How Effective is Cockpit Resource Management Training?

Exploring issues in evaluating the impact of programs to enhance crew coordination.

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The question "Is cockpit resource management effective?" has been asked frequently in the years since 1979 when a National Aeronautics and Space Administration (NASA)/Industry workshop addressed the concepts of crew coordination and effective utilization of all available resources in flight operations (Cooper, White, & Lauber, 1980). If one looks at the proliferation of cockpit resource management (CRM) training programs in domestic and foreign, civil and military aviation, and the enormous investment in time and money that they entail, it would appear that the question has been answered in the affirmative. It is our position, however, that the question remains open and that empirical evidence is just beginning to accumulate.

Scope and Goals of the Paper. Our goals in this paper are (1) to set forth the issues surrounding the evaluation of crew performance and training aimed at improving crew coordination and the utilization of material and human resources; (2) to describe generally the methods involved in research into crew performance; and (3) to outline preliminary findings from a NASA/University of Texas research project on crew performance. It is perhaps equally important to specify what the paper is not. It is not meant to be a handbook for the implementation of CRM training.

Operational implications from the project are presented in a separate technical report, "Critical Issues in Implementing and Reinforcing Cockpit Resource Management Training," (Helmreich, Chidester, Foushee, Gregorich, & Wilhelm, 1989). This paper is also not meant to be a technical monograph on scientific results of the research. Detailed empirical findings are being reported in a series of research papers addressing specific components of the research such as change in attitudes.

Translating "Effective" into Operational Criteria. The outcome usually invoked as justification for CRM training is improved aviation safety, defined as a reduction in the number of accidents caused by failures in leadership, crew coordination, decision making, and/or human information transfer. Given this operational definition, the obvious outcome criterion is the rate of crew caused accidents, whether defined by the number of accidents occurring per hundred thousand passenger miles or by some other rate of incidence metric.

Although the ability to relate accident rate causally to training practices would be a compelling demonstration of effectiveness, it is not an attainable goal. The overall incidence of accidents in the air transport system is very low and hence, statistical measures of rate are greatly perturbed even by single accidents. Although some individuals have, in their enthusiasm, attempted to justify CRM and LOFT (line oriented flight training) by citing decreases in accident rates within single organizations, this is not a valid claim because it cannot be demonstrated to reflect more than the chance variation of a low frequency phenomenon. To understand the impact, if any, of CRM and associated full mission simulator training, we will have to seek other measures which provide more data points and higher reliability. The critical problem then becomes assessing the validity of such measures.

Given that we cannot specify a single, overarching measure of CRM/LOFT efficacy, it seems appropriate to adopt a strategy of employing multiple indicators of crew performance and training-induced change. Three categories of such measures will be discussed: (1) **Outcome measures** defined as objective and subjective indicators of group or organizational performance including incidents showing positive and negative crew performance, attitude measures reflecting crew acceptance of crew coordination concepts before and after training, subjective evaluations of the efficacy of training by active crew members, and indirect indicators such as measures of organizational efficiency; (2) **Process measures** operationalized as indices of the behavior of crew members in line and simulator settings involving both normal and abnormal operating conditions; and (3) **Moderator factors** consisting of additional variables that may directly or indirectly influence both Outcome and Process measures. Included in this category are organizational factors such as policies, resources, morale, facilities, equipment and support for the concept of cockpit resource management; individual factors such as crew member experience, demographics, and personality; situational factors such as acute and chronic stress and fatigue and characteristics of aircraft and the flight environment; and training factors such as the attitudes, personalities and behavior of trainers and evaluators and course content and pedagogical method (i.e. lecture versus participatory exercise).

For each of the measures and moderators, we discuss method of assessment, potential validity, and extent and quality of existing data. The goal is to provide a picture of current and anticipated knowledge about crew coordination practices and the efficacy of training, and to discuss strategies that might be employed to increase the scope and validity of data bearing on these issues.

The empirical basis for the paper is the joint NASA/University of Texas CRM/LOFT evaluation project that has been underway since 1985. We have discussed some of the research questions and methodological issues elsewhere (e.g. Helmreich & Wilhelm, 1987a; 1987b), but this represents the first attempt to describe the full scope of the project and its implications.

Outcome Measures

Incidents. As we have noted, accidents occur too infrequently to be valid indicators of crew performance within an organization. However, incidents involving abnormal circumstances that require formal investigation and reports (either internal within the organization or to the regulatory agency) occur with greater frequency and may, over time, provide a more meaningful index of crew coordination and changes in behavior associated the implementation of CRM training. The project research strategy involves examining and classifying cases in the archive of incidents occurring prior to initiating CRM/LOFT to develop a base rate for comparison with those occurring after the implementation of training. The classification of an incident consists of determining whether or not crew coordination factors were implicated and, for those that do, coding the CRM issues and concepts involved. The majority of pilot implicated incidents reported are negative, reflecting crew error of one form or another. Among the most useful data are those reflecting situations where the crews employed extremely effective crew coordination to deal with a problem. A few of these incidents are now beginning to be recorded.

At the present time, incident databases are being developed in organizations participating in the research, but it is not yet possible to determine the reliability and validity of these data as indicators of CRM practices within an organization. There are several threats to the validity of incident data as criteria. One is that the number of incidents involving crew coordination per year within an organization may be insufficient to provide a reliable database. A second is that heightened awareness of crew coordination issues may result in a spurious increase in reported incidents.

Another factor may be shifts in the flight environment that influence the likelihood of incidents happening, such as increased traffic density and/or changes in air traffic control practices. Overall, the rate of occurrence of incidents is an imperfect measure of system performance, but one that may be cautiously employed as an indicator of status and change.

Attitudes. Analyses of the causes of air transport accidents along with experimental and interview studies of crew coordination by NASA researchers have isolated a number of attitudes associated with effective and ineffective crew performance (Cooper, White & Lauber, 1980; Ruffell Smith, 1979). Building on these data, Helmreich (1983) developed a 25-item Cockpit Management Attitudes Questionnaire (CMAQ) designed to assess attitudes regarding flight deck management. Initial data collection from civilian airline pilots revealed great variability in attitudes regarding issues including personal capabilities under stress, interpersonal communications, captains’ responsibilities, and group climate (Helmreich, 1983). Within single organizations, highly significant differences were found between crew positions (i.e. among captains, first officers, and flight engineers) within aircraft fleets and between aircraft fleets within organizations.

A revision of the CMAQ to replace several items which exhibited relatively low variance was undertaken and a parallel form was designed to measure attitudes of military crews (Helmreich, Wilhelm, & Gregorich, 1988a). The current database on domestic and foreign air crews, military and civilian, contains more than 10,000 completed surveys.

Factor analytic studies of the CMAQ were conducted by Steve Gregorich in independent samples drawn from organizations differing on a number of dimensions including crew member demographics, financial stability, and labor-management relations. These analyses reveal three stable factors or groups of attitudes (Gregorich, Helmreich, & Wilhelm, 1989). The factors consist of a group of attitudes reflecting (1) Communication and Coordination, (2) Command Responsibility, and (3) Recognition of Stressor Effects — acknowledgment of personal limitations under conditions of stress and fatigue.

A validation study demonstrated that attitudes measured by the CMAQ successfully classified more than 90 percent of crew members rated independently as effective or ineffective cockpit managers by specially trained check airmen observers (Helmreich, Foushee, Benson & Russini, 1986). The data demonstrate a strong linkage between measured attitudes and operational behavior.

The encouraging results of the validation study suggested that responses to the CMAQ might serve the dual purposes of providing a base rate measure of pretraining attitudes within organizations and showing the impact of CRM training through changes in attitudes. Using a procedure involving secret code numbers to protect the identity of respondents, it is possible to link individuals' CMAQ scores obtained prior to CRM training with responses to the same questionnaire given on completion of the course.

Preliminary results have been obtained from both civilian and military organizations. The pattern of findings suggests that initial training in CRM concepts produces highly significant attitude change in the direction of more endorsement of CRM concepts on all three factors derived from the CMAQ. However, these findings must be qualified in several important ways. The first is that initial endorsement of newly presented concepts may not reflect lasting change in attitudes. It is imperative that attitudes be measured again after passage of time to see if the measured change endures. The second is that an overall finding of significant positive attitude change does not mean that all participants reacted favorably.

A major finding of the study is that a small, but meaningful percentage of seminar participants show a "boomerang effect" — their attitudes change in the opposite direction from that intended. Table 1 shows the pattern of boomerangs. These findings suggest that there may an important limit on the effectiveness of training and that it will be necessary to look for long-term attitude and behavior change before drawing conclusions about the overall effectiveness of CRM. In a later section we will discuss the role of personality traits as moderators of attitude change and behavior, including boomerang effects. One indication of the general negativity of those exhibiting boomerangs on one or more scales is the fact that these respondents evaluate CRM training as significantly less useful, see significantly less potential for safety, and report being significantly less likely to change their behavior than other participants.

These findings suggest that there may be an important limit on the overall effectiveness of training based on those for whom the training is not only ineffective but apparently deleterious. It is a critical research priority to investigate the causes of this reaction and to determine if the boomerang is an enduring or transitory reaction. Possible individual causes of negative reactions will be discussed in a later section. Empirical results showing the boomerang are presented in Helmreich & Wilhelm (1989).

Table 1. Percentage of Respondents Showing Boomerang (Negative Attitude Change) Effects on Cockpit Management Attitudes Scales in Two Samples.

Scale	Airline (N=1371) Boomerang	U.S. Air Force Military Airlift Command (N=882) Boomerang
Communications/Coordination	2.8%	10.9%
Command Responsibility	2.6%	13.9%
Recognition of Stressor Effects	14.9%	16.8%

Participant Evaluations of CRM Seminars. Despite substantial differences in course content and teaching style, organizational support, and personal characteristics of participants, data suggest that the great majority of participants find such training of considerable value. For illustration, Figure 1 shows the percentage of participants in one carrier's seminar choosing each alternative in response to the item: "Overall, how useful did you find the training?" While overall endorsement of the efficacy of training is strong, that a meaningful minority of participants repudiate the training must be a cause for concern. *The fact that those who reject the training might be those whose crew coordination behavior is poorest is both an issue for more detailed research and another possible limitation on the effectiveness of CRM training.* Not surprisingly, responses to the question asking how much influence the seminar training will have on flight deck behavior show a lower

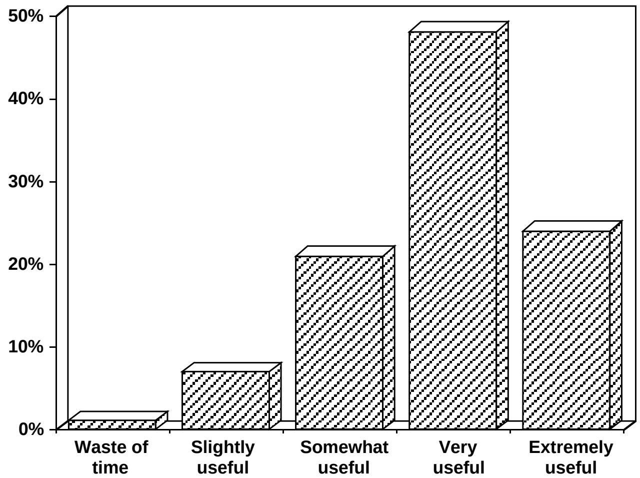

Figure 1. Percentage giving each response to the question: Overall, how useful was the CRM seminar training? (n=1497)

level of endorsement. Behavior change is also more dependent on the behavior of others and on organizational support than changes in individual attitudes. Figure 2 shows the percentage of respondents from the same seminar shown in Figure 1 choosing each alternative on the item asking: “How much will the training change your behavior on the flightdeck?”

