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Author(s)	O'Connor, Paul
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THE U.S. NAVY'S CREW RESOURCE MANAGEMENT PROGRAM: THE PAST, PRESENT, AND RECOMMENDATIONS FOR THE FUTURE.

Paul O'Connor, Robert Hahn, and Eduardo Salas.

INTRODUCTION

Crew Resource Management (CRM) training is the most widely applied technique for providing human factors and team training to operations personnel in high reliability organizations (see Flin, O'Connor, & Mearns, 2002 for a review). CRM training can be defined as "*a set of instructional strategies designed to improve teamwork in the cockpit by applying well-tested tools (e.g., performance measures, exercises, feedback mechanisms) and appropriate training methods (e.g., simulators, lectures, videos) targeted at specific content (i.e., teamwork knowledge, skills, and attitudes)*" (Salas, Prince, et al., 1999: 163). Since its inception over 20 years ago in commercial aviation, CRM training is now recommended by the major civil aviation regulators (e.g., Federal Aviation Authority, FAA; and Joint Aviation Authorities, JAA) and used by virtually all the large national and international airlines, and U.S. military aviation. The

goal of U.S. Navy CRM[1] training is to "*improve mission effectiveness by minimizing crew preventable errors, maximizing crew coordination, and optimizing risk management*" (Chief of Naval Operations, 2001). Every naval aviator must receive ground training and a CRM evaluation during an actual, or simulated flight, by a CRM instructor, or facilitator, once a year.

Unlike commercial aviation, the U.S. Navy considers CRM training to be an *operational* training program, as opposed to a safety training course. However, with more than 80% of naval aviation mishaps attributed to human error (Naval Safety Center, 2006), if CRM's goal of reducing preventable crew errors is achieved, improvements in safety would also be an inevitable outcome of CRM training.

The purpose of this chapter is to discuss the development of CRM training in U.S. Naval aviation, and how that training is managed in a large organization with many different airframes and squadrons (a squadron consists total of 12 to 24 aircraft, depending on aircraft type commanded by a single senior officer). This chapter also discusses early evaluations of the effectiveness of Navy CRM training and suggests considerations for improving the program. Although this chapter is written with reference to the U.S. Navy's CRM program, this chapter is of interest to any organization attempting to implement, or improve, the effectiveness of CRM training.

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[1] For the purposes of this chapter, reference to the U.S. Navy CRM program includes U.S. Marine Corps aviation. Similarly, use of the word *naval* includes both the sea services as both comprise the Department of the Navy.

THE DEVELOPMENT OF CRM TRAINING IN THE U.S. NAVY

The impetus for CRM training in the U.S. Navy came directly from commercial aviation. Throughout the 1970s and 1980s, commercial aviation sponsored increasing amounts of research to identify how failures of human performance had contributed to mishaps. As a result of this research, commercial carriers developed training to reduce error, and increase flight crew effectiveness (the first comprehensive CRM program was initiated by *United Airlines* in 1981; Helmreich & Foushee, 1993).

The first attempt to start a CRM training program in naval aviation was initiated by the Naval Safety Center in 1989 (Alkov, 1989). The program was based heavily upon the training that was being provided in civil aviation at that time. However, the training was not universally accepted by naval aviators across all communities due to the 'one-size-fits all' nature of the training (Prince & Salas, 1993). Oser, Salas, Merket, and Bowers (2001) point out that "*for the naval CRM program to be successful and accepted, it had to be developed for aviators, by aviators* (p 334)." Therefore, CRM training research was started by the Navy with the purpose of designing a program specifically for the needs of naval aviators to coordinate their resources. A brief description of the nine steps that were used to design and deliver the Navy's CRM training program is provided below (for a more detailed discussion of the development of the program, see Oser et al, 2001; Oser, Salas, Merket, Walwanis & Bergondy, 2000; and Prince & Salas, 1993).

Steps 1 and 2: Identify operational requirements and assessment of training needs and coordination demands. To identify requirements, existing training curriculum, standard operating procedures, mishap data, and interviews with naval aviators were

carried out to identify the skills and behaviors required for effective and ineffective

performance (Oser et al, 2001).

