Cockpit-Crew Crisis Decision Making

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The purpose of the present research was to examine pilots' perceptions of crisis and their attitudes toward the decision-making processes used in crises. A scenario and a 19-item questionnaire were used to determine the perception of crisis, the sense of urgency in the situation, and the rigidity of response. The pilots' ratings of the situation as a crisis were positively correlated with their ratings of the characteristics usually attributed to crises. Overall, perception of the situation as a crisis was high, but response rigidity was low. However, pilots who had a high sense of urgency also tended to have higher response rigidity scores. This group differed significantly from pilots who exhibited a low-urgency–low-rigidity pattern. Rigidity scores also differed significantly between the high-urgency–low-urgency groups when crisis perception was high. Lower urgency scores always yielded lower response rigidity scores. The study suggested that a potentially optimal decision pattern in crisis, one more situationally responsive, may be high crisis perception, low sense of urgency, and low response rigidity. Pilots who had formal Cockpit Resources Management training and pilots of two-crew-member aircraft both exhibited this pattern.

The aviation community has long realized that the effective performance of cockpit crews is essential to aviation system safety. Research in the area of flight crew performance conducted in the United States dates back to World War I (*1*). Early experiments—and the bulk of the research conducted during the following six decades—focused primarily on skills acquisition and retention, perceptual requirements, and physical stress. Much less attention was given to the psychosocial aspects of the cockpit environment. Air transport accident analyses and related research during the past decade have, however, produced convincing evidence that pilot training and evaluation systems must address the crucial dimension of crew interaction and decision making in the cockpit (*2–5*).

In response to these findings, several airlines have initiated training programs to encourage effective Cockpit Resources Management (CRM). The history of CRM as a concept and as a training program is well documented in the proceedings of two workshops sponsored by NASA-Ames Research Center in 1979 (*6*) and 1986 (*7*). The proceedings provide general guidelines for program content and instructional strategies. Although CRM programs vary, they are essentially designed to educate pilots about the importance to safe flight operations of interpersonal relations, communication skills, synergistic activity, and participatory decision making.

Subsequent evaluative research has supported the notion that CRM training can improve cockpit performance and suggests that performance-related attitudes are significant predictors of crew coordination in line operations (*8*). However, this research also indicates that crew members lack awareness of the deleterious effects of stress and have unrealistic attitudes about their personal vulnerability to stress (*9*). Some researchers caution that during a crisis the crew is likely to revert to prior well-learned behavior rather than the concepts espoused by CRM (*10*).

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Despite the increased attention to crew interaction, coordination, and decision making, it is clear that further research is requisite to improve present pilot training programs. This viewpoint was emphasized in a recent report by the congressional Office of Technology Assessment (*11*). The authors concluded that long-term improvements in aviation safety will come primarily from human factors solutions, particularly those that encourage the development of explicit training procedures for upgrading crew coordination and decision making.

In the broadest sense, the purpose of the present research was to examine pilots' attitudes toward cockpit crises and the processes and procedures used in making decisions in crises. The study also provided baseline data on specific concepts associated with cockpit crew performance and crisis decision making that can be utilized in future development and modification of pilot training programs. In addition, the findings may be applied to other small, task-oriented groups faced with crisis decision making, especially groups operating in a complex, technical environment.

LITERATURE REVIEW

Implicit in an event labeled as crisis are real or perceived levels of threat, uncertainty, tension, information inadequacy, and time pressure or urgency (*12–16*). The literature regarding group-level processes suggests that strategies utilized or developed to resolve crises can be affected by a multiplicity of variables: the nature of the threat (*16*), psychological and physiological conditions within the individual (*17*), task/role structure and demands (*18*), and interpersonal relationships and interaction (*19*). These group-level effects will be discussed in more detail following a brief discussion of decision-making theory.

Decision-Making Theory

Following decades of research into the decision-making process, theorists have been able to describe a semistructured framework for making decisions. They speculate that the decision maker partially or completely proceeds through several steps before reaching a decisional choice (*20–22*). These steps include problem definition or diagnosis, generation of alternative courses of action, evaluation of alternatives, and implementation of the chosen alternative.

Beyond this general framework for decision making, the literature also provides some insight into decision making in situations characterized by stress, conflict, and uncertainty. Janis and Mann (*22*) have described the successful decision maker under such circumstances as being discriminating in the search for and evaluation of information, thorough in the search for and appraisal of alternatives, confident that a better solution can be found in the time available, and disposed toward contingency planning.

