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Adapting Crew Resource Management to the Air Traffic Control Environment

A U.S. Federal Aviation Administration (FAA) report found that directly adapting crew resource management (CRM) training for flight crews to air traffic control (ATC) was not advisable because of significant differences in the work environments of the two groups. The report did, however, recommend that ATC-specific CRM training be developed based on an analysis of ATC needs after ways of analyzing the effectiveness of such programs have been established.

Robert L. Koenig
Aviation Writer

Since the late 1970s, cockpit training programs have been developed that go beyond individual-pilot instruction to help flight crews work more closely together as teams. The improved interaction and more effective use of resources that these programs aimed at were originally called "cockpit resource management," but the term was later broadened into "crew resource management" (CRM), reflecting its additional application to cabin and dispatch crew. Now, similar team-training methods are being developed for air traffic control (ATC) tasks.

Two university researchers, supported by a grant from the U.S. Federal Aviation Administration's (FAA's) Civil Aeromedical Institute (CAMI) in Oklahoma City, Oklahoma, U.S., examined CRM team-training potential for air traffic control specialists (ATCSs).

The researchers — Charmine Härtel of the University of Tulsa (Oklahoma), and Günther Härtel of Colorado State University (Colorado, U.S.) — believed that CRM programs for flight crews can offer valuable lessons in developing similar training for controllers. But the researchers concluded that "direct adaptation of existing [flight deck CRM] programs to the ATCS profession is not advisable."

Instead, Härtel and Härtel recommended that "the specific needs of the ATCS profession should be systematically analyzed, and appropriate training interventions should be created to meet unique mission and facility needs."

In their report, *Controller Resource Management — What Can We Learn from Aircrews?*, Härtel and Härtel formulated a model for CRM training for controllers by integrating common elements found in the various methods of different CRM programs.

The authors also recommended that "systems for rigorously and objectively analyzing the effectiveness of the resulting training programs must be established from the outset, so that training can be continually improved and updated" for ATCSs.

The first part of the report reviewed the history and theory of flight crew resource management. The second part analyzed the potential for CRM principles to be applied in the ATC realm.

In the 1950s, the U.S. military developed team-training programs for flight crews that were precursors of the current CRM training.

Two decades later, following a series of accidents in the Pacific that were attributed to pilot error, Pan American World Airways began a program that it called "crew concept training." Around the same time, United Airlines and KLM Royal Dutch Airlines also began training programs to improve cockpit management.

In 1979, the U.S. National Aeronautics and Space Administration (NASA) and the airline industry conducted a workshop on the human factors in aviation safety. That discussion provided the impetus for several additional airlines to begin CRM programs, which typically consisted of lectures or videotaped presentations.

CRM has been defined in various ways. Helmreich said that it is "the effective coordination and utilization of all available resources in the service of the flight."[1] For Helmreich and Foushee, it was "the application of human factors in the aviation system."[2] The most recent FAA advisory circular on CRM (1995) called it "one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities. These activities include team building and maintenance, information transfer, problem solving, decision making, maintaining situational awareness and dealing with automated systems."[3]

Researchers have also tried to analyze what skill dimensions are involved in CRM. A summary of four analyses (Table 1) shows some overlapping categories but also some differences.

Evaluating CRM and its components is extremely complex, mainly because of the wide scope of most CRM training programs and the difficulty of measuring the training's impact.

The simplest way to judge CRM's effectiveness would be to measure how successful it has been in helping to prevent accidents and incidents that result from ineffective cockpit teamwork. But several researchers have found that such measurements are difficult because accidents are infrequent.

The easiest thing about CRM to measure — usually by means of a simple questionnaire — is the participant's reactions to the training. To measure changes in attitude, researchers use more complex questionnaires that are designed to measure attitudes before and after the CRM training.

One example is the Cockpit Management Attitudes Questionnaire (CMAQ), developed by Helmreich in 1984. Because some studies indicate that attitudes tend to help predict the behavior of crew members, "changes in measured attitudes on the CMAQ are assumed to impact behaviors that cause or are linked to accidents," the report said.