Step 3. Identify teamwork competencies and knowledge, skills, and attitudes. The

particular emphasis at this stage was on skills. The research goal was to "*develop and*

demonstrate a methodology that could be used by the various aviation communities to

build, validated, mission-oriented, skill-based training for aircrew coordination which

could be integrated with other aircrew training" (Prince & Salas, 1993: 355). Seven

critical skill areas were identified: decision making, assertiveness, mission analysis,

communication, leadership, adaptability/ flexibility, and situational awareness; (Prince &

Salas, 1993).

Step 4. Determine team training objectives. For each teamwork knowledge, skill,

and attitude competency, training objectives were written. The training objectives then

guided the development of the content of the course. Training objectives are crucial as

these can be empirically evaluated to assess whether or not they were achieved through

the training (Goldstein & Ford, 2002).

Step 5. Determine instructional delivery method. Different instructional strategies

were examined to establish the most effective method for training the skills identified

from the research. Based upon prior research on training effectiveness, it was decided to

use a combination of information (lectures), demonstration (video clips of good and poor

examples of CRM), practice (practice the behaviors in the simulator), and feedback to the

training participants (Oser et al., 2001).

6. Design scenario exercises and create opportunity for practice. Scenario-based

(or event-based) training was used to provide the participants the opportunity to practice

the skills they had learned in a simulated environment. "*Event based training is an instructional approach that systematically structures training in an efficient manner by tightly linking learning objectives, exercise design, performance measurement and feedback*" (Dwyer, Oser, Salas, & Fowlkes, 1999: 191). For each training objective, specific learning objectives are identified for inclusion in the training exercises. The next stage is to identify 'trigger events' for each learning objective. These events are the stimulus conditions and cues which are embedded in the exercises and require a response by the participants.

      Step 7. Develop performance assessment/measurement tools. In association with the design of the scenarios, tools were developed to assess the performance of the participants. These tools included behavioral based checklists, subjective evaluation forms, and outcome metrics and criteria (Salas et al., 1999; see the next section for more details on these measures).

      Step 8. Design and tailor tools for feedback. Guidance was provided to instructors as to how to provide feedback to participants on their performance. The purpose of the guidance was to provide instructors with help diagnosing the causes of poor performance, as well as aiding in providing feedback on improving performance in the future.

      Step 9. Evaluate the extent of improved teamwork in the cockpit. The Federal Aviation Authority (FAA; 2004) states that for CRM training "*it is vital that each training program be assessed to determine if CRM training is achieving its goals*" (12: FAA, 2004). Using the tools developed in step seven, a number of studies were carried

out of the effectiveness of the training. The next section provides a detailed description of this research.

Evaluation of the U.S Navy's CRM program

As has been the case with CRM in commercial aviation (see O'Connor, Flin & Fletcher, 2002; Salas, Burke, Bowers, & Wilson, 2001; Salas, Wilson, Burke, Wightman & Howse, 2006a; for reviews), evaluations of the effectiveness of the U.S. Navy's CRM training have been reported in the scientific literature. Kirkpatrick's (1976) evaluation hierarchy provides a useful framework to assess the effects of a training intervention on an organization by considering training evaluations at different levels. The hierarchy consists of four different levels of evaluation: reactions, learning, behavior, and organization.

- Reactions (level one) are concerned with how the participants react to the training. Evaluating reactions is the equivalent of measuring customer satisfaction. For example, did the participants like the training?

- Learning is the second level in the hierarchy, and refers to "*the principles, facts, and skills which were understood and absorbed by the participants*" (Kirkpatrick, 1976: 11). This level is concerned with whether the participants have acquired knowledge, or have modified their attitudes (a tendency to respond in a certain manner when confronted with a certain stimuli or situation; Oppenheim, 1992) or beliefs as a result of attending the training course.

- An evaluation at the behavior level (level three) is the assessment of whether knowledge learned in training actually transfers to behaviors on the job, or a similar simulated environment.

- The organizational level is the highest in Kirkpatrick's (1976) hierarchy. The ultimate aim of any training program is to produce tangible evidence at an organizational level, such as an improvement in safety and productivity. The problems with the evaluation of training at this level are that it can be both difficult to establish discernible indicators, and be able to attribute these to the effects of a single training course.

