AVIATION ACCIDENTS AND THE 'THEORY OF THE SITUATION'[1]

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ABSTRACT

Flight crews can never be entirely certain that they know for sure the situation of their flight. Inevitably, they develop 'theories of the situation'--a set of goals, beliefs, and behaviors that provides a coherent picture of what is happening and what action is appropriate. In many routine situations, those theories accord so closely with reality, that there is little stimulus to be concerned about the validity and appropriateness of the theory. In more complex and difficult situations, the chances of error in the theory become much higher. The skills and willingness of a flight crew to be alert to possible errors in the theory become critical to their effectiveness and their ability to ensure a safe flight.

The paper identifies several major factors that determine the likelihood that a faulty theory will be detected and revised:

1. The 'theories of practice' that pilots have developed through training and experience--and particularly the degree to which those theories build in inquiry and testing in situations of confusion, anomaly, and crisis.

2. The abilities of crew members to combine skills in advocacy and inquiry.

3.. The management skills and style of the captain.

4. The degree to which the role system in the cockpit is well understood, and procedures for role-modification are mutually shared.

All of this has implications for the training of pilots. It is, of course, critical that they receive training in all of the technical aspects of flying an airplane. But it is equally critical that they learn to recognize their own historic patterns for learning, for relating with others, and for managing. They need to understand how to combine

authority with learning, fast response time with flexibility, precision and clarity with willingness to modify. They need to understand the dynamics of role systems, how to create an effective and mutually understood set of role relationships, and how to modify those relationships quickly without creating confusion, overlaps and gaps.

---The captain of a 727 believes he is cleared to an altitude of 1800 feet, even though his approach chart indicates that the altitude is unsafe. Even after noting the problem and discussing it with the crew, he takes no action because he believes ground control would not have cleared him if there were a problem. The plane crashes, and 92 people die.

---An airline crew is having a problem with their plane's landing gear. They neither consult the manual nor ask for help from ground support, either of which might have shown them how to solve the problem. At landing, part of the landing gear collapses and the plane skids off the runway, causing considerable damage to the plane (but no injuries to passengers).

---The crew of a 1011 discovers during an approach that the light on their nose gear is not on, and begin to circle while attempting to correct the problem. The crew apparently assume that altitude is being monitored, but fail to detect an unintended descent. The plane crashes on a clear night. 99 people are killed, and 77 others are injured.

In each case, the captain (or the entire crew) was operating on the basis of a 'theory of the situation' -- a set of beliefs about what was happening and what actions it was appropriate to take. In each case, there was data available to indicate that the theory of the situation was in error. In the first case, the contradictory data was assumed away. In the second case, the crew did not seek data that might have alerted them to their error. In the third, the crew focused so heavily on one element of the situation (the nose gear light), that they inattended to easily available data that would have alerted them to a serious problem. In each case, the error in the theory of the situation led to erroneous action, and in turn to accident or disaster.

If an erroneous 'theory of the situation' (TOS) can lead to serious errors, it become important to explore several related questions:

1. How do pilots (and other humans) create a TOS?

2. What are the factors in background and experience which influence the TOS that a pilot is likely to use?

3. How can education and training activities reduce the probability of errors in a TOS?

4. What are the situational factors that increase the likelihood that pilots will recognize errors in their TOS?

A. What determines the theory of the situation?

The TOS is a short-term theory used by an individual to analyze and make decisions about the immediate environment. As individuals move through different situations, their TOS's change continually. The TOS 'I am in the supermarket buying food' is very different from the TOS 'I am landing a 727 under very difficult weather conditions'. Human effectiveness depends heavily on the degree of correspondence between a TOS and the environment. Error occurs when a TOS and the environment are mismatched. An example is the case in which the crew assumed that the altitude must be safe because they had already received approach clearance from ground control.

The TOS that an individual uses in any given situation is determined by long-term characteristics of the person, short-term characteristics of the situation, and by the interaction between the two.

We can divide the long-term characteristics of the person into two major categories: (1) fundamental cognitive and behavioral parameters in humans; (2) the 'theory of practice' that informs the behavior of a particular individual. The latter may be viewed as a long-term theory (i.e., a theory which is relatively stable, and evolves only through relatively slow, developmental processes). The 'theory of practice' is used by the individual to design, test and implement 'theories of the situation'. Without a theory of practice, the individual could not have any coherent understanding of a situation.