Less successful decision strategies are characterized by (a) a tendency to use a small number of rules of thumb, or heuristics, in making decisions; (b) failure to consider all the possible decision and outcome options; (c) inconsistency in dealing with risks; and (d) inappropriate levels of confidence in one's own decision. It has also been asserted that experts are as likely to make decisions on impulse as on careful analysis (*23*).

Group-Level Process Effects

The theory and research relevant to group-level processes in crisis conditions suggest that the decisional process may be affected by several highly interrelated factors, including leadership, control structures, information search and exchange patterns, and the search for and evaluation of alternative solutions.

The role of the leader in a crisis situation is the subject of competing viewpoints. One proposition is that the group looks to the leader to supply the structure (or anchor) lacking in a crisis and to provide the expertness for coping with the demands of the situation (*24*). Alternatively, it has been hypothesized that experience and judgment may be less useful because of the unique, nonroutine nature of crisis (*15*) and that the motivation to resolve the crisis quickly reduces the importance of traditional roles (*25*).

Further, there appears to be little consensus as to which leader orientation—task or relational—is more effective in crises. One study suggests that effective leaders have a high task orientation, several power bases, and an autocratic decision style (*26*). Other writers have argued that the effective leader shifts from an initially relational orientation to a task orientation as the crisis proceeds toward resolution (*19*).

The disposition of authority and communication structures in crises is no clearer than that of leadership. Researchers have observed that standard operating procedures may be suspended or ignored (*27*) and task assignments reallocated (*15*). Although these tendencies would suggest a loosening of the structure, other writers have reported that the outcome is more likely to be the centralization of authority and communication (*16,28*). There is agreement, however, that centralization of authority and communication commonly leads to role or information overload (*14*), accompanied by the loss or distortion of information (*29*).

The criticality of information exchange to successful crisis resolution was recognized in early research by Torrance (*24*), and the continued search for information is an antecedent condition for successful decision making in the model developed by Janis and Mann (*22*). However, decision makers have been observed to handle information in a less-than-optimal manner in crises—to restrict information, to be indiscriminately open to all information, and to disregard or ignore information that does not support the preferred alternative (*16,22*).

The literature also suggests that fewer alternatives are likely to be considered in a crisis (*14,15*). Such a situation may result from an incomplete search pattern (*16,22*), the centralization of authority or communications, or both (*12,16,28*), the overreliance on previous experience (*14*) or heuristics (*23*), strong leadership (*24*), or the belief that there is not enough time to engage in the search for or evaluation of alternatives (*22*).

COCKPIT ENVIRONMENT

Aircraft operation is primarily a technical task that consists of multiple subtasks. In airline operations these tasks can be quite complex, requiring high levels of information processing, response rates, and subtask coordination. However, a majority of tasks are programmable and can be routinized, as shown by the increasing automation of cockpit functions. Although the effects of automation on crew behavior and system safety are not yet known, preliminary research suggests that cockpit automation may relocate, not eliminate, human error (*30*).

The cockpit "culture" is determined by rather formalized task and role structures, which are in turn legitimated, and often prescribed, by organizational policies and federal regulations. These structures are further reinforced through training, experience, and group norms. Flight crew performance evaluation and norms have traditionally emphasized individualism, mastery of technical skills, and an attitude that loosely translates as "the captain is always right."

Although crises in the cockpit occur in a complex environment, the standardized training procedures, formalized roles, and routinized tasks characteristic of air transport operations would, at first glance, seemingly contribute to successful crisis resolution. However, the history of commercial airlines is marred with numerous accounts of mismanaged crises. Those who support CRM programs hope to improve the accident record by addressing the issues of crew coordination and decision making (*2,7*).

RESEARCH DESCRIPTION AND METHODOLOGY

Research Objectives

The purpose of the study was to examine pilots' perceptions of cockpit crisis and their attitudes toward decision making in such situations. The hypotheses and variables of interest were derived from the literature and from the results of a preliminary study conducted to explore crisis decision making in air transport operations.

The first hypothesis states that the higher the perception of crisis, the higher the ratings of the crisis characteristics. That is, a positive linear relationship is expected between the pilots' ratings of the scenario as a crisis and their ratings of the characteristics of crises—threat, limited availability of decision-relevant information, uncertainty, and tension—specific to the scenario.