Table 1 summarizes the eight scientific studies of the effectiveness of the U.S. Navy's CRM program that have been reported in the literature.

Table 1. Evaluations of the effectiveness of the U.S. Navy's CRM program.

Author	Participants	Reactions	Learning	Behaviour	Organisation
Alkov (1989); Alkov & Gaynor (1991).	90 aircrew		Positive shift in attitudes.		Aircrew error mishap rate declined.
Baker et al. (1991)	41 helicopter pilots.	Positive reaction			
Brannick et al (1995)	51 aircrew			Better than average in performing CRM behaviors	
O'Connor & Jones (under review)	364 aviators		Senior aviators were significantly more supportive of an open cockpit climate than junior aviators.		
Salas et al. (1999)	35 pilots & 34 enlisted helicopter aircrew	Positive reaction.	No significant difference in attitudes pre- and post-training.\n\nSignificant increase in CRM knowledge.	Trained crews performed better than untrained crews.	
	27 helicopter pilots (12 serving as controls).	Positive reaction	No significant difference in attitudes between trained and controls.\n\nTrained aviators scored significantly better on knowledge test than controls.	Trained better during pre-flight brief, and greater number of teamwork behaviours during high workload.	

Table 1. Continued.

Author	Participants	Reactions	Learning	Behaviour	Organisation
Stout, Salas & Folkes (1997)	42 student aviators (20 experimental, 22 control)	Positive reaction	Positive shift in attitudes. Significant increase in knowledge of CRM principles	Trained crews performed better than untrained crews.	
Stout, Salas & Kraiger (1996);	12 helicopter pilots (10 serving as a control group).	Positive reaction	Positive change in attitudes, but not significant. No significant difference in scores on knowledge test than controls.	Trained participants performed on average 8% more desired behaviours than control as measured by TARGETs.	
Wiegmann & Shappell (1999);	290 naval aviation mishap (1990-96) causal factors				56% of the mishaps had at least one CRM causal factors. Comparable to the 58% air crew error rate found by Yacavone (1993) in an examination of 308 naval aviation mishaps (1986-90).

Level 1: Reactions. In the five studies that reported an evaluation of reactions, naval aviators were found to be enthusiastic in their reactions to the training (see Table 1). To illustrate, the first study reported by Salas et al. (1999) reported a strong endorsement of the usefulness of the training (a mean of 4.3 out of 5).

Level 2: Learning. Six studies examined the effect of CRM training on the attitudes of course participants (see Table 1). These studies used adaptations of the cockpit management attitudes questionnaire (CMAQ; Helmreich, 1984) to assess attitude change. It can be seen that the studies generally reported a positive shift in the attitudes of CRM participants.

Four studies examined the effects of CRM training on the knowledge of course participants using multiple choice tests, with three of the studies reporting a significant increase in knowledge (see Table 1). For example, Salas et al (1999) found that, although CRM training did not show an effect on the pilots' attitudes, it did appear to increase their CRM related knowledge. Those who had participated in the CRM training scored significantly better than the baseline group that had not received any training (a mean of 12.6 out of 17, compared to 9.8 respectively).

Level 3: Behavior. Four out of the five studies that assessed behaviors used a behavioral marker system called Targeted Acceptable Responses to Generated Events or Tasks (TARGETs) to assess team performance, with Brannick et al (1995) using a precursor to TARGETs (see Table 1). Behavioral markers are *"a prescribed set of behaviors indicative of some aspect of performance*" (Flin & Martin, 2001: 96). The TARGETs system was based upon the seven critical aircrew behaviors that are taught in the Navy' CRM training (Fowlkes, Lane, Salas, Franz, & Osler, 1994). For each stimulus event in a scenario, there is a predefined set of acceptable behaviors; each is rated as present or absent. It is a measure of crew performance rather than individual performance. All five of the studies reported an increase in CRM behaviors. For example, Salas et al (1999) found that CRM trained helicopter crews performed 15% better than

the untrained crew during the pre-flight brief and 9% better during high workload segments.