1. Cognitive and Behavioral Parameters

There are very important limits on human cognition. Humans can attend to only a very limited number of discrete phenomena at any one time, and have very severe limits on short-term memory. What constitutes a 'discrete phenomenon' is heavily dependent on prior learning. I am not a pilot, and when I look at the controls on an airplane (even a very small, propellor plane), I find the entire thing confusing. I have never learned a set of 'patterns' that would enable me to organize a large number of discrete bits of information into a single, organized concept. A trained pilot could look at the instruments for a few seconds, and would know a great deal about the situation of the plane. I could look at the same instruments for several hours, and still know almost nothing. Patterns or concepts are stored in long-term memory, and require time and effort to learn. Once learned, however, they can be used with enormous speed and accuracy. The pilot who 'seems to have a sixth sense for knowing just what's happening at any given moment' is a pilot who has acquired over time an unusually powerful set of cognitive patterns. While a pattern is being learned, the pilot needs to spend a considerable amount of time consciously and explicitly attending to the information subsumed by the pattern. It is a slow, self-conscious process of organizing discrete bits into a coherent pattern, and storing the pattern in long-term memory. Once the pattern is well-learned, however, it can be used quickly and with no conscious attention at all. The individual can use the pattern without thinking about it, and may not be able to identify what pattern he is using.

The behavioral equivalent to a pattern is a 'skill'. Just as a pattern is built up through the organization of a number of discrete bits of information, a skill is built up through the organization of a number of discrete, molecular behaviors into a molar pattern. Learning a skill requires time, effort, practice, and thought. But once the skill is learned, it can be used in the same way as a well-learned pattern - quickly, effortlessly, and tacitly. It is in fact essential to skilled performance that it become tacit -- that the individual is no longer conscious of the individual components of the skill. Consciousness of those components would retard or even disrupt the execution of the skill. A simple example is typing skill. I can type much more rapidly than I can write longhand, but my typing rate slows down by about 90% if I try to think about which finger I will use to type each letter. My speed will also decline (and I will make more errors) if I try to type a text consisting of nonsense syllables or written in an unfamiliar foreign language. Either of those conditions is outside of my skill range. With practice, I could learn to type nonsense syllables or Swedish texts with high efficiency, but as yet I have felt no need to develop either skill.

The major implications of these parameters for piloting an airplane are:

1. The capacity of a pilot to cope with increasing complex situations will depend on the patterns and skills that the pilot has developed.

2. When situations occur which go outside of learned patterns and skills, the pilot's performance will slow markedly, and the risk of cognitive or behavioral overload will increase

markedly. (This is supported by the work of Ruffell Smith, 1979.)

2. Theories of Practice

Earlier, I introduced the notion of a TOS, which is short-term and situational, and a theory of practice (TOP), which is more general and longer-term. A pilot's TOS changes continually during a single flight; the pilot's TOP (i.e., concepts and skills for flying an airplane) changes very little during a typical flight.

The TOS and TOP are both examples of 'theories for action' (Argyris and Schon, 1974; Bolman, 1974). Humans always operate in environments that are so complex that it is difficult or impossible to attend to everything. The question arises: how do they select? The action-theoretic proposal is that individuals develop theories for action: cognitive and behavioral frameworks that guide them in deciding what variables to attend to, what information to seek, what causal relationships to expect, and what actions to take. The pattern and regularity in any individual's behavior is seen as stemming from a learned program that informs the individual's choices and, if accurately described, can be used to predict the individual's behavior.

That program, or theory for action, can be viewed as containing four major components:

1. Core values: basic criteria for making choices.
2. Beliefs: beliefs or hypotheses about the experienced world, including beliefs about oneself, about one's professional role, about people, about situational contingencies, etc.
3. Skills: learned behavior patterns.
4. Outcomes: consequences of behavior, which feed back to influence (confirm, modify, disconfirm) existing core values, assumptions, and skills.

Argyris and Schon (1974) distinguish two versions of the theory that informs an individual's behavior. The espoused theory represents an individual's own explanation or account of his or her behavior; it is the conscious, cognitive map that an individual uses to explain and to predict his or her own behavior. The theory-in-use is the theory that validly predicts what an individual will do; it is the implicit program that guides an individual's choices.

