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ATC SYSTEM ERROR AND APPRAISAL OF CONTROLLER PROFICIENCY

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FOREWORD

The present report was developed prior to the implementation of Agency Order OA 8020.3, establishing an ATS System Error Reporting Program. To a large extent this new system encompasses many of the suggestions and recommendations made in this paper. This report is not intended as a critique of the present system, but rather represents what is considered as desirable in any ATC system-error reporting program.

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I. Introduction.

Air traffic control has become an increasingly complex system involving men and equipment in a continuous and dynamic descision-making function. Future developments point to the rising use of complex equipment, including high-speed computers, as aircraft speeds and the system's load continue to rise. By projecting current trends, it can be anticipated that future system changes involving equipment, personnel, and/or procedures point to the need for longer and longer lead times as complexity grows. The above considerations point to the need for close scrutiny of the ongoing system failures and/or incidents in order to provide the most accurate feedback information for system correction or modification.

The air traffic control (ATC) system prohibits the experimental manipulation of conditions to produce malfunctions and/or incidents and, consequently, information on system malfunction can only come from spontaneous occurrences. Suggestions for the design of an ATC incident-reporting system aimed at maximizing the amount of corrective feedback to the ATC system are presented in this report. The authors do not pretend to imply that their views, which hopefully reflect psychosociological and systems-engineering principles, are completely compatible with current operational practices and administrative directives. But if new attacks are to be made upon the incident problem, then the authors hope that the views contained herein will contribute to such critical thought and discussion as the importance of the problem demands.

II. An Approach to System Error Evaluation.

As a system, air traffic control performs many functions relevant to its prime duty, that of information processing. These functions, at one time or another in the course of system design and development, have been assigned either to man or machine for the purpose of converting inputs to outputs so that the system can process information in accordance with its assigned responsibility of safe, orderly, and expeditious movement of air traffic. An incident is an index of a failure of one of these system functions. The ultimate goal then of an incident-evaluation program should be not just to collect data but to identify both (a) which system function has been compromised and (b) those contributing factors for each incident, in order that "quick-fixes" may become apparent and, more important, that with time an objective delineation of system weaknesses can be supported. Having done this, one is then in a position to recommend remedial action, whether it be training, display modification, changed illumination, etc., as discussed in a previous report.[2] Note the emphasis of this approach on incident evaluations being system oriented, rather than controller oriented, as seems to be observed so often in the usual approach.

The approach taken here admits that the ATC man-machine system will never be perfectly reliable, efficient, and error-free because of the inherent limitations and idiosyncracies of the human component. Deliberate and objective in process, it is slow in providing answers. But this may be a virtue where there is often a tendency to begin shooting in the dark for sources of error and possible solutions. Often there can be a number of facility problem areas confounded with personnel complaints. In this situation a quick-fix based upon seemingly rational judgment can be a risky, if not uneconomical, choice. For example, apparent inefficiency in controller scanning of flight progress boards might be attributed to inadequate training. But the real answer could be improper illumination, poor visual acuity, glare, poor strip design, or inefficient equipment layout.

A schema felt to contain the basic elements for objective ATC system evaluation is presented in Figure 1. The seven-step process begins (a) with the facility investigation of an incident, followed

(b) by careful analysis of the collected facts and apportionment of "blame" to system components. Conceivably, meaningful quick-fixes might become apparent at this point, but decisions to effect major system changes had best wait until sufficient data are at hand to support conjectures. If a decision is made to implement a quick-fix that "looks good," management should be sure that the solution does not compromise already proven design standards; e.g., using sound-absorbing baffles that nullify the gain derived from an efficient overhead-lighting system. Continuing with the schema, each incident report will be filed (c) at some central point within the agency for later statistical analysis (d). Hopefully, the results (e) when subjected to definitive study by research and operations personnel, will reveal those areas (f) contributing significantly to system error together with an indication of the magnitude that each contributes. From microscopic examination of the problems within such areas, recommendations for system modifications emerge (g). Not to be overlooked in the schema is important insight that can be gained from objective periodic appraisal of individual controller performance. Performance appraisal is considered in greater detail below.