   Level 4: Organizational impact. The ultimate aim of any training program is to produce tangible evidence at an organizational level, such as an improvement in safety and productivity. Only two study reported an evaluation at the organizational level. Alkov (1989) and Alkov and Gaynor (1991; both studies used the same data) reported a decrease in the mishap rate for three naval aircraft communities (helicopters, attack bombers, and multiplaced fighters) as a result of CRM training. However, Wiegmann and Shappell (1999) argued that the initial success of the Navy's CRM program may have been short-lived.

   An analysis of the causes of naval aviation mishaps from 1990 to 1996 found that 56% involved at least one CRM failure (Wiegmann & Shappell, 1999). This can be compared to an aircrew error rate of 58% in naval aviation mishaps from 1986 to 1990-prior to the introduction of CRM (Yacavone, 1993). Wiegmann and Shappell (1999) attributed the lack of change in the aircrew error rate to the lack of specific tailoring of the CRM program to specific needs of the different aviation communities. There certainly could be some truth to this argument, particularly considering that the CRM training was only beginning to be applied in naval aviation during this time period. However, there are other factors that may have contributed to a perceived lack of change in the aircrew error rate. To illustrate, CRM training may have led to an increase in the awareness and understanding of aircrew error. Therefore, there may have been a greater willingness of the mishap investigation board to identify human factors as causal to the mishap than prior to widespread participation in CRM training.

To summarize, the findings from the evaluation studies, apart from the conclusions of Wiegmann & Shappell (1999), there would generally appear to be a positive effect of the Navy's CRM training at each of the levels of Kirkpatrick's evaluation hierarchy. In the next section the methodology for implementing the training to every naval aviator is described.

The Implementation of CRM Training in the U.S. Navy

As described above, after the initial limited success in implementing the civil aviation modeled CRM training to naval aviators in1989, the scientifically grounded course was introduced in 1993. This section is concerned with how the training was, and continues to be, implemented in an organization as large as the U.S Navy, operating a highly diverse range of aircraft types.

Implementation of the 'new' CRM programs into naval aviation began in 1993 and was initiated by the Naval Air Warfare Center Training Systems Division (NAWC TSD). To execute this new far-reaching program required an architecture, or command and control system, suited to the organization it would serve. However, only a portion of the funding required for full-scale implementation was made available. Therefore, when the program was first launched, the extent to which it was put into practice varied considerably from platform to platform (Oser et al., 2001). To this day, there is some variability between both communities, and squadrons, in the quality of CRM training provided to naval aviators. The effectiveness of the program is greatly influenced by the support of the squadron Commanding Officer, and the enthusiasm of the CRM facilitator.

The Navy's CRM program is governed by a Chief of Naval Operations (CNO) Instruction – OPNAVINSTR 1542.7C. This instruction sets the basic administrative organization of the CRM program, and outlines a basic framework for CRM in the U.S. Navy and Marine Corps. The CNO instruction outlines a rudimentary foundation of CRM program academics and the behaviors the program aims to achieve. The instruction sets out the roles and responsibilities of the key personnel in the CRM program (see Table 2).

Table 2. Roles and responsibilities of key personnel in the CRM program

Roles	Responsibilities
Chief of Naval Operations	The resource sponsor for the CRM program
Controlling Custodians	Ensure compliance with the program; forward resource needs to higher authority for various CRM program initiatives; allocate quotas for training of personnel at the Instructional Model Manager's CRM course.
Curriculum Program Managers	Implement the CRM programs that are specific to their type-model aircraft.
Curriculum Model Managers	Responsible for training squadron CRM facilitators within their aircraft community.
CRM Facilitators	Monitor CRM programs in their squadron, and conduct squadron level CRM training.
CRM Instructional Model Manager (IMM)	Providing CRM training to the Curriculum Model Managers. In this capacity, the IMM sets the overall academic theme of naval CRM training.

The naval CRM program can be viewed as 42 separate CRM programs (run by the Curriculum Program Managers and their Curriculum Model Managers) united by a common CRM language and basic tenants as outlined in the CNO instruction. At the same time, the Curriculum Program Managers have the license to make the basic CRM program specific to their aircraft, crew composition, and mission. The CRM IMM trains

the Curriculum Model Managers. This gives rise to a 'train the trainer' system. IMM instructors train the Curriculum Model Managers who train CRM Facilitators who in turn train aviators in the squadrons. It should be pointed out that the only position that is a full time 'job' is that of the IMM. For all of the other positions, the CRM duty is performed in addition to all of their other duties (e.g. flying, instructing, safety officer). Due to the size and complexity of naval aviation this system is functionally expedient.