The distinction between espoused theory and theory-in-use is vital because the two are often different or discrepant. The espoused theory is necessarily incomplete for one reason already discussed: it is essential to skilled behavior that consideration of details become tacit and subsumed under a cognitive pattern or behavioral skill. More troublesome than incompleteness of the espoused theory is irrelevance or direct contradiction between espoused theory and theory-in-use. Under those circumstances, individuals are unaware of important elements of their behavior, and are unreliable in describing and predicting their behavior.

A basic reason the two theories are often discrepant is that they were learned in response to somewhat different environmental contingencies. Espoused theory is often shaped as much or more by considerations of positive self-presentation as by accuracy of self-presentation. Theory-in-use is shaped by environmental responses to specific behavior. I learned as a child to espouse honesty as a general value, and was not taught to say about myself, "Sometimes I lie." But I was also taught that there were certain situations in which I was expected to lie. I was further taught not to talk about the possible discrepancy between the general value of honesty and the specific situations in which I was expected to be dishonest. Under those conditions, it is relatively easy for me to develop an espoused view of myself as honest, and a theory-in-use that is only partly consistent with the espoused theory.

The distinction between espoused theory and theory-in-use implies an epistemological distinction among three different kinds of knowing. Knowledge is 'intellectual' when it exists in the espoused theory but not in the theory-in-use: the individual can think about it and talk about it, but cannot do it. Knowledge is 'tacit' when it exists in the theory-in-use but not the espoused theory: the person can do it, but cannot explain how it is done. Knowledge is 'integrated' when there is synchrony between espoused theory and theory-in-use: the person can both think it and do it.

Different forms of education are likely to produce different forms of knowledge. 'Academic education' -- in which learners think about and discuss the practice environment, but do not perform within it -- is likely to produce changes in espoused theory, but no corresponding changes in theory-in-use. The result is intellectual knowledge, but the knowledge may be useless or even harmful if the knowledge is abstracted at a level too far removed from practice, if application requires skills that the learners have not developed, or if successful application is blocked by the learner's lack of self-awareness. In the extreme, the education may help the learner to become more inconsistent and self-contradictory, rather than more effective.

'Field education' places the learner directly in the practice environment, and requires the learner to perform within it. But the field may not require, and may prevent, the learner's reflection on their performance. Thus, the field is an ideal setting for the acquisition of 'tacit' knowledge. The learners develop skills which enable them to cope in the practice environment, but may not be fully aware of the skills they have developed, and of possible deficiencies in their skill repertoire.

It is considerations like these that have led many training organizations to attempt to integrate academic, field, and 'simulator' training so as to develop practitioners who are self-conscious and self-reflective about their practice, and who also have the skills needed for effective performance.

But such programs do not always pay adequate attention to the distinction between espoused theory and theory-in-use, the possibility of inconsistency between the two, and the effectiveness problems which may result. When individuals are unable to describe accurately significant aspects of their theory-in-use, any of several processes are often at work:

1. The individual is unable to acknowledge the discrepancy (because of the anxiety that the discrepancy creates), and will defend against any information suggesting that a discrepancy exists.

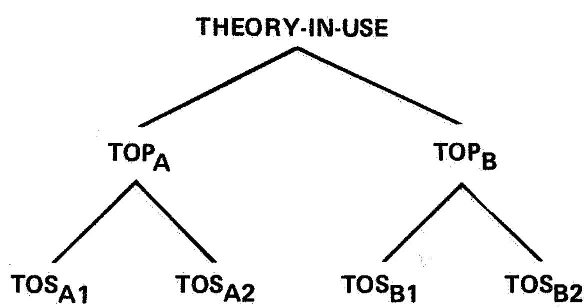
2. The gaps between espoused theory and theory-in-use may generate learning errors, particularly self-fulfilling and self-sealing processes. (If, for example, I believe I am being pleasant and friendly when others perceive me as cool and aggressive, there is a good possibility that I will misinterpret their responses to me as evidence of their personal deficiencies, rather than as appropriate responses to my behavior.)