Another issue to consider is the fact that the same material presented by the same instructors elicits significantly different evaluations from different groups, implying that there may be some systematic variability in participants' reactions. This is illustrated in Figure 3 which shows ratings of usefulness from more than fourteen hundred participants in sixty-three presentations of the same seminar. This is an as yet unexplored topic that warrants research attention. Our working hypothesis is that different group dynamics, which may impact the affective tone and impact of the training, develop in different sessions (Helmreich & Wilhelm, 1989). Consideration of the multiple factors that may influence seminar outcomes is a high priority for research.

Participant and Observer Evaluations of LOFT. A critical, but imperfect, source of information on CRM training and LOFT is the perceptions of participants. These evaluations demonstrate whether the training has credibility and which components have more or less impact. Such measures also provide overall indications of self-perceived behavioral change. However, subjective self-reports are prone to self-deception in the sense that intentions do not necessarily reflect real behavior and/or the stability of behavior change over time. For example, it is possible that individuals may initially report great personal impact and change in behavior, but this effect may decay with the passage of time.

Conversely, some of the concepts presented in training may not achieve maximum impact until individuals have had the opportunity to consider them over time. Nonetheless, it is probably safe to conclude that if training is overwhelmingly seen as without value by participants, it is not likely to have a significant, positive impact on crew behavior.

Two instruments have been developed to obtain participant evaluations (Helmreich, Wilhelm, & Gregorich, 1988a). The first asks for quantitative, overall evaluations of initial CRM training and its impact. It also solicits recommendations for improvement of the training and ratings of specific include the particular “skills” the training is designed to impart. The practice of these skills is assessed in both line and simulator settings as discussed in the section under Process Measures.

The second questionnaire asks for evaluations of the training value of LOFT, self-ratings of crew performance, and prior familiarity with the scenarios employed in LOFT. Preliminary data from more than 2,000 participants in different civilian and military CRM programs have now been collected, but the collection of participant ratings of LOFT has just begun.

First results from the participant survey evaluating LOFT suggest that crew members find the training very useful. Figure 4 shows ratings of the value of LOFT for crew coordination training so they represent, for most individuals, reactions following initial exposure to this type of training. The data show that the training is seen very favorably by a large majority. However, it is important to see how LOFT is perceived by individuals who have had the training a number of times.

Another issue that may significantly influence the utility of LOFT is whether or not participants are aware in advance of the details of the scenario they experience. It is certainly possible that knowledge could diminish the value of the training substantially and that this could be very likely in organizations where only a lim-

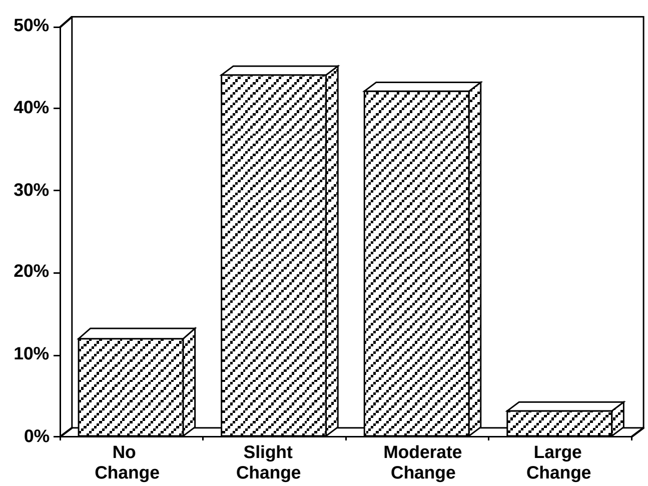

Figure 2. Percentage giving each response to the question: Is the CRM training going to change your behavior on the flight deck? (n-1497)

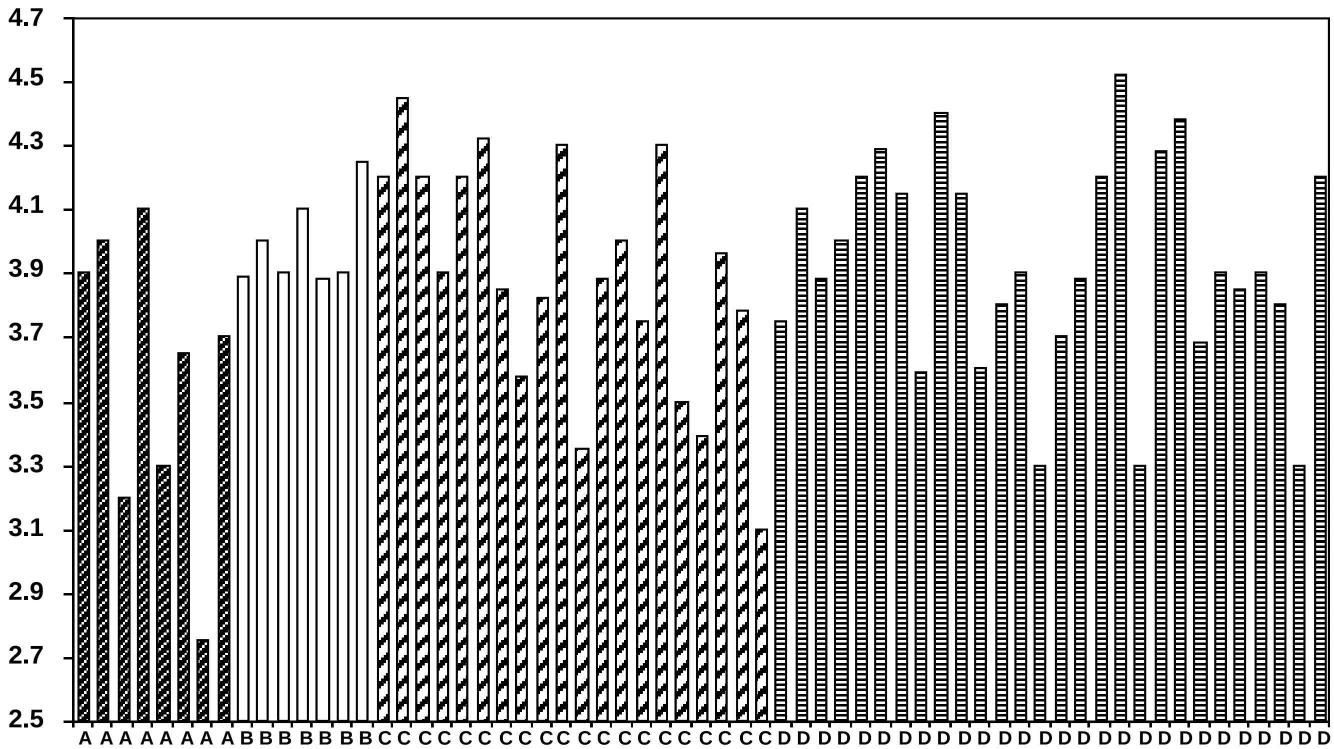

Figure 3. Average rating of Usefulness by participants in each of 63 CRM seminars in 4 locations (location A, B, C and D) Scale: 1=Waste of time … 5=Extremely useful (n=1497)

ited number of scenarios are utilized. In the present case, approximately 20 percent of respondents indicated having some familiarity with the scenario they experienced and one third of these report that it detracted from the training value.

More extensive data from additional sources are urgently needed and efforts are underway to broaden their collection. Overall, both types of self-reported data appear to provide important information on both seminar training and LOFT and to support a cautiously optimistic evaluation of their utility.

Indirect Measures. The types of criteria we have discussed thus far all relate to flight operations. However, it has been suggested that CRM training, with its focus on improving communications, may have other, positive influences on organizations. According to this line of reasoning, improving communications and interpersonal relations should, other things being equal, improve the organizational climate. One would expect the effects to be strongest in organizations where CRM concepts are stressed in training for other personnel such as cabin crew members, the maintenance force, and customer service representatives.

At this time there are no available data to support or refute these hypotheses, and it will be difficult under any circumstances to separate causal effects of CRM training from the noise surrounding measurement of changes in job satisfaction and morale. Nonetheless, assessment of these factors is worthwhile as indicators of organizational state, and their collection has been planned for at least one of the participating organizations.

Process Measures

The second class of criteria for assessing crew coordination consists of measures of crew behavior in line and simulator settings. Conceptually, variables in this class should provide the most sensitive indication of how crews communicate and interact and what changes, if any, are induced by formal training (e.g. Foushee, 1984; Foushee & Helmreich, 1988; Ginnett, 1987).

Within this class are two types of measures, expert ratings of specific behaviors and overall performance and micro-analyses of communications through the application of detailed coding schemata to transcripts and video or audio recordings of actual or simulated flight segments.

The first, expert rating technique, is designed to capture data relevant to the evaluation of operational line flights and LOFT sessions while the second, labor intensive methodology, is more applicable to analysis of experimental simulations and accidents and incidents.

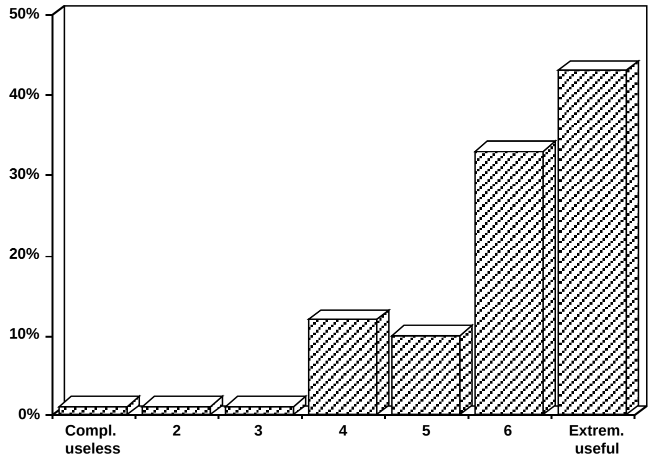

Figure 4. Percent giving each response to the question: Overall, how would you rate the value of this LOFT session for crew coordination training? (n=129)

Expert Ratings. An instrument, the Line/LOFT Worksheet, with versions designed for use by expert observers in both civilian and military settings, has been developed and is currently being employed in the evaluation project as well as in experimental simulations (Helmreich & Wilhelm, 1987b). The initial version of the Line/LOFT Worksheet elicited ratings of each crew member on 15 behavioral dimensions and global ratings of the crew as a unit on 10 more. Psychometric analyses of two samples with more than 500 observations each indicated that, in addition to being cumbersome and onerous to use with as many as 55 discrete ratings (for three person crews), the individual ratings were not generally providing useful information beyond that provided by ratings of the full crew.

Accordingly, a major revision was undertaken that yielded a more user-friendly form containing 17 ratings of the crew as a unit on topics ranging from the highly specific (such as briefings, communications, inquiry, advocacy, critique, workload, conflict resolution, and management of abnormal or emergency situation) to the general, including overall performance and technical proficiency (Helmreich, Wilhelm, & Gregorich, 1988b). In addition, the instrument has provisions for rating individual crew members whose actions are particularly significant to the outcome of the flight — either positively or negatively — and allows for open-ended comments elaborating on unusual behavior or circumstances.

Statistical analyses have been conducted to determine how many underlying dimensions are represented in the items of the worksheet. Factor analyses of worksheet responses (excluding performance criteria) revealed one major factor which includes communication and interpersonal variables and a secondary factor defining task enactment that includes ratings of vigilance, distractions, and workload distribution. These analyses suggest that there are no more than two underlying dimensions in the ratings of crew performance.

Although the relatively high correlations among worksheet items imply that they are tapping common factors, we feel that it is important to maintain the evaluation of specific behaviors rather than moving to fewer, global ratings. The more detailed ratings relate to particular skills and can provide specific information on the impact of training in areas such as decision making and conflict resolution.