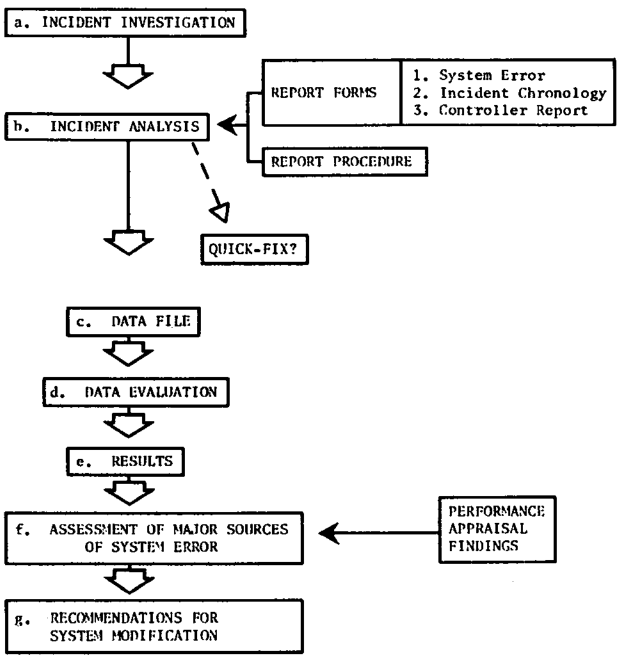

FIGURE 1.—Schema for incident evaluation.

In assessing the degree of controller involvement in an ATC incident, it may be helpful to consider a classification of factors that can determine controller performance. As seen in the list below, poor controller performance can be attributed to a man's job capacity, to the "machinery" with which he works, or to certain factors that determine the context in which man interacts with machine. What this approach acknowledges then is that an incident can be a product of a multiplicity of factors, many of which are beyond control of the controller involved; in colloquial terms, the controller is "sandbagged." It seems inconceivable that an individual controller would be assigned sole responsibility for an incident without knowledge that the man, equipment, and work environment have been first selected so as to minimize the opportunity for system error. This viewpoint should be considered in the design of report forms, in the development of routines for statistical analysis, and in the final stage, in which assessment of system-error sources is made.

DETERMINANTS OF CONTROLLER PERFORMANCE

A. Personnel Capability.
- 1. Selection.
  - a. Ability.
  - b. Experience.
  - c. Personality, attitude, interests, physical fitness.
- 2. Training.

B. The System.
- 1. Design.
  - a. Equipment design; displays and controls.
  - b. Work-space layout.
  - c. Communications networks.
  - d. Memory aids.
  - e. Environmental considerations.
- 2. Operation.
  - a. Workload.
  - b. "Noise."

C. Modifiers of Context.
- 1. Supervision.
- 2. Operating procedures; policy; rules.
- 3. Health and morale.
  - a. Drugs, diet, sleep.
  - b. Family problems as source of mental distraction.
- 4. Work schedule and watch rotation.

In evaluating an incident, it will also be important to identify the principal and secondary controller functions, or behaviors, involved with any contributing factors from the system or the context. Since there will be interviews with controllers, it is important that the investigator carefully weigh any remarks falling within the topic of "morale gripes." After a half-decade of attention from social scientists and industrial-relations personnel, the relationships between morale and worker behavior are still not clearly understood. One cannot say with any credibility, for example, that the happy worker is the "best" worker. So, although all of us would like to have an easier and more enjoyable job, it is important that the investigator distinguish between the discomforts and pressures that are inherent in the task and those that could be attributed to poor environmental conditions, unsatisfactory supervisory practices, etc. Hence, the focus of attention in the present context should be first upon those factors that determine controller performance and only secondarily upon questions of morale.

III. The Philosophy of Corrective Action.

One question that must be answered in this approach to ATC system-error evaluation is to what purpose will incident information be used. This purpose, to a large part, will determine the manner of reporting as well as what will be reported, and calls for the design of a complete system of reporting that takes into account the sources of information, its availability to those who are responsible for reporting it, and, finally, the uses of the information by those who receive it.