3. There may be contradictions in the theory-in-use that the individual does not recognize, but which create confusion for others. (Suppose that I am continually sending to the same person the following two messages: (1) you should get out and take more initiatives in life; (2) you are too weak and incompetent to get anywhere. If I fail to recognize the contradiction (because I feel there is a consistent message that says 'get out and do more to overcome your weaknesses'), I may create double-binds for the other person, yet blame the other person for not responding in a more positive way to my efforts to help.)

The implication is that any educational program which aspires to produce successful practice must help learners to understand their espoused theories and their theories-in-use, and the interdependence between the two.

An individual's theory-in-use is the overall program for the design of behavior, from which all other theories (including the espoused theory) are derived. The theory-in-use is a long-term program, which begins to develop at birth, and gradually evolves through the individual's life. A program learned over so long a period of time is heavily overlearned, and can be altered only through learning experiences which extend over considerable periods of time. In any short-term learning experience (e.g., an experience of a few hours), the theory-in-use is just short of unalterable.

I have discussed theories for action at three different levels: the theory-in-use, the theory of practice, and the theory of the situation. The relationship among the three is hierarchical, and can be illustrated by the figure below:



My theory-in-use consists of the core values, beliefs, and strategies which provide direction, meaning, and uniqueness to everything that I do. The theory-in-use is my 'executive program'. It incorporates a number of TOPs for different practice arenas. For example, I have a TOP for driving an automobile, and another for giving lectures. My TOP for automobile driving incorporates a number of different TOS's (e.g., 'I am parking my car', 'I am driving 5 miles above the speed limit').

Since a TOP is usually learned after an individual's theory-in-use is well-established, the theory of practice will be significantly influenced by the previous theory-in-use. The nature of that influence is likely to be different for different elements of the practice environment. Some areas of the practice environment--particularly the highly technical areas--are likely to be relatively unfamiliar to the individual. They represent problems for which the theory-in-use has not developed established routines. Learning in such areas is more a question of adding new elements to the existing theory than of altering elements which are already present. Other areas of the practice environment -- particularly those dealing with communications, interpersonal influence, and management of human resources -- represent areas in which overlearning has already occurred, and the existing theory-in-use is relatively difficult to alter. This can lead to misleading assumptions like, "You can teach a man to fly, but you can never teach him to lead. He's either got it, or he doesn't." The problem is not that the individual cannot learn about leadership; it is just that new leadership skills are difficult to acquire because they require extensive revisions in a theory which is already overlearned.

The question then becomes under what conditions will an individual revise a theory. To understand this issue, it is important to recognize a dilemma that is always present. Revision of a theory that is already developed is always costly--it requires time, energy, effort and, often, emotional stress.

Marris (1975) calls the tendency to hold on to our existing theories the 'conservative impulse', and argues that it is intrinsic to the human capacity to survive and learn from experience:

> (The conservative impulse) is a condition of survival in any situation, even for the most radical innovator. We cannot act without some interpretation of what is going on about us, and to interpret it, we must first match it with something familiar... Each discovery is the basis for the next, in a series of interpretations which gradually consolidate...into an understanding of life. Hence, there is a deep-seated impulse in all of us to defend the validity of what we have learned, for without it we would be helpless. (Marris, p. 10)

> (T)he experience of psychoanalytic treatment suggests that it is slow, painful and difficult for an adult to reconstruct a radically different way of seeing life, however needlessly miserable his preconceptions make him. In this sense, we are all profoundly conservative, and feel immediately threatened if our basic assumptions and emotional attachments are threatened. (Marris, p. 12)

So we find innumerable examples of situations in which an individual, a group, or a nation clings desperately to a theory which is no longer working, rather than to risk the uncertainty, ambiguity and loss of meaning that would come from abandoning a familiar way of interpreting the world. A teacher who has been teaching the same grade in the same way for many years is asked by his superiors to adopt a new pedagogy. If his sense of himself and his effectiveness as a teacher is attached to his old ways, the change is profoundly threatening. It would take great effort and time for him to learn a new approach, and he is not at all sure that he will feel comfortable and effective even if he can learn it.