Initial data in organizations are obtained from line checks of crew members without formal training in CRM and exposure to LOFT. The purpose of such data is to provide a base rate of crew coordination and resource management prior to the initiation of training. The research methodology involves providing special training in evaluation for key personnel (instructors and check airmen charged with evaluating crew performance). These individuals then complete additional ratings (beyond normal evaluation) of individual and crew performance using the Line/LOFT Worksheet.

Although more than 2,000 observations have now been recorded, the data collection process does not yet allow conclusions to be drawn regarding the behavioral impact of CRM/LOFT because the post-training samples are still small relative to the number of organizational, aircraft type, and training factors that must be considered. However, one clear finding that is emerging from the data within organizations is that highly significant differences exist between aircraft fleets on most rated dimensions. The findings of significant fleet differences raises a critical methodological issue for evaluating crew behavior. Unlike the evaluation of such maneuvers as steep turns and approaches where objective criteria of success and failure exist, the standards for making judgments of coordination and resource management are more subjective.

Although research has demonstrated that reliable and valid evaluations can be made in this area, there is the possibility that observed fleet differences represent differences in the application of standards of judgment rather than systematic differences in crew behavior. In other words, it raises the possibility that different subgroups within an organization may develop their own idiosyncratic practices and/or rating standards. This poses a major problem for researchers attempting to understand the impact of CRM and LOFT and for organizations attempting to achieve standardization in practices and evaluation. Normal practice is for instructors and evaluators to function exclusively within a single fleet (for example, the Boeing 737).

A strategy must be employed that takes observers across aircraft types so evaluators' standards are constant, thus making certain that any observed differences are real and not a function of observer idiosyncrasies. Such a strategy not only provides the type of information necessary to validate the impact of training, it also gives organizations a better picture of overall flight standards. While a price must be paid in terms of observer familiarity with particular equipment, the concepts involved in effective resource management are not equipment specific and it should be possible for individuals to make equally valid judgments in a variety of aircraft.

Exactly the same issues are involved in attempting to determine levels of crew coordination across organizations since observers operate within single organizations. As long as data regarding crew performance in line and LOFT situations are based exclusively on data generated by observers limited to single organizations, it will be impossible to determine what national standards exists. We feel that an extremely high priority should be given to training and deploying a team of skilled observers who can collect data in different organizations and aircraft to provide a reliable picture of crew coordination and to standardize ratings from diverse organizations. In our view, such data should be collected under strict assurances of confidentiality and employed only for research to determine system status and regulatory needs.

Because evaluators are identified by a secret code number in the database, it is possible to examine the distributions of ratings given by individual raters. Results show large differences between evaluators in the distribution of their ratings. For example, where training of observers was conducted as an additional session added to formal CRM seminar training, with few exceptions evaluators used the scales completely and produced data normally distributed around scale midpoints. In contrast, in an organization where training of evaluators was done in a less systematic fashion and not yoked with specific training in CRM concepts, the results were much less satisfactory (Helmreich & Wilhelm, 1988). Using the category of "overall effectiveness" as an example, the following distribution was obtained: more than 60 percent of the ratings were "3" (average) with 31 percent receiving "4" (above average) and only eight percent getting "2" (below average). Less than a half of one percent of the ratings fell at the extremes (1 = "poor"; 5 = "excellent"). Looking at the ratings of individual instructors further clarifies the phenomenon. A third of the evaluators used only two points on the scale, "3" and "4", while one gave all thirty-two of his crews ratings of "3". Others used only the "4" option. This restriction in range, which appears to reflect evaluator bias or lack of sensitivity to behavioral variation, represents a major threat to the credibility of evaluation efforts.

To obtain meaningful data in an organization where CRM and LOFT were established before the initiation of the current research, a different procedure was employed on an experimental basis. In addition to the standard ratings on the Line/LOFT Worksheet by evaluators, crew members were asked to complete the same form following their debriefing and observation of the videotape of the LOFT, thus adding participants' perceptions of their own performance as a new dimension. A trend in the data was for the performance of crews who have had more exposure to LOFT and recurrent CRM to be rated as more effective overall and to receive more positive ratings on components of cockpit resource management from both types of raters. Observers rated crew performance and CRM components significantly less favorably than did participating crew members. These differences for crew members and observers across several aircraft fleets are shown in Figure 5.

The similarities within crews of ratings by observers and crew members were examined by computing the correlations between observer and crew member ratings on each measure. Although some were statistically significant, the magnitude was generally quite low. One can argue that, in this case, observers have a broader perspective on performance from viewing multiple crews while crew members employ only themselves as referents.

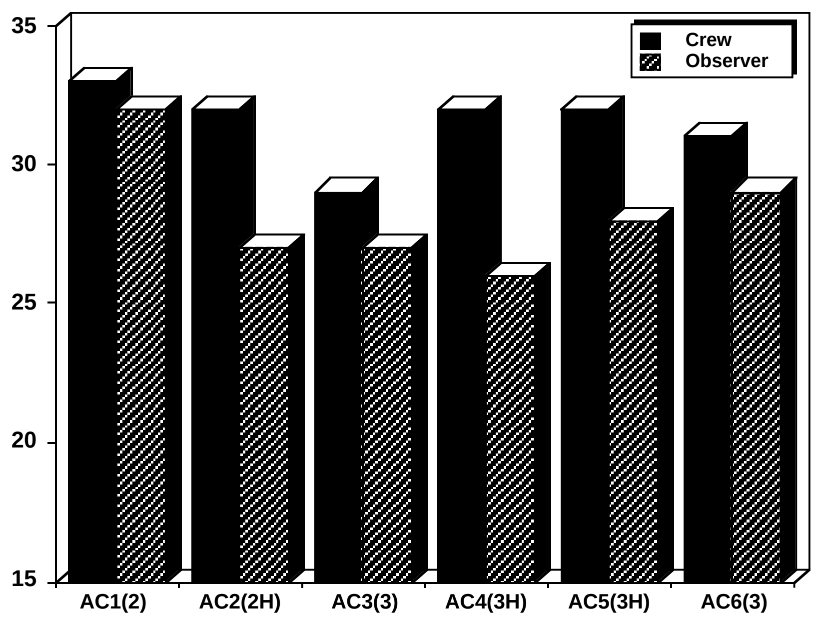

Figure 5. Crew and Observer Ratings of Composite Measure of CRM Effectiveness by Aircraft (Number in Parentheses is Number of Cockpit Crew — H=Widebody)

Additionally, however, there is a substantial research literature exploring systematic differences in the explanations for behavior advanced by participants and observers. Indeed, systematic differences between actors (participants) and observers in their perceptions of situations and the causes of behavior form a key element of attribution theory (Jones and Nisbett, 1972). According to Jones and Nisbett, participants in a situation (actors) are more likely to attribute the causes of their behavior to characteristics of the situation while nonparticipant observers are more likely to see behavior being determined by the personalities of participants. In a highly relevant study of attributions of the causes of behavior, Storms (1973) used two video cameras to tape a discussion from the perspective of each member of a dyad. A major finding was that a viewing of oneself from the perspective of the other participant (in effect, making oneself an observer) changed the nature of evaluations in the direction of greater congruence with those of observers. The assumed impact of observing oneself on videotape is, of course, a central tenet in the taping of LOFT and use of videotapes in debriefing (e.g. Helmreich, 1979). The actor-observer discrepancy also implies that the degree of consensus reached in evaluations of crew coordination by participants and LOFT instructors or facilitators could serve as a rather sensitive indicator of the effectiveness of debriefing.

Overall, we feel that the use of expert evaluators rating crew coordination and performance in both line and LOFT settings can provide useful, reliable information, although additional efforts aimed at achieving observer standardization are needed to enhance the utility and reliability of data. Using check airmen and LOFT facilitators or instructors to collect much of the data has an additional advantage in focusing attention on these key groups and providing them with a template for debriefing and discussing CRM concepts. This point will be discussed in greater detail later.

Micro-analysis of Communications. It is evident that crew coordination is achieved (or fails) through communication among individuals and dynamic group processes occurring across time (Foushee, 1984; Foushee & Helmreich, 1988). This is an area where theoretical ideas have outreached empirical progress (e.g. Helmreich, Hackman, & Foushee, 1989). The logistics of capturing and coding interpersonal communications are formidable as is the sheer volume of data which is generated even in relatively short interactions. Equally daunting are the analytic feats required to understand and interpret patterns of communications and their relationships with performance criteria and other factors such as personality.

There are only a few studies that provide detailed analyses of communications among flight crew members at level of individual utterances. Foushee and Manos (1981) examined communications from the first large simulation study sponsored by NASA (Ruffell Smith, 1979) and found that patterns of communications were significantly associated with crew errors. A fair summary of these findings would be that superior performing crews communicate more and better than less effective teams. More recently, Kanki and Foushee (Kanki, Lozito, & Foushee, 1987; Kanki & Foushee, in press) analyzed communications from another NASA simulation conducted with two-person crews in the Boeing 737 (Foushee, Lauber, Baetge, & Acomb, 1986) and replicated the overall pattern found in the earlier research. Although the mechanisms and dynamics of the communications process have yet to be isolated, the data provide strong evidence for linkages between communications and performance

A major simulation study was recently conducted with volunteer airline crews using the NASA-Ames Boeing 727 and air control simulation facilities (Chidester & Foushee, 1988). A total of 23 crews were run in a five flight segment simulation which extended across two days and significant differences between experimental conditions were found in both expert ratings of performance and objective measures of crew errors. Complete video recordings of crew behavior were made. Critical segments of the flights are being transcribed from videotape and entered into a computer-resident database.

This record for each crew can then be combined with the longitudinal record of error type and severity and segment by segment performance ratings. The specific communications elements can then be coded using systems designed to capture key elements of interpersonal behavior. Statistical analyses can then be conducted at both the case and group level. As crews in this study were composed on the basis of personality characteristics, it has the potential to provide critical information on both the dynamics of crew interaction and the relationship among personality, crew interaction, and performance. The hoped for product of these efforts will be principles of interpersonal communication that can be applied to understanding crew performance in actual and simulated flight under normal and emergency conditions.

Because of their labor intensity, it is unlikely that these exhaustive analytic techniques would ever be applied to the analysis of routine LOFT or flightcrew behaviors. Their primary use is likely to be in the development of knowledge and theory about communication and crew coordination that can be applied in the evaluation and training of crews. There are, however, several other uses that may prove important. One is to explore the interpersonal dynamics involved in accidents and incidents and how these relate to the either favorable or unfavorable outcomes. One of us (Helmreich) has applied micro-coding techniques to the cockpit voice recorder records of several accidents including a fire aboard a wide-body jet which resulted in multiple system failures during a 32-minute period and the ultimate deaths of more than 300 passengers and crew (Helmreich, 1988). The analyses in this case demonstrated clearly the accumulation of stressors and their impact on crew interaction. Microcoding may prove to be a useful tool for quantifying critical aspects of crew behavior in investigations where accuracy and understanding are paramount.

A second potential use of the system is to provide a metric for quantifying the workload imposed by various LOFT scenarios and the number and complexity of tasks imposed on participants. This type of quantification might be employed in conjunction with self report ratings of workload such as that developed by Sandra Hart at NASA (Hart & Staveland, 1988). The need for further definition of LOFT characteristics is discussed in the following section and in Helmreich, Wilhelm and Gregorich (1988b).

The third, and most potentially useful application, would be to isolate critical marker variables in crew interaction that can be reliably coded in real time without transcription to provide valid indicators of group process. Developing such a streamlined measurement and coding system would allow direct recording of critical elements of communication into a database using a modern, electronic version of Chapple's (1940, 1949) interaction chronograph, an early attempt to create a longitudinal record of interpersonal interactions. This outcome would make a variety of detailed analyses cost effective if coders could work reliably from videotape or audiotape records.

In summary, we feel that measures of process factors in crew interaction and their relationship with performance are an unevaluated, but potentially very important component of our understanding of capabilities and limitations of training in this area.

