

N 77-18119

RETROSPECTIVE STUDIES OF OPERATING PROBLEMS IN AIR TRANSPORT

C. E. Billings, J. K. Lauber, G. E. Cooper,
and H. P. Ruffell-Smith
NASA Ames Research Center

SUMMARY

Studies of human factors in aircraft accidents provide a substantial yield of human errors which contributed to those accidents. It is probable, however, that accidents are the least common of the outcomes which can follow a human error in the aviation system. An epidemiological model for the study of human errors in aviation is presented. In this approach, retrospective data are used as the basis for formulation of hypotheses as to system factors which may have contributed to such errors. Prospective experimental studies of aviation operations are also required in order to prove or disprove the hypotheses, and to evaluate the effectiveness of intervention techniques designed to solve operational problems in the aviation system.

INTRODUCTION

This paper is designed to accomplish two objectives. Its first intent is to present human error in aviation in terms of an analogy which may be useful in attacking the problem of human errors and their effects upon aviation safety. Its second purpose is to present a systematic methodology for the attack upon this omnipresent problem.

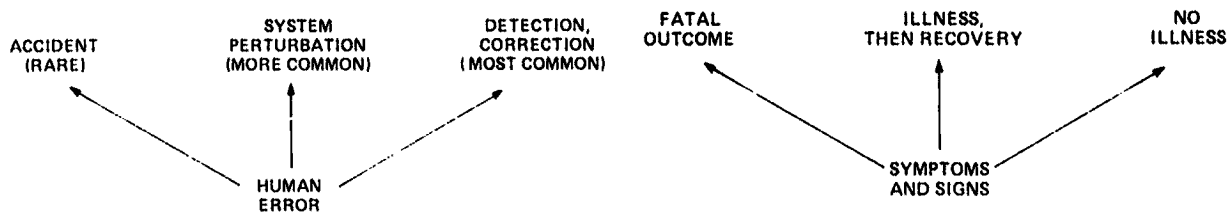
BACKGROUND

Studies of aviation safety over the years have nearly all had certain common attributes. Nearly all such studies have focused upon aircraft accidents. Nearly all have been essentially descriptive, though the recent study by Kowalsky et al. at the Lovelace Foundation utilized sophisticated analytic techniques in an attempt to elucidate factors associated with the sample of accidents under study. Most of these studies, like most accident investigations, have had to rely heavily upon inference to determine what went on prior to the accident itself.

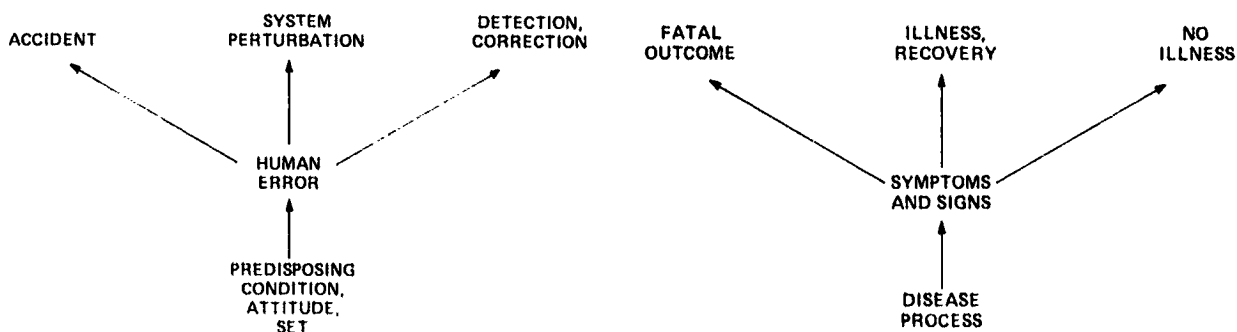
There have been many studies of accidents in other forms of transportation and in industry. They have given rise to various theories about the persons and circumstances in which accidents are especially likely to occur, but none, to our knowledge, has withstood the test of time. Is it possible that attempts to improve accident statistics have not been more successful because attention has been focused upon the wrong phenomenon, or upon only one facet of the overall problem?

Since the introduction of turbojet aircraft into civil transport, between 60 and 70% of all fatal accidents in airline transport have been attributed in whole or part to human error. The figures for general aviation are substantially higher. The problem of human error, then, is clearly the most serious one facing the aviation industry.

