall be integrated with other parts of training. The same five categories of training are represented (CRM training for those who have not received such training previously, upon changes of operators or aircraft types, as recurrent training and in conjunction with cabin manager training). That there are differences, however, are underscored by the formulation in Section 2 (ACJ OPS 1.1005/1.1010/1.1015 [ ]), where it is stated that:

> 2.1 Cabin crew CRM training should focus on issues related to cabin crew duties, and therefore, should be different from flight crew CRM training. However, the co-ordination of the tasks and functions of flight crew and cabin crew should be addressed.

Before a cabin crew member may begin in-flight duty, he or she shall have completed an initial CRM course. This course shall be conducted by at least one CRM instructor for training of cabin crew. (In the general recommendations in Section 2, just as for pilots, there is a required profile for CRM instructors for cabin crew.) In common with pilots, cabin crew shall undergo CRM training as part of conversion training when changing operators or aircraft types, and during recurrent training, which should cover the content of an initial course over a period that may not exceed three years (just as for pilots). These courses shall at least include the subjects found in table 1.2.3.1.

One of the most important differences in regard to the corresponding text for pilots is that there is not any times specified at all CRM training, not even for the initial course (which for pilots is specified to be one or two days long). At the same time, there is a text for cabin crew in Section 2 (ACJ OPS 1.1005/1.1010/1.1015 [ ]) that provides the opportunity to combine all of the five types of CRM training. This provides the option of performing mixed and very brief CRM courses, and there are examples of initial CRM courses being only two hours long (with the justification being that CRM is integrated in other types of training).

Another difference is that table 1.2.3.1 (presented at the end of this section), which specifies content of the various types of CRM training for cabin crew, is provided as an appendix to Subpart O, while for pilots, it can be found among the recommendations (AMCs). In a strict legal interpretation, this could imply that the specification of content for the various CRM courses has a stronger status for cabin crew than for pilots. In practice, this has probably limited or no significance.

Another odd difference is that those who conduct the courses for cabin crew are referred to as cabin crew CRM instructors, while for pilots, the term CRM trainers is used. This probably has no significance and is likely the result of the regulations being written at different times and by different people.

Just as for pilots, at the end of ACJ OPS 1.1005/1.1010/1.1015 [ ] there is a formulation that recommends coordination between the two categories in regard to CRM training:

> 9 Co-ordination between flight crew and cabin crew training departments
> 9.1 There should be an effective liaison between flight crew and cabin crew training departments. Provision should be made for flight and cabin crew instructors to observe and comment on each other's training. Consideration should be given to creating flight deck scenarios on video for playback to all cabin crew during recurrent training, and to providing the opportunity for cabin crew, particularly senior cabin crew, to participate in Flight Crew LOFT exercises.

The text here is very detailed in that it expressly recommends use of video and participation in LOFT for pilots.

Subjects included in training a)	**Initial training** b)	**Operator's CRM training** c)	**CRM that is associated with aircraft type** d)	**Recurrent training** e)	**Training for cabin managers** f)
General principles					
The human factor's significance in aviation General instructions for CRM principles and goals	Included	Not required	Not required	Not required	Overview
Human capabilities and limitations					
From the individual cabin crew member's perspective					
Personality awareness, human error and reliability, attitudes and behavior, sell-assessment	Included	Not required	Not required	Overview (three-year period	Not required
Stress and stress management					
Fatigue and lack of sleep					
Vigilance					
Situation awareness, obtaining and handling information					
From the entire aircraft crew's perspective					
Identification and prevention of faults	Not required	Included	Relevant for type/types	Overview (three-year period	Maintenance of knowledge (relevant for cabin manager duties)
Shared situation awareness, obtaining and handling information					
Workload management					
Effective communications and cooperation between all crew members, including the flight crew and inexperienced cabin crew members, cultural differences					
Leadership, cooperation, interaction, decision-making, delegation					
Individual responsibility and group responsibility, decision-making and actions					
Identification of passengers' human capabilities, crowd control, passenger stress, conflict management, medical factors					
Factors related to aircraft type (narrow body or wide body, one or more passenger decks), composition of flight and cabin crew, and number of passengers		Not required	Included		
From the operator's and organization's perspective					
The company's safety culture, SOPs, organizational factors, factors that are related to type of operations	Not required	Included	Relevant for type/types	Overview (three-year period	Maintenance of knowledge (relevant for cabin manager duties)
Effective communications and cooperation with other operative personnel and ground service					
Review of reports and failures related to cabin safety					
Case-based studies (see note)		Required		Required	

Table 1.2.2.1. Overview of CRM course content for cabin crews
(Supplement 2 to JAR-OPS 1.1005/1.1010/1.1015 Training)

1.2.4 Human Factors training for technical personnel

That no chain is stronger than its weakest link is never more clearly illustrated than when safety is in focus. In JAR-66 and JAR-145 NPA 12, there are requirements for initial and recurrent Human Factors training for technical personnel. Such training has in certain contexts been referred to as MRM (Maintenance Resource Management). Just as for pilots and cabin crew, the intention of this training is to reduce the number and impact of errors, but in this case in regard to inspections, maintenance and repairs.

Such training is basically only an application in another operational area of the knowledge base and principles of Human Factors and CRM, which also is common for both pilots and cabin crew. It is all about applying the same type of knowledge in a different context and being able to illustrate it with examples and case studies from this context.

It should be noted that this more technically oriented aspect of Human Factors and CRM has become increasingly important and has been highlighted by being brought up at an increasing number of conferences and in books being published in recent years. Because the field is relatively new and JAR-145 has not yet been updated with NPA 12, this report does not go into the details concerning Human Factors training for technical personnel.

1.2.5 CRM training for other personnel categories

Certain airlines even provide CRM training for personnel for whom it is not a mandatory requirement according to JAR-OPS. This has been the case for check-in personnel, ramp personnel, flight dispatchers and other personnel who in different ways work with planning, management and follow-up of operations. In the United States, a separate version of CRM called Dispatch Resource Management (DRM) has been developed for flight dispatchers, similar to the training provided for pilots and cabin crew. CRM training provided to more categories of personnel can thus support a safer and more efficient execution of operations. Moreover, it can increase understanding of the work of other personnel categories, especially for those who work with planning, control and follow-up of operations, CRM training can lead to a common language in regard to safety matters and consequently increased understanding of the balance between safety and execution of operations, which in turn can result in better cooperation with crews. There are, however, no demands in the regulations for CRM training to be provided for these other personnel categories.

The most common question from crews who have received CRM training is whether management has received or will receive CRM training. Because there are no such demands according to the regulations, the answer in most cases is this has not occurred and will not occur. When management has participated in CRM training, this has been perceived as very positive by pilots and cabin crew. Exactly as mentioned above, this can lead to a common language, increased understanding and improved cooperation. (This assumes that the CRM training provides those who have completed it with knowledge and capabilities for this.) If a good conversational tone can be established during CRM training, the discussion of its content can produce useful information for management staff and also provide them with the opportunity to present their perspective on various issues. Despite this being entirely beyond the scope of the regulations, it is nonetheless recommendable that management does participate in CRM training.

1.2.6 Joint CRM training for pilots and cabin crew

There are advantages with joint CRM training for pilots and cabin crews. For these personnel categories, it is a necessity that they can cooperate effectively so that both routine situations and emergencies can be managed safely. Pilots are confined in a limited space, and despite their access to various monitoring systems, they thus have limited opportunities to obtain information beyond what is provided by technical sensors in the aircraft. What cabin crew have seen, heard or smelled can in certain situations – such as when there are engine problems, smoke or fires – be of crucial importance for the decisions that pilots make. Cabin crew can be entirely dependent on pilots' assessments and decisions, such as when they are dealing with violent passengers or if a passenger has medical problems. Joint CRM training can contribute to improving such cooperation between pilots and cabin crews.

Even though it is desirable to conduct joint CRM training for pilots and cabin crew, and the fact that this is also recommended in the regulations, there are nonetheless also some disadvantages. It may mean that a CRM course must be conducted on a more general level, without in-depth study of any of the crews' special areas of knowledge or the use of detailed case studies. Without such in-depth study, there is a risk that relevant knowledge is not covered and that interest in the training declines. Even if it is worthwhile with joint training from a cooperative standpoint, CRM contains much more than what can solely be related to cooperation between pilots and cabin crew. Viewed over a longer period, it may be desirable that both joint and separate CRM courses are planned and conducted for pilots and cabin crews.

1.3 Delivering CRM training – Practical aspects

A number of practical aspects in regards to CRM training are presented below, as well as comments regarding what can be required of operators to ensure that they perform CRM training in accordance with both the letter and intent of the regulation. The matters formulated are intended to contribute with guidelines and support for how operators can further develop their CRM training.

According to what is specified in Section 2 (AMC 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)), the following applies to CRM:

> 1.1 Crew Resource Management (CRM) is the effective utilisation of all available resources (e.g. crew members, aeroplane systems, supporting facilities and persons) to achieve safe and efficient operation.
>
> 1.2 The objective of CRM is to enhance the communication and management skills of the flight crew member concerned. The emphasis is placed on non-technical aspects of flight crew performance.

These definitions are usually well known to operators and entirely non-controversial but it can nonetheless be good to point out that the text above constitutes the fundamental formulations in regards to the intention of CRM training.

1.3.1 Planning and preparation of CRM training

Many operators work under considerable pressure in regard to the resources they have for carrying out their operations. This means that training (that does not contribute to resolving direct operative problems) often has a lower priority than what is reasonable in consideration to its long-term significance for flight safety. The chief reason for this is that training creates short-term operative problems by taking time away from normal operations.

This applies to CRM in particular because in relation to training with more clearly practical content (such as handling of medical problems, firefighting, evacuation and similar areas), the consequences of placing less emphasis on CRM training can be less obvious in the short term. Quality differences in CRM training are often apparent to those who experience it, but it is difficult to prove, and impossible to know for certain, whether the differences will have a direct impact on operations within the immediate future.

It can be especially difficult to determine if the time scheduled for CRM training is sufficient since the only time specified in JAR-OPS is the two days for initial operator training (and this is found among the recommendations in Section 2). For all other types of CRM training, times are unspecified. To be able to determine if the time set aside is sufficient, assessments must be made of the set-aside time in relation to the content. It can be a difficult task to weigh the intent of the applicable regulations against the space for interpretation that exists in regard to time for CRM training (and the risk of training being all too limited).

When it comes to pilots who have previously experienced CRM training with another operator, conversion training shall be performed. With some operators, doubt has been expressed in regard to when initial operator training and/or conversion training is to be performed. In consideration to the requirements of initial operator training (see Section 2.3), it can seem that such training should be performed when changing operators. However, it is stated in the regulations that a two-day initial operator course need only to be performed for those who have never before undergone such training before. That there are operators who despite this, perform initial CRM courses for pilots who only needs a conversion course is probably an indication that they see this as an investment in training that produces desired effects in the form of increased safety and effectiveness. A shorter conversion course is however in compliance with the requirements for CRM training that apply in conjunction with change of operator.

For CRM, operative demands in combination with limited resources for training can result in planning for CRM being negatively affected, e.g. in regard to adapting training to the specific conditions of an operator. Preparation in particular can be too short for a CRM course to be performed as a well-adapted and effective training intervention. It is unfortunately rather common that CRM instructors are contacted on short notice to solve the “problem” of getting CRM training performed.

Of special importance to effective CRM training is that it is adapted to the operations of the company it concerns. This can only be optimally accomplished, however, after initial CRM training ensures that pilots of the operator actually have the fundamental knowledge of CRM that they should have. That this CRM training shall be adapted to operations is specified in JAR-OPS Section 2 (AMC 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)):

> 2.3 An operator should ensure that initial CRM training addresses the nature of operations of the company concerned, as well as the associated procedures and the culture of the company. This will include areas of operations which produce particular difficulties or involve adverse climatic conditions and any unusual hazards.

This means that resources must be set aside either to integrate events and incidents from an organization’s operations into the training material or to base training material entirely on such incidents. Even though this also is preferable, this task is not commonly carried out due

to the large amount of resources such work requires. Few operators in Sweden have in-house knowledge resources for the fields of Human Factors and CRM that can carry out such work, and regardless of this, the question remains of how much time can be set aside to produce and adapt training material to the operations of the company. (When CRM instructors are engaged as external resources, each hour constitutes a cost and it is therefore rare that they are given the opportunity to make extensive preparations funded by the operator.)