Moderator Factors

For the purposes of this discussion, moderator factors will be defined as variables that may, in combination with other factors, serve to enhance or diminish the desired effects of training in crew coordination. They represent, in many cases, factors that are very difficult to quantify. In discussing these factors, we attempt to make clear the evidence base for considering them important.

Organizational Commitment and Support. Richard Hackman (1987), in his cogent discussion of the extra-cockpit factors influencing crew behavior described these influences as the "shell" within which these crews perform. Under the shell label he included the demonstrated concern of management for CRM and its dedication to implementing it for reasons of merit rather than financial advantage. Organizations in which management-pilot relations are hostile and adversarial might be expected to have more difficulty promoting CRM/LOFT than those with more positive relationships. A strike, or the threat of a strike, for example, could alter acceptance of a program sponsored by management. However, evaluation data from one organization with a very negative climate did not provide much support for this view. Many respondents devoted their open-ended comments to expressions of hostility toward management, but overall the training was seen as important and useful and global ratings were not markedly different from those in organizations with more positive relationships.

In the NASA/UT project, the major indicator of organizational commitment has proven to be the roles and status assigned to check airmen and instructors or facilitators in implementing and reinforcing effective crew coordination (Helmreich, 1987). In pioneering CRM programs, seminar training and/or LOFT were seen as the central elements, and the importance of the check airmen and instructor role was not clearly understood. Data from the current project suggest that endorsement by respected role models in the standards area greatly influences initial acceptance of CRM concepts and may be essential in producing long-term behavioral effects (Helmreich & Wilhelm, 1987).

Several organizations have adopted a procedure of providing further, specialized training for check airmen and instructors as an addition to the initial CRM seminar. Such training consists of providing guidelines and practice in debriefing observed CRM practices and training in formal evaluation of crew performance using, for example, the Line/LOFT Worksheet as a template. One airline stressed its commitment to CRM by incorporating the *Check Airmen/Instructor Reference Manual* (Helmreich & Wilhelm, 1987) into its flight operations manual, another by publishing the same manual under its logo as a training document.

In contrast, another organization did not provide any guidelines or training for line evaluations. From anecdotal reports, line evaluations remain focused on the technical aspects of flight. Similarly, many LOFT instructors in this organization appear to have held attitudes at variance with the concepts taught in the seminar and indeed preliminary results indicated that the performance of crews trained in CRM was rated significantly lower than that of crews without formal training (Helmreich & Wilhelm, 1988).

Data from an airline where the attitudes of check airmen, instructors, and line crew members were measured prior to the initiation of CRM training and LOFT, indicated that, normatively, check airmen and instructors held more positive attitudes. However, there were still a number of individuals in these groups whose measured attitudes were clearly at variance with the concepts to be communicated and reinforced. At this time we cannot yet quantify how significant organizational effects are and how much impact check airmen and instructors have on behavior. It appears, though, that the check airman and instructor group may prove to be the most important single determinant of outcomes.

Individual Factors. It has been suggested on theoretical grounds that personality characteristics of crewmembers may be a limiting factor on the potential impact of crew coordination training (Helmreich, 1983; 1987). The thrust of this argument is that, while training can be shown to change attitudes (as on the CMAQ), it is not likely to alter deeply ingrained, stable, personality traits. To the extent that traits influence interpersonal behavior and communications, training is not likely to produce enduring change. Recent research has provided strong support for this position. A battery of extensively validated personality scales has been employed in research with pilots and other professional groups (Helmreich, 1982; 1986; 1987; Helmreich Spence, Beane, Lucker, and Matthews, 1980; Chidester, in press; Gibson, 1988).

As a means of determining the distribution of personality attributes, cluster analyses were performed on the scores from crew members and revealed three distinct groups (Chidester, Helmreich, Gregorich, & Geis, in preparation). Cluster 1 was characterized by high scores on traits defining high achievement motivation and interpersonal sensitivity; Cluster 2 reflected high negative instrumental attributes (hostility, arrogance, etc.) and low interpersonal sensitivity; while Cluster 3 was characterized by low motivation and interpersonal sensitivity.

Analyses of initial attitudes and patterns of attitude change after initial CRM training reveal both significant correlations between personality dimensions and some attitudes and relationships between personality and attitude change (Helmreich & Wilhelm, 1989; Chidester, et al, in preparation). Results for the CMAQ scale reflecting command responsibility are shown in Figure 6. The greatest attitude change showed an overall negative change, a direct demonstration of the previously discussed boomerang effect, and indeed, boomerangs are concentrated in this group. These results support the view that, at least initially, the training may be most beneficial to those whose personalities are most congruent with positive interpersonal relationships and high achievement.

Perhaps negative change reflects a defensive reaction on the part of those who find themselves threatened by training emphasis on positive communication, as this requires skills lacking in their personality make-up. Indeed, from a theoretical viewpoint this type of reac-

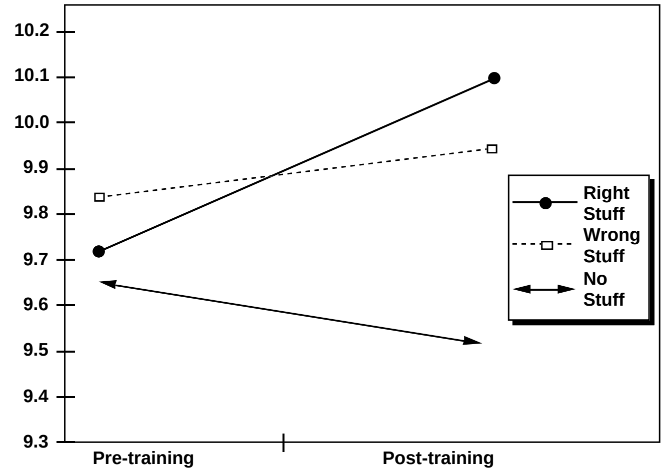

Figure 6. Mean values of the CMAQ Command Responsibility Scale: Before and after CRM training (USAF sample: n-882)

tion appears to reflect psychological reactance (Brehm, 1966). The critical research question is whether those showing little change or boomerang effects will become receptive to CRM concepts at a later time.

Perhaps more compelling are the personality and performance results from the NASA simulation study mentioned previously (Chidester & Foushee, 1988.) In this study there were significant differences among three experimental groups defined by the personality cluster classification of the aircraft captain. These differences were paralleled in both expert ratings of performance and in the objective criterion of number of operational errors committed.

Results for the rating criterion are shown in Figure 7. As the figure indicates, crews led by captains from Cluster 1 performed consistently better than those led by captains from the other two clusters across all five flight segments while those led by Cluster 3 Captains performed worst on all but one segment. The pattern of performance for the "wrong stuff", Cluster 2 Captain group shows a different pattern. Initially quite similar to the Cluster 3 Captain group, their performance was notably bad on Segment 3, which involved several abnormal mechanical conditions and poor weather. On the day following this segment, their performance improved and approached that of crews with Cluster 1 Captains. It is particularly noteworthy that all participants in this study had received formal CRM training and had experienced LOFT. These data provide strong additional evidence for the view that personality factors are a limiting factor on training effectiveness, at least as courses are currently organized and presented.

The pattern of findings for crews with Cluster 2 Captains suggests that over the course of time (in this case by the second day), crews adapt to each other and perform more effectively. This parallels a familiarity and performance relationship found by Foushee et al (1986) in another simulation study. It is a plausible hypothesis that the behavior of captains with the constellation of traits reflecting hostile dominance and interpersonal insensitivity remains consistent over time while other crew members learn to adapt to this style of leadership, thus enhancing overall performance. A major goal of the analysis of process data from this study is to test this hypothesis and, if it is confirmed, to determine if new principles can be extracted to apply to crew training.

Another possibility worth further investigation is that different teaching techniques may have differential impact on persons with differing personalities. It might be possible to develop remedial programs for individuals with particular difficulties in crew coordination.

Stress Effects. Psychological stress has demonstrably negative effects on individual and group behavior, including a narrowing of perceptual focus, increased difficulty in dealing with multiple, cognitive demands, and reversion to earlier, overlearned patterns of behavior. The most negative implication of this phenomenon is that CRM training may be least effective when it is needed most — in times of emergency and high workload. In other words, concepts of crew coordination may be practiced consistently in low stress situations but behavior may revert to earlier, overlearned individualistic patterns in crises.

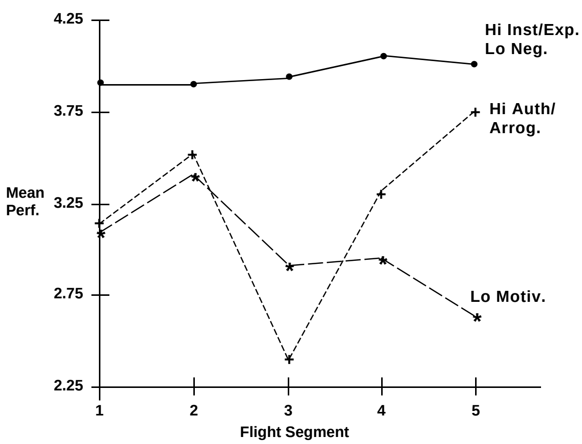

Figure 7. Performance of Crews in Two Day Simulation as a Function of Captain's Personality Cluster Assigment (From Chidester & Foushee, 1988)

It can be argued that the levels of stress induced in CRM/LOFT training do not approach those found during critical inflight emergencies (a testable but unverified hypothesis). There are several corollaries relating to the issue of stress in CRM/LOFT. One is that as crew coordination becomes normative and overlearned in organizations, the probability of its employment under stressful conditions should increase. The second, more controversial, is that it might be advisable to increase the stress level of training, for example, the LOFT in accordance with principles of same learning, i.e., increased likelihood of behavior being elicited in the same state in which it was learned. Theoretically, the optimum strategy for training would probably be to provide overlearning of CRM skills under low stress conditions and subsequent practice under high stress.

Data needed to evaluate hypotheses about stress effects will be difficult to obtain under current training practices. The best hope is likely to be extensive analyses of incidents involving high stress to determine the extent of crew coordination.

Training Factors — CRM Seminars. The intellectual origins of CRM programs rest in managerial training. There are, however, substantial differences among programs in terms of topics covered, length, and employment of didactic versus experiential techniques. In terms of participant evaluations, there do not appear to be large differences in reactions to the programs being assessed. We agree with the premise that a central function of formal, classroom training in CRM is to foster awareness of crew coordination issues and to introduce a common vocabulary for describing interpersonal behavior. However, we also feel that the training can and should improve attitudes about resource management issues and should provide participants with skills they can employ in interpersonal interactions.

Two practical functions of the current project are to specify CRM issues that may need particular attention in training and to provide feedback on the impact of particular training topics. The CMAQ, used as an attitude pretest prior to final seminar design can provide such base rate information. For example, a consistent finding across organizations has been that crew members lack awareness of the deleterious effects of stress and have unrealistic attitudes about their personal invulnerability to stress. Several recently developed seminars have built on these data and have incorporated segments on stress effects and stress management. Posttest data indicate that such training receives highly favorable evaluations and results in highly significant attitude change.

Similarly, data from the Line/LOFT Workshop completed on LOFT sessions in one airline indicated that a critical seminar topic and tool, critique of decisions and actions, was not being used by between 17 and 40 percent of crews, depending on aircraft fleet. These data suggested that a high priority topic for recurrent training would be the use and usefulness of critique and debriefings.

Examination of the acceptance of topics and their manifestations in Line and LOFT both assists in the evaluation of the concept of CRM training and provides feedback aimed at optimizing individual programs. As the database increases, it should become possible to evaluate the relative efficacy of differing techniques, such as the use of video recording and feedback within the seminar, and to assess the value of various types of experiential techniques for such critical topics as decision making.