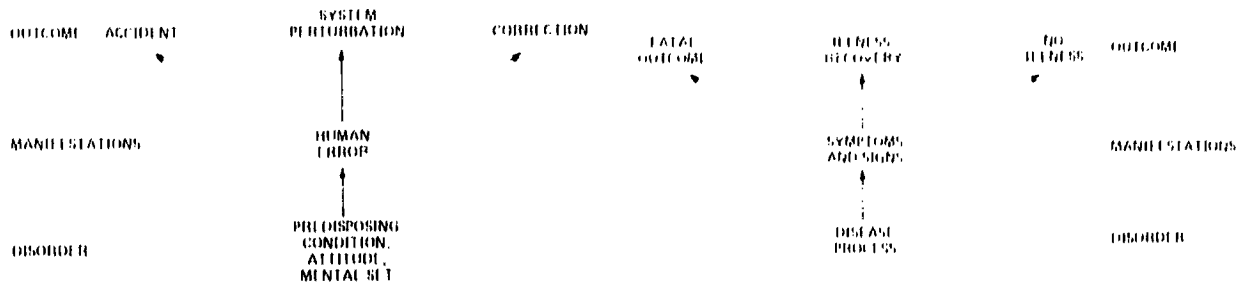
Yet while case studies of aircraft accidents are a convenient and highly productive method of collecting instances of human error in aviation, it is less generally acknowledged that an accident is only one — and the least common — of the outcomes which can result from a human error in the aviation system. A human error may cause a perturbation in the aviation system, but under circumstances which allow time and space for recovery. More frequently still, the error may occur, be detected, diagnosed and corrected or compensated for without a significant perturbation in the system. There is an analog to this in clinical medicine, in which symptoms and sometimes signs of illness may occur. They may progress to a fatal outcome; they may herald a significant illness from which recovery occurs, or they may appear, be compensated for by the physiological reserves of the body and disappear without a significant disturbance of overall function.



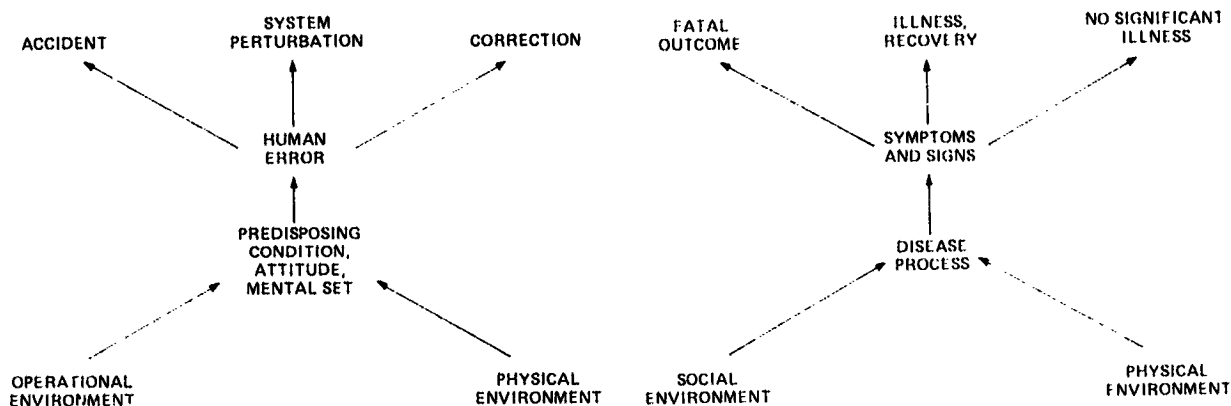
If one is to understand the problem of human error, it would seem necessary to examine cases in which recovery occurred, as well as those which had a fatal outcome. What factors differentiate these classes of errors? Or are they but one class occurring under different sets of circumstances? Or to different sorts of people who respond differently?



More important still is the question of what a human error is. Is it a spontaneous phenomenon — an intermittent disorder which affects people at random? Or can its occurrence be predicted? If so, by what criteria? Or is an error but a manifestation — a symptom — of some underlying disorder in the human mind or body? If so, can we gain an insight into the disease, or diseases, which give rise to these ubiquitous symptoms?



