

## **Efficient Decision Strategies on the Flight Deck**

Ute Fischer, Judith Orasanu, & Mike Montalvo  
NASA Ames Research Center  
Moffett Field, CA

Decision making in aircraft crews becomes most pertinent when abnormal situations occur, such as system malfunctions, or bad weather conditions. In these circumstances, workload is high: Crews have to determine the nature of their problem, and what course of action they should take. Moreover, additional tasks have to be performed aside from standard procedures. On the other hand, we know from psychological research that humans can attend to and interpret only a limited amount of information at any given point in time (e.g., Broadbent, 1982; Miller, 1956). In light of these constraints, both crew productivity and flight safety depend critically on efficient crew problem solving and decision making. But what constitutes efficient problem solving and decision making behavior?

Efficient behavior is generally understood as “productive of desired effects; esp.: productive without waste” (Webster's 3rd). We need to modify this generic definition in several ways to be able to apply it to aeronautical decision making. Orasanu et al. (1993) list Situation Assessment, Risk Assessment, and Time Assessment as integral parts of decision making in the cockpit. Accordingly, efficient cockpit decision making behavior could be characterized as follows: Efficient crews gather crucial information that is needed to make as optimal a decision as possible under the given circumstances, and they are doing so without wasting mental energy, time and money. The important phrase in this context is “under the given circumstances.” The efficiency of decision making behavior cannot be determined independent of situational constraints; i.e., the nature of the problem, the risk involved, time constraints, and crew size (Orasanu, 1993).

However, to date we know little about how efficient crew problem solving and decision making behavior changes as a function of different situational constraints. Previous work (Mosier, 1991; Predmore, 1992) has focused on crew performance in the context of a specific problem type. The present study differs from these analyses in two respects. First, we describe how aircraft crews cope with different types of problems. And second, we attempt to discern characteristics of optimal task management behavior. For this reason, we contrasted the behavior of more effective and less effective crews. Underlying this approach is the assumption that crews who commit few operational errors also demonstrate optimal problem solving and decision making behavior.

### **Method**

Our data were drawn from a two-day B-727 full mission simulation study conducted by Chidester et al. (1990). The study was comprised of two scenarios which confronted the subjects with various system malfunctions and/or bad weather conditions. Twenty-three three-member commercial airline crews participated as subjects.

The performance of the crews were videotaped and their verbal interactions transcribed. Crew performance data were collected from two sources (1) expert observation, and (2) video coding of operational errors such as poor airplane control and omissions of required procedures. Operational errors were further classified in terms of their severity (see Chidester et al. for further details).

From the total of 23 crews, we selected 20 crews - 10 crews per scenario - for our analyses. For each scenario, we took the five crews that had committed the fewest operational errors (= more effective crews), and the five crews with the highest number of operational errors (= less effective crews). Not all crews were consistent in their

performance, and more effective and less effective crews were not completely identical for the two scenarios.

We analyzed the following problem situations in the day 1 scenario: The crews flew from Sacramento to Los Angeles. During descent, the stabilizer ran away and eventually jammed in a nose-down position. Soon after, the oil filter bypass light for no. 2 engine illuminated and the oil pressure gauge gave a cautionary reading. On day 2, the problem situation was as follows: The crews were required to conduct a missed approach at Sacramento due to RVR below minimums. During climb-out, the hydraulic system A lost all fluid. As a result of this failure, the gear and the flaps had to be extended by alternate means.

Our analyses focused on the following problems: (1) Stabilizer trim problem, (2) Low oil pressure problem, (3) decision on alternate landing site after the missed approach, (4) coordinating alternate flap and gear extension. These problems represent different types of problems (see Orasanu et al., 1993, for a detailed characterization of problem types). The stabilizer trim problem is an example of a rule-based problem. Once the crews had determined the nature of their problem, they simply had to initiate the appropriate checklist procedure. Problem (2) and (3) are choice problems. The low oil pressure confronted the crews with the decision on whether or not to shut engine no. 2 down. The missed approach required the crews to choose an alternate. Problem (4) represents a scheduling problem. The alternate flap and the gear extension had to be coordinated.