The example illustrates a pervasive dilemma - it is often difficult to know in advance whether it is useful in a given situation to continue to use the theory I have (and save the costs associated with re-design), or to re-design (and save the costs associated with error in my present theory). Taking account of this dilemma, we can assert several propositions about factors that affect an individual's willingness to engage in theory-revision:

1. The more central a theory is to the individual's self-concept and self-esteem, the less likely that the individual will revise. (Returning to an earlier example, viewing myself as 'honest' has become so central to my valuing of myself, that I find it difficult even to consider modifying that part of my theory about myself.)

2. The more a theory is 'overlearned' (i.e., the more that I have learned the same thing through iterations of the same or similar experiences), the less likely is the theory to be revised.

3. The more that inquiry and learning are built into the existing theory, the more likely is revision. (For example, many of the theories of practice used by scientists incorporate inquiry as a central value, and increase the likelihood of theory revision.)

4. The more the situation makes disconfirming evidence available, the more likely is revision of the theory. (In other words, if my theory is inaccurate, but I get no feedback from the environment to alert me to the problem, I may interpret the experience as further confirmation of the theory's validity.)

5. The greater the amount of ambiguity, confusion, information overload and stress that an individual is experiencing, the less likely is revision of the operating theory. (Anything that overload an individual's cognitive and performance capabilities increases the incentive to solve problems in the simplest possible way--usually by relying on a theory that is well-learned, rather than searching for new ones.)

To summarize:

1. Individuals develop over the course of their lives theories for action, including a theory-in-use which informs all of their behavior, and an espoused theory, which guides the individual's perception of self.

2. An individual's theories for action may contain errors and gaps, but be designed in such a way as to prevent the person from recognizing the problems.

3. Even if the individual does recognize problems in the theory-in-use, s/he can alter the theory only with considerable effort and time.

4. In order to perform in specified practice domains, individuals develop 'theories of practice'. In some areas--usually areas that are highly technical or unique to the practice domain--those theories represent additions to rather than revisions in the pre-existing theory-in-use. In other areas--particularly issues of how an individual relates to and works with others--learning is likely to be much more difficult because it requires

revisions to pre-existing patterns. In the former areas, the theory of practice is more likely to be dominated by the standards prevalent in the practice domain. In the latter, the individual's theory of practice is likely to be dominated by the standards of the individual's theory-in-use.

5. The theory of practice will interact with situational factors to produce a 'theory of the situation'--a short-term set of goals, assumptions, skills and outcomes for use in a specific situation.

6. There is always a dilemma associated with the decision to revise a theory (at any of the three levels): is it more economic and efficient to continue to implement the present theory, or is it more efficient to revise the theory in order to correct its errors and deficiencies.

7. Revision is more likely under conditions of (a) low stress and overload, (b) accessibility of relevant feedback, (c) inquiry skills built into the existing theory.

8. Theory-revision is less likely when a theory is central to an individual's self-esteem, when it is overlearned, and in crisis situations which overwhelm the individual's cognitive and performance capacities.

B. The Problems of On-Line Theory Revision

The air accident cases cited above--like many other cases in which crew errors occur--all occurred in situations where the captain (or the entire crew) was operating on a faulty theory of the situation, and was overlooking data that raised questions about the validity of that theory. I have already suggested that the TOS arises from the interplay between the pilot's theory of practice (TOP) and situational factors. When the TOS is in error, we can argue that the answers to two basic questions determine whether the TOS will be revised:

1. Is information showing the TOS error available in the environment? (E.g., if a faulty instrument is producing error, is there other data available that would alert the crew to the misinformation? If the crew needs information that they do not have, is it possible for them to obtain the information?)

2. Do pilots' theories of practice lead them to use the information that is available?

The availability of information to detect error is necessary, but not sufficient. Many questions about availability of information go to design issues - the design of aircraft and aircraft instrumentation, the design of air controller systems, the availability of accurate and useable manuals and check-lists, etc. But some questions go to issues of management and interpersonal relationships. Take the following conversation, which occurred in a DC-8 shortly before it crashed into a mountain:

First officer: We should be a little higher here, shouldn't we?

Captain: No, 40 DME, you're all right.

The first officer was correct; the captain was wrong. Both were killed because the captain continued to rely on his faulty TOS. The captain's TOP did not lead him to test the possible validity of the first officer's suggestion. The captain was following a time-honored precedent: leaders in all sorts of organizations reject subordinate questioning of their beliefs day in and day out. It enables them to get on with implementing their current TOS, rather than having to delay and test its validity.