Attention to these conditions can be given by focusing on the following operator conditions in regard to planning of CRM training:

- Scheduled times for different types of CRM training
  (to identify lead times and planning prior to courses)
- Time set aside for various types of CRM training
- Preparations that are normally conducted prior to CRM training
- Information to the CRM instructor about operations
  (How has the instructor received information about the operator, especially about incidents or other CRM-related incidents at the company?)
- Use of own company-specific operative incidents in CRM training

1.3.2 Syllabus for CRM training

JAR-OPS requires that operators have a detailed syllabus for CRM training in their operations manuals. Whether a syllabus is relevant and satisfactory for an operator's operations is difficult to assess. In practice, it is probably uncommon that CRM constitutes a prioritized part of an operations manual. A carefully considered and documented plan for CRM training, however, constitutes the basis for training being able to be planned and conducted so that it has the desired effect on safety and efficiency in operations. When it comes to the content of such a syllabus, table 1.2.2.1 determines the general syllabus structure of various types of CRM courses.

A sign that a syllabus has not come about through careful preparation is that it contains extensive elements of physiology. It can be relevant to include some physiology (e.g. in regards to optical illusions) within the framework of CRM training, but if there are large elements of physiology in the syllabus, this indicates a lack of knowledge of CRM. If there are also text corresponding directly to the content of the syllabus for the physiology element of the initial training subject HPL (Human Performance and Limitations), this is an even more distinct sign of deficiencies in the syllabus. Sometimes the physiology element of HPL may even have been copied word for word or used in rewritten form in a syllabus. Even if there is nothing to prevent the use of this text, it is most likely a sign of deficiencies in the development of the syllabus for CRM training.

There shall also be differences between various CRM syllabi. Even if the same content is to be covered in several different types of CRM courses, this shall be done in varying ways in regard to the content's scope and depth, all depending on the type of course. Such planning and adjustment of the course content should be clearly visible in the syllabi for the various types of CRM courses.

It is naturally preferable that operators possess thorough knowledge of the strengths and weaknesses of their own operations, and how CRM plays a part in contributing to operations being conducted safely and effectively. This should be reflected in the operators' syllabi for the various types of CRM courses, and if it does not, there is reason to encourage efforts to further develop the syllabi. For this purpose, the following can be worthwhile for operators to consider:

- Background information about how syllabus for CRM courses are prepared (which resources and competences have been utilized)
- Presence of physiology elements in syllabi for CRM
- Comparison of syllabi for CRM training with the syllabus for HPL, especially in regard to the physiology element to find out if there are significant similarities between them
- Adaptation of syllabi for CRM training to the company's operations and checks of how this has effected the execution of CRM training
- Overview of syllabi for various types of CRM courses and auditing of how they are adapted to the actual knowledge needs of the various types of CRM training (and how these knowledge needs have been identified)

1.3.3 CRM instructors

In JAR-OPS, the fundamental requirement for CRM instructors/trainers is that they shall be acceptable to the authority. This requirement is open to a wide range of interpretations that may need clarification. Discussions between authorities and representatives for CRM instructors concerning which requirements are to be established for CRM instructors have been ongoing for several years, both in Sweden and in other countries in Europe. The British as well as the Swiss Civil Aviation Authority have come furthest in creating a system for approval of CRM instructors (CRMI) via designated CRM instructor examiners (CRMIE). These systems include that besides showing their qualifications, those who want to work as CRM instructors must also be assessed by a CRMIE when they perform CRM training. (The British regulations for this encompass everything from criteria and procedures for approval to specific sums for fees that are to be paid for the approval process.) In this context, there is also a requirement for periodic renewal every third year by instructors being observed while conducting CRM training.

It is worth pointing out that JAR-OPS Section 1 does not address specific requirements for CRM instructors, but only that they shall be acceptable to the authority. However, in Section 2 (AMC 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)), there is an advisory passage that provides further clarification for CRM instructors (which in part constitutes the foundation of the system created by the British Authority, UK CAA):

2.2
a. A CRM trainer should possess group facilitation skills and should at least:
i. Have current commercial air transport experience as a flight crew member; and have either:
(A) Successfully passed the Human Performance and Limitations (HPL) examination whilst recently obtaining ATPL (see the requirement applicable to issue of Flight Crew Licenses); or,
(B) If holding a Flight Crew Licence acceptable under JAR-OPS 1.940(a)(3) prior to the introduction of HPL into ATPL syllabus, followed a theoretical HPL course covering the whole syllabus of HPL examination.
ii. Have completed initial CRM training; and
iii. Be supervised by suitably qualified CRM training personnel when conducting their first initial CRM training session; and
iv. Have received additional education in the fields of group management, group dynamics and personal awareness.
b. Notwithstanding paragraph (a) above, and when acceptable to the Authority;
i. A flight crew member holding recent qualification as a CRM trainer may continue to be CRM trainer even after cessation of active flying duties;
ii. An experienced non-flight crew CRM trainer having knowledge of HPL, may also continue to be a CRM trainer;
iii. A former flight crew member having knowledge of HPL may become a CRM trainer if he maintains adequate knowledge of operation and aeroplane type and meets the provisions of paragraphs 2.2a ii, iii and iv.

Because these formulations allow considerable flexibility, it is difficult to interpret who may conduct CRM training (especially due to them being general recommendations in Section 2). The problem is that the flexibility is greater than what it may appear from the beginning. Attempting to set requirements that are specific enough to ensure a certain quality of CRM training may initially seem entirely realistic. With these requirements, however, it is much more difficult to be specific than for other proficiencies in the aviation industry. The issue of which knowledge CRM instructors should possess and which courses that may provide this knowledge cannot be easily resolved in with a syllabus, certain number of hours of instruction and a test based on multiple choice questions. Trying to formulate requirements for CRM instructors despite these difficulties entails the risk of creating an unclear legal situation and opening the way for appeals and conflicts as to who will be able to refer to themselves as CRM instructors. It remains to be seen if the British regulations will exert influence in other countries or if the present situation will continue, but for the time being, legally resilient restrictions concerning who may conduct CRM training are few.

It should also be mentioned that CRM is a field that many people are interested in and are studying on their own. In combination with the lack of requirements for competence and experience, and the unclear paths for becoming a CRM instructor, a situation has been created in which interested and motivated persons can enter this field without restrictions, regardless of their suitability for the role as CRM instructor.

Because many operators in Sweden have relatively small organizations, they may often not possess internal competence for conducting CRM training. This means that CRM training must be conducted by a third party. (This is also mentioned in JAR-OPS Section 2 (AMC 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)). In these cases, it is important for an operator to make sure that the engaged CRM instructor can conduct proper CRM training and is acceptable to the authority. For third-party instructors, it is important that they are informed of the specific nature of operations and receive internal company information, e.g. in regards to safety events, associated with CRM so that such information can be integrated into CRM training. (This is just as important for internal CRM instructors, but then often comes more naturally.)

Due to the situation concerning regulations for CRM instructors, it can be difficult to make progress regarding the issue of instructor approval. In regard to CRM instructors, the following points can nonetheless be worth considering by operators:

For CRM training conducted by one or more internal instructors:

- Operator's requirements and preferences regarding CRM instructors
- Description of each CRM instructor's background and suitability for the role
- Available working hours for CRM instructors to prepare material, planning and execution, as well as following up CRM training
- CRM instructors' access to current information related to flight safety (to be able to integrate this into CRM training)
- Planning of further training and skills development for CRM instructors

For CRM training by third-party instructors, the same points as above can be used, but then adapted to the current conditions and including clarification of the relationship between the operator and CRM instructors. When third-party instructors are used, it is preferable that the same instructors are engaged for subsequent courses because they will then already have some knowledge of operations. When instructors are replaced too often, it can be difficult to comply with the requirement concerning adaptation of CRM training to actual operations.

1.3.4 Evaluation and follow-up of CRM training

Evaluation is an important aspect of all training, especially if it is intended to have an impact on operations. Evaluation of CRM training can be considered as more important than for other training since the impact of it normally is not easy to see in the short term, compared with other training more oriented to developing technical proficiencies. For an evaluation of CRM training to be of value, it must subsequently be used for follow-up and further development of the training. This is all about closing the circle that was begun by using information about operations to form the basis of CRM training, which was then subsequently performed and then evaluated to see if it has moved operations in the desired direction.

At a minimum, evaluation of CRM training should include systematic course evaluation, providing the opportunity to assess and comment on course content and execution (for example, in regard to training methods and CRM instructor performance). Specific questions should cover what is desired by crews prior to future CRM training. Based on the evaluation, CRM training is followed up and improved.

The method for further developing CRM training specified in the regulations calls for feedback and assessment of CRM skills. Such information about observed behavior with respect to CRM, in conjunction with training and checks, can indicate what needs to be focused on in CRM training (see chapter 3). Properly used, the method can be a powerful tool for further developing CRM training and improving operator performance in relation to CRM.

Other methods for collecting information that can form the basis for development of CRM training can be discussions with pilots, or more structured interviews or questionnaires. For smaller operators, discussions with pilots, individually or in groups (such as in conjunction with other meetings) can contribute the information needed to improve CRM training. It is, however, important that such information is documented so that it is available to CRM instructors.

Unfortunately, experiences indicate that evaluation and follow-up is an area that does not receive the attention necessary for it to contribute to effective CRM training. What is most important for daily operations is primarily that the training is properly performed, even if evaluation, follow-up and measures for improving future training may then receive less attention than they deserve. Well-functioning evaluations and follow-ups can, however, contribute to improving CRM training, which in turn can lead to crews demanding even better training, and a spiral of improved training can thus be initiated.

In regard to evaluation and follow-up of CRM training, the following points can be worth consideration by operators:

- Routines in conjunction with evaluation and follow-up of CRM training
- Use of course evaluations for CRM training
  (Review of both configurations and different compilations of evaluations)
- Design of course evaluations
  (If there are rating scales, are there instructions for how they are to be used? What is considered as good? What is considered as bad? What is done when something is considered as bad?)
- Feedback to participants after completion of course evaluation
- Use of course evaluations for future CRM courses
- Examples of how changes to CRM training are based on course evaluations
- Examples of influence on operations based on evaluation and follow-up of CRM training

1.3.5 CRM training for foreign pilots engaged by Swedish airlines

Despite that Swedish operators mostly employ Swedish personnel, some operators occasionally engage pilots or cabin crew from other countries to handle production peaks, such as in conjunction with charter contracts. There can naturally be other reasons for recruiting personnel from other countries and this is probably something that will become more common.

The pilots recruited from abroad can be very experienced. This experience normally means that they usually have also experienced CRM training on a number of occasions, but even so, this is no guarantee that cooperation concerning CRM will be problem-free.

It is important to emphasize that the basis for functioning CRM, apart from the individual aspects, is communication. Even if operations are regulated by standardized procedures, fundamental conditions concerning communication can create problems in cooperation. Moreover, even if English serves as a common language in aviation, communication in a language other than one's own mother tongue places considerable demands on language skills in abnormal situations or in emergencies, especially if operations are normally conducted in Swedish.

When conversion training is performed for pilots and cabin crew from other countries, it is therefore important that communication in abnormal situations and emergencies is in focus. Even more routine aspects of communications and potential occasions for misunderstanding can be included. Group and leadership aspects, as well as the cultural aspects of working with Swedes, particularly in regard to the relationship between pilots and cabin crew, should also constitute a significant element of the training.

Special attention should be given to what is customary when crew meets prior to a flight and how briefings are conducted, since this sets the tone for cooperation in the operations. There is unfortunately a risk that during briefings, problems have already been created in the form of lack of understanding or trust, which can later contribute to producing unclear situations or worsen an already difficult situation during flight. This certainly applies to Swedish pilots as well, but the capability to detect or correct misunderstandings or problems is reduced when one's native language is unavailable as a communication tool.

In conjunction with conversion training for foreign pilots and cabin crew, it can therefore be worthwhile to bring up the following points with the operator:

- Time allocated for CRM conversion training
- Content and focus concerning conversion CRM
- Whether training concerning briefings and other forms of communication and cooperation are to brought up in CRM or in other parts of the conversion training
- Available elements of supplementary training in regard to communication in other parts of conversion training
- Differences between content in this conversion training in relation to corresponding conversion training concerning CRM for Swedish pilots and cabin crew
- Training and exercises concerning communications in abnormal situations or emergencies (and how this is to be brought up in CRM training)
- Training concerning group and leadership aspects, as well as Swedish working culture (how this is to be brought up in CRM training or in other part of conversion training)

2 Threat and Error Management (TEM)

TEM is a relatively new concept within aviation Human Factors and one which has received considerable attention in recent years. The concept has been described in many different ways, including it being a new generation of CRM or even an alternative to CRM. Several airlines have partially adapted their CRM courses and other aspects of their operations to TEM, e.g. in regard to checklists and manuals. The ICAO (International Civil Aviation Organization) has prepared guidelines intended to make training in TEM mandatory for some categories of operators. TEM is also included as an integrated part of the new MPL (Multi-crew Pilot License).

Even if it may not yet be entirely clear as to what TEM is (or is intended to be), it is reasonable to consider it as a general systematic approach and tool for flight safety and for how risks in operations can be identified and resolved. TEM thus constitutes a framework for CRM within which various parts of CRM (such as information management, communications cooperation and leadership) can be used for dealing with the threats and errors which are present in operations.