CMAQ is a self-rating report using 25 items, many of which question whether specific behaviors are appropriate. For example, crew members are asked to agree or disagree with such statements as: "Crewmembers should avoid disagreeing with others because conflicts create tension and reduce crew effectiveness." One limitation of the approach is that some crew members' attitudes may not have changed on that question, but they can answer correctly because they learned in CRM what the answer should be.

Taking a more objective approach to determining if CRM training is effective, some evaluators use the line-oriented flight simulation (LOS) checklist to compare the performance of crews that have undergone CRM with crews that have not had the training.

Taken together, such studies have been interpreted as confirmation that CRM training is effective. But Härtel and Härtel cautioned that "all these studies lacked randomization or experimental control," and were therefore not scientifically conclusive. They suggested that more effort should be made to evaluate CRM results objectively.

Because CRM's goal is to improve flight safety, it would seem logical to extend some form of team training to air traffic controllers.

Sherman and Helmreich found that several accidents had been blamed on air traffic control specialists' "lack of adequate communication and coordination with air crews."[8] And the

Table 1
Comparison of Crew Resource Management (CRM) Dimensions

Prince & Salas, 1989[4]	FAA, 1989[5]	Helmreich & Foushee, 1993[2]	Lauber, 1979[6], 1987[7]
Situational awareness	Situational awareness	Situtational awareness	
Leadership	Interpersonal skills, team management	Leadership, workload management and task delegation	Leadership, delegation of tasks and assignment of responsibilities, establishment of priorities
Adaptation		Use of available resources	Use of information
Communication	Communication	Communication	Communication
Mission analysis	Team review or mission analysis		Monitoring and cross-checking
Decision making	Decision making		Problem assessment
	Stress management	Building and maintaining team	Distraction management

Source: U.S. Federal Aviation Administration and authors referenced above

FAA's 1989 "Profile of Operational Errors in National Airspace Systems Report" found that "human error was listed as the primary cause of most operational errors and deviations."[9]

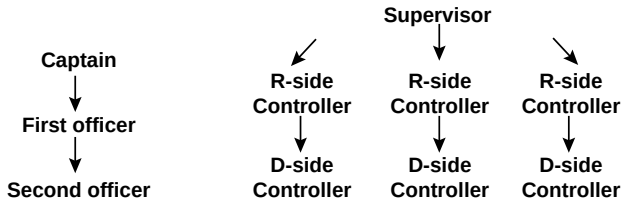
But there is a big difference between the cockpit environment and the control-tower environment. The typical airline flight crew consists of the pilot (or captain), the copilot (or first officer) and in some cases a flight engineer (or second officer). Duties are clearly defined for each crew member, with the captain having the ultimate responsibility for the flight's safety.

In the nature and timing of their tasks, flight crews differ from other types of work teams. Aviators sometimes describe their work as "hours of intense boredom punctuated by moments of sheer terror." During a normal flight, the flight crew's workload is predictable, but uneven. "There is a substantial workload near the beginning of the flight, and then again near the end, with very little work in between," the report observes.

Another characteristic of such cockpit teamwork is "the short time aircrew teams spend working together." Hackman and Helmreich[10] noted that many airline crews work together for only about a month. "In contrast," Härtel and Härtel wrote, "although the R-side and D-side controllers change about every hour, in most cases, especially in towers, controllers work as part of a controller 'crew' and tend to work together for a relatively long period of time, often years. Many ATCSs can get to know each other fairly well. Therefore, team formation is likely to evolve differently for controllers than for flight crews." [R-side controllers follow flights on radar and maintain contact with pilots; D-side controllers handle administrative and computer-entry tasks associated with radar coverage.]

Controllers also work under a different authority structure than do flight crews, the report said. Flight crews have a clear hierarchy from the captain down through first and second officers and then cabin crew. "An en route controller crew," Härtel and Härtel said, "has a much more lateral or horizontal authority structure, with one supervisor at the top, and a number of R-side and D-side controllers below at the same authority levels [as others performing the same function]" (Figure 1).

Simplified Comparison of Flight Crew and En Route Controller Authority Structure



Source: U.S. Federal Aviation Administration

Figure 1

To what extent could existing CRM programs developed for flight crews be used to help train ATCSs?