Our analyses utilized a variety of dependent measures: Elapsed time from occurrence of a problem and initiation of the appropriate checklist; completeness of procedures; sequence of crew events; information requests and planning statements.

## Results and Discussion

### Rule-based problem: Coping with a runaway/jammed stabilizer

In scenario 1, while the crews were preparing for descent, the vertical stabilizer trim ran away, and eventually jammed in a nose-down position. Both situations are covered by checklist procedures. From a decision making point of view, the interesting aspect of this situation lies in the correct diagnosis of the problem. Once the runaway stabilizer stopped, the crews had to make sure that the malfunction was not caused by a faulty electrical system, and that the stabilizer indeed was jammed. Table 1 shows that more effective and less effective crews needed approximately the same amount of time to initiate the Runaway Stabilizer Checklist. Whereas only the more effective group completed this checklist, most crews did the Jammed Stabilizer Landing Checklist. These findings indicate that the more effective crews spent more time in diagnosing the problem. By going through the runaway checklist, they ruled out alternative causes of the problem. Admittedly, all crews diagnosed the problem correctly, and initiated the appropriate procedures. However, only the more effective crews took steps to prevent misjudgment and fruitless problem solving efforts.

**Table 1**  
**Coping with Runaway/Jammed Stabilizer**

	More effective Crews	Less effective Crews
Time elapsed between occurrence of rway trim and initiation of checklist	2:41 min	2 min
No. of crews that completed Runaway checklist	4	0
No. of crews that completed Jammed Stabilizer Landing Check	5	4

### Choice Problem

1. Choice of action after low oil pressure light illuminated: For nine of the ten crews that we analyzed, the oil pressure light illuminated while they were working on the stabilizer problem<sup>1)</sup>. The crews thus had to make two decisions. First, they had to decide on what to do with the no. 2 engine. Given a cautionary oil pressure gauge reading, the checklist left them with a choice. At the Captain's discretion, they could either shut the engine down, or reduce the thrust to idle. Second, the crews had to decide on how to distribute their efforts between the control and the engine problem.

If a crew chose to shut the engine down, they had to complete additional checklist procedures, and possibly dump fuel. Both procedures would increase their workload considerably. Furthermore, the crew would lose one generator. The other option, reducing the thrust to idle, kept the generator intact for use during landing. As can be seen in Table 2, the majority of crews opted to put the thrust of no. 2 engine to idle.

**Table 2**  
**Decision regarding engine problem**

	More effective Crews	Less effective Crews
No. of crews that reduced thrust to idle	5	3
No. of crews that shut engine down	0	2

Differences between more and less effective crews were observed with respect to their coordination of the engine and the control problem. Sequence (a) and (b) in Figure 1 display how more effective crews allocated their resources. Crews that followed sequence (a), postponed the ongoing stabilizer checklist procedures and immediately dealt with the engine problem. After completion of the appropriate checklist and their decision to put the engine to idle, they resumed the stabilizer checklists. Alternatively, as depicted in Sequence (b), three of the more effective crews completed the control problem first before they finalized their decision concerning the engine problem. These crews briefly discussed the level of oil pressure, oil temperature, and oil quantity of engine no. 2 in response to the oil pressure warning light. Once they had determined that there was no immediate danger, they reached the preliminary decision to monitor the engine until they were finished with the stabilizer checklists. The sequence of monitoring->preliminary decision->monitoring->final decision is mentioned in Mosier (1991) as the predominant strategy of expert pilots.

As Sequence (c) shows, less effective crews traded one problem for the other. They either dropped the control problem once the oil pressure warning light illuminated, or they initially disregarded the engine problem, and turned to it only after they had completed all procedures required for the control problem. Other crews immediately decided to reduce the engine thrust to idle, and never verified this decision with the appropriate checklist (= Sequence d).