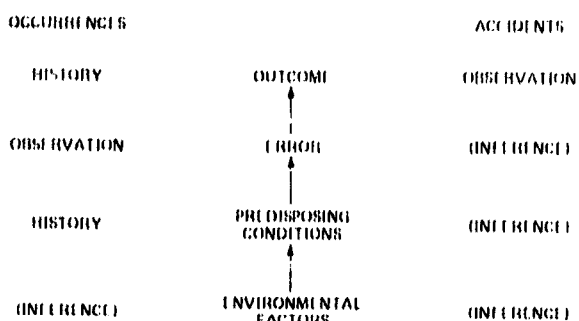
It is instructive to consider human error as a manifestation, or symptom, occurring in the presence of a variety of human conditions, which by virtue of its occurrence produces at least a potential perturbation of the man-machine system of which the human is a part. That perturbation may lead to any of a variety of outcomes. Viewed in this manner, it becomes possible to examine the human attributes and attitudes which give rise to errors. More important, it becomes possible to look beyond the human to the environment in which he is operating, in order to discern factors which may make it more likely that he will err, or less likely that he will recover given an error.



There is a powerful methodological tool for dealing with this sort of problem. Epidemiology is conventionally thought of as a tool for dealing with point-source epidemics of disease, but it is much more. Epidemiological methods have been used successfully for over a century to examine factors in the environment which contribute to a great variety of problems which beset man and animals; present concerns under concerted attack using these methods include the problems of heart disease, cancer, alcoholism and drug addiction, among non-infectious illnesses. Using epidemiological methods, it is possible to examine symptoms in terms of the diseases which produce them, and to study diseases in terms of the factors which determine their incidence, prevalence and often their outcome.

METHODOLOGY

When one is investigating a fatal aircraft accident, it is often necessary to infer the behavior which preceded it. It is more difficult still to infer with any accuracy the attitudes or attributes which may have determined



or contributed to the behavior which presumably caused the accident. Even with cockpit voice recorders, helpful though they have been, the retrospective view of the cockpit is at best clouded and fragmentary. It must also be pointed out that hindsight is not necessarily better than foresight. They are fundamentally different processes. The occurrence of a certain outcome following the demonstration

of a particular phenomenon does not necessarily indicate that the outcome was causally related to the phenomenon, tempting as it may be to draw that conclusion.

It is possible to minimize bias due to this sort of reasoning by examining errors which did not lead to fatal accidents, though the possibility exists that the errors are of different classes, and therefore, not comparable. One very effective way to do this is by direct contact with the pilots and air traffic controllers who have committed the errors. While results with this method are not free of bias, injected either by the reporter or the interviewer, it is possible under the right circumstances to determine fairly precisely what occurred, how it occurred, and sometimes why it occurred. It is usually possible to gain an appreciation of the environment in which the error took place. Sometimes, though by no means always, one can gain an understanding of the psychosocial setting and background of the occurrence.

The NASA Aviation Safety Reporting System, and the flight crew interview studies which preceded it, are attempts to collect a large and comprehensive sample of occurrences in the aviation system, with enough detail about how and why they happened to permit reasonable inferences to be drawn about system factors associated with such occurrences. This voluntary, confidential reporting system was implemented in April, 1976. The System is designed to collect, analyze and disseminate information regarding potential hazards in the aviation system so that appropriate action can be taken to correct problems and thus prevent aircraft accidents. In its first six months of operation, the Aviation Safety Reporting System has received over 2900 reports describing potential threats to aviation safety.

Preliminary analysis of these reports indicates that a considerable fraction of them describe human errors, often in great detail. It has been learned that those who live and work in the aviation system will discuss mistakes they have made, often in exhaustive depth. There is great willingness to examine and analyze the possible reasons for these mistakes. It is also clear that "trivial" errors, given enough of them, may have catastrophic outcomes; study of accidents suggests that no type of human error in aviation should be considered too trivial for detailed study.

Using these techniques, it can be inferred that certain problems in the aviation environment are commonly associated with human errors in aviation operations. Problems in the transfer of information to those responsible

for tactical decision-making, as an instance, appear in nearly 50 percent of the human error incidents examined in detail to date. This, in turn, has led to questions about the types of information which are necessary for efficient operations, the ways in which such information can best be made available to those who need it, and the best ways to present it when it is called for.