Training Factors — LOFT. Although LOFT is overwhelmingly endorsed as the critical arena for practicing and reinforcing crew coordination, substantially less is known about LOFT than about classroom training in CRM concepts. Lauber and Foushee (1981) provided guidelines based on the state of knowledge at that time. Although the employment of LOFT has increased dramatically, no systematic research on factors that may increase or decrease the training value of simulations has been conducted.

A recent white paper (Helmreich, Wilhelm, & Gregorich, 1988b) discussed a number of factors that might affect the usefulness of LOFT for enhancing crew coordination and proposed an agenda for research. Several of these issues that relate directly to the evaluation of CRM training will be discussed here. As we have noted, familiarity with LOFT scenarios could greatly reduce their training value by eliminating the decision making interaction required of the crew.

The fact that many organizations employ only a limited number of scenarios increases the likelihood of scenario compromise. The limited data obtained to date indicate that some crewmembers do report familiarity with scenarios and further report that the training value of LOFT was reduced. It will be important to expand the database on familiarity, especially as programs mature. Should familiarity prove to be serious problem, it will become necessary to choose from a large inventory of scenarios. One possible solution is to create scenarios from a computer resident inventory of environmental conditions and operational problems allowing for a large number of combinations.

A second potential problem consists of the availability of solutions for problems posed in LOFT. If quick reference to an onboard manual can provide the optimal course of action, it is unlikely that the scenario will generate the type of deliberation and debate on the merits of alternative strategies and critique of actions taken that is desired. Anecdotal reports suggest that some current LOFT scenarios allow essentially "textbook" solutions. We feel that it is possible to specify the number and quality of alternative courses of action possible in response to scenario problems and that this should become part of the evaluation of a scenario's utility. We now recognize that it will be necessary to evaluate the qualities of the scenarios being used in our research in order to understand fully what ratings of observed crew behavior mean.

A related problem is the variability in workload imposed on crew members by LOFT scenarios. Lauber and Foushee (1981) correctly noted that many early LOFT designs tended to impose a large number of problems on crews, sometimes loading them up until they inevitably failed. Currently LOFTs tend to avoid this practice and to combine periods of normal flight with a limited number of abnormal conditions.

We suggest, as a testable hypothesis, that the pendulum has swung too far away from the demanding LOFTs of yesteryear. Anecdotal reports from a number of organizations suggest that some crew members feel that problems are too simple and that the exercise wastes much time. We realize that the motivation for initial normal flight conditions is to establish realism and crew familiarity and do not question this goal but feel that scenarios should be evaluated in terms of total workload imposed.

The arguments raised earlier regarding making the training more stressful to increase the generalizability of responses to emergency conditions would support making the workload high. As we have noted, the process coding used for experimental simulation analysis may prove to be a useful method of quantifying the workload imposed by LOFT scenarios. This is an area in great need of intensive research because there are important implications for the design and conduct of the most critical component of CRM training.

From a pedagogical point view, the timing of debriefings in many organizations would appear to be less than optimal. Learning theory suggests that rewards and feedback should occur as close to targeted behavior as possible. However, the cost and availability of simulator time tends to separate feedback from practice. For example, one airline procedure consists of a two and one-half hour LOFT followed by one and one-half hours of proficiency training and then the debriefing of the LOFT, including viewing of the videotape of the crew's behavior. This means that participants are both fatigued and have had a demanding activity interpolated before their LOFT is debriefed. We feel that the impact of such procedures should be investigated, along with that of alternative strategies for providing more immediate feedback.

Anecdotally, it does appear that the power of videotaping LOFT sessions is not being realized in many cases.

We have already noted the discrepancies found between participants and observers in one dataset. It is likely that the impact of video may be much greater when a skilled debriefer provides insights during the viewing, another argument for the centrality of the instructor role. Comments also suggest that video debriefings are either omitted or abbreviated in many instances. Certainly if a crew has been through demanding proficiency training session following LOFT and preceding debriefing, both fatigue and the passage of time may reduce motivation to attend closely to the behavioral implications of a videotape of earlier behavior. A number of testable hypotheses about how to increase the impact of debriefing can be generated and should receive high research priority.

Several other generally accepted premises about LOFT are worth empirical verification. One is that high fidelity simulation adds substantially to impact. Another is that simulation should encompass all aspects of a normal flight from planning and briefing through departure and cruise to arrival. In many cases with larger aircraft, this may consume a substantial proportion of the available simulator time. It is possible that very effective LOFT may be conducted in relatively low fidelity training devices and that short vignettes of inflight situations may be as effective as complete, highly realistic segments. Research in these areas is clearly needed.

Overall, we remain convinced that LOFT is a highly effective technique. However, research in the areas described above could answer a number of open questions and lead to greater training efficiency and effectiveness. Because of the large number of moderator factors, we suggest that the best research designs should involve experimental comparisons regarding LOFT within organizations and fleets.

Technical Proficiency. Attempts to evaluate the level of crew coordination within an organization should not be conducted without simultaneous assessment of technical proficiency. An inadvertent concomitant of introducing CRM training could be a diminished emphasis on the technical aspects of airmanship. Although an unlikely outcome, it is important to maintain precise evaluations of proficiency. On the Line/LOFT Worksheet, observers rate technical performance as well as components of crew coordination. At the system level, it can be argued that the Pass/Fail criterion applied to proficiency checks is an insensitive measure of organizational performance (Hackman & Helmreich, 1987; Helmreich, Hackman & Foushee, 1989).

An alternative measure, proposed by Capt. Roy Butler of Pan American World Airways, is to record the number of times a maneuver has to be repeated for an airman to demonstrate satisfactory proficiency during both proficiency training and current proficiency check. Initial data from this repeated maneuvers criterion suggest that it is sensitive to aircraft and crew differences and provides a good indication of proficiency.

Automation Factors — The "Glass Cockpit." Automation of many cockpit functions has created a very different working environment in new generation aircraft — the so-called glass cockpit, characterized by CRT displays of information replacing many conventional instruments (Wiener, 1988). Changes associated with automation include computerized flight management systems and the control of very large and complex aircraft by a two-person crew. In an earlier discussion of automation related phenomena, it was suggested that the computer may come to fill the role of "electronic crewmember." The manner in which crew members relate to their computer peer may be a factor which, alone in or concert with other moderators, may influence crew behavior and performance.

There is at least some indication that there may be a reluctance on the part of crew members to disconnect computer systems, even in the face of evident malfunction, a phenomenon that has been labeled "automation complacency" (NTSB, 1984). There is also an apparent tendency for some to persevere in reprogramming flight management systems under high workload conditions where revision to manual flight would be more adaptive.

It is possible that there are trainable strategies to optimize crew coordination and performance in glass cockpit aircraft, for example in prioritizing and distributing work and avoiding overload. At least one CRM seminar under development contains a module on automation. There may also be personality factors that relate to success and satisfaction in automated aircraft. The evaluation project contains all of the modern, automated aircraft. Behavior of crews in these fleets will be examined separately. Particular attention will also be addressed to workload demands imposed on crews in these aircraft by LOFT scenarios.

Status Of The Evaluation Project

A number of organizations are participating in the project but not all are contributing the same information. Table 2 shows the types of organizations involved and the nature of the data. The analysis of these data will be necessarily long and complex process because it is necessary to examine complex interactions among the many variables and especially involving moderator factors such as organizational policy, characteristics of training, and individual characteristics.

Critical analyses must await the passage of time on longitudinal outcome and process measures because we must know the temporal stability of training effects. Analyses are further complicated by the fact that available data vary from organization to organization. In addition to the goals of providing information about the impact of training and about how to optimize training for all crew members, optimal techniques, we have the further hope of developing a simplified data collection and analysis model that can be economically and simply employed to monitor system performance.

A Final Note

The current project has its roots in a long-standing research program aimed at isolating the determinants of individual and group performance in demanding professions. Examining the impact of CRM training in aviation represents a particular focus and application for the methodology of the large study. From the researchers' perspective this provides and ideal setting in which to examine a variety of theoretical issues as well as to attempt to provide meaningful answers for impor-

Table 2. Data Structure of the CRM/LOFT Evaluation Project
(X means data collection, P means collection planned)

Organizational	CMAQ BASE	CMAQ PRE	CMAQ POST	LINE OBS	LOFT OBS	LOFT SUR	INCID. BASE	REP MAN	DELAYED ATTITUDE	PERSNLITY
MAJOR 1	X	X	X	X	X	X	X	X	P	
MAJOR 2	X	X	X	X	X	X	P	X	P	
MAJOR 3			X	X						
MAJOR 4			X	X	X	P	X			
NATIONAL 1	X			X						X
NATIONAL 2	X	X	X							
COMMUTER 1	X	P	P							
COMMUTER 2	X	P	P	P						
USAF-MAC		X	X						X	
FOREIGN 1		X			P					X
FOREIGN 2		P	P	P	P	P	P		P	
				P						
FOREIGN 3		P	P	P	P					

Table Notes

CMAQ BASE: 25 Item Cockpit Management Attitudes Questionnaire, demographs and evaluation of previous CRM training (if any) administered to pilots before introduction of CRM seminar or LOFT.

CMAQ PRE: 25 Item Cockpit Management Attitudes Questionnaire plus demographics survey administered immediately before CRM seminar. This survey includes “secret ID” number which is later related to CMAQ POST survey.

CMAQ POST: Re-administration of 25 item CMAQ immediately after CRM seminar. This survey also includes an “evaluation and recommendations” section which queries reactions to individual seminar components as well as overall ratings, and both positive and negative comments about the training.

LINE OBS: Observations of crew performance by qualified check airmen during routine line checks.

LOFT OBS: Observations by qualified LOFT instructors during LOFT sessions.

LOFT SUR: LOFT survey filled out by crew members after LOFT.

INCID BASE: Recording, for each incident or accident, a summary of the causes of the accident and what type of crew coordination activity was at fault, if any. No generic form has been developed.

REP MAN: Recording the number of times an airman is required to repeat a maneuver to obtain proficiency during periodic training/checking by training or checking pilots using PT/PC worksheet.

DELAYED ATTITUDE: Re-measuring attitudes using the CMAQ at specific periods after initial CRM seminar.

PERSONALITY: Paper and pencil survey of personality characteristics using the Extended Personal Attributes Questionnaire (Spence, Helmreich & Holahan, 1979), the Work and Family Orientation Questionnaire, (Helmreich &

tant practical questions centered on improving safety and efficiency in the aviation system.

Finally, it should be noted that the database being assembled should prove to be an important national resource for researchers with a variety of theoretical and applied interests. The deidentified raw data can be made available to investigators seeking to test a variety of hypotheses, thus increasing the potential return on the investment required to assemble them. ♦

References

Brehm. J. (1966) *A theory of psychological reactance*. New York, N.Y., U.S.: Academic Press.

Chapple E.D. (1940) *Measuring human relations: An introduction to the study of the interaction of individuals*. Genetic Psychology Monographs, 22, 1-147.

Chapple, E.D. (1949) *The interaction chronograph: Its evolution and current application*. Personnel, 25, 295-307.

Chidester, T.R. (in press) "Trends and individual differences in response to short-haul flight operations." *Aviation, Space and Environmental Medicine*.

Chidester, T.R. & Foushee, H.C. (1988) *Leader personality and crew effectiveness: A full mission simulation experiment*. Moffett field, Calif., U.S.: NASA Ames Research Center.

Chidester, T.R., Helmreich, R.L., Gregorich, W. & Geis, C. (in preparation) *Isolating subgroups of pilots on performance-related personality dimensions: Implications of cluster analyses for training and selection*.

Cooper, G.E., White, M.D, & Lauber, J.K. (Eds.) (1980) *Resource management on the flightdeck: Proceedings of a NASA/Industry Workshop*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, CP2120.