After surveying the available research, Härtel and Härtel concluded that it is "not advisable" to apply CRM programs designed primarily for flight crews to ATCSs. However, they believed a modified CRM approach would be helpful.

"As air traffic controllers increase their involvement with CRM, they can benefit from lessons learned from over 15 years" of flight-deck CRM, the authors wrote.

"Although we believe that CRM can benefit ATC, it should not be characterized as a panacea. CRM is unlikely to rectify problems caused by deficient basic skills training or inadequate safety standards," said the two Härtels. "Moreover, it is unlikely that CRM will prove to be cost-effective in every ATC work setting and mission."

At Seattle-Tacoma International Airport, Washington, U.S., and some other airports, officials already have started implementing CRM programs for ATCSs.

The Controller Awareness and Resource Training (CART) program began in 1988 at Seattle's Air Route Traffic Control Center (ARTCC) facility. Similar U.S. programs have begun in Boston, Massachusetts, Memphis, Tennessee, and some other airports. CART's emphasis is on teamwork, communication and human factors.

After the 1991 Controller Resource Management Conference, participants created the Air Traffic Teamwork Enhancement (ATTE) steering committee the following year to develop CRM training materials and help other ARTCC facilities to begin their own team-training programs.

That 1991 conference identified four main CRM issues:[11]

Work environment. The current ARTCC work environment tends to promote individuals rather than teams, and is often marred by poor communication, attitude problems and negative reinforcements. "Controllers are thrust into an environment that requires them to use their energy to survive rather than to grow and learn," the conference found.

Attitudes. Some ATCSs have attitudes, such as a reluctance to ask for help, that should be changed. Such attitudes tend to prevent teams from working effectively together.

Communication. Poor communication at many levels "causes conflict and disagreement rather than effective relationships," and makes it more difficult for groups to develop common goals and work as teams.

Trust. To promote teamwork, steps must be taken to foster the development of greater trust among controller-team members, between controllers and pilots, between controllers

and their supervisors and in the system itself. One important step is to ensure that all team members are fully competent.

The ATTE steering committee's goals are to help controllers work better together as teams, to improve their team skills and problem-solving skills, to help them relate better to one another, and to help them more effectively manage both their personal and team resources.

ATTE has sponsored three-day workshops that included both controllers and their supervisors in sessions conducted by a facilitator. The workshops, with classes of a dozen to 15 participants, offered sessions in teamwork, communication, managing stress and handling conflicts. At each workshop's end, participants were asked to evaluate the sessions overall and then to rate their knowledge or effectiveness in nine areas (e.g., "awareness of potential resources" and "listening to others"), before and after the training.

"The facilitator never lectures" at the ATTE sessions, Härtel and Härtel reported. "Instead, videotaped presentations, group discussions, team presentations, analyses of case studies, team exercises and activities, and self-assessment questionnaires and critiques of videotaped behaviors are used to convey course content."

For example, one team exercise asked five or six participants, who chose a leader, to use straws and pins to design and build a tower that was supposed to be tall, stable and appealing. When the time expired for the tower-design stage, the team leaders (and their designs) were reassigned to another team.

"This is expected to cause some interesting team and leadership dynamics," the authors said.

To help evaluate such CRM training for ATCSs, Sherman and Helmreich[8] revised the CMAQ questionnaire for use with ATC. The new form, called the CRMAQ, asked participants to rate 25 statements involving controller resource management concepts, on a five-point scale ranging from "disagree strongly" to "agree strongly."

After administering the CRMAQ to 390 ATCSs, Sherman and Helmreich found "consistent differences between facilities and between different controller job descriptions. … Due to its short length, it is not a highly reliable scale." The two researchers were working on a revision of the CRMAQ to iron out the problems.

Adapting CRM to ATCSs may require substantial revision of existing CRM programs, or the development of customized programs, some researchers say.

"It is important that the development of ATCRM concepts be based on research specifically identifying and addressing controller issues," Härtel and Härtel reported. "The ATCS profession has its own unique challenges and needs, and should not be treated as an extension or variation of flight crews."