Of the possible approaches to reporting errors, one would involve two distinct reporting systems. The first, the "legal" one, would be concerned with who was responsible for the error, assuming, of course, that the error was attributable to performance of a controller. The second reporting system would operate independently of this, for the purpose of getting an objective description of what transpired. The assumption behind this entire system would be that if responsibility is being assessed, not all parties will speak forth with frankness and objectivity, while, on the other hand, they would be willing to speak if there were available a second reporting system not involving penalties. A serious objection to this dual system is that there would come about an undermining of the "legal" system, since the controller could say, "Oh, well, I have ample opportunity to give the information of what actually transpired to the second 'objective' system"; consequently, the assignment of responsibility where there is a personnel error would be come more difficult.

A second possible reporting approach would be to maintain essentially the present system of reporting but to shift the emphasis on awarding penalties. Thus, this system would place very high penalties on failure to report an incident or on incidents where there is evidence of willful negligence. In this manner, the controller who is aware of the incident would be faced with much greater penalties for failure to report than were he to report such an incident. Where errors are attributable to incompetence, we must consider who was responsible in the first place for that controller being in the position to make the error. Anytime a judgment is made that the error was primarily attributable to the incompetence of the controller, this is also a basis for considering if some portion of responsibility lies with his administrative superiors. Therefore, where the error was due not to willful negligence but to incompetence, there is no need to invoke a penalty other than possibly removing the man from active controlling or, in extreme cases, downgrading him to a position of lesser controller responsibility. Downgrading does not necessarily mean the loss of GS level, but shifting over to a less demanding control position. There are additional ways, already in practice, of dealing with the negligent controller or the one who fails to keep proficient in his duties. Low performance ratings can deny him the chance of promotion and ultimately even endanger his job security. Supervisors can cite him for failure to maintain an acceptable level of competence and thus make him ineligible for a within-grade salary increase.

This second approach would also essentially take notice of the fact that some errors represent accidental or nonintentional behavior such as a slip of the lip or a transposition of digits. Obviously, this type of behavior should not be encouraged but, on the other hand, it is not negligence or incompetence. This system of penalties would encourage controllers to take a more objective professional approach to the system problems of air traffic control. Admittedly, there is a tendency not to mention one's own mistakes; however, it should be emphasized to the controller that this admission is professional behavior, since it represents a concern for the task in hand. It also indicates a willingness to adopt an attitude of self-objectivity, which would enhance the amount and quality of information currently being received on system failures. An unreported incident can involve the most serious considerations, since the controller who observes the incident is not always able to determine that it was his fault. In many cases, of course, the incident may be due to a malfunction of equipment. There may be an Omni that needs calibration or other electronic devices that are in need of repair. The controller is only aware, however, that two aircraft have come too close together and is not necessarily aware of all the causes behind this. Under the present system, if he felt that the incident would go unnoticed, he might not report it. On the other hand, if he recognized that there would be the severest penalties for covering it up, he would not wish to run the risk of being discovered. At any rate, we must encourage, by some means or another, a greater willingness to report the occurrences of incidents. Increasing the penalty for error when the controller is involved in the incident tends to discourage reporting. It is highly desirable to develop an incident-reporting system that would encourage the controller to take a more objective analytical position with respect to his behavior and failure.[3] With high penalties being assessed for errors, however, it is unlikely that the controller will take this position; he will probably become defensive or apathetic. Consequently, it is felt that putting the penalties on failure to report and/or negligence would encourage the controller to have a greater willingness to admit honest mistakes. It also follows that he would be more predisposed to reveal his thinking, his feelings, his reactions, and his part in the incident that precipitated the event. Errors are a part of human functions that can never be completely eliminated. Furthermore, not every controller error reflects deficient capability. It is contended by some that only the better controllers become involved in incidents since it is these men who man the high-load positions. The analogy may be drawn with the baseball shortstop, where the better fielders usually commit more errors since they involve themselves in the more difficult attempts.