A considerable body of research on the theories-in-use held by managers and professionals suggests that it is normative for them to respond to questioning or confrontation of their TOS by defending it rather than inquiring into the possibility of error. Even in situations where the stakes are not so high nor so irrevocable as in air traffic safety, the costs can be serious. In the cockpit of an air carrier, the costs are unacceptable. That suggests two important implications for the TOPs that training programs should seek to produce in flight crews:

1. Whenever a member of a flight crew senses the possibility that the crew's operating TOS may lead to significant error, that member has a positive obligation to raise the issue and request that the TOS be tested.

2. Whenever a member of a flight crew is challenged by another about the possibility that his/her operating TOS is leading to significant error, that member has a positive obligation to seek information to test the validity of the TOS.

Those propositions may seem reasonable enough, but they are difficult to implement, for two reasons:

1. The propositions are much easier to adopt at the level of espoused theory than theory-in-use, because they require willingness and skill in confrontation, inquiry, and conflict-management that crew members may not have.

2. There is a problem of how to design a management system which insists that the captain has a positive obligation to inquire when challenged, but also has the authority to make binding decisions.

The problems are related, because both require that flight crew members have a set of management and interpersonal skills which are rarely observed in any organizational setting. Basically, they require the ability to combine advocacy (behavior which advocates one's beliefs, values and opinions) with inquiry (behavior which seeks to test the validity of one's beliefs, behavior, and values). Advocacy and inquiry are often perceived as polar opposites--with the implication that it is impossible to do both at the same time. Empirical observation of managers is consistent with the polar opposite theory--it is rare to find managers who are good at both. But there are some. And both skills are essential in a cockpit. It is essential that all members of a flight crew be willing to express their beliefs and advocate their view of the situation. The first officer of the DC-8 engaged in very weak advocacy when he asked, "We should be a little higher here, shouldn't we?" The captain's response (No, 40 DME, you're all right.") showed no inquiry at all, and the first officer did not push the issue (perhaps fearing that he might seem insubordinate, or might upset the captain, or might make himself appear foolish by questioning the judgment of an experienced pilot who was familiar with the area). Supose that each had an operating TOP which led them to combine advocacy and inquiry. An alternative conversation might have been:

First officer: I'm really concerned about whether our altitude is safe. What leads you to think we're o.k.?

Captain: I think we're o.k. at 40 DME, but what's your concern?

Theories of practice, pilot skills and cockpit norms that favor high levels of advocacy and inquiry can help to ensure that crewmembers communicate effectively whenever someone in the crew senses error. An additional step is to train crewmembers to develop TOP's which call for testing and inquiry whenever there is ambiguity or anomaly in their current TOS. That is, whenever the crew recognizes that something is happening that does not completely fit their theory of the situation, they need to begin asking questions like, 'Could we be mistaken?' 'Is there some other explanation for what's happening?' 'Is there any information we have (or can obtain) to help us understand the situation?'

For example, consider the case of a 727 which crashed because the flight crew did not recognize the nature of their problem. They had inadvertantly failed to turn on the pitot heaters. When the pitot heads became blocked by atmospheric icing, they gave erroneously high airspeed readings. The crew was very surprised by the high airspeeds, but attributed them to unusual weather conditions and the fact that the plane was flying light. They did not consider the possibility that the airspeed indicators were erroneous, although the plane's altitude should have alerted them that such high airspeeds were improbable or impossible.

The sounds of a stall warning were mistaken for a Mach buffet (partly because the crew had just heard an erroneous overspeed warning). In this situation, a disaster might have been prevented if anyone had thought to question the puzzling result by asking, "Could the airspeed indications be wrong?"

C. Theory-revision and Management of Human Resources

Anomalous or confusing situations tend to overload flight crews. Overload increases the likelihood of error. The optimal use of available human resources becomes a critical factor in aviation safety. It is precisely in crisis situations that the demands on both information-processing and performance skills are highest. In those situations, a flight crew needs to ensure that each member of the crew is performing effectively and working on the right set of tasks for the situation. The way in which tasks are defined and allocated constitutes a set of role definitions for a given moment (and those role definitions are one aspect--often implicit--of the crew's theory of the situation).