Nevertheless, Helmreich[12] noted that "the same analytic strategy employed to identify problems [in CRM] is applicable in the ATC setting."

The first challenge is to identify ATC "teams." In the en route setting, a team could be defined as either the pair of D-side and R-side controllers working a given position; or as the "crew," consisting of all controllers who report to the same administrative supervisor.

Each of those definitions has disadvantages. Two controllers are not always assigned to work on an en route position. And supervisors and specialists are not fully part of a "team" because they are often not members of the same bargaining unit. Also, the configuration of ATC teams would differ in en route, terminal radar control (TRACON) and tower settings.

"The group dynamics in some of these situations may not even warrant a team approach, as such," Härtel and Härtel contended. "It may be useful to view teams on a continuum ranging from tightly interacting and interdependent members to loosely connected individuals who cooperate with each other."

The authors noted that "controllers often have to deal with issues of mature groups, such as how to deal with difficult individual team members, and how to develop trust among team members."

The communications patterns and the dynamics among ATC teams vary considerably, depending on the mission or work settings. For example, in radar settings other than en route settings, such as approach control, the ATCS "often works more independently of other team members, except when using an R-side/D-side pair." In nonradar settings, there is more verbal communication among all ATCSs.

"The question of who the members of an ATCS team should be, and what the dynamics of the team are, will require further research," Härtel and Härtel concluded. They also suggested the likelihood that "more than one type of ATCS team will have to be defined."

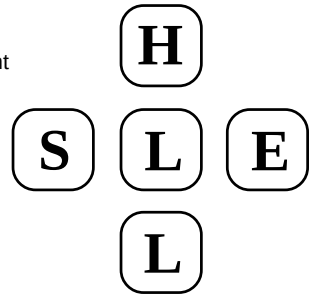
The tasks of ATC teams also differ fundamentally from flight crews' tasks.

Although the flight crew's prime mission — to operate a complex aircraft — helps create a singular team focus, the mission and human factors setting of ATCSs tend to be more complex.

In 1972, in the infancy of CRM theory, Edwards proposed the SHEL model (Figure 2, page 5) for analyzing the setting in which human factors operate in flight crew coordination.[13] SHEL is an acronym for Software, Hardware, Environment and Liveware. In terms of flight crew coordination, software

SHEL Model for Analyzing the Crew Resource Management (CRM) Human Factors Setting*

S = Software
H = Hardware
E = Environment
L = Liveware



*See text for details.
Source: U.S. Federal Aviation Administration

Figure 2

includes operating manuals, operations bulletins, charts and other information sources, and the concept could be extended to include programming of computer-operated flight controls in newer aircraft. Hardware includes "autopilots, autothrottles and other advanced avionics." Environment is the physical conditions of the cockpit (temperature, noise, lighting, etc.) and liveware is "other accessible people in the system."

One way of analyzing the ATCS's tasks is to use the SHEL terminology. If the controller is represented by the center "L," then the L-L connection represents all communication and information flow between the controller and other persons in the system, including flight crews, flight management and other controllers in related sectors.

The L-H connection represents the interface between persons and machines, which can be considerable for ATCSs. Researchers say the automation of controller functions could strongly influence a controller's cognitive functioning.

For example, Thackray and Touchstone[14] argued that installing highly automatic air traffic systems could change the role of ATCSs from that of "active planners" to that of a "passive responder to alternate courses of action presented by the computer."

Researchers warn that such advanced automation could lead to problems such as controller complacency, inattentiveness, boredom and reduced readiness.

The L-E connection represents the interaction of the controller and the environment. That environment in the control tower or at other sites can be uncomfortable, and can influence controllers' performance.

Finally, the S-L link represents any human factors related to the system's nonphysical aspects, including procedures and computer programs. Each of those factors introduces possible sources of human error.

One way to identify ATCS areas that might benefit from CRM training is to examine the relationship of aircraft accidents and incidents to communication patterns within ATC, between ATC and cockpits, and within cockpits.

An analysis of more than 28,000 incident reports to the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) from 1976 to 1981 determined that more than 70 percent of the reports cited the "transfer of information" as a problem. Billings and Cheaney[15] said that those incident reports focused mainly on "pilot-controller interactions and controller communications more often than on within-cockpit communication."