It was also anticipated that the combined effects of pilot training, the hierarchical structure of the cockpit, and the very nature of crisis itself would promote mechanistic, relatively rigid responses to crises. Thus, the second hypothesis states that the higher the rating of the situation as a crisis, the higher the level of response rigidity. For the purposes of the present research, response rigidity includes decision process rigidity (reluctance to engage in participatory decision making), role rigidity (role differentiation, centralization of authority, and reliance on the captain's authority and capabilities), and procedural rigidity (adherence to flight manual operating procedures and company policy).

Following preliminary analysis of the data, a third concept related to the crisis-rigidity hypothesis developed. The decision maker's belief that there is time to search for and evaluate alternatives has been posited as an antecedent condition for optimal decision making in crises (*22*). A high sense of urgency, on the other hand, evokes the dysfunctional coping pattern referred to as hypervigilance. It was hypothesized that a high sense of urgency would result in high response rigidity.

In addition to testing the hypotheses stated above, another objective of the present research was to examine differences in pilots' perceptions and attitudes based on background variables such as flight position, type of aircraft flown, flight time, and age of pilot. A comprehensive background information sheet was developed to provide the data for making these comparisons. Of particular interest are differences in attitudes toward crises and decision making among pilots based on their exposure to CRM training.

Pretest

As a first step, a preliminary study was conducted to assess pilot attitudes toward cockpit crisis and decision making across a broad range of variables drawn from the literature. The pretest instruments, a scenario and questionnaire, were developed with the assistance of airline personnel involved in CRM training programs. The scenario, which follows, includes several factors associated with mismanaged critical situations in air transport operations.

The crew is en route from Cancun to Houston Intercontinental in a Boeing 727 when a crossfeed valve failure renders the fuel in tank No. 2 unusable. Although the weather is deteriorating, the captain favors pushing on to Houston. The second officer has apprised the captain of the fuel situation—if they are forced to make a missed approach at Houston because of the inclement weather, they do not have enough fuel to reach their alternative airport. The first officer has stated that he thinks they should divert to New Orleans, which is closer and where the weather is better. The captain, however, is certain that they can make it into Houston. At this point, the scenario ends. The complete scenario can be found in the Appendix to this paper.

The scenario and survey instruments were pretested during personal interviews with 24 airline pilots to ensure that they understood both the scenario and questionnaire regardless of their flight experience or airline affiliation. Pilots were asked to read the scenario and then to respond to seven open-ended questions and to complete a closed-ended questionnaire. The background information sheet was also completed for each subject.

Data analysis indicated that pilots differed in their perception of crisis and the decision-making process in the scenario depending on their flight position and the aircraft they had flown. The pretest sample included only a few pilots who had not attended some type of CRM training program, so it was not possible to make comparisons with respect to this factor.

Measurement of the Research Variables

The concept of crisis was measured in two ways. The perception of crisis was determined by asking pilots to respond to the statement "At the point where the scenario ends, this crew is in a crisis situation" (Question 1, Part 1) on a Likert-type scale numbered 1 (strongly agree) through 7 (strongly disagree). In Part 2 of the questionnaire pilots were asked to rate five characteristics of the scenario on a Likert-type scale numbered 1 (low) to 9 (high). The second measure of crisis is a combination of the mean ratings of four crisis characteristics—level of threat to the safety of the flight, level of situational uncertainty, availability of decision-relevant information, and the level of tension.

The perception of urgency was measured by combining the responses to Questions 3, 7, and 10 in Part 1 and Question 4 (level of time pressure) in Part 2 of the questionnaire.

Response rigidity, as previously stated, is characterized by the restriction of participation and adherence to or reliance on authority and procedures. In Part 1 of the questionnaire, a response in the "agree" end of the scale to Questions 4, 6, 9, 12, and 13 indicates response rigidity, as does a "disagree" response to Questions 2, 5, 11, and 14.

Survey Distribution

Based on feedback from the pretest subjects and an analysis of the results, both the scenario and questionnaire were modified to clarify ambiguities. The survey materials included a cover letter, a background information sheet, and the revised 6-page scenario and 19-item questionnaire.

The chief pilots from three Los Angeles-based airlines were contacted. They reviewed the survey instruments and agreed to distribute the materials to each of their line pilots after the anonymity of the airlines and their pilots was assured. Six hundred sixty survey packets with a prepaid return envelope attached were distributed among the three airlines.

RESULTS

One hundred eighty-five usable surveys were returned, a 28 percent return rate. Table 1 presents descriptive information on the pilots who responded to the survey. As the table suggests, a relatively broad cross section of the pilot population is represented.