The IMM has an additional responsibility not often delegated to 'schoolhouses' – that of conducting periodic site visits to the Curriculum Program Manager sites. In this capacity the IMM provides oversight to the naval CRM program. This oversight is limited and advisory in nature, rather than punitive. The IMM looks for basic compliance with the CNO instruction in the Program Managers' programs, and ensures that academic literature in the Curriculum Program Managers' CRM training covers the basic academic tenants addressed in the CRM curriculum. In this manner, naval CRM achieves both broad standardization in language, basic academics, and implementation; and relevance in specific CRM programs which have adapted the same to specific issues in the given aircraft model. This unique IMM duty helps serve to provide a form of standardization in the naval CRM program.

The organization of the US Navy CRM program has remained intact since its inception. Although there have been minor updates to the IMM's curriculum, the basic CRM instruction in naval aviation has not changed greatly in the last decade. The last systematic update of the training curriculum was in 1999 by NAWCTSD (Oser et al., 2001). There are cases however, of some Curriculum Program Managers making exhaustive efforts to improve CRM in their communities. Some training commands have

drawn extensively on airline models for multi-place CRM training while the MV-22 Osprey program has developed robust CRM courseware and models for their CRM program. The CRM curriculum in these communities exceeds the basic requirement in the CNO instruction and augments the curriculum promulgated by the IMM. These are generally the exception: most Curriculum Program Managers' CRM programs reflect the basic academics taught by the IMM. Promulgating the latest academic themes in a 'train the trainer' system is sometimes a challenge in a large organization.

RECOMMENDATIONS FOR THE U.S NAVY'S CRM PROGRAM

It is possible to make a number of suggestions for improving the U.S. Navy's CRM program. However, these recommendations do not only apply to the U.S. Navy, but have implications for any large high reliability organization that has, or is developing, a CRM training program.

1. Use and apply what we know from the science of team training

The design and delivery of training is a science (Salas & Cannon-Bowers, 2000), grounded in a systematic process of creating a robust learning environment. Training should be based on theoretically-driven and empirically-validated instructional principles to drive the design of the instructional process (Salas, Wilson, Burke, Wightman, & Howse, 2006a). The design and delivery of *team* training is no different. And over the last two decades a wealth of knowledge has emerged about how to design and deliver

team training (Salas et al, 2007). There are now solid principles, guidelines, tips and specifications that can be applied to update and modernized CRM programs.

2. Conduct evaluations of the effectiveness of the CRM program.

It is important to track the effects of CRM training to allow for the identification of topics for recurrent programs, and to ensure that it continues to improve performance despite changes in aircraft design, operational conditions, emerging risks and pilot demographics. However, the majority of the studies evaluating the Navy's CRM program were carried out in the 1990s. Very little has been done to evaluate the effectiveness of CRM training in the last decade. Therefore, there is a need to regularly collect data at as many levels of Kirkpatrick's evaluation hierarchy as is feasible. This evaluation data could be used for internal performance auditing, as well as for benchmarking across different aircraft types to ensure an optimal return on CRM training investment.

3. Update and improve on the content of the existing training course.

Much has changed in the twenty years since CRM training was introduced in the Navy, and updated in 1999. A wealth of more recent research that is relevant to CRM training has been published. Examples of this research include: situation awareness (e.g. Endsley & Robertson, 2000); naturalistic decision making (e.g. Klein, 1999); metacognition (e.g. Cohen, Freeman, & Wolf, 1996); shared mental models (Campbell & Kuncel, 2001); and teamworking (e.g. Salas, Burke, Stagl, 2004). Further, naval aircraft have become increasingly automated, so for many aviation platforms there is also a need

to increase the training provided on the effects of automation on crew coordination (e.g. Woods & Sarter, 2000).