TEM was developed by the University of Texas Human Factors Research Project (UTHFRP), along with a method for producing information about operations called Line Operations Safety Audit (LOSA). TEM and LOSA have been received by both regulatory agencies and airlines around the world as valuable tools for maintaining and improving flight safety (although the response in Europe has been less accommodating than in other parts of the world). It is therefore logical to begin with a description of LOSA to later be able to explain TEM's background and purpose.

2.1 Background – Line Operations Safety Audit (LOSA)

LOSA (Line Operational Safety Audit) is a method for collecting information about operations that may not be available from other information sources connected to operations, flight training or audits. The method is based on the assumption that these other information sources may not be providing a complete picture of daily operations, i.e. the assumption that there always are differences between how operations are intended to be performed and how they actually are performed. This can be illustrated with the following figure:

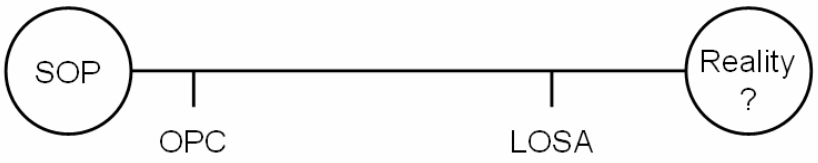


Figure 2.1.1. Illustration of LOSA's role

In this case the understanding of operational activities is based on that even though regulations, procedures and routines are intended to cover all situations, they do not. Furthermore, crews and organizations will always attempt to carry out operations in spite of any adversities. Taken together, this can result in deviations from rules, procedures and routines that create risks, but which in specific situations may be effective and safe ways of adapting operations to altered circumstances or new situations. Such deviations may be

revealed to management through reporting, observations during flight training or, for example, in OPCs (Operator Proficiency Checks). Because the latter is an “examination” situation, however, it is unlikely that deviations will be revealed during OPCs particularly often. Even if information about deviations can be acquired through reporting and flight training, in most cases this will represent information concerning isolated cases. This means that it can be difficult to motivate changes to operations based on such information.

LOSA is based on accompanying observers taking notes on the threats and errors that occur during flights, as well as on how these threats and errors are managed. Accepting an observer on a flight is a voluntary decision, made by the crew. Normally observations and reports from a large number of flights are collected during the period that LOSA is performed. The reports from the observers are compiled in a database from which information can be produced, analyzed and presented in various ways. This can provide an operator with information about the most commonly occurring threats and errors in daily operations. Moreover, comparisons can be made with other operators to see which differences exist. This information can be further analyzed and result in proposals for changes of procedures, training, organizational structure or other factors that affect operations. Because LOSA involves a large number of flights, decision-makers are provided with a material that can justify changes to operations.

Among the airlines to implement LOSA early were Delta and Continental. Others that have implemented LOSA are Singapore, Cathay and Emirates. Several airlines have already conducted a second LOSA to find out if changes which were implemented after the first one have produced the desired results. Continental followed up its initial LOSA in 1996 with a second in 2000. The following are comments from Captain Don Gunther, Senior Director of Safety & Regulatory Compliance at Continental in regards to its second LOSA:

> The 2000 LOSA, when compared to the results of 1996, showed the pilots had not only accepted the principles of error management but incorporated them into everyday operations. LOSA 2000 showed a sizeable improvement in the areas of checklist usage, a 70 percent reduction in non-conforming approaches (i.e., those not meeting stabilized approach criteria), and an increase in overall crew performance. It could be said that Continental had taken a turn in the right direction.

That LOSA has been accepted by the aviation industry has resulted in ICAO promoting prepared guidelines for how information from daily operations can be gathered and used to improve flight safety. These guidelines refer to “Normal Operations Monitoring”. Even if such monitoring can be performed in various ways, LOSA is the only accepted method to date and is even recommended as industry best practice. (The equivalent to Normal Operations Monitoring for ATC is Normal Operations Safety Survey, NOSS.) An intention has also been expressed by ICAO to make Normal Operations Monitoring (in practice LOSA) mandatory for some categories of operators, certainly for major international carriers.

According to ICAO, there are ten operational characteristics specifying the conditions that must be fulfilled to ensure that collection of data from operations will produce results that are sufficiently reliable to be used for improving the safety of an operator. These ten conditions are of equal importance for successful implementation and all must be fulfilled for the collection of information to be considered as a LOSA. These ten conditions are that data collection shall be based on:

1. Jump seat observations during normal flight operations.

2. Anonymous and confidential data collection

3. Voluntary flight crew participation

4. Joint management / pilot association sponsorship

5. Safety-targeted data collection form

6. Trusted and trained observers

7. Trusted data collection site

8. Data cleaning roundtables

9. Data-derived targets for enhancement

10. Results feedback to line pilots

The resulting report of a LOSA may be about 60 pages long and include an account of collected data by use of various statistical methods presented in different types of tables and diagrams. These present the occurrence of threats and errors in operations, as well as to what extent they are resolved by crews. For the observations, there are usually not just categorizations in terms of threats and errors, but also more detailed descriptions of observed incidents. This is important, since it can be difficult to categorize an observation, and with a description available, the initial categorization can be evaluated and modified on a later occasion.

The LOSAs that have been gathered by the LOSA Collaborative, an organization founded by the University of Texas, are stored in the LOSA Archive. This archive is constituted by a database that contains anonymous data (in regards to individuals and airlines) from all airlines that have performed a LOSA in cooperation with the LOSA Collaborative. The database is intended to be used for use research. The following collected data was in the LOSA Archive for the period 2002 to 2006:

- LOSAs from 25 airlines
- 4,532 observation occasions
- 19,053 categorizations of observed threats in conjunction with operations
- 13,675 categorizations concerning crew errors in conjunction with resolving threats
- 2,589 occasions when threats and errors were not appropriately resolved and resulted in undesired aircraft states

To summarize, LOSA can be described as a method for systematically collecting information from normal operations for the purpose of acquiring a picture of the threats and errors which impact on flight safety. LOSA can thus be seen as a way of dealing with risks in flight operations by attempting to identify them before they result in reports from incidents or other safety related occurrences in operations. Implementation of LOSA can result in improvements to operations in regard to flight safety and consequently in reduced insurance costs, especially as the results in the reports are being presented in a form (data processed with statistical methods) which appeals to insurance companies. It is also worth emphasizing that some airlines (such as VARIG) have independently conducted LOSAs without direct collaboration with the University of Texas.

2.2 Threat and Error Management (TEM) – Concept and model

TEM's origin is closely related to that of LOSA. Concurrent with the development of LOSA, the first observation form for evaluation of behaviors linked to CRM was created. The form was later expanded to cover crew errors and how these were managed by the crews. Observing an error, without observing the conditions under which it occurred, makes it difficult to understand what happened in conjunction with the error. Also, this does not provide sufficient information to support learning from the error. Threats and management of threats were therefore included on the observation form to provide a description of the entire sequence of events, which in the worst case can escalate from a threat to an accident.

The three basic concepts in the TEM model are "threats", "errors" and "undesired aircraft state". The concept of threats refers to external conditions that endanger flight safety during flight operations. Threats can be defined as:

Events or errors that:

- Occur outside the influence of the flight crew (i.e. not caused by the crew)
- Increase the operational complexity of a flight
- Require crew attention and management if safety margins are to be maintained

Threats in conjunction with commercial aviation are divided into two primary categories: environmental threats and airline threats. These in turn can be divided into subcategories, which are presented below with examples:

Environmental threats:

- Weather – Thunderstorms, turbulence, poor visibility, wind shear, icing conditions, IMC
- Airports – Poor signage, faint markings, runway/taxiway closures, INOP navigational aids, poor braking action, contaminated runways/taxiways
- ATC – Tough-to-meet clearances/restrictions, reroutes, language difficulties,
- controller errors
- Environmental operative pressures – Terrain, traffic, TCAS TA / RA, radio congestion

Airline threats:

- Aircraft – Systems, engines, flight controls, or automation anomalies or malfunctions; MEL items with operational implications; other aircraft threats requiring flight crew attention
- Airline operational pressure – On-time performance pressure, delays, late arriving aircraft or flight crew
- Cabin – Cabin events, flight attendant errors, distractions, interruptions
- Dispatch/Paper work – Load sheet errors, crew scheduling events, late paperwork, changes or errors
- Ground/Ramp handling – Aircraft loading events, fuelling errors, agent interruptions, improper ground support, de-icing
- Ground maintenance – Aircraft repairs on ground, maintenance log problems, maintenance errors
- Manuals/charts – Missing information or documentation errors

Some threats can be anticipated while others cannot, such as those that occur suddenly and without warning. Furthermore, some threats are latent and impossible to directly identify or observe by the crew. Environmental threats can either be predictable or non-predictable (and thus must be resolved as they occur), while airline threats can usually be contained (eliminated or minimized) within the organization responsible for operations.

A threat which is not managed properly is connected to crew error (simply since it was not properly managed), in other words, an inappropriately managed threat constitutes a crew error. We have now arrived at the next concept in TEM, "errors", which are defined as follows:

An error is defined as flight crew actions or inactions that:

- Lead to a deviation from crew or organizational intentions or expectations
- Reduces safety margins
- Increases probability of adverse operational events on the ground or during flight

Errors are also divided into a number of categories. General descriptions of these categories, along with examples of each, are provided below:

Aircraft handling errors

- Automation – Incorrect altitude, speed, heading, autothrottle settings, mode executed or entries
- Control systems – Incorrect flaps, speed brakes, autobrake, thrust reverser or power settings
- Ground navigation – Attempting to turn down wrong runway/taxiway, missed taxiway/runway/gate
- Manual flight – Hand flying vertical, lateral, or speed deviations, missed runway/taxiway failure to hold short, or taxi above speed limit
- Systems/radios/instruments – Incorrect pack, altimeter, fuel switch or radio frequency settings

Procedural errors

- Briefings – Missed items in the brief, omitted departure, takeoff, approach, or handover
- Callouts – Omitted takeoff, descent, or approach callouts
- Checklists – Performed checklist from memory or omitted checklist, missed items, wrong challenge and response, performed late or at wrong time
- Documentation – Wrong weight and balance, fuel information, ATIS, or clearance recorded, misinterpreted items on paperwork
- Pilot Flying (PF)/Pilot Not Flying (PNF) duty – PF makes own automation changes, PNF doing PF duties, PF doing PNF duties
- SOP cross-verification – Intentional and unintentional failures to cross-verify automation inputs
- Other procedural errors – Other deviations from government regulations, flight manual requirements or standard operation procedures

Errors regarding communications

- Crew to external - Missed calls, misinterpretation of instructions, or incorrect read-backs to ATC, wrong clearance, taxiway, gate or runway communicated
- Pilot to pilot – Within-crew miscommunication or misinterpretation

Lastly, there is the concept of “undesired aircraft state”, which is defined as follows:

An undesired aircraft state is a position, speed, altitude or configuration of an aircraft that:

- Results of from flight crew errors, action or inactions
- Clearly reduces the safety margins

Various types of undesired aircraft states are categorized as follows:

- Aircraft handing – Vertical, lateral or speed deviations, unnecessary weather penetration, unstable approach, long, floated, firm or off-centreline landings
- Ground navigation – Runway/taxiway incursions, wrong taxiway, ramp, gate, or hold spot, taxi above speed limit
- Incorrect aircraft configuration – Automation, engines, flight control systems or weight/balance events

The fundamental idea of the model is that threats and errors, as well as management of these, are part a part of everyday operations for a crew. Management can however be optimal or less than optimal and lead to an undesired aircraft state. An undesired aircraft state may in worst case induce the risk for an accident. Errors and undesired aircraft states should be managed by detection and application of procedures in order to return to controlled and safe flight. Management of undesired aircraft states constitutes the final opportunity to avoid reduced safety margins during flight.

Figure 2.2.1. Illustration of the TEM model

The TEM model can be illustrated as in figure 2.2.1. At the top is the concept of threats. To manage threats and subsequently avoid errors, there are various strategies, such as pre-flight briefings (including weather forecasts and NOTAM), inspections of aircraft prior to flight, cooperation with cabin crew regarding suitable times to enter the cockpit, procedures for resolving technical problems, in-flight briefings (e.g. in the case of a runway change) and adding extra fuel in regards to uncertainties at destination or alternate airports.

If threats are not properly managed using available strategies, they can lead to errors. While threats exist or arise beyond the control of the crew, errors originate from the way in which the crew carries out its duties (even if errors of other people, such as mistakes by ATC or technical personnel, can constitute threats to the crew). A decision to not add extra fuel for a flight to a destination where weather or other conditions are uncertain factors can lead to problems, and is therefore an error. (In this case, operator guidelines for fuel or the method for fuel calculations can constitute a threat that contributes to this error).