Responses to Questionnaire

The responses to Part 1 of the questionnaire are presented in Table 2, responses to Part 2 in Table 3. Each table indicates the mean and standard deviation for each question in the

TABLE 1 DESCRIPTIVE INFORMATION ON RESPONDENTS

Variable	Response	
	Number	% of Total
Current Position		
Captain	85	46.0
First Officer	62	33.5
Second Officer	38	20.5
Years in Current Position		
0 - 3 Years	69	37.3
3.1 - 10 Years	60	32.4
10.1 - 20 Years	31	16.8
20.1 - 25 Years	24	13.0
Missing	1	.5
Current Aircraft		
Three Crewmember	149	80.5
Two Crewmember	34	18.4
Missing	2	1.1
Years in Current Aircraft		
0 - 1 Year	42	22.7
1.1 - 4 Years	84	45.5
4.1 - 10 Years	47	25.4
10.1 - 20 Years	11	5.9
Missing	1	.5
Total Flight Time		
Less Than 7000 Hours	67	36.2
7001 - 14000 Hours	64	34.6
14001 - 29000 Hours	54	29.2
Years With Current Airline		
0 - 10 Years	64	34.6
10.1 - 20 Years	33	17.8
20.1 - 35 Years	88	47.6
Age		
20 - 29 Years	11	5.9
30 - 39 Years	59	31.9
40 - 49 Years	54	29.2
50 - 59 Years	61	33.0
Duties Other Than Line Pilot		
No	166	89.7
Yes	19	10.3
Formal CRM Training		
No	124	67.0
Yes	61	33.0

TABLE 2 RESPONSES TO PART I OF QUESTIONNAIRE

Question	Mean	SD
1. At the point where the scenario ends, this crew is in a crisis situation.	2.23	1.47
2. This crew's decision making would be more effective if the Captain encouraged the other crewmembers to participate more in the decision process.	1.96	1.18
3. The crew in this scenario has time to try and find a better alternative course of action.	3.28	1.98
4. In this scenario, effective resolution of the problem is primarily dependent upon the Captain's flying skills.	5.30	1.77
5. A better decision could be reached if all crewmembers agree on a course of action.	2.60	1.66
6. Since the Captain wants to go to IAH, now is not the time for the other crewmembers to come up with creative alternatives.	5.79	1.79
7. At this point, it is more important for the crew in this scenario to make a decision than to search for new, alternative courses of action.	3.79	2.03
8. The crew in the scenario has all the information needed to make a good decision.	3.30	1.94
9. The Captain should be making a decision based on his experience rather than the opinions of the other crewmembers.	5.35	1.50
10. The crew in this scenario might make a better decision if they took the time to reevaluate the positive and negative consequences of all the alternatives before making a final decision.	2.42	1.58

TABLE 2 *(continued)*

Question	Mean	SD
11. If the other crewmembers feel that the Captain has made a bad decision, they should question the Captain's decision.	1.63	1.02
12. A better decision would be made if this crew paid more attention to following operating procedures than debating which course of action to take.	4.30	1.76
13. If a crewmember suggests an alternative course of action not covered by standard operating procedures, it should not be given serious consideration.	5.54	1.68
14. Since the First Officer has suggested an alternative different from the one suggested by the Captain, the Second Officer should verbally support whomever he thinks is right.	2.19	1.63

Note. Responses were on a scale from 1 (strongly agree) to 7 (strongly disagree).

TABLE 3 RESPONSES TO PART II OF QUESTIONNAIRE

Crisis Characteristic	Mean	SD
1. Level of threat to the safety of the flight	6.65	1.79
2. Level of uncertainty in the situation	6.43	1.78
3. Level of time pressure	6.44	1.74
4. Availability of information needed to make a decision	6.60	1.93
5. Level of tension	6.83	1.47

Note. Responses were on a scale from 1 (low) to 9 (high).

survey. Table 4 presents a summary of significant differences in responses to the questionnaire between selected subgroups based on background variables. The null hypothesis that there were no differences between these groups was tested with *t*-tests for independent samples.

Fewer captains disagreed with the statement that "the captain should be making a decision based on his experience rather than the opinions of other crew members" than did first and second officers. Pilots with formal CRM training and pilots who fly in a two-person cockpit both tend toward participatory decision making (Questions 2 and 5). Although pilots who fly in two-person-crew aircraft perceived higher levels of threat and uncertainty in the scenario than those in three-person crews, they believed that the crew should be more participatory in their decision making and that there was more time available for the evaluation of alternative courses of action (Question 10).