As discussed in the previous section, thanks to the dedication of the individuals that have run the Navy CRM program over the years, the training has not remained stagnant- one of the largest recent changes has been the introduction of the concept of threat and error management (see Helmreich, Wilhelm, Klinect & Merritt, 2001, for a discussion). However, these changes have been made on a piecemeal basis, and vary between aviation communities. Therefore, there is a need to systematically evaluate if the training is meeting it's objectives, and whether updates should be implement to the content to based upon recent research and changes in aircraft design.

4. Exploit the use of simulation to practice and provide feedback on team performance.

Follow the science of simulation-based training. There is a wealth of research on designing effective simulator scenarios (e.g. Shrestha, Prince, Baker, & Salas, 1995), training simulator instructors (e.g. MacLeod, 2005), and tools for providing feedback to participants on performance (Flin, O'Connor, & Crichton, 2008). The design of scenario exercises, was part of the original nine steps for designing and delivering CRM training. However, the effective utilization of simulators to provide aviators with the opportunity to practice and receive objective feedback on their CRM behaviors is largely missing from a number of the Navy's CRM programs. This fact is detrimental to the impact of the training. In a recent meta-analysis of CRM evaluation studies, those studies that were found to be most effective were those in which the training participants were given the

opportunity to practice the behaviors they had learned in CRM training course, in a simulator (O'Connor, Campbell, Newon, Melton, Salas, & Wilson, 2008). A combination of lectures, the opportunity to practice desirable behaviors, and feedback regarding performance is a well established mechanism for delivering effective training (Baldwin & Ford, 1988, Bandura, 1977).

5. Establish CRM in other Navy communities

Despite the fact that CRM training has been used in the U.S. Navy for almost two decades, there has been no systematic effort to expand the training to communities beyond naval aviators. Bridge Resource Management (BRM) was introduced into the curriculum of the Surface Warfare Officers School (the command that trains officers who will work on ships) three years ago. However, it is still in the process of becoming established. The only other isolated examples of the use of CRM training by non-aviation personnel are naval medicine and navy diving (O'Connor & Muller, 2006). However, outside the military, CRM training is being applied in a wide range of high reliability industries. Those industries that adopted it first were, unsurprisingly, involved in the aviation business. However, CRM training has also begun to be used in a number of other high-reliability industries unrelated to aviation (see Flin, et al., 2002 for a review). Civilian applications of CRM training that directly related to the roles of U.S. Navy personnel include: aviation maintenance, air traffic control, nuclear power generation, commercial shipping, and medicine. However, if naval aviation CRM is to be adapted for other military domains, the training materials must be customized. As in the example of naval aviation, this effort must be fully supported at all levels from the deckplates to the

Chief of Naval Operations. The framework of nine steps for designing and delivering training will service as a guide for developing CRM training in other domains (see Salas et al., 2006b for a further refinement of this approach).

For the training to be effective it is imperative that the skills which are required be identified through a training needs analysis. The language and psychological concepts of the research effort must be translated for ease of use and understanding of by participants. Relevant practical examples and case studies should be used to illustrate the concepts. The training is not likely to be effective unless examples poignant to the particular domain are used. One of the main criticisms of participants of the early aviation CRM courses was that there was too much psychological theory and not enough relevance to aviation (Helmreich, Merritt, & Wilhelm, 1999). "*I am not suggesting the mindless import of existing programs; rather, aviation experience should be used as a template for developing data driven actions reflecting the unique situation of each organization* (p784)".

CONCLUSION

An organization's CRM training program must not remain stagnant. Much as occurred in the two decades since CRM training was first introduced in the U.S. Navy. It is reasonable to suggest that a program that two decades ago delivered on it's goal to improve mission effectiveness needs review to ensure its vitality. As new glass cockpit aircraft (e.g. V-22 Osprey) are brought into the Marine Corps, new behavioral based safety training and monitoring are needed to match these machines (e.g. operational risk management, military flight operational quality assurance; see O'Connor & O'Dea, 2007

for details). These new programs must be assessed to ensure they are meeting naval

aviation's operational needs.

Given that more than 50% of naval aviation mishaps have been attributed to

CRM failures (Wiegmann & Shappell, 1999). A robust, scientifically-driven, CRM

training program is an important mechanism for addressing the human component of

aviation mishaps in the U.S. Navy.

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