In managing errors, there are two different levels available – countermeasures (resist) and problem-solving (resolve). Resist refers to preparations, technical systems, instructional information or other resources that contribute to resolving errors before the crew must find a way of resolving them on their own. A countermeasure can be training of scenarios in simulators, technical warning systems (such as GPWS or ACAS/TCAS), as well as manuals, procedures and checklists, and ATC or technical support from the ground.

If countermeasures are insufficient to manage an error, the crew must attempt to manage the error with the resources available to them as crew members (resolve). This means that they have to rely on their own capabilities relating to, e.g. information management, effective communication, cooperation and leadership, as well as on their experience to manage the error.

If this also would be insufficient for successful management of threats and errors, or if applied solutions are incorrectly performed, the consequence can be an undesired aircraft state and reduced safety margins for the flight. This situation must then be managed by the crew, and in such a situation, the capabilities of the crew, e.g. in handling of aircraft in abnormal situations, will be crucial to regain the desired safety margins.

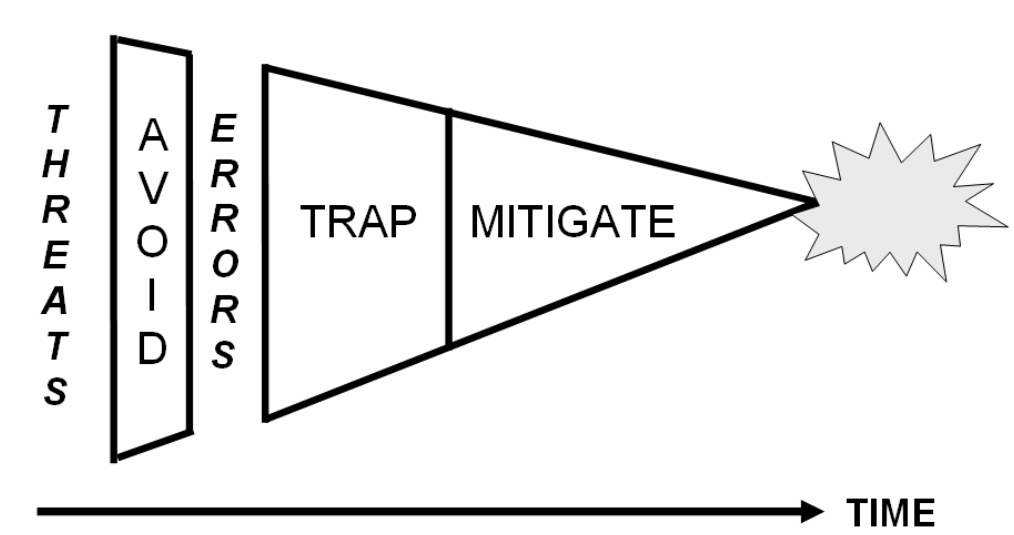


Figure 2.2.2. Alternative illustration of TEM model

A different way of presenting the TEM model that is used in CRM training is shown in figure 2.2.2 above. In this case, the concepts “avoid”, “trap” and “mitigate” are used, which also originate from the University of Texas. The focus here is primarily on how threats can be avoided long before they result in errors or undesired aircraft states, on how errors can be trapped shortly before or in concurrent with them occurring and on how consequences of errors can be mitigated. This model can be illustrated by the management of the threat of thunderstorm activity. If such activity is mentioned in a weather forecast, the planned route

can be changed prior to the flight and the problem can be avoided. If the thunderstorm activity is discovered during flight, the problem can be trapped and the option of flying around it may still be available. If it is not discovered until the aircraft has entered into it, the only option left may be to mitigate the consequences by choosing a different altitude and putting the seatbelts signs on. Fatigue can be used for another illustration of this model. When a pilot sees on his roster that there are a high number of night flights scheduled during a certain period he can request a roster change to avoid problems with fatigue. If this is not done, the pilot can trap the problem by resting before a flight (or, if possible, use "controlled rest" during the flight). If the pilot gets fatigued during flight, the only remaining option may be to mitigate the consequences, e.g. by drinking coffee.

The TEM model constitutes a framework for understanding events that can affect safety margins during a flight. This means that it can be used in several different ways, such as:

- *Training*
  TEM constitutes a framework within which CRM training can be linked to the occurrence of various errors and threats within an organization. CRM training can thus be oriented towards the areas in which it can most effectively contribute to increasing the abilities of crews to deal with threats and errors.

- *Reporting*
  Reporting forms configured according to the TEM model create a structure in which crews can describe incidents using the concepts of threats and errors, and thereby facilitate their understanding of the events which have occurred and their possibilities for describing it.

- *Analysis*
  The TEM model can during an analysis of an occurred incident contribute to the focus being shifted from the individual incident to an understanding of more general systematic problems, for example, through the model's close association with LOSA.

TEM and LOSA are based entirely on the same concepts and structure in explaining how flight safety can be negatively affected by threats and errors. Together these constitute the currently most widely spread methods for working with flight safety issues. More airlines are planning to implement LOSA and several intend to carry out second or third LOSAs to follow up and continue the work they have begun.

To summarize, the intention of the TEM model is to describe and create an understanding of how a crew work with planning and executing a flight can be affected by various conditions and events. As a model, TEM can be used for preventive purposes, for reporting or for analysis of occurred incidents on individual or organizational level.

2.3 Criticism of TEM

The acceptance that TEM and LOSA have received in the aviation industry during a relatively short time indicates that they represent important tools for current work with developing and improving flight safety. Even though they can by no means still be considered as new tools, there is still considerable criticism regarding several aspects of them. This criticism is presented here because it can contribute to increased understanding of the limitations and weaknesses of the TEM model and LOSA as a method. Armed with such an understanding, an operator can avoid the risk of using TEM and LOSA in a manner that does not effectively contribute to increased flight safety or choose to find other models and methods to improve flight safety.

An often mentioned criticism of TEM is that the model only represents the way in which all pilots have always approached flight safety, in the form of questions such as: What can cause problems for a planned flight (threats)? What can these lead to (errors)? How can these be managed (threat and error management, meaning TEM)? According to critics, TEM only contributes to the conceptual model that all pilots have applied since the early days of aviation with a more academic and difficult language. The apparent simplicity of the model, as it has been presented at international conferences, is also contradicted by the more complicated flow chart for it which has been presented in scientific papers. It thus seems that its promoters are simultaneously attempting to both emphasize the simplicity of the model (and consequently, how easy it is to understand) and its complexity (and consequently, how well it represents reality). Regardless of whether this criticism is entirely justified, it can still be said that TEM can contribute with standardized terminology and a structured approach to use this perhaps already well established mental model of pilots and the TEM model can subsequently facilitate development and progression in regard to flight safety issues.

When it comes to LOSA, there has been criticism based on, among other things, that it is an unnecessary time-consuming and resource-intensive method of collecting data from normal operations. Alternative methods for this could comprise collection and analysis of data from:

- Line checks
- Flight data monitoring
- CRM skill assessments
- Reporting (mandatory, voluntary, confidential or other type of reporting)
- Focus groups (discussions with small groups which can be considered to represent the views of larger groups)
- Crew interviews
- Questionnaires to crews

The criticism is based on that the same information content that is obtained from LOSA can be produced just as effectively with the methods above but using less of resources and at a significantly lower cost. The resources and money that then would be available could subsequently be used to actually resolve identified problems, e.g. by increasing time for flight training in simulators or to increase other training.

It should be kept in mind that crews have the right to deny a LOSA-observer from accompanying them on a flight. For some LOSA-projects there have been a high number of denials. It is not unreasonable to question why crews would not let an observer accompany them and how data from these flights could have affected the conclusions drawn from the data that was collected. In this context, there may also be reason to question the influence of an observer's presence on crew behavior during flights. A very simple but convincing argument

advanced by pilots at airlines that have conducted LOSA has been that it if management had only have taken the time to create a secure environment for discussion, they could have obtained the same information directly from the pilots.

Another point of criticism in regards to TEM and LOSA is based on questioning of the degree to which it is possible for an accompanying and passive observer to identify and categorize errors during a flight. The criticism regarding TEM consequently concerns whether there is consensus as to what an "error" is. For starters, LOSA is based on the assumption that flights are often conducted in a way that differs from only following procedures. Nonetheless, an observer is supposed to be able to identify what constitutes an "error" in the crew's behavior in a given situation. In the same way, it is decisive for TEM that "threats" and "errors" can be identified for the model to be meaningful. A problem is that management of a threat or error cannot commence until the threat or error has been identified, and how identification is to be accomplished is not specified by TEM. Moreover, one crew's error can be another's way of avoiding threats and errors. For example, crews can be hesitant in contacting ATC because of the knowledge they have of ATC workload based on experiences from previous flights. They thus avoid a situation in which they are forced to wait for ATC response and risk forgetting the contact they have taken. Whether this is to be considered as an error or an effective adaptation to actual operational conditions can be difficult to determine. For each clear case of a possible error that a crew can make, grey zones can also be imagined in which it can be difficult or impossible to determine if an action is an error, or whether an action that prevents later threats and errors constitutes an error.

Additionally, the division between threats and errors in the TEM model is not always easy to bring in line with everyday use of language. If threats are external in relation to the crew (they come at the crew) and errors are internal (they come from the crew), how should a private problem that affects a pilot be perceived? Is this external even if it affects the pilot's thought processes? Is it a threat or error if the pilot is thinking about private problems prior to or during a flight? Even if these questions can be answered by someone who is experienced in applying the TEM model, they are examples of how it is not always easy to interpret the world by using the concepts provided by the model.

It is also important to emphasize that TEM in no way replaces CRM. Viewed favorably, TEM constitutes a framework for understanding operations and their associated risks, and can thereby contribute to directing attention to the areas in which CRM training can best equip crews with tools for handling these risks. All areas taken up in CRM training according to the regulations must still be addressed. Information about risks in operations based on various information sources (where LOSA is one of many possible), combined with a structured approach to these risks (TEM is one such in this context), improves the preparatory framework for performing effective CRM training. Unfortunately, TEM and CRM are all too often confused with one another. Even if training in TEM can be integrated with CRM training, these two concepts do not represent the same thing.

Because all descriptions of reality are simplifications, the final judgment is not actually focused on whether TEM is faultless, since no model can represent all aspects of reality. The judgment that must be made is whether the TEM model increases understanding of risks in flight operations and whether it is a more effective tool for maintaining and improving flight safety than other models or methods that can be applied for this purpose.

2.4 Current situation and practical aspects concerning TEM

TEM (and LOSA) are still relatively unknown concepts with operators in Sweden and probably also in other countries. Nonetheless, they may at least have been encountered by many at conferences or in aviation publications. (Additionally, Braathens performed a LOSA a few years ago and how this was done has been presented at meetings and seminars also in Sweden.) This seems, however, not to have lead to any widespread knowledge about the TEM model or even less that it has affected training, reporting or analysis to any higher degree at Swedish airlines. A contributing reason for this is probably that practically all material on TEM and LOSA is available only in English; at least this is an explicit limitation for smaller countries. Another is that TEM may represent the way in which operators already perceive threats and errors, and how they can be managed. The degree to which flight safety could be positively affected by training and use of the TEM model by Swedish operators is difficult to assess. But regardless of this, ICAO and large portions of the aviation industry are advocating TEM and LOSA, which makes it inevitable that knowledge of these concepts must increase, if they are to be implemented in Sweden.

Based on this, a few more points can be brought up in regards to increased attention concerning usage of TEM in Swedish commercial aviation. The following issues can be brought up to direct operators' attention on TEM and LOSA:

- Conducted (or planned) training in TEM
- Integration of TEM in instruction, training and other activities
- Availability of collected information from normal flight operations (which information is collected, how it is analyzed and how it is used)
- Analyses of threats to flight safety in operations (see the previous point)
- Analyses of which errors these threats can lead to (see the previous point)
- Feedback to instruction and training regarding information from normal flight operations and from analyses of threats and errors in operations

3 Assessment of CRM skills

3.1 Background information

It is important to initially note that work in this area, as well as corresponding regulations and recommendations, have to date focused on pilots and there are currently no requirements for assessments of CRM skills for cabin or technical personnel (even if this represents possible future developments). Subsequently, this chapter will focus on the pilot role and the assessment of CRM skills for pilots.

The best possible proof that CRM training increases flight safety would be if increased efforts in CRM training could be related to a reduced number of serious incidents and accidents over a specific period. Because the total number of serious incidents and accidents in commercial aviation are very few, it is however very difficult to produce any results that can statistically prove such a correlation. On the other hand, there are studies from military aviation that have shown that CRM has resulted in a significant reduction in accidents.