In addition to being more participatory, those who had formal CRM training were significantly more likely to indicate that they believed that the crew might not have all the decision-relevant information needed (Question 8) and that they should search for alternative courses of action despite the captain's preference to proceed to Intercontinental (Questions 6 and 7) than were those pilots who had no formal CRM training.

Results Pertaining to the Hypotheses

Responses to the statement that the crew in the scenario is in a crisis situation (Question 1) ranged from high agreement (1) to high disagreement (7); however, 90.8 percent of the respondents indicated some level of agreement. The mean was 2.27. The combined-mean rating of the four crisis characteristics ranged from 2.25 (low) to 7.5 (high). The mean was 5.8.

Pearson's correlation coefficient was used to test the hypothesis that the perception of crisis and the ratings of the crisis characteristics were positively correlated. The correlation was .36 (p = .000). Thus, the first hypothesis appears to be true: the higher the perception of crisis, the higher the rating of the crisis characteristics. However, the relationship was not as strong as anticipated.

The concept of response rigidity was derived by combining the means of Questions 2, 4–9, and 11–14 in Part 1 after recoding Questions 4, 6, 9, 12, and 13 to obtain consistent directionality. The rigidity scores ranged from a low of 1.25 to a high of 7.5. The mean rigidity score was 4.08. Both crisis measures were used separately to test the second hypothesis using Pearson's correlation coefficient. The correlation between Question 1 and the rigidity variable was −.30 (p = .000), indicating a linear relationship in a direction opposite to that

TABLE 4 SIGNIFICANT DIFFERENCES IN RESPONSES BY GROUPS (*t*-TESTS)[a]

Question	Mean		df	t
	Current Position			
	Captain	First/Second		
Q9	5.00	5.65	182	2.98
	Aircraft Flown			
	2-Crewmember	3-Crewmember		
Q2	1.59	2.06	181	2.31
Q5	2.09	2.70	181	1.98
Q10	2.00	2.52	181	1.72
Threat	7.21	6.52	181	2.03
Uncertainty	7.06	6.31	181	2.27
	Formal CRM Training			
	No	Yes		
Q2	2.10	1.69	183	2.73
Q5	2.78	2.23	183	2.33
Q6	5.58	6.21	183	2.58
Q7	3.59	4.25	181	2.09
Q8	3.09	3.75	183	2.21

[a] All differences are significant at the .05 level.

predicted by the hypothesis. The correlation between the ratings of crisis characteristics and the rigidity variable was low, $-.18$, but significant ($p = .001$) and similarly indicates a relationship opposite to the hypothesis. The results suggest that the higher the perception of crisis, the lower the response rigiditv

It was also hypothesized that a high sense of urgency would result in a high rigidity score. The correlation was .23—again, a signficant ($p = .002$) but relatively weak relationship. However, the relationship was in the direction hypothesized. A higher sense of urgency resulted in a higher rigidity score.

In order to further explore the relationship among the crisis characteristics, urgency, and rigidity variables, the responses were transformed to a percentage score to compensate for differences between the scales used in Parts 1 and 2 of the questionnaire. The mean percentage score for the crisis characteristic variable was 64.75; for the urgency variable, it was 53.20; and 35.02 was the mean percentage score for rigidity. The crisis characteristic variable was used as the measure of crisis perception because it is considered to be a more comprehensive measure of crisis.

Table 5 shows, as previously noted, that crisis and rigidity are negatively related (high-low, low-high), but the rigidity scores are not significantly different as a result of a high or low perception of crisis. Urgency and rigidity are, however, positively related (low-low, high-high), and pilots with a low sense of urgency have significantly lower rigidity scores ($t = 2.88$; $p = .004$).

The last section of Table 5 shows the interrelationship among the three variables. Respondents who rated the situation as more urgent also had higher rigidity scores, regardless of the perception of crisis. However, rigidity scores differed significantly as a result of urgency only when the perception of crisis was high ($t = 2.74$; $p = .007$).

Table 6 shows the differences based on aircraft flown and CRM training in relation to the hypotheses. (No significant differences were found between groups based on flight position with respect to the variables central to the hypotheses.) *T*-tests for independent samples showed that pilots who flew in two-person cockpits had a significantly higher perception of crisis than their counterparts in three-person crews ($t = 2.68$; $p = .009$) as well as a lower sense of urgency and lower rigidity.