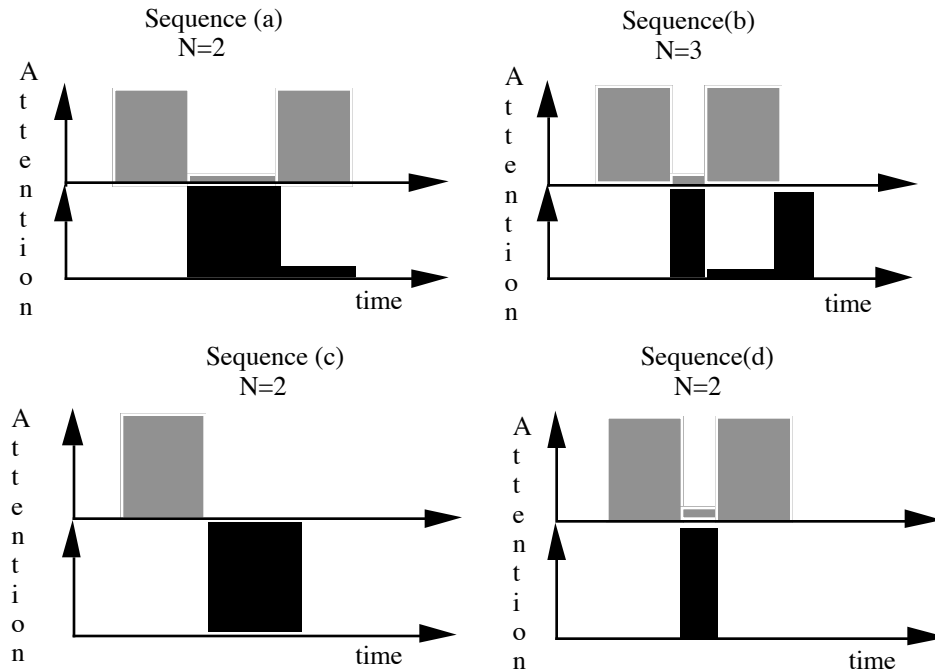
More effective crews foregrounded one problem at a given point in time, and kept the other problem "running" in the background. By switching back and forth between foreground and background, they were able to cope with two problems in parallel without wearing themselves out. More effective crews apparently did not isolate the engine

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<sup>1)</sup> One crew had already completed the jammed stabilizer checklist when the engine problem occurred and will be excluded from our analyses.

problem from the control problem. Their decision to reduce the thrust to idle was sensitive to the constraints imposed by the jammed stabilizer. Less effective crews, in contrast, did not appreciate the complexity of the situation. They got absorbed with one problem and lost sight of the other. They were also more likely to shut engine no. 2 down. This decision required the crew to land in an abnormal configuration.