Another point should be raised, which, while independent of the type of reporting system or penalty system established, still represents a weakness in the present system. Very often where there is controller error, recommendations are made for training, with the controller in some cases being sent through the entire facility training program. It is highly questionable if this training is effective since it represents a shotgun approach; that is, a tacit admission on the part of the administration that "We don't know what particular deficiency led to this error; therefore, train him in everything." Is it not reasonable to assume that in general the controller is a capable and efficient person who has made a mistake? To assume that he is completely incompetent and needs a total retraining raises serious doubts concerning the management system permitting such an unqualified man to work.

Following an incident and its analysis, the analysis should be sent back to the controller, where he, with the aid of a senior controller, would review the case to ascertain where he has made his error and to determine a custom program of retraining. Psychologically, this would have maximal benefit since the controller would be directly involved in developing the analysis. This element is lacking in lecture approaches and reviews of material, most of which he has long since mastered. This self-critique should encourage greater objectivity and self-analysis on the part of the controller. The controller and his advisor would be formally obligated to state their opinions as to the determinants of the controller's error and to further indicate what remedial action was undertaken. This procedure would also indicate that the administration is not simply concerned with pointing out who was at fault but is concerned with finding out who was at fault in order that the controller himself can actively correct what has gone wrong. From the point of view of maximizing system efficiency, the prime reason one would want to find out who made the error is in the hope that the controller could correct his procedure.

IV. Incident Reporting Format.

It should be clear that these views dictated a new approach to incident-report-form design. Facility-incident reviews often focus upon the air traffic procedure or rule that has been violated; e.g., failure to maintain separation. Regional offices sometimes consider broad categories of classification that appear to overlap; e.g., attention, coordination, technique, and communication. These approaches tell the systems analyst little about what aspects of the system were compromised. If one is to seek sources of system error in terms of the human functions assigned to and involved in that system's operation, then the required data from incident investigations obviously must be phrased in human-function terminology.

A discussion of the various levels of human functioning, including related sensory, attentional, and memory processes, is beyond the scope of this paper.[1] An example, however, may provide clarification.

Suppose that a radar controller failed to maintain separation between two aircraft. One might first determine whether the radar display was adequate and that the controller had no visual problems. Then, one might ask if the controller was briefed on new procedures at his position and was he experienced in the tasks required? Was his attention focused upon the targets in question? Next, did he identify these targets (from knowledge of their speed, track and position)? Finally, having identified the targets, why wasn't a confliction interpreted? Answers to such questions have implications for corrective actions. The purpose of selection is to screen out operators who fall below a given standard applicable to a particular sense mode. Attentional sets and task routines are established through training. If identifying is involved, the purpose of training is to establish the standards or models found in memory that are required by this function. Selection can also enter here to pick out those individuals who can readily acquire and store such models. If the error is in interpreting, then the analyst must determine that the prior function of identifying can be performed and that the required models have been established by training. Procedural manuals and checklists come under scrutiny insofar as they (a) establish different behavior patterns that are needed as the controller moves from one station to another, or (b) become aids in maintaining long-term memory retention of models and routines.

In Table 1, Appendix, is listed, in the first four sections, a total of 21 behaviors, phrased in function terminology, that could lead to an incident. The breakdown into four categories—sensing, memory, judgment, and communication—is an arbitrary one. It is likely that whoever is charged with the duty of incident evaluation at a facility would require training in the use of a form containing such items because of the difficulty inherent in isolating the primary function at fault.

Items such as appear in Table 1 are the heart of the whole incident report, and the identification of one item as the primary cause is *raison d'etre* of the entire investigation process.

The report form itself should be limited to no more than four pages and should be referred to as a system-error, rather than a deviation, report in accordance with the philosophy of this paper. Thus, it would not necessarily focus attention on any particular controller or controllers. The first page should include the following: information on the facilities involved; the date of the incident and time of occurrence; a list of the facility personnel involved and their ratings; a list of aircraft, vehicles, or objects involved, to include flight plans; how the incident was reported and by whom; data on the route structure; weather information; type of control (radar, nonradar); beaconry data; standards and procedures involved. The second page would be devoted to a summary narrative. The third page would include Table 1, the work-bed from which the primary and contributing factors are identified. The fourth page would have space for recommendations for remedial action and boxes for the responsible officer to indicate whether appropriate data are being attached, to include: airway-structure and flight-path sketches; a sketch of the facility layout as appropriate to the analysis of the incident; letters of agreement as appropriate; flight strips and tape recordings of controller-pilot communications. Also, it may be desirable to have on this page some indication of review action.