The flight situation makes very high demands on the role system--simultaneously demanding high levels of role clarity (so that everyone is clear about their tasks) and role flexibility (so that tasks may be shifted or re-allocated as changes in the situation warrant).

A role is a set of activities or performances that are defined by the expectations of 'role-senders'--persons who have expectations about how a role-occupant will perform in the role. Role-senders for an airline captain include the captain himself, other members of the flight crew, the passengers, airline management, air controllers, other airline pilots, etc. Each role-sender has expectations for how a captain is to behave (although those expectations vary greatly in breadth, specificity and clarity among different role-senders) and has the potential to exert influence on the captain (the amount varying greatly among different role-senders: the captain usually pays much closer attention to air controllers than to passengers). Role clarity exists when the expectations are well-defined and there is agreement among those role-senders who are significant for a particular situation. If the expectations are vague, then role ambiguity exists. If the expectations conflict with one another, there is role conflict. To avoid role ambiguity and conflict in the cockpit, the members of the flight crew need to have mutual role expectations that are clear and mutually understood. When this does not occur, a variety of role problems can lead to serious errors. Those problems include excessive role restriction, inappropriate role differentiation, errors in managing interdependence, and problems in managing role boundaries.

1. Role restriction

Excessive role-restriction is the common result of over-controlling management styles. Many individuals have great difficulty making the transition from 'doing it themselves' to 'getting it done through managing others'. In many cases, they doubt that anyone else can do it as well as they. In others, they are fearful that subordinates will make errors unless closely controlled. The result is a controlling style of management which creates a very restrictive role for subordinates. Managers who try to succeed through over-control often fail, because their subordinates are unable to accomplish very much. Warwick (1975) describes in vivid, if depressing detail how such a management style pervades the U.S. State Department and helps to produce enormously slow and cumbersome performance. The subordinates are 'disempowered' and prevented from making optimal use of their skills and capacities. The manager's primary task is not to do it himself/herself, but to make the best possible use of available human resources.

Ruffell Smith's (1979) simulator study of crew response to overload found that one source of errors in many crews was the captain's tendency to do too much by himself, and to overcontrol his crewmembers. For example, some captains attempted to fly the plane and command during a difficult, emergency condition. They became overloaded, while other members of the crew were underloaded. In other cases, the captain gave so many discrete orders that other crewmembers never finished important tasks because of constant interruptions.

2. Role differentiation and management of interdependence

Role differentiation refers to the degree to which different roles are clearly distinct from one another. It is possible to under-differentiate or over-differentiate. Under-differentiation leads to excessive overlap (too many people doing the same thing), which often coincides with significant gaps (some activities that no one is doing). A clear example is the crew which permitted their 1011 to crash because everyone was worrying about the nose gear light, but no one was monitoring the plane's flight performance. The under-differentiation (too many people focusing on one problem) led easily to gaps (significant problems that no one focused on). Under-differentiation often leads to conflict--as people trip over each other, or resent one another's intrusions into their turf. In the DC-8 which crashed into the mountain, the captain had apparently taken over the navigational role by developing his own personal approach plan, which he did not share with anyone else. Shortly before the accident, the first officer asked the captain if he was planning to make a procedure turn. The captain replied, "No, I ... I wasn't going to." But the captain did not say what he was planning to do. The first officer asked about the terrain, and the captain said, "Mountains everywhere." The first officer then asked, "We should be a little higher, shouldn't we?", but he did not have enough information about the captains plan to be sure.

Overlap can have one advantage--redundancy can reduce the likelihood of error. A number of such redundancies are planned into aircraft and into the roles of air pilots. What is important is that crews be clear about the areas in which redundancy is expected and needed, and the areas in which overlap is wasteful and hazardous.

Over-differentiation occurs when different roles are so completely distinct, that different individuals have great difficulty knowing what one another is doing. The risk is that they make erroneous assumptions about one another, and fail to communicate enough to test those assumptions.

In the airline setting, that risk is particularly high between pilots and flight controllers, whose roles are highly differentiated. Many of the interdependencies between the roles have been worked out over time and have achieved high levels of precision and reliability. But some areas are not completely resolved (e.g., the responsibilities of pilots and controllers with respect to detecting and communicating possible conflicts among aircraft). An example of pilot-controller misunderstanding occurred in the case (discussed earlier) of the 727 which crashed on an approach. The captain believed that the controller had cleared him to an elevation of 1800 feet. Even though his approach chart suggested a possible problem, the captain relied on the assumption that it was the controller's responsibility to be sure that an approach is not given unless it is safe. The crew had plenty of time to re-check the charts or to check again with ground control, but did not do so. The plane crashed, killing everyone aboard.