Attempts have been made in commercial aviation to find a way of measuring the effects that CRM training has on flight safety. Focus has been placed on pilot behavior, which is expected to have an effect on flight safety, and attempts to create a base for "measuring" pilot behavior in regards to CRM, in other words, the degree to which pilots can be considered to be carrying out operations safely and effectively based on how they, for example, manage information, make decisions, communicate and cooperate. This is what constituted the base for the work initiated in the mid-1980s when the University of Texas and NASA started to cooperate on development of a template of so-called "behavioral markers" to be able to assess crews' CRM skills. The concept of behavioral markers refers to a set of predetermined behaviors that can be related to performances which influences the outcome of a flight. A few examples of behavioral markers could be the degree to which a pilot is able to acquire available information, perform follow-up and checks of the effects of decisions which have been made, or the clarity with which he informs the other pilot of what he is doing. The idea is that by determining desired behavior and developing a method for systematic assessment of behavior, pilot behavior can be assessed, trained and improved with an approach similar to the one used for other more "technical" aspects of flying (e.g. for instrument approaches). Some important aspects of behavior markers are that they must:

- Correspond to specific and observable behavior.
- Be based on analysis of data from incidents and accidents
- Include a clear relationship between behavior and performance
- Be simple, clear and adapted to the operative environment

Work with preparing suitable assessment templates for behavior markers has constantly moved forward and been further refined. But even though many operators, such as KLM, have been driving forces in developing such systems, there are still many airlines that do not have any system at all for assessment of CRM skills.

When work with the first method for assessment of CRM skills was initiated with the collaboration between the University of Texas and NASA, there were two primary goals. The first was that the markers should be possible to use for evaluating the effectiveness of CRM training. The second was that they should support work with defining the scope of CRM training. Strengths and weaknesses concerning crews' actions and cooperation could be indicated by systematically assessing their CRM skills. The first system used to assess these factors was produced in 1987.

This first set of behavioral markers was included as an appendix to a document (IAC-150A) from the Federal Aviation Administration. At the same time, the University of Texas began collecting data concerning all aspects of airline operations via the LOSA program (see the previous chapter). The markers were compiled in an assessment template and named Line/LOS Checklist (Line Oriented Simulation.) As both experience and the database expanded, it was obvious that there were considerable variations in crew behavior in respect to CRM. To increase the accuracy of the assessments, the template was modified for use for the respective phases of a flight. During 1995, a study was conducted to attempt to prove the included behaviors' positive or negative effects during aircraft accidents and incidents. The analysis showed strong support for their usability as indicators of crew performance and the importance of using these in CRM training.

Assessment of CRM skills can be seen as a way of closing the circle for training (see figure 3.1.1 below). Pilots can undergo CRM training to improve their skills used to ensure safe and efficient flights. But it is only if their behavior can be observed and assessed (so that the degree to which their actions are in compliance with training can be determined) that the effect of training can be verified. If the training has not produced the desired effect, more (or different) training can be performed. If the training has produced the desired effect, assessment of CRM skills can identify other issues that need to be focused on in CRM training.

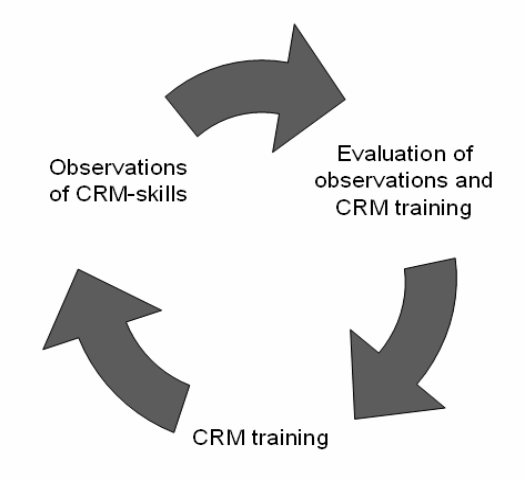


Figure 3.3.1. Development of CRM skills

As mentioned earlier in this report, CRM training is too often performed without that it is based on an analysis of a particular airline's training needs. Systematic assessment of CRM skills can form the basis of planning and preparation of CRM training, and if integration of an airline's events in regard to flight safety is added, this could significantly improve the quality of the training. Among other strong arguments for assessment of CRM skills are the following:

- It can create a common language for CRM
- It can contribute to systematic CRM development on the individual and organizational levels
- It can serve as evaluation and input for development of training, procedures and other operative aspects
- It can contribute to identification of positive examples of good CRM behaviors that would otherwise not have been identified

Despite all of these good opportunities, it must be emphasized that there are also risks involved in developing and using a method for assessment of CRM skills. If the method is not based on a company's particular values, routines and operating conditions, there is the risk that it will miss the mark and be perceived as irrelevant. If those who perform assessments are not properly trained, particularly in being able to conduct reasonably similar assessments for similar situations, the system will appear as arbitrary and unfair. To avoid these risks, operators must be fully committed and prepared to set aside time and resources for either developing a method or adapting an existing method to their own operations. The behaviors that are to be assessed must be relevant to operations and firmly established in the organization. Assessors must also be trained so that they have the knowledge and capability to conduct assessments, and training must ensure that there is consensus between different assessors in regard to similar situations. What operators receive in return are CRM courses and other training which is better adapted to their organizations' needs, and as a result of this, safer and more effective operations due to, for example, improved information management, communication, cooperation and leadership.

3.2 Regulations concerning CRM skill assessments

In Supplement 1 to JAR-OPS 1.965, under the heading 3) Checks during production flight, there is the following passage in regard to assessment of CRM skills:

ii) Flight crews' skills in regard to CRM shall be assessed according to a method that is acceptable to the Authority and published in the operations manual. The purpose of such assessment is to:

A) provide crew members with feedback both individually and in groups, and to identify the need for retraining, and
B) improve the training system for CRM

Under the following heading in Section 2 in JARS-OPS there are more details about assessments of CRM skills:

[ ] [ACJ] OPS [(AMC)] 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)
Crew Resource Management (CRM)
See JAR-OPS 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)/1.965(a)(3)(iv) See [ ] [ACJ] OPS [(IEM)] 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)

8 Assessment of CRM Skills (See [ACJ] OPS [(IEM)] 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e), paragraph 4)

8.1 Assessment of CRM skills should:
a. Provide feedback **[**to the crew and**]** to the individual and serve to identify retraining **[**where needed**]**; and
b. Be used to improve the CRM training system.

8.2 Prior to the introduction of assessment of CRM skills, a detailed description of the CRM methodology including terminology used, acceptable to the Authority, should be published in the Operations Manual.

8.3 Operators should establish procedures, **[**including retraining,**]** to be applied in the event that personnel do not achieve or maintain the required standards (Appendix 1 to 1.1045, Section D, paragraph 3.2 refers).

8.4 If the operator proficiency check is combined with the Type Rating revalidation/renewal/check, the assessment of CRM skills will satisfy the Multi Crew Co-operation requirements of the Type Rating revalidation/renewal. This assessment will not affect the validity of the Type Rating.

[ACJ] OPS [(IEM)] 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)
Crew Resource Management (CRM)
See JAR-OPS 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)/1.965(a)(3)(iv)
[ ] [ACJ] OPS [(AMC)] 1.943/1.945(a)(9)/1.955(b)(6)/1.965(e)

4 Assessment of CRM Skills

4.1 Assessment [of CRM skills] is the process of observing, recording, interpreting and [ ] [debriefing crews' and crew member's] performance and knowledge **[ ] [**using an acceptable methodology**]** in the context of overall performance. It includes the concept of self-critique, and feedback which can be given continuously during training or in a summary following a check. **[**In order to enhance the effectiveness of the programme this methodology should, where possible, be agreed with flight crew representatives.**]**

4.2 **[ ] [**NOTECHS or other acceptable**]** methods of assessment should be **[**used**] [ ]**. **[**T**]**he selection criteria and training requirements of the assessors and their relevant qualifications, knowledge and skills **[**should be established**]**.

4.3 **[ ] [**Methodology of CRM skills assessment**]**:
a. An operator should establish the CRM training programme including an agreed terminology. This should be evaluated with regard to methods, length of training, depth of subjects and effectiveness.
b. A training and standardisation programme for training personnel should then be established.
c. **[ ] [**The assessment should be based on the following principles:
i. only observable, repetitive behaviours are assessed,
ii. the assessment should positively reflect any CRM skills that result in enhanced safety,
iii. assessments should include behaviour which contributes to a technical failure, such technical failure being errors leading to an event which requires debriefing by the person conducting the line check,
iv. the crew and, where needed, the individual are orally debriefed.

4.4 De-identified summaries of all CRM assessments by the operator should be used to provide feedback to update and improve the operator's CRM training.**]**

It is thus clear that assessments of CRM skills shall be performed even though there are no detailed instructions on how this is to be done. Assessments shall, however, be performed according to a method, which suggests that more is required than just formulating general comments in regards to desired behaviors. It is also clear that the assessments shall be related to technical consequences for the flight (e.g. errors in maintaining altitude or following an approach path). When it comes to JAR-FCL, there is not the same clarity, but that some form of assessment of CRM skills or equivalent shall be conducted is expressed in the following formulations from Supplement 1 to JAR-FCL 1.240 and 1.295:

11 The following points, which cover a captain's duties, shall be specially checked during testing/control of applicants to a ATPL(A) or to a type certification for multiple-pilot aircraft, regardless of whether the applicant serves as PF or PNF:

a) Capacity to lead collaboration in the crew.
b) Capability to establish a general overview of the aircraft's function though suitable monitoring.
c) Capability to set prioritizations and make decisions in agreement with safety aspects and applicable rules and regulations that are suitable for the current situation, occurred emergency

13 The applicant shall demonstrate the ability to

…
c) demonstrate good judgment and air-mindedness
…
f) be familiar with and be able to implement procedures for crew collaboration and, in applicable cases, procedures upon incapacity on the part of a crew member, and
g) in applicable cases, be able to communicate with other crew members in an effective manner.

Even if these formulations do not explicitly state that assessments must be conducted according to a method, it is clear that assessments of behavior with respect to CRM are to be conducted and it is then reasonable to assume that these should be able to be conducted in a similar manner to that intended in JAR-OPS.

3.3 NOTECHS

NOTECHS is the method for assessment of CRM skills that is most known in Europe. This is because it was developed in an extensive European research project initiated by JAA. NOTECHS is also considered by many in Europe as not being merely one of several possible systems for airlines to choose in assessing CRM skills, but rather "the" method that shall be used if an airline has not developed its own. In this way, NOTECHS has been put forward as a "standard" and become the method that others are compared against. It is also mentioned directly as a method in JAR-OPS, Section 2 (see above) and is the baseline for the text about assessment of CRM skills in this section. In the document CAP 737 concerning CRM from UK CAA, it is established that the two recognized methods for assessments of CRM skills are NOTECHS and the equivalent system from the University of Texas. To be able to understand and deal with matters related to assessment of CRM skills, it is therefore important to be well informed about NOTECHS.

3.3.1 Background information

Concurrent with the development of the JARs, an advisory group (JAA-Project Advisory Group on Human Factors, JAA-PAG) expressed a wish in 1996 to carry out research intended to clarify how assessment of Non-technical Skills (NTS) could be conducted in practice. The reason was that requirements for such assessments was about to be introduced in the JARs at the time. While JAR-OPS include text that stipulates assessment of CRM skills, and JAR-FCL includes similar (if less clear) text, they do not provide explicit guidelines on what type of method that should be used.

To attain harmonization, JAA-PAG contacted four research institutes (in Holland, Germany, France and Great Britain) for the research project and this study later became known as the NOTECHS project. To also include operational expertise, three pilots were invited to participate (from KLM), and these pilots were already working with assessments of CRM skills. The study was conducted from March 1997 to March 1998.

Some of the work within NOTECHS consisted of compiling an inventory of existing methods for assessment of CRM skills (or of Non-technical Skills, both terms are commonly used). A conclusion was that such assessments were not performed anywhere in Europe for formal pilot examinations. However, training of CRM skills had existed for quite some time in the form of, for example, CRM training. It was found that in existing systems developed for assessment of NTS, the assessment was performed separately from the assessment of technical skills (such as being able to fly an aircraft) except in KLM's then newly developed SHAPE rating system, where this dividing line was removed.

During the NOTECHS project, the difficulties of drawing a sharp line between skills which are technical and non-technical were highlighted, since their application normally is simultaneous during a flight and they are difficult to differentiate from each other. Reviews of existing behavioral maker systems showed that while various systems assess and describe various capabilities, they often cover the same behavior in respect to CRM skills. It was also

found that there were only a few studies that attempted to show that there is a connection between assessments of CRM skills and how a pilot actually performs in reality.

3.3.2 Explanation of NOTECHS

The method for assessment of CRM skills that was developed by the NOTECHS project is most easily illustrated by the figure below, which shows how the assessment form is configured (figure 3.2.2.1).