Pilots who had no formal CRM training indicated a lower rating of the crisis characteristics, but had higher urgency and rigidity scores than those pilots who had attended a formal CRM program. They differed significantly on the urgency variable ($t = 2.16$; $p = .032$) and on the rigidity variable ($t = 2.06$; $p = .026$).

CONCLUSION

Overall, pilots perceived that the crew in the scenario was in a crisis situation and, as hypothesized, this perception positively correlated with their ratings of the crisis characteristics.

TABLE 5 COMPARISONS AMONG CRISIS CHARACTERISTICS, URGENCY, AND RIGIDITY VARIABLES

Variables						
Crisis	n	Urgency	n	Rigidity (%)	t	p
High	97			34.3	1.03	.305
Low	87			35.8		
		High	87	37.3	2.88	.004
		Low	95	33.0		
High	97	High	44	37.5	2.74	.007
		Low	53	31.7		
Low	85	High	43	37.2	1.17	.244
		Low	42	34.8		

TABLE 6 COMPARISION OF PERCENTAGE SCORES IN CRISIS CHARACTERISTICS, URGENCY, AND RIGIDITY VARIABLES BY AIRCRAFT FLOWN AND CRM

Group	n	Variable		
		Crisis	Urgency	Rigidity
Current Aircraft[a]				
2-Person Crew	34	68.6	49.8	33.1
3-Person Crew	149	64.1	53.8	35.4
Cockpit Resources Management[b]				
No Formal	124	64.5	54.9	36.0
Formal	61	65.6	49.4	32.9

[a] Significant differences were found between two-person and three-person cockpit crews on Crisis (t=2.68; p=.009).

[b] Groups differ significantly on Urgency (t=2.16; p=.032) and on Rigidity (t=2.06; p=.026).

An unexpected finding was that a higher perception of crisis resulted in a lower rigidity score. The high-crisis–low-rigidity relationship was opposite to that hypothesized, and, further, pilots had overall surprisingly low rigidity scores.

The hypothesis that a high sense of urgency would evoke high response rigidity was supported by the data. Rigidity scores were higher when urgency was high, regardless of the perception of crisis. It appears that flexible, participatory decision making is more a function of low urgency than high crisis perception. Interestingly, pilots with a high perception of crisis had significantly lower mean rigidity scores when urgency was also low.

It is possible that a high perception of crisis is indicative of high arousal. If so, the high-crisis–low-urgency–low-rigidity pattern may represent an optimal approach to crisis decision making. In other words, the decision maker perceives the situation as a crisis and consequently is motivated to act. But the low sense of urgency (the belief that there is sufficient time to search for and evaluate alternative courses of action) allows for more flexibility with respect to participation, roles, and procedures.

This high-crisis–low-urgency–low-rigidity pattern was exhibited by both CRM-trained pilots and pilots of two-crew member aircraft. The similarities between these two groups are probably due to the fact that 29 of the 34 members of two-crew-member cockpits had attended formal CRM training programs. In any case, the results of the study support the notion that CRM training does, in fact, encourage more situationally responsive decision patterns.

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APPENDIX
Crisis Scenario

On January 6, 1989 at 19:00Z Flight 451, a Boeing 727-200, departed Cancun bound for Houston's Intercontinental Airport. The flight was dispatched with 32,500 lb of fuel on board as follows:

En route	1:49	17,500
Alternate (DFW)	:42	7,000
Reserve	:45	6,000
Contingency	:15	2,000
	3:31	32,500

All three fuel tanks were fueled evenly at 10,834 lb each. There were 151 passengers on board and a crew of 7. The takeoff gross weight was calculated at 167,500 lb, with a planned landing weight at IAH of 150,000 lb.

The flight was cleared via the standard Center-stored route of CUN J-52 ELGAR A-766 GLS DIRECT IAH. The computer flight plan indicated that the Equal Time Point was 51 min into the flight with a 9,500 lb fuel burn.