Foushee, H.C. (1984) "Dyads and triads at 35,000 feet: Factors affecting group process and aircrew performance." *American Psychologist*, 39, 886-893.

Foushee, H.C., & Helmreich, R.L. (1988). "Group interactions and flightcrew performance." In E. Wiener & J. Nagel (Eds.), *Human factors in Aviation*. San Diego, Calif., U.S.: Academic Press.

Foushee, H.C., Lauber, J.K., Baetge, M.M. & Acomb, D.B (1986) *Crew factors in flight operations III: The operational significance of exposure to short-haul air transport operations*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, TM 88322.

Foushee, H.C. & Manos, K.L. (1981) "Information transfer within the cockpit: Problems in intracockpit communications." In C.E. Billings & E.S. Cheaney (Eds.) *Information transfer problems in the aviation system*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, TP-1875.

Ginnett, R.G. (1987) "First encounters of the close kind: The first meetings of airline flight crews." Unpublished doctoral dissertation, Yale University.

Gregorich, S., Helmreich, R.L., & Wilhelm, J.A. (1989) "The structure of cockpit management attitudes." Austin. NASA/UT *Technical Report 89-1*.

Gregorich, S., Helmreich, R.L., Wilhelm, J.A., & Chidester, T.R. (1989) "Personality based clusters as predictors of aviator attitudes and performance." Paper presented at the Fifth International Symposium on Aviation Psychology, Columbus, Ohio, U.S., April, 1989.

Hackman, J.R. (1987) "Group level issues in the design and training of cockpit crews." In H.W. Orlady & H.C. Foushee (Eds.), *Cockpit resource management training: Proceedings of the NASA/MAC Workshop*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, CP-2455.

Hackman, J.R. (1988) *NASA-Ames Research Center Cooperative Agreement*.

Hackman, J.R. & Helmreich, R.L. (1987) "Assessing the behavior and performance of teams in organizations: The case of air transport crews." In D.R. Peterson & D.B. Fishman (Eds.), *Assessment for decision*. New Brunswick, NJ: Rutgers University Press.

Helmreich, R.L. (1979). *Social psychology on the flight deck*. Proceedings of the NASA Workshop on Resource Management Training for Airline Flight Crews, NASA, CP-2120.

Helmreich, R.L. (1983a) "Cockpit management attitudes". In R.S. Jensen (Ed.), *Proceedings of the Second Symposium on Aviation Psychology*, 173-184.

Helmreich, R.L. (1983b). "What changes and what endures: The capabilities and limitations of training and selection." In N. Johnston (Ed.), *Proceedings of the Aer Lingus/Irish Airline Pilots Association Flight Symposium*, Dublin, Ireland.

Helmreich, R.L. (1984) "Cockpit management attitudes." *Human Factors*, 26, 583-589.

Helmreich, R.L. (1086) "Pilot selection and performance evaluation: A new look at an old problem." In G.E. Lee (Ed.), *Proceedings of the Tenth Symposium:*

*Psychology in the Department of Defens*e. Colorado Springs, CO: U.S. Air Force Academy USAFA-TR-86-1.

Helmreich, R.L. (1987a) "Theory underlying CRM training: Psychological issues in flightcrew performance and crew coordination." In H.W. Orlady & H.C. Foushee (Eds.), *Cockpit resource management training: Proceedings of the NASA/MAC Workshop*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, CP-2455.

Helmreich, R.L. (1987b) "Exploring flightcrew behaviour." *Social Behaviour*, 2, 63-72.

Helmreich, R.L. (1988) "Crew behavior during a prolonged inflight emergency": Saudi 163. Austin. *NASA/UT Technical Memorandum* 88-2.

Helmreich, R.L., Chidester, T.R., Foushee, H.C., Gregorich, S., & Wilhelm, J.A. (1989) "Critical issues in Implementing and Reinforcing Cockpit Resource Management Training." Austin. NASA/UT *Technical Report 89-5*.

Helmreich, R.L., Foushee, H.C., Benson, R., & Russini, R. (1986). Cockpit management attitudes: "Exploring the attitude-performance linkage." *Aviation, Space and Environmental Medicine*, 57, 1198-1200.

Helmreich, R.L., Hackman, J.R., & Foushee, H.C. (1986). "Evaluating flightcrew performance: Policy, pressures, pitfalls, and promise." Austin. *NASA/University of Texas Technical Report 86-1*.

Helmreich, R.L., & Spence, J.T. (1987). "The Work and Family Orientation Questionnaire: An objective instrument to assess components of achievement motivation and attitudes toward family and career." *JSAS Catalog of Selected Documents in Psychology*, 8, 35, MS #1677.

Helmreich, R.L., & Wilhelm, J.A. (1986) "Evaluating CRM training: I. Measures and methodology." Austin. *NASA/University of Texas Technical Report 86-8*.

Helmreich, R.L., & Wilhelm, J.A. (1987) "Evaluating cockpit resource management training." *Proceedings of the Fourth Aviation Psychology Symposium*, Ohio State University, 440-446.

Helmreich, R.L., & Wilhelm, J.A. (1987b) "Reinforcing and measuring flightcrew resource management: Training Captain/Check Airman/Instructor Reference Manual." *NASA/University of Texas at Austin Technical Manual 87-1*. (Revised 4/15/88).

Helmreich, R.L. & Wilhelm, J.A. (1989) "When training boomerangs: Negative outcomes from Cockpit Resource Management programs." Paper presented at the Fifth Aviation Psychology Symposium, Ohio State University.

Helmreich, R.L., Wilhelm, J.A., & Gregorich, S. (1988a) "Revised Versions of the Cockpit Management Attitudes Questionnaire (CMAQ) and CRM Seminar Evaluation Form." Austin. *NASA/UT Technical Report 88-3*.

Helmreich, R.L., Wilhelm, J.A., & Gregorich, S. (1988b) "Notes on the concept of LOFT: An agenda for research." Austin/ *NASA/UT Technical Report 88-1*.

Jones, E.E. & Nisbett, R.E. (1972) "The actor and the observer: Divergent perceptions of the causes of behavior." In E.E. Jones et al. (Eds.) Attribution: *Perceiving the causes of behavior*. Morristown, N.J. U.S.: General Learning Press.

Kanki, B. (in progress) "Analyses of communications in a full mission simulation."

Kanki, B. & Foushee, H.C. (in press) "Communication as a group process mediator of aircrew performance." *Aviation, Space, and Environmental Medicin*e.

Kanki, B.G., Lozito., S., & Foushee, H.C. (1987) "Communications indexes of crew coordination." *Proceedings of the Fourth Aviation Psychology Symposium*, Columbus, Ohio, U.S.: Ohio State University, pp. 406-412.

Lauber, J.K. & Foushee, H.C. (1981) *Guidelines for Line Oriented Flight Training*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, CP-2184.

NTSB: *National Transportation Safety Board (1984) Scandinavian Airlines System, DC-10-30, John F. Kennedy International Airport, New York, February 28, 1984*. (Report No. NTSB-AAR-84-15).

Ruffell Smith, H.P. (1979) *A simulator study of the interaction of pilot workload with errors*. Moffett Field, Calif., U.S.: NASA-Ames Research Center, TM-78482.

Spence, J.T., Helmreich, R.L., & Pred, R.S. (1987). "Impatience versus achievement striving in the Type A pattern: Differential effects on students' health and academic achievement." *Journal of Applied Psychology*, 72, 522-528.

Storms, M.D. (1973) "Videotape and the attribution process." *Journal of Personality and Social Psychology*, 27, 165-175.

Wiener, E. (1988) "Automation." In E. Wiener & J. Nagel (Eds.), *Human factors in aviation*. San Diego: Academic Press.

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Flight Instructor/Maintenance Technician Awards Recognize Excellence

The annual Flight Instructor/Maintenance Technician Award program is seeking nominees to honor for 1990. All full- and part-time certified civilian flight instructors and full-time general aviation maintenance technicians are eligible to be recognized for outstanding contributions to aviation safety.

Award nomination forms are available at FAA Flight Standards District Offices (FSDOs) and from certain chapters of the Experimental Aircraft Association (EAA) and the Ninety-Nines, the international organization of women pilots. Completed forms are due at FSDOs by July 16. Regional and national categories of winners will be selected.

The national Flight Instructor and Maintenance Technician of the Year will each receive an expense-paid trip to Washington, D.C., where he or she will be honored at an awards ceremony and luncheon, and will be presented other awards by organizations supporting the government-industry program.

The awards program is sponsored by the U.S. Federal Aviation Administration, the AOPA Air Safety Foundation, the National Business Aircraft Association, and the General Aviation Manufacturers Association, with participation by other businesses and organizations.

Reports Received at FSF Jerry Lederer Aviation Library

Books

Lightning Protection of Aircraft / F.A. Fisher, J.A. Plumer (Lightning Technologies, Inc.), Rodney A. Perala (Electro Magnetic Applications, Inc.). — Pittsfield, Mass., U.S. : Lightning Technologies, Inc., 1990. xv, *499p.*, ill. Available from Lightning Technologies Inc., 10 Downing Plaza, Pittsfield, MA 01202, $99.95 plus shipping and handling. Telephone: (413) 499-2135.

Key Words
1. Aeronautics — Safety Measures
2. Lightning Protection.
3. Airplanes — Design and Construction.
4. Electromagnetic Fields.
5. Meteorology in Aeronautics.

… "follows an earlier book of the same title published by NASA in 1977." … "commissioned by the Federal Aviation Administration Technical Center; contract FAA DTFA03-86-C-0049."

This handbook will assist aircraft design and certification engineers in protecting aircraft against the direct and indirect effects of lightning strikes, in compliance with U.S. Federal Aviation Regulations pertaining to lightning protection. It is also intended to assist FAA certifying engineers in assessing the adequacy of proposed lightning protection designs. It will also be useful for designers of major subsystems, such as engines and electrical and avionics systems. … The book is organized … with the first half dealing with the direct effect (burning and blasting) of lightning and the second half with indirect effects (electromagnetic induction of voltages and currents) of lightning. [introduction]

Contents: An introduction to High Voltage Phenomena — The Lightning Environment — Aircraft Lightning Attachment Phenomena — Lightning Effects on Aircraft — The Certification Process — Direct Effects Protection — Fuel System Protection — Introduction to Indirect Effects — The External Electromagnetic Field Environment — The internal Fields Coupled by Diffusion and Redistribution — The Internal Fields Coupled through Apertures — Experimental Methods of Analysis — Response of Aircraft Wiring — Shielding — Design to Minimize Indirect Effects — Circuit Design — Test Techniques for Evaluation of Indirect Effects — References — Index.

Contributed to FSF Lederer Library by J.A Plumer, President, Lightning Technologies, Inc.

Reference

Advisory Circular 90-76B, Flight Operations in Oceanic Airspace. — Washington, D.C. : U.S. Federal Aviation Administration, ATO-340, 1/29/90. 6p.

This circular provides basic information applicable for flights into oceanic airspace under U.S. air traffic control (ATC) jurisdiction.

Federal Aviation Regulations, Part 135 - Air Taxi Operators and Commercial Operators; Change 34. — Washington, D.C. : U.S. Federal Aviation Administration, [1990].

This change incorporates three amendments and amends two Special Federal Aviation Regulations (SFARs) in Federal Aviation Regulation (FAR) Part 135: Amendment 135-32 and SFAR 50-2, Revision of General Operating and Flight Rules, effective August 18, 1990; Amendment 135-33 and SFAR 36-5, Organizational Changes and Delegations of Authority, effective October 25, 1989, and Amendment 135-34, Independent Power Source for Public Address System in Transport Category Airplanes, effective November 27, 1989.