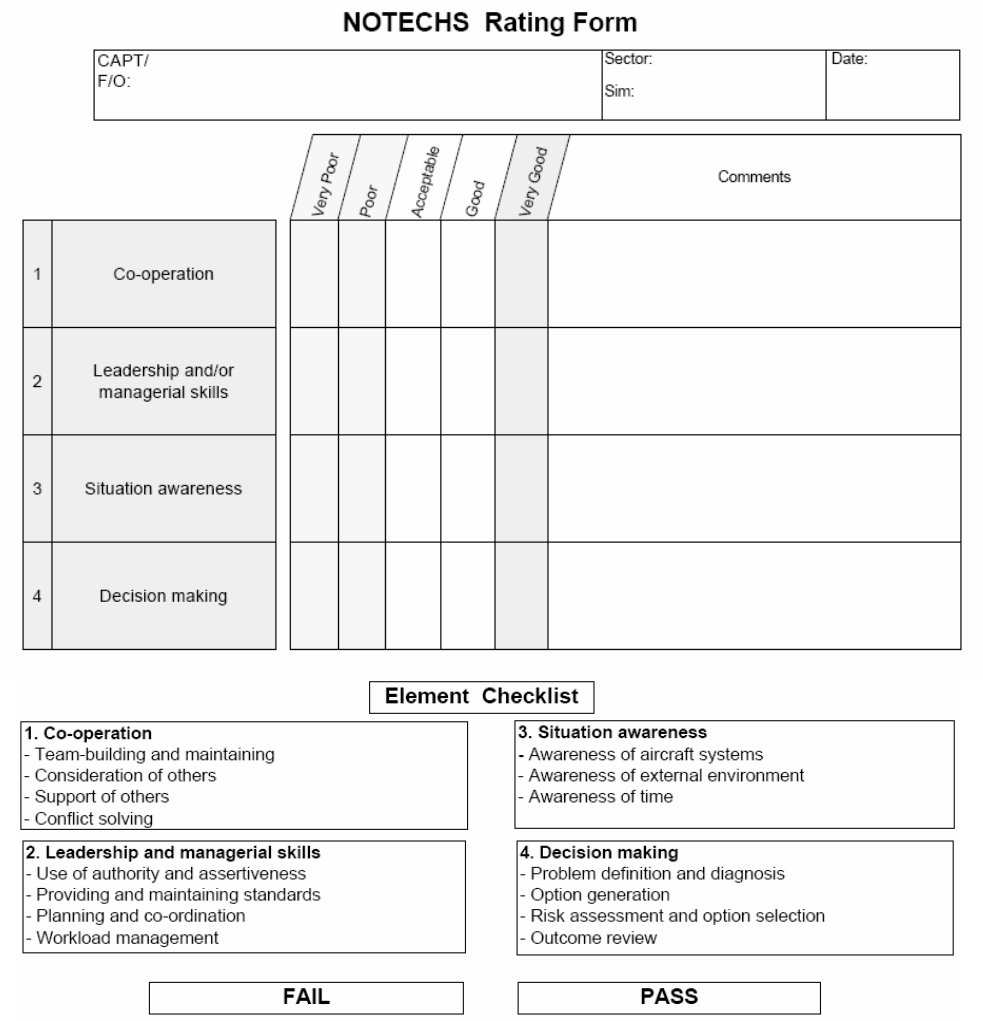


Figure 3.3.2.1. NOTECHS assessment template (including fields for supplementary comments)

The assessment form of NOTECHS is divided into three different levels for the greatest possible precision in making assessments. These levels are:

1. Category
2. Element
3. Behavior

The four categories for observable behavior are as follows:

- Cooperation
- Leadership and/or managerial skills
- Situation awareness
- Decision-making

These categories represent the behavior that should be possible to observe in simulators or during flight. For the respective categories of behavior, there are then a number of subcategories or elements (these are towards the bottom of the template shown in the preceding figure). For the cooperation category, these are:

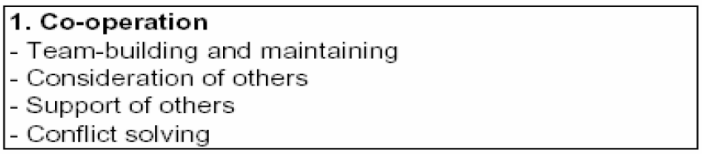


Figure 3.3.2.2. Subcategories or elements in the NOTECHS category for cooperation

For each subcategory, the specific behavior that is to be observed is listed. For the subcategory of conflict solving, these are:

- Keeps calm in conflicts
- Suggests conflict solutions
- Concentrates on what is right rather than who is right

These are the observable behaviors that are to be assessed. The reason for attempting to use daily language to describe various behaviors is that both assessors and the assessed pilots will be able to understand the various terms. To ensure that the assessment of CRM skills will be consistent, regardless of where and by whom it is performed by, a number of guidelines were provided. These are summarized as follows:

Use of two-point rating scale
The assessment shall only lead to observed behavior being acceptable (“Acceptable”, “Good” or “Very Good” on the rating scale) or unacceptable (“Poor” or “Very Poor”). The behaviors that shall be assessed are specified with a negative description, meaning the lowest level that is to be achieved. Everything that is better than the described is to be considered as acceptable.

Requirements for technical consequences of unacceptable results
Deficiencies concerning CRM skills shall not lead to a fail result for the entire assessment if they have not led to technical consequences for the flight which endangers safety. The primary purpose shall be to attempt to reveal the underlying reasons for technical mistakes. An unacceptable rating in any of the categories of the template shall be interpreted as supplementary training being needed within the specific area. However, there shall be nothing to prevent observed deficiencies from being reported.

Explanation of the assessment system
The assessment shall be conducted on the category level. An unacceptable rating for any subcategory/element shall always lead to the entire category being assessed as unacceptable. The person performing the assessment shall indicate the subcategory in which there were behavioral deficiencies and which technical consequence this behavior produced. Moreover, an explanatory text shall be entered. This should be done even if the deficiency did not produce any technical consequences. If the entire assessment (of technical and non-technical skills) leads to acceptable results, but with observations of unacceptable behavior regarding CRM skills, this shall be interpreted as more training being needed.

Repetitive behavior
The goal of an assessment shall not be to identify a person who, for example, on an isolated occasion, overlooks asking another crew member about his view before a decision is made. However, if such behavior is repeated several times, an unacceptable rating shall be assigned for the applicable category.

Solely observable behavior
An assessment shall be based solely on observable behavior. The assessment shall therefore omit assessments that concern, for example, the personality of the pilot.

The rating scale of the assessment form for NOTECHS was prepared in a subsequent project – Joint Aviation Requirements Translation and Elaboration of Legislation (JAR-TEL) – which was intended to evaluate how the assessment template worked in practice. The project consisted of two parts. The first was an experimental part, in which 105 instructors from 14 European airlines tested the assessment template's usability and how well the system worked in the light of cultural differences within Europe. This was done with the help of various scenarios, recorded on video. The subsequent part was based on collection of instructor ratings of CRM skills in actual in-flight situations.

The resulting rating scale was a five-point scale on the element and category levels with the following scale steps:

Rating	*Definition*
Very poor	Behavior directly endangered flight safety
Poor	In other conditions the behavior could endanger flight safety
Acceptable	Behavior does not endanger flight safety but needs improvement
Good	Behavior enhances flight safety
Very good	Behavior optimally enhances flight safety and could be an example for other pilots

Figure 3.3.2.3. Rating scale for NOTECHS assessment template

If a behavior cannot be observed, this shall be indicated with "not observed". In regard to the overall assessment of pass or fail, the fail rating is specified to be used if behaviors concerning CRM skills on the whole endangered flight safety, and a pass rating if they did not endanger flight safety. Simply put, the five-point scale is used for behaviors on the subcategory/element level and thereafter on the category level. Lastly, the overall assessment of the person being assessed shall be considered as being either pass or fail.

The pilots who participated in the JAR-TEL tests of NOTECHS were satisfied with the assessment template and believed that it would be usable. The consistency of the template was viewed as good because the assessments on the subcategory/element and category levels were generally reflected in the overall pass/fail assessment. The categories for situation awareness and decision-making were those considered as most difficult to assess correctly. There were also difficulties in separating behaviors and areas of responsibility for the two pilots, and with, for example, determining how persistent a first officer can be without further worsening a difficult situation. The overall conclusion from the evaluation in JAR-TEL was, however, that on the category level, NOTECHS is a useful and reliable method for assessment of CRM skills.

There are also several other methods available for assessing CRM skills that to various degrees, resemble NOTECHS. An example of this is PAMs (Pilot Assessment Markers), which encompasses eight categories (Management – Knowledge – Procedures – Handling – Communication – Problem-solving - Situational Awareness – Leader/Follower) and the rating scale: Very Good – Good – Satisfactory – Minimum Acceptable – Unacceptable. An example of the rating scale for observed behaviors in the category Leader/Follower is shown in the table below:

5	Adopted style consistently appropriate to circumstances. Team participation actively encouraged and supported. Common goals established.
4	Adopted style generally appropriate to circumstances. Team participation encouraged and supported. Common goals generally established.
3	Fixed style or occasionally inappropriate to circumstances. Team participation encouraged and supported with some lapses. Common goals may be occasionally ignored.
2	Adopted style either inconsistent or totally rigid and often inappropriate to circumstances. Very limited encouragement or support of team participation. Common goals rarely established.
1	Adopted style totally inappropriate. Team participation neither encouraged nor supported. Common goals never established.

Table 3.3.2.1. Pilot Assessment Markers, an alternative method of assessment of CRM-skills. (http://www.raes-hfg.com/reports/CRM_Behavioural_marker_systems.doc)

3.3.3 Criticism of NOTECHS

Even if NOTECHS as a method for CRM skill assessment is based on research, there are a few reasons to be cautious about how useful it may be in Sweden. The first problem is that the method must be translated from English into Swedish. Regardless of the level of language skills, it is hardly reasonable to believe that it would be easy to correctly interpret the English terms used in NOTECHS.

That two of the categories in NOTECHS are situation awareness and decision-making should be reason for thought for a company preparing to implement a system for assessment of CRM skills. Both of these represent processes that play out in a pilot's mind, and were perceived as difficult to assess even for those who participated in JAR-TEL. Even if it is possible to identify behaviors that can indirectly indicate situation awareness and decision-making, it is prudent to urge a certain amount of caution with how they can be defined and assessed in an objective manner.

Another potential problem could be the rating scale. Rating of people is in Sweden a more sensitive issue than in many other countries and especially to fail someone. Even rating is nothing unusual in aviation, neither in Sweden nor anywhere else, it can be worth noting that the JAR-TEL report concluded that:

- "The "very poor" label seems to have a strong psychological impact on the trainee."
- "The 2-point scale for the final judgment – Fail or Pass – that is viewed negatively by instructors in that the context for retraining should be replaced by "Further training is required/Acceptable"."

Despite these conclusions, there is nothing in the report to indicate that there were plans to change any of the two-point rating scales. To provide someone who has undergone a session in a simulator with the feedback that his or her decision-making was "very poor" would probably be considered as unnecessarily brutal in a Swedish context. The assessments of CRM skills are intended to function as both an evaluation and development tool for pilot skills. For ratings to be effective in a development and learning context, continued consideration probably may be needed concerning methods of feedback and how they can be set up to facilitate learning. From a learning and human-to-human interaction perspective, potential objections to the rating scale focus of NOTECHS can be important to consider.

It can also be mentioned that it is not necessarily easy, not even in Swedish, to reach consensus on assessments based on the criteria in NOTECHS. Remaining "calm during conflicts" and "helping other crew members in demanding situations" are presented in NOTECHS as observable behaviors. There can certainly be grey zones between these in, e.g. for an observer to conclude whether someone was remaining calm but not helping other crew members, or helping others but not remaining calm. This is just one example that illustrates the difficulties of specifying observable behaviors, for both NOTECHS and other systems for behavioral assessment.

Regardless of the deficiencies noted here, NOTECHS is probably the most established and well documented method for assessment of CRM skills that operators can easily obtain information about. Its emphasis on solely assessing behaviors that have a technical consequence is also important and should be included in all methods for assessment of CRM skills to prevent them from degenerating into statements of opinion. The method has also come to be used by several operators in Europe, either in its original form or adapted to individual operator needs. Even if it cannot be overlooked that NOTECHS can involve translation difficulties, both in regard to language and cultural factors, operators would be wise to carefully study and attempt to understand NOTECHS when considering implementation of a method for assessment of CRM skills.