Researchers found that the most common reasons cited for such communications failures were: the person who had the critical information did not believe it was necessary to transfer it; or the information was communicated, but incorrectly.

Analysis of the ASRS incident reports showed that factors that interfered with such information transfers included "frequency saturation, high workload and inadequately presented data." Also, communication could be hampered by behaviors such as "distraction, failure to monitor and complacency."[16]

"Findings like these suggest that at least some of the CRM principles should be useful for ATCS," Härtel and Härtel said. "The ATCS plays a 'pivotal role' in the information transfer or communication structure in today's aviation system."

Instead of trying to adapt existing flight-crew CRM training to controllers, Härtel and Härtel recommended a model for analyzing the special needs of ATCSs and designing a CRM program that focuses on those needs. The program would be developed in six steps:

Analyzing needs. Conduct a "systematic needs analysis" by examining accident reports, interviewing controllers and observing ATC operations, to identify which behaviors by ATCSs contribute to accidents, errors and other problems. The analysis should also identify the controller behaviors that lead to efficient, safe operations.

Analyzing the job. Examine ATCS tasks to identify whether resources available to ATCSs, including software, hardware and liveware, are being used to the greatest benefit. The examination of human resources should analyze where teaming controllers might be helpful.

"It may become evident that some positions are not suitable for teaming at all, and in some cases, it may be difficult to define who the members of the team should be," the report said. Analyzing information flow in ATC facilities will help identify potential teams. If team membership is transient, then the concept of teaming may not be helpful unless staffing policies are modified.

Setting goals. Using the information derived from the needs analysis, experts should draw up an inventory of skills or CRM dimensions that ATCSs need to function well and avoid making errors. "A systematic comparison of effective and less effective controllers can shed light on which skills are most important for effective team operations," the authors suggested.

That inventory should form the basis for training goals.

Identifying training content. Once the CRM goals are set, experts should list the specific behaviors and the knowledge, skills and abilities that can be taught and evaluated. The definitions of behaviors may vary depending on the controller's position, the specific task layout and the characteristics of the ATC facility. Periodically, experts should validate those behavior-based definitions to ensure that the CRM training helps lead to optimum performance and has no negative effects.

Evaluating training's impact. To evaluate the effectiveness of the new CRM training for controllers, experts should develop valid, objective measures of performance. One possible approach might be developing a checklist that would help give a quantitative score of the presence or absence of specific behaviors in a participant's performance. Another approach would use trained observers to evaluate qualitative aspects of performance, such as team coordination, clear communications and relations with other team members.

"A combination of these two approaches would provide both objective and subjective criteria for evaluation," the authors suggested. Ideally, the evaluation should be used only for training and program development, keeping participants' ratings confidential. If employers or supervisors want to use assessments of individual or team effectiveness for certification or a similar job-related purpose, then a separate program should be developed that "disassociates certification from training.

"Attempting to train and certify at once is not only ethically questionable; the potential chilling effect on trainee behaviors can potentially undermine the optimal effectiveness of both activities," Härtel and Härtel wrote.

Updating the program. The curriculum must be evaluated continually to refine the training and keep it current, the report said. "Periodic reassessment of training needs should be included whenever there is a significant change in the task design or work environment (e.g., changes in air traffic patterns, automation or regulations)." Härtel and Härtel also recommended that a formal group, perhaps composed of experienced instructors, controllers, managers and education experts, be charged with program redesign. The authors added that a means of evaluating the impact of an ATCRM program must be in place before the program is implemented, so that curriculum developers will have a baseline by which to judge the program's effectiveness.

A new CRM training program for ATCSs should make participants aware of CRM's importance, give them an opportunity to practice team skills, get feedback from experts and require refresher sessions to reinforce those skills, the report said.

Awareness. Using videotapes, role-playing sessions or simulations, the new ATCRM program should teach trainees the basic resource management concepts to help them understand the importance of human factors in effective team performance.