3. Boundary Management

A role is a set of tasks defined by the expectations of role-senders. Those expectations can be seen as defining a 'boundary' around the role. Tasks inside the boundary are part of the role; tasks outside of the boundary are not part of the role. Role boundaries are never completely precise, and role-flexibility requires that individuals be able to re-define boundaries. Many of the role problems discussed above occur because the boundaries are ill-defined, or because there is little agreement on the process for re-defining boundaries. Under-differentiation, for example, is very likely to occur when roles are ambiguous and boundaries are ill-defined.

For a flight crew to be effective under anomalous or crisis conditions, they need to be conscious of the need for boundary clarity, and clear about the legitimate ways in which role boundaries may be redefined. The latter is critical, because emergencies will often require very rapid role shifts; the crew needs a way to accomplish this without producing confusion, role restriction, or innappropriate gaps and overlaps. One obvious approach to the problem--'role boundaries are whatever the captain says they are'--is effective in producing rapid shifts, but does not always guarantee correct shifts. On the other hand, a system in which anyone has the right at any time to resist or appeal the captain's decisions would make rapid shift very difficult to achieve. It might lead to good decisions in the long-run, but that is no help if the plane crashes in the short run.

What is needed is a system that preserves the captain's authority to make binding decisions, but places a positive responsibility on other crew members to raise questions or suggest alternatives when they perceive that the captain's strategy might lead to significant error. Captains, in turn, need to value such input as part of the help they expect from their flight crew, rather than rejecting it out of hand or seeing it as a threat to the command structure.

D. Training in Human Resource Management

The arguments in this paper imply a need to devote more attention to topics that have been largely neglected in pilot training. Pilots need to understand the interaction between situations and their own theories for practice. They need to appreciate the distinction between espoused theory and theory-in-use, and be able to explore the possibilities of discrepancy in their own theories. They need to understand the importance of skill in inquiry and on-line learning, and they need to learn theories of piloting that emphasize those skills. They need a conceptual understanding of the interpersonal processes and role issues that are critical to the flight deck situation, and they need practice and skill in implementing those concepts.

We have begun to develop educational approaches to accomplish similar goals in working with other professionals, including managers (Argyris, 1976, Bolman, 1976), lawyers (Bolman, 1978), educational administrators (Bolman, 1976), and ministers (Bolman and Gallos, 1979). All of the methods emphasize the importance of integrating theory, self-reflection, and practice. The design of such training varies with the learning context, but always includes some version of the following elements:

1. Presentation of relevant theory (e.g., theory about inquiry

and learning, interpersonal skills, role dynamics, communication in small groups, etc.)

2. Discussion of case examples from the learner's experience (e.g., discussion by pilots of particularly challenging situations that they have faced), as a way to apply the theory and to encourage learners to reflect on their own practice.

3. Simulation of practice problems, with the chance for discussion, feedback, and repeated practice. (As an example, a crew could work through a crisis situation in a full-mission simulation. They would then discuss the experience with assistance from faculty. Next they would practice the same situation again.)

The design of such training is a challenging but exciting task. Part of the challenge is creating effective training experiences. Another part of the challenge is integrating new experiences with existing training. A significant part of the challenge is that the training must begin to question traditional assumptions about management and superior-subordinate communications. Those questions go beyond the flight deck--the same questions can be raised about the entire training activity, and about the management of the airline. If the management patterns that lead to pilot error are the same patterns used at every level of management in an airline (where they presumably also lead to error), then the question of training pilots in effective management of human resources is closely tied to the larger questions of organizational climate and human resource management for the entire system.

Those are large and difficult questions, and many of the answers remain to be discovered. But I believe that the air transport industry has little choice--sooner or later those questions will have to be confronted. Personally, I would prefer to fly with the airlines that do it sooner.

NOTES

1. This is a working paper prepared for the NASA Workshop, "Resource Management on the Flight Deck," San Francisco, June 1979.

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