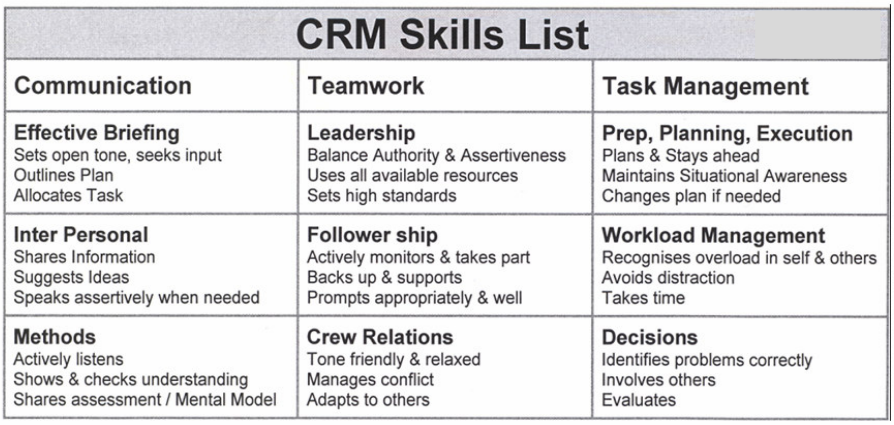
3.4 Assessment of CRM skills in Sweden

Discussions with CRM instructors and inspectors indicate that at present, it is rare that Swedish operators apply any form of systematic method for assessing CRM skills despite this being stipulated in the regulations. This is probably due neither to disinterest nor to inability to see the benefits, but rather more likely due to insufficient knowledge of this area among both operators and in the Swedish Civil Aviation Authority. In both cases, the "normal" working situation usually involve vast workload as well as limited resources, something that hardly benefit the process of acquiring knowledge and taking action in relation to new available information.

For many operators, the document that is used for training and checking sessions simply contains a field with "CRM:" and nothing else. The intention is that his field is to provide

space for observations and assessments of behaviors related to CRM for those who undergo training or checks. (This is however often expected to be done without any other instructions or support for these observations or assessments, and without appropriate training on assessment having been carried out.)

In rare cases, there is also some form of overview concerning which CRM skills that are considered as important and that can serve as guidance when filling in the empty field. (See figure 3.4.1 for an example.)



CRM Skills List		
Communication	**Teamwork**	**Task Management**
Effective Briefing Sets open tone, seeks input Outlines Plan Allocates Task	**Leadership** Balance Authority & Assertiveness Uses all available resources Sets high standards	**Prep, Planning, Execution** Plans & Stays ahead Maintains Situational Awareness Changes plan if needed
Inter Personal Shares Information Suggests Ideas Speaks assertively when needed	**Follower ship** Actively monitors & takes part Backs up & supports Prompts appropriately & well	**Workload Management** Recognises overload in self & others Avoids distraction Takes time
Methods Actively listens Shows & checks understanding Shares assessment / Mental Model	**Crew Relations** Tone friendly & relaxed Manages conflict Adapts to others	**Decisions** Identifies problems correctly Involves others Evaluates

Figure. 3.4.1 An example of a CRM Skills List, in which desirable CRM behavior is listed

An overview such as in figure 3.4.1 can be of considerable help when assessing CRM skills, even if it must be emphasized that it should preferably be properly anchored in the organization and that this in itself cannot serve as a method for assessments of CRM skills. For this, the assessments must be formalized and provided with guidance for how it is to be performed, and those who perform the assessments must be trained to a level where there assessments can be considered reliable and consistent.

The most extensive work conducted in Sweden in regard to assessments of CRM skills has been performed at SAS. It was decided at SAS that they were to develop their own method. This development initiative finally resulted in CAMS (CRM Assessment Method in SAS). An example of this method is provided in the following figure.

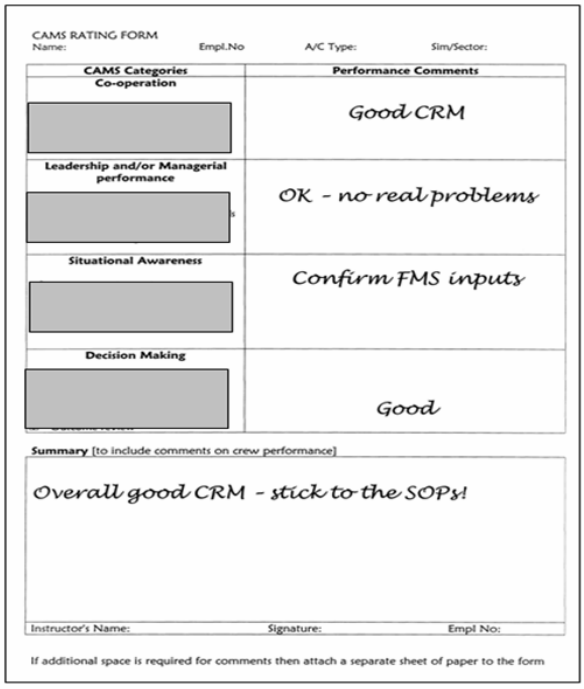


Figure 3.4.2. Illustration of CRM Assessment Method in SAS, CAMS
(presented in this report with permission from SAS)

Even if the comments provided as an example in the figure above may seem slightly trivial, CAMS is the result of extensive development work at SAS. Moreover, even if the categories are the same as for NOTECHS, there are substantial differences. Worth noting is that it was decided by SAS not to use any form of rating scale. A manual was prepared instead with detailed descriptions and criteria for various behaviors that are to be observed. The behaviors are to be described in the boxed areas by the assessor. This is intended to avoid focus on ratings and instead provide a better overall picture of the observed behaviors in their contexts. In this respect, it can be claimed that CAMS is more representative of focus on the assessment as a tool for development and learning, rather than a "measurement tool". The disadvantage of this, however, can be that the assessments may be perceived as unclear, something that a specific rating on a rating scale can seldom be criticized for.

CAMS has been presented at international conferences and attracted considerable attention. The initiative regarding instruction and training of own personnel in conjunction with implementation of CAMS was extensive. CAMS is viewed by SAS, however, as a product that can be sold to others. There is thus no free access to details regarding this system. Whether CAMS can become a model for other operators for assessment of CRM skills remains to be seen.

3.5 Operators' development of own systems for assessment of CRM skills

There are primarily two alternatives for an operator when it comes to implementation of a method for assessing CRM skills – either an existing method is chosen and adapted to their own operations, or one is developed in-house. Even if the first alternative may seem most interesting in economical terms (and consequently will be chosen by most operators), there is reason to mention certain arguments against using an existing method. Time and other

resources will be necessary to allocate for information, training and evaluation, regardless of the alternative selected. If an operator chooses an existing method, this may lead to less money being spent on development but there is the risk that costs will arise later due to unexpected consequences (indistinctness, misunderstandings, distrustfulness) when there is no "ownership" within the organization in which the method is implemented. For an "imported" method, the risk for credibility being undermined is potentially greater in that any deficiencies that may arise can always be attributed to someone outside the organization.

With this in mind, a general process for implementation of a method for assessment of CRM skills can be outlined. It must be emphasized that this is not an exhaustive description and that it has no formal status. The description below is only intended to illustrate possible ways for how this can be accomplished, and it does not differ significantly from how any project should be carried out for implementation in an organization of anything else that is new.

First of all, before work with implementing a method for assessment of CRM skills is initiated, the operator should consider why this work is to be performed (beyond the obvious requirements in the regulations). To only refer to regulations may weaken the opportunities for implementing the method and increases the risk that it will not be able to produce the effect on safety and effectiveness that a well-functioning method for CRM skill assessments can contribute with. The purpose of the implementation project and the goals one wishes to achieve with the assessments should be clearly formulated. This will assist in providing good arguments for the project, as well as in facilitating periodic evaluations regarding if assessments are contributing to progression towards set goals. After this, the following steps are recommended:

1) Information gathering
One or more persons should initially be assigned responsibility for acquiring knowledge about assessment of CRM skills. Regardless of if a new method is to be developed or an existing adapted, there must be fundamental knowledge in the organization of how these work. This can also serve as preparation prior to a decision about which existing method should be chosen or if an own method is to be developed.

3) Management support
To ensure that everyone in the organization is aware of what it entails to implement a method for assessment of CRM skills, information and plans for this should be shared with both operational and other management in the organization. This not only creates support for the plans, but also provides the opportunity to receive any criticism prior to commencement of work and thus avoid problems during later phases. It is also important that various parts of the organization or persons in management are not played against one another if problems or conflicts arise in regard to implementation.

3) Information dissemination
For a time, it is important to regularly inform of the plans for implementing a method for assessment of CRM skills. This can provide the opportunity for suggestions, speculations and reservations to be taken up and dealt with before work has progressed all that far. A recommendation is therefore that this part of the process be allowed to take the time necessary for everyone in the organization that will be affected by the assessments to have the opportunity to contribute with opinions.

4) Creation or adjustment of the method
If an own method is to be created, this entails acquisition of information concerning the fundamentals of the method in regard to operations, such as in respect to the existing threats regarding flight safety, and the behaviors that are considered as desirable for managing these threats. These behaviors must then be ordered into categories, provided with descriptions and perhaps with a scale for assessments. It is practical if this results in some form of handbook for the method.

If an existing method is to be adapted or adjusted to an operator, the same tasks should be conducted, but in this case the focus will be on finding out how the method can be adapted and used under the particular operator's existing conditions and that this results in supplementary information, such as a handbook.

5) Training of assessors
All concerned personnel should receive some sort of training on the method for assessment of CRM skills. (Such training can possibly be integrated in recurrent CRM courses or other training.) Moreover, assessors need to receive further instruction, as well as practical training and opportunities to practice use of the method. This can include "calibration training", i.e. providing the opportunity for assessors to discuss and agree on which assessments are to be made in various situations with the aid of video scenarios (produced by the operator or taken from aviation videos).

6) Preliminary phase prior to implementation and evaluation
If possible, it is preferable to not fully implement the method in one single step. An initial phase of implementation and testing out is preferable because this can provide opportunities for resolving uncertainties and deficiencies not previously encountered.

7) Full implementation
The better prepared this phase is, the fewer the problems that will need to be addressed. If the preparatory phase has been short for any reason, it is important that upon implementation to be initially open to receiving and dealing with reactions that can encompass confusion, misunderstanding and frustration concerning use of the system.

8) Follow-up and evaluation
It is difficult to imagine that even the most carefully considered method for CRM skill assessments could be implemented in an organization without it requiring adjustments based on the experiences gained from using it. Following up and evaluating the initial results are therefore of great importance for the method to run smoothly in the long run. If this is done, the assessments can contribute to providing information about how operations function from a CRM perspective and form the basis for determining where the emphasis is to be placed in CRM instruction and other training.

Even if this description can make implementation of a method for assessment of CRM skills appear as a major effort, there are a few things that deserve emphasis. First of all, some form of assessment of CRM skills probably already exists with all operators, regardless of whether it is in the form of an explicit and documented method or not. Pilots are always assessed on their technical skills in various forms of training, tests or checks, and it is unavoidable that this also includes some form assessment of non-technical skills. If this is not documented, it can lead to assessments that no one needs to take responsibility for, and in worst case even to the spreading of rumors concerning pilot performance. If assessments are not performed systematically and connected to good instruction and training of assessors, it can lead to

unfairness and conflicts. When the alternative of trying to avoid implementation of a method for assessment pf CRM skills is proposed, it can be countered with these arguments.

Assessments of CRM skills can be one of many possible tools for an operator to increase safety and effectiveness in operations. But just as when it comes to choosing the right tool in any situation, here too it is a matter of choosing the right tool and ensuring that it can be used correctly so as to achieve the intended goal.

3.6 Assessment of CRM skill – Practical aspects

Some of the challenges involved in assessment of CRM skills will be presented in this section, along with ways of dealing with them. The section is intended to serve as an aid in encounters with operators to monitor and support their efforts in implementing or using a method for assessment of CRM skills.

3.6.1 Choice of existing method or development of own method

It is important that the choice of method for assessment of CRM skills is thoroughly considered and anchored in the organization so that it will contribute to improved CRM, and in turn, to safer and more effective flights. The following points may be considered by operators in regard to the chosen method and why it was chosen.

- Background concerning choice of method for CRM skill assessment (adaptation of existing method or development of own)
- The process for implementation – concerning how crew were informed, how information was gathered about assessment of CRM skills and how the implementation plan was structured
- Main categories and subcategories included in the method
- Explanation of which specific behaviors are to be observed and how they can be related to the categories they belong to
- If method for assessment of CRM skills is lacking or only consists of a “CRM:” field or other incomplete assessment, whether this is a matter of not complying with explicit requirements in the regulations (Because what this can consequently entail is beyond the scope of the authors’ expertise, no further comment is provided.)

3.6.2 Adaptations to operations

Just as for CRM training, it is important for assessment of CRM skills that the method is adapted to the operations. If this is already properly managed for CRM training, the step is shorter for also accomplishing this for assessments of CRM skills. Even if desired CRM behaviors should be the same in most cases, there may be operators that want to put more emphasis on communications because they operate extensively at heavily trafficked airports, while others fly in regions that are more isolated and, for example, want to focus more on caution in regard to illusions during night flights. Regardless of how CRM training and assessment of its effects are performed, what is most important is that it is performed at all.