Reports

Future Aviation Activities - Sixth International Workshop./National Research Council (U.S.). — Washington, D.C.: Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418, February, 1990. Transportation Research Circular Number 352, *58p.*

Key Words
1. Airlines.
2. Corporate flying.
3. Private flying.
4. Airports — Traffic Control.

Presentations and summaries of workshop held September 13-15, 1989 in Washington, D.C. Workshop was sponsored by the U.S. Federal Aviation Administration, and the TRB Committee on Light Commercial and General Aviation. Contents: Introduction — Major Findings — Overview Presentations: Aviation's Role in the National Transportation Policy / Dale E. McDaniel, FAA — Data Needs for National Transportation Policy / Rolf R. Schmitt, U.S. DOT — U.S. Airline Industry

Overview / Hans J. Plickert, The Transportation Group — Airport Capacity Overview / J. Donald Reilly — Workshop Summaries: Common Carrier Aviation: International Aviation / Louis P. Gialloreto, Air Canada — U.S. Domestic Majors / Edmund S. Greenslet, ESG Aviation Services — Regional Aviation / J. Bruce McClelland, British Aerospace Inc. — Airline Aircraft Manufacturers / John F. Walsh, Rohr Industries, Inc. — Air Carrier Airports / Peter Reaveley, Miami International Airport — General Aviation: Business and Executive Aviation / Gerald S. McDougall, Wichita State University — Helicopters / W. Fred Tiller, McDonnel Douglas Helicopter Co and Susan H. Godar, Agusta Aerospace Corporation — Light General Aviation (Fixed Wing) / Ronald L. Swanda, GAMA.♦

Aviation Statistics

The Head and Tail of U.S. General Aviation

A Review of Safety and Activities in the Eighties

Improvement of Safety

According to general aviation accident statistics released by the U.S. National Transportation Safety Board (NTSB), the year 1989 is the tenth consecutive year that the number of total aircraft accidents dropped. In terms of fatalities, the year 1989 is the eighth consecutive year that both fatal accidents and fatalities dropped. In all, the total number of accidents decreased 57 percent from 3,818 in 1979 to 2,617 in 1989, while general aviation aircraft hours flown reduced only 21 percent from 38 million hours in 1979 to 30 million hours in 1989. The rates of 7.25 accidents and 1.4 fatal accidents per 100,000 aircraft hours for calendar year 1989, are the lowest accident and fatal accident rates in the last decade. The continuing downward trend of accident rates over the past 10 years is an indication that general aviation aircraft design relating to safety is improving, the aeronautical knowledge and piloting skill of general aviation pilots is advancing, and the U.S. Federal Aviation Administration (FAA) “Back to Basics” general aviation safety program is working.

Slowdown of Activities

The safety record of general aviation in the past decade is very encouraging, but there are also some discouraging trends. Since 1979, there has not been a single general aviation activity indicator, including aircraft hours flown, new aircraft shipments, FAA towered-airport operations, pilot population, annual new student certificates issued and number of active aircraft, that has shown an upward trend.

General aviation aircraft hours flown dropped from 38 million hours in 1979 to 30 million in 1989, a reduction of 21 percent; the number of active aircraft fluctuated between 200,000 and 210,000 and the average annual flying hours per aircraft declined from 180 to 140 hours. Annual general aviation aircraft shipments fell 91 percent from 16,000 aircraft to 2,456 in 1989. As a result, employment in general aviation over the past 10 years dropped more than 50 percent. According to the General Aviation Manufacturer’s Association (GAMA), the industry faces a major impediment to its growth in the continuing product-liability crisis which caused this long-term drop in employment.

Pilot Population Reduction

Another significant indicator showing the overall slowdown of general aviation is the continuing reduction in pilot population. Table 1 shows annual changes in pilot population for the last decade and Table 2 shows the changes of pilot population by pilot certificate, annual

Table 1
General Aviation Pilot Population Annual Changes CY 1988-1989

Year	Total	Annual Changes	Accumulated Gains/Losses
1977	783,932	—	—
1978	798,833	14901	14901
1979	814,677	15844	30745
1980	827,071	12394	43139
1981	764,182	-62889	-19750
1982	773,225	9043	-10707
1983	718,004	-55221	-65928
1984	722,376	4372	-61556
1985	709,540	-12836	-74392
1986	709,118	-422	-74814
1987	699,653	-9465	-84279
1988	694,016	-5637	-89916
1989	700,010	5994	-83922

new certificates issued and annual attrition. “Active pilot” defined by the FAA, refers to those pilots who hold both a pilot certificate and a current medical certificate. An airman would be categorized as inactive if he either gave up his airman certificate or failed to provide a current medical certificate. Table 2 part 1 Column 2 shows the new student certificates issued — the indication of increase of pilot population change every year. Note that the number of new student certificates dropped from 137,032 in 1978 to 87,698 in 1989. columns (8), (9), (10) and (11) of Table 2 shows the annual attrition of student, private, commercial and ATR pilots. Column (12) is the total attrition of pilots. These figures represent the annual number of pilots who were active in the beginning of the year but did not hold either a pilot certificate or a current medical certificate at the end of the year. In other words, this is the number of pilots who retired from flying each year. The annual pilot attrition ranged from a low of two percent of ATR pilots to a high of 33 percent of student pilots. On an average, about 100,000, or about 15 percent of the total pilots, annually retired from flying. As a result of pilot attrition and reduction of new student pilots over the decade, the student pilots shrank from 200,000 to about 140,000, and both private pilots and commercial pilots dropped about 40,000. Only the population of ATR pilots increased from 50,000 in 1978 to 100,000 in 1989, the direct result of U.S. airline expansion because there was an increasing demand for airline pilots after airline deregulation. Since airline pilots are required to retire from air carrier flying at age 60, the decrease of annual new student pilots may result in an airline pilot short-

Table 2
General Aviation Pilots, Annual New Certificates Issued and Attrition
By Pilot Certificate
Calendar Year 1977-1989

(Part 1)

Year	Student Pilot (1) Total	Student Pilot New(2) Issues	Private Pilot (3) Total	Private Pilot New(4) Issues	Commercial Pilot (5) Total	Commercial Pilot New(6) Issues	ATR Pilot (7) Total	ATR Pilot New(8) Issues
1977	203,510	138,331	327,424	54,657	188,763	11,211	50,149	5,697
1978	204,874	137,032	337,644	58,064	185,833	11,789	55,881	6,912
1979	210,180	135,956	343,276	54,466	182,097	12,627	63,532	8,971
1980	199,833	102,301	358,479	50,458	183,442	12,452	69,569	7,116
1981	179,912	111,531	328,562	45,713	168,580	10,657	70,311	4,763
1982	156,361	90,816	322,094	52,144	165,093	11,048	73,471	5,037
1983	142,197	92,239	318,643	41,210	159,495	8,789	75,938	5,643
1984	150,081	90,085	320,086	36,545	155,929	7,702	79,192	5,099
1985	146,562	86,060	311,008	35,402	151,632	8,404	82,740	6,081
1986	150,273	88,699	305,736	34,816	147,798	8,889	87,186	6,498
1987	146,016	85,611	300,949	42,278	143,645	11,314	91,287	7,678
1988	136,913	86,193	299,786	39,900	143,030	12,042	96,968	7,461
1989	142,554	87,698	293,179	35,360	144,540	12,698	102,087	7,829

(Part 2) **Pilot Attrition**

Year	Student Pilots (9)	Private Pilots (10)	Commercial Pilots (11)	ATR Pilots (12)	Total (9)+(10) +(11)+(12)	Annual Attrition Rate %
1977	-77,604	-36,055	-7,807	-1,180	-122,646	15.6
1978	-76,184	-36,027	-7,392	-1,320	-121,103	15.1
1979	-62,190	-22,803	-3,991	-1,079	-90,063	11.1
1980	-85,739	-64,973	-20,756	-4,021	-175,489	23.5
1981	-62,223	-47,564	-9,498	-1,877	-121,162	16.9
1982	-65,193	-35,872	-8,744	-3,176	-112,985	16.2
1983	-45,656	-27,400	-6,169	-1,845	-81,070	11.5
1984	-54,177	-35,998	-6,620	-2,533	-99,328	14.4
1985	-50,172	-31,277	-6,225	-2,052	-89,726	13.0
1986	-47,590	-35,751	-7,789	-3,577	-94,707	13.9
1987	-55,396	-29,021	-5,196	-1,780	-91,393	13.3
1988	-46,707	-29,269	-3,359	-2,710	-82,045	13.0

Source: FAA Airmen Statistics 1977-1989 age during the years to come and thus may hinder the growth of public air transport as well.

Obstacles to General Aviation Growth

There are several reasons for the slowdown of general aviation activites. Industry attributes the significant drop of aircraft shipments to the product-liability crisis, which drove up the price of new general aviation aircraft by more than 300 percent. The high cost of flying also prevented many aviation enthusiasts from taking flying lessons, since it normally costs at least $2,000 to meet the minimum requirement of 40 flight hours for a private pilot certificate.

Some general aviation enthusiasts complain that the U.S. government suffocates general aviation because it imposes too many restrictions on general aviation flying. There is also evidence that general aviation pilots' attitudes toward the FAA have changed from "cooperative to less cooperative" in keeping aircraft registry data updated. ♦

Accident/Incident Briefs

This information on accidents and incidents is intended to provide an awareness of problem areas through which such occurrences may be prevented in the future. Accident/incident briefs are based upon preliminary information from government agencies, aviation organizations, press information and other sources. The information may not be accurate.

Air Carrier

A Light in the Gloom Almost Spelled Doom

Boeing 737-200: Minor damage. No injuries.

The U.S. air carrier was approaching to land at 2130 hours on a fall evening. According to the ATIS (Automatic Terminal Information Service) information that was a half-hour old, the weather was 2,500 feet scattered, 7,500 feet overcast, visibility 10 miles. A special report at 2127 hours that was not transmitted to the crew included the following: indefinite ceiling, one-half mile visibility, thunderstorms and heavy rain.

The aircraft flew into the unexpected maelstrom. Initially, the crew was given vectors for a visual approach. However, since two preceding aircraft missed the approach because of low visibility in heavy rain showers, approach control switched runways and set the aircraft up for the back course localizer to another runway.

The first officer retuned the navaids and the aircraft was cleared for the localizer back course approach. The 2127 special weather observation was not broadcast until after the aircraft had been handed off to the control tower. The tower also did not provide updated weather information to the flight.

The aircraft intercepted the final approach course in rain showers. The captain was hand flying and the crew reported seeing lights that they related to the approach end of the runway. That runway has runway end identifier lights (REIL) and visual approach slope indicator (VASI) lights, but no approach lights. The captain descended below MDA (Minimum Descent Altitude) — 375 feet — before the aircraft reached the decision point. When the rain became heavier, the windshield wipers were turned on and the approach was continued.

A government air carrier inspector who had recently become rated in the Boeing 737 was sitting it the cockpit jump seat. He did not notice anything irregular about the approach and provided no input to the crew. The first officer, who recently had completed a windshear training course, became aware of a flattening of terrain cues and called for a go-around. The captain responded immediately by rotating the nose upward and pushing the throttles all the way forward.

At this time the aircraft struck and severed three electrical power lines about 75 feet above the ground and 1.2 miles short of the runway threshold. The crew felt the aircraft lurch and heard a bang, but did not perceive these as indications of an obstacle strike. Passengers later reported seeing a bright, blue flash at the same time the aircraft pulled up for the go-around. A short time later, all system fluid was lost in hydraulic system

B and the flight was diverted to an alternate airport and landed without further incident.

An inspection carried out after the landing revealed a deep cut in the leading edge of the vertical fin approximately two feet below the top of the stabilizer. The cut ran back to the front spar that apparently had enough strength to break the three-quarter-inch-thick ground wire the aircraft had struck. Two of the four 1.25-inch-thick power lines strung below the top ground wire had been severed by the nose gear assembly. The impact had separated the right nose gear door and damaged the left one. One of the snapped wires flailed and damaged the shimmy damper and antiskid electrical connections on the left main gear. It also severed a line in the B hydraulic system that caused the fluid to become depleted.