That day a stationary front was lying along the Texas Gulf Coast swinging northward over the Texas/Louisiana border, bringing widespread low stratus, drizzle, and fog to the region. The crew received the following weather briefing:

CUN FT 061111	250 SCT. 12Z 80 SCT C250 BKN. 20Z 30 SCT C80 BKN 250 BKN 0415. 05Z VFR.
CZM FT 061111	250 SCT. 12Z 70 SCT C250 BKN. 20Z 30 SCT C70 BKN 250 BKN 0510. 05Z VFR.
MID FT 061111	CLR. 14Z 50 SCT C100 BKN. 18Z C50 OVC 0915. 00Z C10 OVC 3R 0915. 05Z MVFR CIG VIS R.
IAH FT 061212	C2 X 1L-F. 14Z C5 BKN 8 OVC 2L 3215. 18Z C10 OVC 2RF 3210 OCNL C2 X 1/2RF. 00Z C4 OVC 1 L-F 3410. 06Z LIFR CIG LF.
HOU FT 061212	C2 X 1L-F. 14Z C5 BKN 8 OVC 2L 3215. 18Z C10 OVC 2RF 3210 OCNL C2 X1/2 RF. 00Z C4 OVC 1 L-F 3410. 06Z LIFR CIG LF.
DFW FT 061212	C10 OVC 3L 0110. 15Z C10 BKN 25 OVC. 18Z 30 SCT C100 BKN 0110. 21Z 100 SCT 0310. 06Z VFR NO CIG.
CRP FT 061212	C3 OVC 1 LF. 14Z C2 X 1/2 L-F. 16Z C4 OVC 1 R-F 0310. 20Z C2 X 1/2LF. 06Z LIFR CIG LF.
SAT FT 061212	C5 OVC 1 LF 2RF 3010. 15Z C5 BKN 8 OVC 2R-F 3015. 21Z C2 X 1/2 LF. 06Z IFR CIG.
MSY FT 061313	C8 OVC 2RF 0610. 15Z 8 SCT C20 OVC 0615. 20Z C20 BKN 0710. 07Z VFR.
IAH SA 1650	M9 OVC 3R 113/65/62/3009/986
HOU SA 1645	E10 OVC 2RF 113/64/61/3110/986
SAT SA 1650	E6 BKN 10 OVC 2R 132/69/60/2915/992
CRP SA 1650	M4 OVC 1 R-F 113/64/61/0310/986
DFW SA 1645	M10 BKN 6 132/70/55/0105/992
MSY SA 1655	M15 OVC 3L 114/68/60/0609/987

The flight departed Cancun at 19:04Z with an undetected inoperative number 2 crossfeed valve. The valve failed in the closed position.

19:58

Second Officer: Number 2 is spooling down.
Captain: Turn on the ignition.
Second Officer: It's on. No help.
Captain: All right, get out the book and try a relight.

20:01

Second Officer: It says airspeed and N1-N2 relationship within appropriate envelope. Should be 24 and 31—looks good. Nacelle anti-ice off, fire handle push in. Don, is the fire handle in?
Captain: Yeah, it's in. Just get the checklist done. The airspeed is bleeding; we can't stay at this altitude. John, get me lower.
First Officer: Merida Center, 451 needs lower.

20:02

Merida: 451, say again.
First Officer: 451 has lost an engine. We need a lower altitude.
Merida: Stand by.

20:03

Merida: 451, descend, maintain FL310.
First Officer: 310. 451.
Second Officer: Don, it won't relight.
Captain: What do you mean, it won't relight? You got the fuel pumps on?
Second Officer: Yes, sir.
Captain: You fly this thing. I'll get it started. Give me that book.

20:05

Captain: You're right. It's not going to run. What altitude can we maintain?
Second Officer: The book says 20 max at 157.

20:06

First Officer: Shouldn't we run the engine failure checklist?
Captain: Yeah, let's get that done.
Second Officer: Throttle closed . . . start lever cutoff . . . essential power check . . . electrical load check . . . I'll finish up the secondary items.

20:08

Captain: Request FL200.
First Officer: Merida Center, 451 would like FL200.
Merida: 451, descend and maintain FL200. Report reaching.
First Officer: 451, roger.

20:10

Second Officer: Engine failure checklist is complete.

20:12

Merida: 451, say your Nuley estimate.
First Officer: I forgot to report Nuley.
Center, 451. Stand by.
We must've crossed it at about 02. What's our true airspeed now? About 380?
Captain: 360.

20:14

First Officer: 451 passed Nuley 20:02, descending to FL200. Estimating Barow at 20:29. Earns is next.
Merida: 451, roger. Say your altitude.
First Officer: Leaving FL270.
Merida: 451, roger. Contact Houston Center on 132.65.
First Officer: 132.65. 451.