Also recommended is the submission of an "ATC Personnel Report" for each controller or supervisor involved in the incident. This form would be completed, in part, by the responsible officer and also by the controller/supervisor involved. It would contain the name of the individual, his facility, age, grade, and marital status; time entered into duty, time in control functions, and months in that function; the controller's experience, with number and type of facilities worked, their locations, and his length of service at these locations; his ATC training and previous history of incidents; his work schedule for the previous months; the amount of sleep the previous "night"; information on recent physical examinations, their dates, and results in terms of current health; recent illnesses and use of medications. This adjunct form would also contain data on the number of aircraft under this particular individual's control before, at the time of, and after the incident. The above items would take up approximately one-third of this page; the remainder of the page would be devoted to space for several paragraphs wherein the controller could make a personal statement of his involvement in the incident; perhaps room for a paragraph statement on his recommendations for remedial action; and finally, a brief statement as to whether the controller agrees or disagrees with the findings of the facility review committee.

Finally, we encourage the use of an incident-chronology form (Table 2, Appendix) to aid in the time-series analysis of the involved parties. This should save considerable time and confusion in determining "who did what, when and where?"

V. Implementation and Data Analysis.

The best possible form and procedure should be developed for implementation. Haste in introducing a new report form into the field without adequate pretesting could endanger the success of the program. Special consideration should be given to the manner in which the program would be introduced into the field, including perhaps a manual describing the purpose of the new system, with an example of how the report should be completed.

In establishing the new report format, some thought will be required to make it compatible with (a) not only the kinds of questions to be answered but (b) the coding system to employ for rapid data retrieval and statistical analysis. For ease and economy of data processing, initially an edge-punch card system would seem sufficient, unless access to a computer were available. A feature of this system is the ability to derive summary statistics rapidly and accurately. In order to properly conduct the kinds of analytical studies that this system is capable of generating, personnel versed in system research and statistics are a necessity.

VI. Performance Appraisal.

As indicated earlier, we feel that periodic appraisals of controller proficiency should become an intimate part of the effort to determine system effectiveness. Although one can hear complaints that there are too few "good" controllers, there has been no clear-cut case presented to show that the present group of controllers constitute a major source of system inefficiency. One can just as readily indict equipment design or layout, supervision, or operating procedures. Admittedly, since the controller constitutes such a critical communication link in the ATC system, inefficient performance is cause for concern; but objective data are needed on proper use of phraseologies, visual-search efficiency, flight-strip marking, etc., if individual and group weaknesses are to be pinpointed and corrective actions are to become clear. Problems begin with the new controller. When is he ready to be put on a position? Then, later, how well is he progressing? Can he take on more difficult assignments? Should he be promoted? And finally, when traffic gets heavy, the supervisor must ask, "Should I keep him on the position?" What guidelines does the supervisor have to follow in the latter case? If he makes a poor decision and a near midair collision results, does the supervisor share part of the blame?

A formalized proficiency rating could serve as a guideline for position-assignment choices, reducing the conflict inherent in supervisory decision. It could be used to identify areas of training and as a basis for personnel actions. In interviews with controllers, the supervisor would have an objective basis upon which to discuss individual actions.

An objective and valid index of controller performance on the job would also serve to answer the question of the relationship of controller proficiency and incident involvement. The relationship could very well be curvilinear; that is, top-quality controllers who man high-stress positions and poor controllers would have more incidents than the average controller.

A special checklist would be required, and a 20-item prototype is presented in Table 3, Appendix. This checklist is not intended to be any formal merit-rating system, but merely a means to identify elements of proficiency that need to be improved. For optimum benefit, it probably should be completed monthly by the controller's crew chief. Since supervisor personnel would ultimately be responsible for the appraisal findings, they accordingly would have to be prepared to demonstrate the appropriate behaviors basic to shaping the growth of their subordinates.