Another Reason Smoking and Flying Do Not Mix

Boeing 747 combi: Substantial damage. No injuries.

The aircraft had just taken off from Hong Kong for Frankfurt. When it was passing through 1,500 feet during the initial climbout, the lower aft cargo compartment fire warning activated. The crew activated the fire extinguishing system and returned to the airport.

Inspection revealed that the fire, caused by a smoldering cigarette that ignited trash left in the cargo compartment, had been burning approximately 15 minutes before the detection system activated; the fire was smothered by the extinguishing system. Another 10 minutes passed while the flight turned around and returned to the airport; no fuel was dumped. It was determined that high airflow through the lower aft cargo compartment had created a chimney effect that fanned the flames which ignited insulation blankets. The fire was estimated to have burned at 600 degrees C (1,112 degrees F) and produced heavy structural damage. Investigators estimated that the aircraft would have been lost had the fire not been extinguished shortly after it was discovered.

The carrier is enforcing no smoking regulations for cargo handlers and requiring removal of trash and debris from cargo compartments regularly.

Overzealous Nose Lowering Leads to Confusion

Lockheed L-1011 Tristar: No damage. No injuries.

The widebody was arriving at London's Heathrow Airport after a flight from Bermuda. An automatic landing was being made with the captain handling it. When the nose appeared to be lowering too slowly after touchdown, the captain applied forward pressure. The autopilot limit annunciator and the stabilizer servo channels C and D warnings illuminated. The autopilot was disconnected and the rollout was completed without further trouble.

Investigation revealed no fault with the autopilot system, although the flight control electronic system computer was changed as a precaution. Analysis of the recorded flight data showed that substantial force had been applied to the captain's control column during the ground roll portion of the automatic landing, and that the system warnings were appropriate to that input. The amount of force applied to the control column was discussed with the captain.

When the Whistle Blows, It's Time to Go Around

McDonnell Douglas DC-10-30: No damage. No injuries.

The aircraft was landing at London's Gatwick Airport after a flight from Dallas. The captain was the handling pilot and reported that the aircraft was high on the approach. The rate of descent was increased to approximately 1,200 fpm in an attempt to reestablish the aircraft on the glidepath. At 1,300 feet a ground proximity warning occurred and a go-around was flown to a landing with no further incident.

However, a later analysis of the recorded flight data revealed that, during the first approach, a Mode 1 ground proximity warning occurred at a radio altimeter height of 642 feet in response to a barometric rate of descent of 1,740 fpm. The approach was continued and another Mode 1 ground proximity warning occurred at a height of 284 feet because of a 1,500-fpm rate of descent. A go-around was flown after the second warning and the landing was made, during which no further ground proximity warnings occurred. The pilots were counseled regarding the failure to report both warnings and the lack of required action after the first warning.

It's a Pull — Not a Yank

Boeing 737: No damage. No injuries.

The aircraft was taking off from a U.K. airport with the copilot flying the aircraft. A stall warning occurred at rotation but the flight proceeded to its destination without incident.

The stall warning incident was reported and the stall warning systems were checked out by maintenance. Everything was normal. The flight data recorder was also analyzed; it showed a nose-up rotation rate during takeoff of between 3.9 and 5.7 degrees per second to a final pitch-up attitude of 21.5 degrees. The stall warning was confirmed as real. The flight manual requires that on takeoff the aircraft be rotated smoothly at three degrees per second and that pitch attitude be limited to 20 degrees.

The crew was counseled about the specified rotation rate and the relationship of higher-than-normal rotation rates to the stall warning alarm.

Air Taxi
Commuter

Base Leg was the Final One

L410 Turbolet: Aircraft destroyed. Fatal injuries to 6; serious injuries to 8.

The Soviet aircraft had departed Boguchany and was approaching Kodinsk with a crew of two and 12 passengers aboard. The crew members had changed seats prior to departure for this leg.

The aircraft struck the terrain during base leg turn, three miles short of the runway and 2,400 feet to the left of the centerline. The aircraft impacted in a 48-degree left bank and a descent path angle of 24 degrees. The aircraft was destroyed and both crew members and four passengers were killed; eight passengers survived with serious injuries.

Investigators found that the radio altimeter warning had not been set to the safety altitude and that the approach was made without flying to the outer marker. Causal factors included improper crew coordination, directives not being followed and inadequate currency in position for the copilot.

Go-Around Against the Odds

Fokker F.27: Aircraft destroyed. Fatal injuries to two on ground, none in aircraft. Serious injuries to five on aircraft.

The commuter aircraft was approaching Bauru Airport, about 200 miles northwest of São Paulo, Brazil. There were three crew members and 37 passengers aboard.

The aircraft touched down long and a go-around was attempted. The aircraft was unable to gain sufficient altitude and hit and damaged the roofs of two houses. It then dropped into a street where it fell on an automobile and caught fire, killing a mother and child in the vehicle. The aircraft was destroyed. There were no fatalities aboard the aircraft, although four passengers were injured. The pilot, seriously injured, was freed from the wreckage by firemen.

Corporate
Executive

With One Engine Gone, It Didn't Carry On

Cessna 340: Aircraft destroyed. No injuries.

The aircraft was taking off from an airport in the Federal Republic of Germany. The pilot was the only person aboard for the mid-afternoon flight.

The right engine of the twin failed during the initial climb. The pilot was unable to maintain altitude and made an emergency landing in a meadow. The aircraft collided with a fence post during the forced landing and incurred substantial damage. The pilot evacuated without injury.

Investigation revealed that the damage to the propellers indicated that both engines were operating at touchdown. There were no indications of technical defects in the engines. Investigators indicated that the pilot may have simulated an engine failure and mishandled the emergency procedures.

Classic Case of Wrong Handle-itis

Aerostar 601: Substantial. No injuries.

The aircraft was arriving at Ashawa, Canada in midday. The approach and landing were without incident.

During the later stage of the landing roll, the landing gear retracted and the aircraft sustained damage to the fuselage underside. The pilot and the one passenger evacuated the aircraft without injury.

The pilot had intended to raise the flaps during the rollout — but inadvertently selected gear up.

Other General Aviation

Watch Out For the Wind Machine

Reims Cessna F152: Substantial damage. No injuries.

The aircraft, taxiing out for a departure from the U.K. airport, was cleared by the control tower to a holding point via the northern taxiway. There were an instructor and a student aboard. As the aircraft approached the designated holding area, the pilot noticed that it was already occupied by another lightplane that had just landed, and he asked the tower if he could do his pretakeoff runup checks in the southern parking area, instead. The request was approved.

A Boeing 757 had been cleared to the runway via an entrance opposite to the southern parking area where the Cessna was doing its runup checks. As the air carrier turned towards the runway, its jet wash was directed at the lightplane. The Cessna was tipped over to the right, causing the right wingtip and propeller to strike the ground. After the aircraft righted itself, the instructor shut down the engine and electrical switches and the two occupants evacuated the aircraft without injury.

Because of its position on the southern parking area in which a number of aircraft were parked, the Cessna was not visible from the control tower.

Assumed Zig Became Zag

Stolp Starduster Too and Luscombe Silvaire: Substantial damage to both aircraft. Serious injuries to one, minor injury to one.

The traffic pattern for the U.K. fly-in was extremely busy with a mixture of aircraft, both with and without communications radios, converging on the airport after many had been delayed because of poor weather earlier. The grass runway was 2,600 feet long with a 1,500-foot extension. A control tower was established for the event.

The pilot of the Luscombe entered the left-hand traffic pattern for runway 07 on the downwind leg and, with a hand-held transceiver, radioed his position to the tower. He had to extend his downwind leg because of conflicting traffic; there were at least nine aircraft in the pattern at the time, according to ATC tapes. As he turned to base leg, he notified the tower that he was following a Rapide and extended his base leg so that his aircraft went to the right of the runway centerline.

Just before the Luscombe pilot began his turn to intercept the final approach leg, he saw the Starduster become established on final ahead of him. The Starduster landed on the runway extension prior to the normal threshold and slowed to taxi speed approximately at the normal runway threshold opposite the temporary control tower that was to the right of the runway. Witnesses stated that it swung slightly to the left before turning right toward a taxiway leading to the parking area.

Since the Luscombe pilot had intended to land at the regular threshold rather than earlier in the extension as the Starduster had done, he performed an S-turn and sideslipped for traffic separation from the previous aircraft. When he saw the Starduster moving toward the left, he assumed that the other aircraft was clearing the runway in that direction and continued with his landing. However, due to sloping ground to the left of the runway, it was not possible to clear the runway in that direction. The passenger in the Luscombe, also a licensed pilot, stated that the aircraft touched down about halfway to two-thirds along the runway extension and he also assumed that the Starduster was clearing the runway to the left. The Luscombe pilot anticipated passing the slowing Starduster that was on his left side.

Then the Starduster reversed its direction and turned to the right to taxi diagonally across the runway, in the path of the Luscombe. The latter was travelling between 40 and 50 mph when it struck the Starduster on the right side just behind the wing root.

The Starduster was heavily damaged and the pilot in the rear seat was seriously injured. He was wearing protective headgear which was credited with minimizing his injuries; the front passenger received minor injuries. The Luscombe was also extensively damaged but the two occupants evacuated the aircraft without injury. There had been no radio communications between the Starduster and the control tower; an incorrect frequency was found to have been selected on its radio.

Rotorcraft

Sun Gets in my Eyes

Bell 47: Substantial damage. No injuries.

The crop dusting pilot was flying his rotorcraft in a southerly direction. The sun was directly before him.

The helicopter collided with a wooden power pole, the main rotor blade striking the obstruction on the right side of the rotorcraft. The helicopter nosed up and rolled to the left and impacted the ground. It came to rest on its right side; there was no fire. The pilot was able to evacuate without sustaining injury, but the helicopter was damaged substantially.

Inadvertently Entered Clouds

Bell 206B: Substantial damage. Minor injuries to one.

The aircraft was on a night cross-country flight. During the flight, the pilot encountered considerable thunderstorm activity and lightning, and at one point he landed and waited about 20 minutes for the weather to improve before proceeding.

The pilot inadvertently flew into some low clouds and descended to obtain visual flight conditions. When he broke out of the clouds the aircraft was at treetop level. The pilot became disoriented and confused, and realized that the helicopter was descending and traveling backwards. The tail rotor struck some tree branches, followed by the aircraft striking more trees and impacting the terrain. The rotorcraft rolled over and sustained substantial damage. The pilot was able to leave the aircraft without injury.

Unexpected Tie-Down

Aerospatiale SA-316B: Substantial damage. Fatal injuries to one; serious injuries to three and minor injuries to one.

The aircraft was being used for an external-load mission. The pilot lifted off between loads without detaching a 100-foot steel cable. As the rotorcraft departed, a hook on the end of the cable became caught on an equipment trailer, broke free and rebounded into the main rotor blades. The aircraft became uncontrollable and fell into a parking lot. The aircraft was extensively damaged. One passenger was fatally injured, the pilot and three passengers were seriously injured and one passenger sustained minor injuries.

Midair Stop Went Awry

Bell 47: Substantial damage. Serious injuries to one; minor injuries to one.

The aircraft was engaged in aerial application activities. There were the pilot and one passenger aboard.

The pilot stopped the rotorcraft in midair to reverse direction but, with power reduced, it began to descend. The pilot applied full power and raised the collective pitch control, but the aircraft continued to descend. The helicopter collided with trees during the uncontrolled descent and impacted the ground. The aircraft was damaged substantially. The passenger received serious injuries and the pilot sustained minor injuries.♦