But inference is not enough, and historical data, however provocative, proves only that an association exists between a factor and a manifestation. It remains to be proven whether that factor is causally, or non-causally, related to the phenomenon under study. Especially in a very complex man-machine system such as the aviation system, where many factors are interdependent and therefore correlated, it is necessary to take a rigorous approach toward the question of cause and effect, for manipulation of the wrong variable in search of a solution is expensive and may cause more problems than it solves. There is evidence that this has occurred in the area of alerting and warning systems.

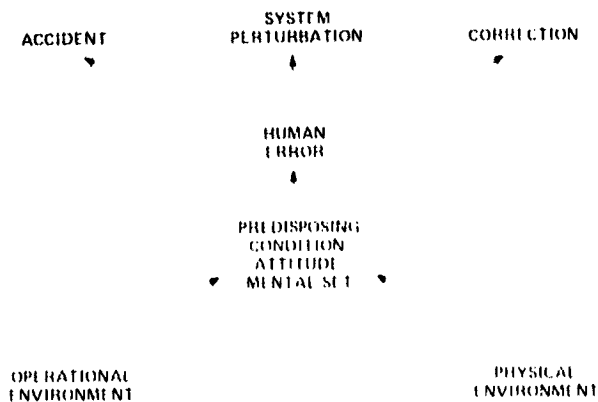
It is necessary to construct a rigorous set of hypotheses and to design experiments with great care if one is to be able to sort out the various factors which may have produced or contributed to a particular unwanted effect in the aviation system. Even then, it may be difficult to partition out the variance associated with uncontrolled variables in the complex environment of aviation operations.

It has become clear, however, that such experiments are absolutely necessary, that they can be performed in a setting which has face validity, and that they can contribute measurably to our understanding of the root causes of human errors in the aviation system. The report which follows (ref. 1) describes a first effort to examine the question of information transfer in the airline cockpit. It illustrates the concepts, techniques, and some of the problems involved in such epidemiological research.



RÉSUMÉ

To summarize, then: several assumptions have been made in order to try to understand more clearly the problem of human error in aviation operations. It has been assumed, first, that errors do not "just happen." They are rather manifestations of the human condition, attitude or mental set at a particular time. That condition is in turn the result of a considerable number of internal and external, or environmental, factors.



It has been assumed further that the best, albeit an imperfect, source of information about the factors contributing to human error is the person who committed the error. We are aware that the reporter may bias his report, but we know of no more authentic source.

We have assumed that persons in the aviation system who volunteer information in circumstances which do not involve personal risk do so for fundamentally altruistic motives. They will therefore attempt to be truthful in their reporting. We are concerned about certain facets of the Aviation Safety Reporting System which require reporting as a prerequisite to avoidance of disciplinary action, for we have been unable thus far to evaluate possible bias due to this factor. We hope in the near future to conduct a study which may shed some light on this problem.

We have assumed that the population of errors from which our sample is drawn contains also the errors which under specific circumstances can lead to aircraft accidents. While there is suggestive evidence that this assumption is justified, there may be specific types of errors which we are not sampling and our conclusions may be biased by the nonrepresentativeness of the population and, therefore, of our sample. The study to which we referred will examine this question as well.

Finally, we have assumed that the concepts and methods of classical epidemiology are appropriate tools for this research. We have assumed that if we choose appropriate hypotheses to explain the phenomena we are examining and inject the appropriate factors in a valid simulated operational setting, we shall be able to observe the phenomena of interest. In at least one experiment thus far, this appears to have been true. If we can now design an appropriate and specific intervention technique to neutralize the hypothesized effect of these factors, repeat the experiment and observe a change in the effect, we believe we shall have reasonably firm evidence that the factor causes the effect, together with some data regarding ways of mitigating the effect in aviation operations.

This is the task we have set ourselves: to attempt, by understanding the factors which cause human errors, to remove or ameliorate the unwanted effects of those factors and thus, hopefully, to make it less likely that serious errors will be committed. We also believe that an understanding of the causes of human error can enable us to design better and more rational methods of coping with the errors when they do occur, in order to improve the likelihood of a uniformly successful outcome. There are many potential points of attack upon a disease once the genesis and course of that disease are understood. Without such understanding, it is nearly impossible to provide more than symptomatic relief from its effects.

REFERENCE

1. Lauber, John K.; Billings, Charles E.; Stevenson, James L.; Rutherford-Smith, H. P.; and Cooper, George E.: Simulation Studies of Air Transport Operational Problems. Aircraft Safety and Operating Problems, NASA SP-416, 1976. (Paper no. 34 of this compilation.)