To understand how such an adaptation is to be carried out, or to provide support in carrying out an adaptation, the following points can be important for an operator to focus on.

- The operational conditions regarding CRM which are special for this particular operator
- Influence of operational aspects on the method for assessment of CRM skills (preferably clarified with concrete examples)
- Influence of pilots on the method as it was being adapted to the operator
- If the responses to the above indicate that an adaptation has not occurred, an alternative is to carry out an adaptation in conjunction with further development of the method for CRM skill assessment.
- If an adaptation has not occurred or if a method for assessment has not been implemented, it is important to emphasize that an adaptation to own operations should be conducted.

3.6.3 Behaviors and rating scale

The choice regarding rating method for various behaviors is important. It is also important to emphasize that behaviors need to have a technical consequence to be assessed. How the behaviors that are to be observed are formulated largely determines the potential to correctly observe and assess them. It is therefore important that different people participate in critically examining the proposed behaviors and how they are formulated in written form.

Even if a rating is not a necessary element in a method for assessment of CRM skills, some form of rating is normally used. Since ratings may be a sensitive issue it is important that the terms are carefully chosen, explained, accepted and correctly used by assessors to avoid misunderstandings and conflicts. The following points are to be taken up by an operator:

- Anchoring of assessments of behaviors in clear descriptions of them
  (Is this based on descriptions of positive behaviors, negative behaviors or both?)
- Background information about how descriptions of behaviors were tested before they were used in assessments so as to avoid indistinctness
- Explanation of the used rating scale and of the delineation between scale steps
- Explanation of how the assessment of behaviors and/or categories leads to a judgment regarding pass or fail (is this occurs)
- Measures taken if the overall assessment on the whole cannot be a pass

3.6.4 Training of assessors

That those who are to carry out assessments of CRM skills are trained is a decisive factor for assessments to be an effective tool for development of CRM. In scientific literature, there is considerable information about how this can be conducted to attain a high level of coherence among assessors (often referred to as inter-rater reliability). Even if use of advanced methods for this probably not will be an option for most operators, coherence in assessment is a matter that all operators should consider. The following points can help to clarify conditions related to instruction and training of assessors.

- Implementation of initial instruction and training of assessors (content, time and training elements, for example)
- Recurrent instruction or training of assessors (content and frequency, for example)
- Clarification of how training to improve coherence in assessments has been conducted and how often it is expected that such training should be repeated
- Explanation of how coherence in the assessments is continually evaluated to ensure reliability in the assessments
- Experience and handling of any difficulties in training of assessors

3.6.5 Evaluation and follow-up

It is unreasonable to expect that everything will be working smoothly from the start when implementing a method for assessment of CRM skills. It is therefore important that before the method has been implemented there have been plans made for how the implementation will be followed up and evaluated, and how to continue to develop the method. Evaluation and follow-up are also necessary to provide feedback from the assessments to CRM training, which is one of the most important purposes of the assessments. To check if an operator has made plans for this, the following points can be brought up:

- Evaluation of implementation of assessments of CRM skills
  (Ask to see assessment templates, compilations and other documents.)
- Conclusions that have been drawn from the evaluation and of which measures are planned for further developing the method
- Clarification of how the assessments of CRM skills are fed back to planning of CRM training

4 Further reading about CRM, TEM and CRM skill assessments

The following literature only constitutes a small selection of available material in regard to what is taken up in this report. Books and articles that are general in nature and that can be bought or accessed via the Internet have been prioritized. The literature under the "About CRM" heading is relatively easy to read, while those under the following headings consist more of research reports (due to there not being other literature for these topics). Even under the other headings, literature has been selected that is more general and easier to read than other literature within the field. (For further help in regard to suitable literature, please contact the author.)

About CRM

Books

Beaty, D. (1995). *The Naked Pilot.* (Airlife)

Dekker, S. (2006). *The Field Guide to Understanding Human Error.* (Ashgate)

Dismukes, R. K., Berman, B. A. & Loukopoulos, L. D. (2007). *The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents.* (Ashgate)

Fahlgren, G. (2001). *Du och din mänskliga faktor.* (Sellin & Partner bok och idé AB)

Fahlgren, G. (2005). *Life Resource Management CRM & Human Factors.* (Creative Book Publishers)

Orlady, H., & Orlady, L. (1999). *Human Factors in Multi- Crew Flight Operations.* (Ashgate)

Wiener, E., Kanki, B., & Helmreich, R. (1993). *Cockpit Resource Management.* (Academic Press)

Articles and other material

CAP 737. (2006). *CAP 737 Crew Resource Management (CRM) Training.* (UK CAA)

Helmreich, R., Merritt, A., & Willhelm, J. (1999). *The Evolution of Crew Resource Management Training in Commercial Aviation.* (University of Texas)

Lundh, E. & Nilsson, M. (2007). *CRM i Sverige – Utvecklingen av Crew Resource Management ur svensk synvinkel.* (Trafikflyghögskolan)

Neil Krey's CRM Developers Forum.
This website constitutes the best collective resource for CRM on the Internet. There are also literature tips (http://www.crm-devel.org/resources/index.htm) and a CRM "Quick Start" page (http://www.crm-devel.org/resources/quick.htm).

About threat and error management

Articles and other material

Ashleigh, M.& Klinect, J.(2006). *Defensive Flying for Pilots: An Introduction to Threat and Error Management.* (University of Texas)

Federal Aviation Administration (2006). *Line Operations Safety Audits.* (Advisory Circular AC No: 120-90 from the Federal Aviation Administration)

International Civil Aviation Organization (2002). *Line Operations Safety Audit (LOSA).* (Doc 9803 AN/761 from ICAO)

Klinect, J. (2005). *Line Operation Safety Audits (LOSA)*: *Definition and operating characteristics.* (University of Texas)

Thomas, M (2004). *Predictors of Threat and Error Management: Identification of Core Nontechnical Skills and Implications for Training Systems Design.* (International Journal of Aviation Psychology 14(2), pages 207–231)

About assessment of CRM skills

Articles and other material

Andreasson, M., Avedal, A. & Ludvigsson, A. (2003). *Bedömning av Non-Technical Skills.* (Trafikflyghögskolan)

van Avermaete, J. (1998). *Non-technical skill evaluation in JAR-FCL.* (Report TP-98518 from the Dutch National Aerospace Laboratory)

Baker D. & Dismukes R. (2002). *A Framework for Understanding Crew Performance Assessment Issues.* International Journal of Aviation Psychology, 12(3), pages 205-222.

Flin, R. & Martin, L. (2001). *Behavioral Markers for Crew Resource Management: A Review of Current Practise. (Internationa*l Journal of Aviation Psychology 11(1), pages 95-118)

Goldsmith, T. & Johnson, P. (2002). *Assessing and Improving Evaluation of Aircrew Performance.* International Journal of Aviation Psychology, 12(3), pages 223-240

O'Connor, P., Hörmann, H., Flin, R., Lodge, M., Goeters, K., The JARTEL Group (2002). *Developing a Method for Evaluating Crew Resource Management Skills: A European Perspective. (The International J*ournal of Aviation Psychology 12(3), pages 263-285)

Appendix 1

Issues regarding CRM training

1 Planning and preparation of CRM training

- Scheduled times for different types of CRM training
  (to identify lead times and planning prior to courses)
- Time set aside for various types of CRM training
- Preparations that are normally conducted prior to CRM training
- Information to the CRM instructor about operations
  (How has the instructor received information about the operator, especially about incidents or other CRM-related incidents at the company?)
- Use of own company-specific operative incidents in CRM training

2 Syllabus for CRM training

- Background information about how syllabus for CRM courses are prepared (which resources and competences have been utilized)
- Presence of physiology elements in syllabi for CRM
- Comparison of syllabi for CRM training with the syllabus for HPL, especially in regard to the physiology element to find out if there are significant similarities between them
- Adaptation of syllabi for CRM training to the company's operations and checks of how this has effected the execution of CRM training
- Overview of syllabi for various types of CRM courses and auditing of how they are adapted to the actual knowledge needs of the various types of CRM training (and how these knowledge needs have been identified)

3 CRM instructors

For CRM training conducted by one or more internal instructors:

- Operator's requirements and preferences regarding CRM instructors
- Description of each CRM instructor's background and suitability for the role
- Available working hours for CRM instructors to prepare material, planning and execution, as well as following up CRM training
- CRM instructors' access to current information related to flight safety
  (to be able to integrate this into CRM training)
- Planning of further training and skills development for CRM instructors

For CRM training by third-party instructors, the same points as above can be used, but then adapted to the current conditions and including clarification of the relationship between the operator and CRM instructors. When third-party instructors are used, it is preferable that the same instructors are engaged for subsequent courses because they will then already have some knowledge of operations. When instructors are replaced too often, it can be difficult to comply with the requirement concerning adaptation of CRM training to actual operations.

4 Evaluation and follow-up of CRM training

- Routines in conjunction with evaluation and follow-up of CRM training
- Use of course evaluations for CRM training
  (Review of both configurations and different compilations of evaluations)
- Design of course evaluations
  (If there are rating scales, are there instructions for how they are to be used? What is considered as good? What is considered as bad? What is done when something is considered as bad?)
- Feedback to participants after completion of course evaluation
- Use of course evaluations for future CRM courses
- Examples of how changes to CRM training are based on course evaluations
- Examples of influence on operations based on evaluation and follow-up of CRM training

5 CRM training for foreign pilots engaged by Swedish airlines

- Time allocated for CRM conversion training
- Content and focus concerning conversion CRM
- Whether training concerning briefings and other forms of communication and cooperation are to brought up in CRM or in other parts of the conversion training
- Available elements of supplementary training in regard to communication in other parts of conversion training
- Differences between content in this conversion training in relation to corresponding conversion training concerning CRM for Swedish pilots and cabin crew
- Training and exercises concerning communications in abnormal situations or emergencies (and how this is to be brought up in CRM training)
- Training concerning group and leadership aspects, as well as Swedish working culture (how this is to be brought up in CRM training or in other part of conversion training)

Appendix 2

Issues regarding TEM

- Conducted (or planned) training in TEM
- Integration of TEM in training and other activities
- Compilations of collected information from normal flight operations (which information is collected, how it is analyzed and how it is used)
- Analyses of threats to flight safety in operations (see the previous point)
- Analyses of which errors these threats can lead to (see the previous point)
- Feedback to training regarding information from normal flight operations and from analyses of threats and errors in operations

Appendix 3

Issues regarding assessment of CRM skills

1 Choice of existing method or development of own method

- Background concerning choice of method for CRM skill assessment (adaptation of existing or development of own)
- The process for implementation – concerning how crew personnel were informed, how information was gathered about assessment of CRM skills and how the implementation plan was structured
- Main categories and subcategories included in the system
- Explanation of which specific behaviors are to be observed and how they can be related to the categories they belong to
- If method for assessment of CRM skills is lacking or only consists of a "CRM:" field or other incomplete assessment, whether this is a matter of not complying with explicit requirements in the regulations (Because of what this can subsequently entail is beyond the scope of the authors' expertise, no further comment is made.)

2 Adaptation to operations

- The operative conditions regarding CRM that are special for this particular operator's operations
- Operative aspects' influence on the method for assessment of CRM skills (preferably clarified with concrete examples)
- Pilots' influence on the method in conjunction with it being adapted to the operator's operations
- If the responses to the above indicate that an adaptation has not occurred, an alternative is to carry out an adaptation in conjunction with further development of the method for CRM skill assessment.
- If an adaptation has not occurred or if a method for assessment has not been implemented, it is important to emphasize that an adaptation to own operations should be conducted.

3 Behaviors and rating scale

- Support for assessments of behavior in clear descriptions of them (Is this based on descriptions of positive behaviors, negative behaviors or both?)
- Background information about how descriptions of behaviors are tested out before they are used in assessments so as to avoid indistinctness
- Explanation of the used rating scale and of delineation between the various scale steps
- Explanation of how the assessment of behaviors and/or categories leads to a collective judgment regarding pass or fail (is this occurs)
- Measures taken if assessment on the whole cannot be approved

4 Training of assessors

- Implementation of initial instruction and training of assessors (content, time and training elements, for example)
- Recurrent instruction or training of assessors (content and frequency, for example)
- Clarification of how training to improve consensus in assessments has been conducted and how often it expected that such training should be repeated
- Explanation of how consensus in the assessments is continually evaluated to ensure reliability in the assessments
- Experience and handling of any difficulties in training of assessors

5 Evaluation and follow-up

- Implementation of assessment of CRM skills have been evaluated.
  (Ask to see assessment templates, compilations and other documents.)
- Conclusions that have been drawn from the evaluation and of which measures are planned for further developing the method
- Clarification of how the assessments of CRM skills are fed back to planning of CRM training