Practice and feedback. The training program must provide opportunities for participants to practice CRM skills and behaviors, and for experts to give them feedback on their performance, the report said. The practice could come from high-fidelity ATC simulations, desktop computer simulations, role playing or feedback from actual critical incidents on the job. The following are some examples:

- Using high-fidelity ATC simulators, which control the scenarios and ensure that errors do not result in dangerous situations.

- Seeking to achieve a reasonable level of realism, at relatively low cost, by combining standard desktop computers with custom-designed components such as special keyboards, software and work stations that give realistic positions of controls and monitors.

- Developing role-playing exercises that simulate group dynamics and pose challenges that require team coordination and resource-management skills. One example is the tower-building exercise used by the FAA's ATTE workshop. Another example is United Airlines' exercise in which one crew member plays a role reacting to the scripted roles of the other crew members.

- Using an FAA system to give feedback on actual on-the-job behavior. That system uses FAA tape logs to reproduce radio transmissions and radar images of critical incidents, thus allowing controllers to observe how well they handle real situations. A less expensive option would be videotaping the routine ATC work-station operations.

Härtel and Härtel concluded that "trainees are more likely to have more faith in a real-life situation than a simulation, and it presents a training mechanism that can be employed on the job." They warn, however, that such on-the-job tapings and evaluations must be treated with confidentiality.

Continual reinforcement. By setting up regular refresher sessions, CRM experts can help reinforce the team lessons learned in the regular training.

Depending on the facility, refresher sessions might be integrated into other, regular training, or could be held as separate training sessions. The authors recommended that CRM training be provided as part of other training occasions, such as for newly hired or recently promoted controllers, or

for transition training when a controller moves to a new post or to new equipment.

Another way of providing reinforcement would be "mentoring" programs, such as those in which the FAA has paired experienced controllers with relatively inexperienced controllers. By enabling such pairs to work together for extended periods, "the level of coordination and cohesiveness of controller teams can be strengthened," the authors suggested.

Yet another reinforcement technique tried in some FAA facilities is to adapt the Total Quality Management (TQM) approach of "quality control circles."

Special teams of controllers would be formed to accomplish certain segments of work. At some facilities, teams might involve eight to a dozen controllers working under one area supervisor; other facilities might try smaller teams.

"Each team would hold regular meetings, possibly daily or weekly, where recurrent training and feedback would take place," the report said. "Those meetings could include brief refreshers of a CRM topic and discussion of any critical incidents or special situations where CRM was or would have been useful."

The most effective feedback tends to come as close as possible to the event being evaluated, the report said. Ideally, specially trained team leaders might conduct short debriefing sessions for their teams after each work shift.

Härtel and Härtel wrote that, to avoid focusing too much attention on one aspect of performance at the expense of others, it might be useful to develop a feedback/debriefing form or checklist that would review positive and negative key aspects of performance. The form might require adjustment from time to time.

Team meetings also could be used to develop strategies and arrangements for improving the coordination of their team's work flow. Such meetings would give team members an opportunity to discuss and resolve problems.

But the authors cautioned that such feedback sessions should be held only where there is "a team climate in which errors are viewed as the team's problem, not the individual's." That sort of climate is often not present at ATC facilities, where controllers are individually disciplined for triggering operational error detection patch (OEDP) errors.

"By making these errors a responsibility of the whole team, the whole team works to avoid such errors and find systemic solutions," the authors contended.

"If an error is due to a problem with an individual controller, the team can provide mentoring and training, or even use peer pressure to modify a resistant controller's behavior."

Controller teams might also benefit from external feedback from flight crew teams or similar controller teams, the report said. For example, some current programs encourage controllers to accompany flight crews in the cockpit on occasion, and encourage pilots to observe ATCSs in action.

"Facilitating regular, cross-specialty observation among controllers on a regular basis could help controllers better understand their areas' effect on the others," the authors concluded. "Unfortunately, there currently is little structure to exchange feedback and allow flight crews and ATCS teams to clarify barriers to more effective performance."♦

Editorial note: This article was adapted from *Controller Resource Management — What Can We Learn from Aircrews?* Report no. DOT/FAA/AM-95/21, July 1995, by Charmine Härtel of the University of Tulsa's Department of Psychology and Günther Härtel of Colorado State University. The 36-page report includes charts and a bibliography.

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