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APPENDIX

Table 1. Identification of Incident Causes

Category	Place one check under A to indicate which of the items below was the primary cause of the incident. Also check any of the items that may have been contributing factors, indicating Major (B) or Minor (C).	Primary A	Contributing: Major B	Contributing: C Minor
SENSING	—failure to detect critical aircraft, vehicles, radar targets, or obstacles.			
	—failure to scan flight strips for significant data (e.g., altitude).			
	—misidentification of aircraft or radar target.			
	—acceptance of flight strip or pilot readback with erroneous data.			
	—acceptance of flight strip on nonexisting flight.			
	—failure to acknowledge (detect) radio or verbal communication.			
	—misreading of display data (flight strips, etc.).			
	—misunderstanding of radio or verbal communication ("hears it wrong").			
	—misinterprets other controller's response to query (nonpositive communication).			
MEMORY	—failure to record, retain, or pass on critical information.			
	—failure to give instructions or information needed by pilot when able to do so.			
JUDGMENT	—error in judgment of and/or computation of aircraft speed, direction, or distance.			
	—failure to comprehend significance of situation, to see problem developing (e.g., aircraft position report and posted data are incongruent).			
	—failure to note discrepancy of information at hand (e.g. ETA incongruent with reported airspeed).			
	—use of poor judgment or faulty reasoning in making a decision.			
	—failure to plan, coordinate, or take initiative when indicated by situation.			
	—makes unreasonable assumption about airspeed, aircraft position, or altitude.			
COMMUNICATION	—makes speech error in transmission of information or instructions to pilot or other ATC or ground personnel.			
	—marks strip or moves "boat" incorrectly.			
	—marks wrong strip or moves wrong "boat."			
	—incorrect strip posting (e.g., wrong fix).			
OPERATIONS	—poor supervisory coordination and judgment.			
	—"static" or erroneous information from air carrier, pilot, or ground personnel.			
	—shortage of qualified controllers to operate positions effectively.			
	—shortage of qualified supervision at time of incident.			
	—inadequate preduty familiarization.			
	—ambiguity apparent in procedures, standards, or letters of agreement.			
	—controller proficiency; controller operating above his skill level or "filling in" at unfamiliar position.			
TASK ENVIRONMENT	—inefficient equipment or workspace layout.			
	—inefficient communication channels.			
	—unreliable or malfunctioning equipment or radio communications.			
	—equipment unavailable or out of service.			
	—vision reduced or obscured—weather, airfield construction, radar clutter, etc.			
OTHER	—heating and ventilation; lighting, glare, noise.			
	—distractions from horseplay or VIP visitors.			
	—work attitude; job satisfaction; personal problems.			
	—controlled health, especially vision, hearing.			
	—fatigue, drugs.			
	—work schedule; watch rotation.			

Table 2. Incident Chronology

No. ________

Facility ________
Date ________
By ________

Instructions: Briefly note location, action, or activity of controller/supervisor/aircraft/vehicle at critical minutes of involvement. Use additional sheets if required.

Time	Controller/Supervisor	Controller/Supervisor	Aircraft	Aircraft/Vehicle

Table 3. Controller Performance Checklist

Name____________________ Date____________ By________________

ITEM	Satsifactory	Needs Improvement	Unsatisfactory
1. Use of proper phraseology.			
2. Completeness of strip marking.			
3. Legibility of strip marking.			
4. Quality of voice transmissions.			
5. Scanning efficiency (tower, radar, boards).			
6. Keeps boards in order—strips sequenced, deadwood removed.			
7. Accuracy of computations.			
8. Effectiveness of long-range control planning.			
9. Coordinates effectively and judiciously.			
10. Keeps pilots posted on traffic, weather, etc.			
11. Uses good judgment in decision-making.			
12. Accurate memory; stores data without need of memory aids.			
13. Familiarity with procedures and letters of agreement.			
14. Team cooperation; responsiveness.			
15. Work attitude; conduct.			
16. Initiative; knows when to take action.			
17. Ability to handle emergencies or heavy traffic under pressure.			
18. Willingness to accept responsibility.			
19. Knowledge of *own* capabilities, limitations.			
20. Awareness of *others'* capabilities, limitations.			