**Figure 1**  
**Coordinating Engine Problem and Control Problem**

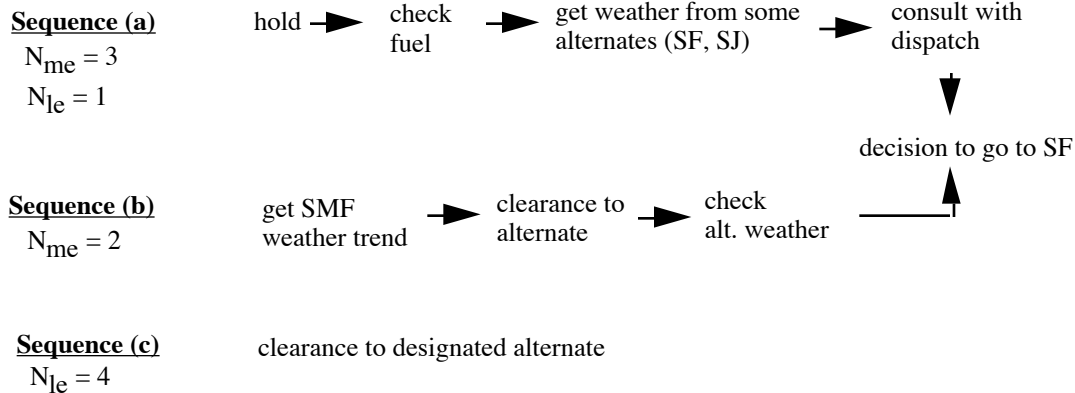


2. Choice of alternate after a missed approach: In the day 2 scenario, the crews conducted a missed approach at Sacramento due to RVR below minimums. The crews then had to decide whether they wanted to try a second approach, or divert to another airport, and in case of a diversion, what alternate would be best. The scenario was designed in such a way that all crews ultimately had to divert to San Francisco. The crews, however, took different steps to reach this decision. Two sequences of crew events were observed for more effective crews and are depicted in (a) and (b) of Figure 2. Three crews requested a holding pattern, checked their fuel, got updated weather reports from some candidate alternates and consulted with dispatch. Based on the obtained information, they decided to go to San Francisco. Two crews asked for the weather trend in Sacramento, and since RVR was reported unchanged requested clearance either to San José, their designated alternate, or to San Francisco, the alternative the crew had agreed upon prior to the missed approach. Only after they had received clearance to their alternate, did the crews do a weather check for this airport. This information made the crew that had originally decided on San José, change to San Francisco. The behavior of four less effective crews is shown in Sequence (c). The crews immediately requested clearance to their designated alternate, San José, and never verified this decision. They changed their alternate to San Francisco, once they were advised by ATC that weather in San José was deteriorating.

As Sequence (a) and (b) demonstrate, more effective crews responded to the task demands of this choice situation in two alternative ways. Some created a situation in which they had time to consider several options simultaneously. Others evaluated

options serially: They quickly settled on a likely solution, checked on the appropriateness of their choice, and if required, generated a new candidate (see Mosier, 1990, for a similar interpretation). A different strategy can be discerned for the less effective crews that went for their designated alternate. Unlike the more effective crews, they never followed up on their decision. In so doing, they reduced the choice problem to a simple condition-action problem: If you cannot land at your destination, you divert to your designated alternate. That is, they followed a rule instead of making a choice.

**Figure 2**  
**Choice of alternate: Sequence of Crew Events**



Legend:  $N_{me}$ : Number of more effective crews  
 $N_{le}$ : Number of less effective crews

Scheduling Problem: Scheduling flaps and gear extension

During the missed approach, the hydraulic system A failed. As a result of this failure, the gear and flaps had to be extended by alternate means. In coping with this problem, the crews had to make several decisions: Which procedure, flaps or gear, should they do first? When should they do each procedure? And, who is to do each?

**Table 3**  
**Scheduling flap and gear extension**

	More effective Crews	Less effective Crews
Sequence	Gear -> Flaps (N=4)	Gear -> Flaps (N=4)
Timing	Gear early /in time (N=4) Flaps early (N=5)	Gear early (N=5) Flaps early/in time (N=2)
Preview	2 Procedures (N=3) 1 Procedure (N=2)	2 Procedures (N=0) 1 Procedure (N=0)
Structure	procedure called by CA 60% of time	procedure called by CA 27% of time
Actor	CA and SO (N=5)	FO and SO (N=3)

As can be seen in Table 3, most crews extended the gear first and then the flaps. All crews started the gear extension early or in time, but only the more effective crews extended the flaps early. Performance differences between more effective crews and less effective crews were most pronounced with respect to previewing required checklist procedures and structuring the task. All more effective crews, but none of the less effective crews, read through the required checklist procedures prior to their implementation, and their captains played an active role in structuring the tasks and in performing them. More effective crews prepared themselves for the upcoming tasks: They knew what laid ahead, and were thus able to structure their workload. Since less effective crews did little planning, they were controlled by the task demands. They were reactive to them, and thus more likely to run out of time.

### Summary and Conclusion

Our analyses showed that more effective crews were also efficient problem solvers. In their decision making, they accounted for the complexity of the situation while they kept their mental workload manageable. This aspect of their behavior was the distinguishing characteristics of more effective crews. Less effective crews lacked sensitivity to contextual constraints, and were more likely to simplify problem situations. The contrast between more effective and less effective crews highlights a shortcoming of the dictionary definition stated previously. According to this definition, less effective crews performed efficiently: They were able to land safely, and certainly without wasting mental energy, time and money. Yet, we found that they did not sufficiently appreciate the nature of a given problem. Efficient behavior thus needs to be defined with respect to both task demands and cognitive economy. How situational complexity and cognitive economy are balanced, depends on the characteristics of the situation, such as problem type, risk involved, time constraints, and availability of resources. The implication for crew resource management training is clear: Curriculum and assessment procedures need to reflect the context-dependency of efficient decision making behavior.

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