20:15

Captain: When you check in ask for the IAH weather.
First Officer: Houston Center, 451 descending to FL200.

20:16

First Officer: Houston Center, 451.
I'll go back to Merida.
Captain: Don't bother. We'll pick 'em up in a few minutes. We're still a ways out.

20:21

Captain: Dale, try to get that fuel in balance, will ya. Burn out of the center tank.

Second Officer: I am. Something's wrong here, Don. I've been crossfeeding for about 15 minutes.
Captain: Looks right. Try cycling the crossfeed valve.
First Officer: What's going on?
Captain: Aw, the fuel's all screwed up.

20:23

Second Officer: I'm not getting an in-transit light.
Captain: Check the breaker.

20:25

Second Officer: It's still not working.
Captain: Are you sure you checked the right breaker? Which one did you cycle?
Second Officer: This one—the manifold valve.

20:29

First Officer: Well, the fuel in that tank is going to be unusable.
Captain: Yeah. Give Houston another call.
First Officer: Houston Center, 451.
Houston: 451, Houston Center. Go ahead.
First Officer: 451, FL200.

20:30

Houston: 451, squawk 2641 and indent.
First Officer: 2641.

20:32

Houston: 451, radar contact 10 north of the Barow intersection. Cleared direct Scholes, direct IAH.
Captain: Get the IAH weather.
First Officer: Direct Scholes, direct IAH. What's the IAH weather?
Houston: Stand by.

20:35

Houston: 451. The IAH weather at 19:50Z, 500 overcast, visibility 1, temperature 64, dewpoint 62, wind 300 at 4, altimeter 29.85.
First Officer: Thanks.

20:40

Second Officer: I've got the latest weather for IAH and MSY. IAH's now 200 overcast, visibility 1/4, rvr on 8 is 1800 variable 2400. MSY is 800 overcast, visibility 1 mile.
Captain: Well, Houston's above minimums. What's the current weather at DFW?
Second Officer: I can't get an update for DFW. Anyway, according to this chart, if we can't use the fuel in the number 2 tank, we won't have enough to make the alternate.
First Officer: What?

20:41

Second Officer: If we miss the approach at IAH, we won't have enough fuel to make it to DFW. The fuel in tank 2 is unusable.
First Officer: How much fuel do we have now?
Second Officer: 8,700 usable. How far is it to MSY?

20:43

First Officer: It's about 215 to MSY and 335 to DFW.

20:45

Second Officer: If we divert now, we'd land at MSY with 3,700 and DFW with about 1,000.
Captain: Oh, we'll make it into IAH o.k. I've made it in there in worse conditions than this.

20:46

First Officer: Don, I think we should go to MSY. We have a real fuel problem here and the weather in IAH is getting worse.
Captain: We're scheduled into IAH—we'll make it.

REFERENCES

1. J. M. Koonce. A Brief History of Aviation Psychology. *Human Factors*, Vol. 26, 1984, pp. 499–508.
2. H. C. Foushee. Dyads and Triads at 35,000 Feet. *American Psychologist*, Vol. 39, 1984, pp. 885–893.
3. H. P. Ruffell Smith. *A Simulator Study of the Interaction of Pilot Workload with Errors, Vigilance and Decisions*. NASA Report TM-78482. NASA-Ames Research Center, Moffett Field, Calif., Jan. 1979.
4. R. L. Sears. *A New Look at Accident Contributions and the Implications of Operational and Training Procedures*. Boeing Commercial Aircraft Company, Seattle, Wash., 1986.
5. J. L. Wheale. An Analysis of Crew Coordination Problems in Commercial Transport Aircraft. *International Journal of Aviation Safety*, Vol. 2, 1984, pp. 83–89.
6. G. E. Cooper, M. D. White, and J. K. Lauber, eds. *Resource Management on the Flight Deck: Proceedings of a NASA/Industry Workshop*. NASA CP-2120. NASA-Ames Research Center, Moffett Field, Calif., 1979.
7. H. W. Orlady and H. C. Foushee, eds. *Cockpit Resources Management Training: Proceedings of the NASA/MAC Workshop*, NASA CP-2455. NASA-Ames Research Center, Moffett Field, Calif., 1987.
8. R. L. Helmreich, H. C. Foushee, R. Benson, and R. Russini. Cockpit Managment Attitudes: Exploring the Attitude-Performance Linkage. *Aviation, Space and Environmental Medicine*, Vol. 57, 1986, pp. 1198–2000.
9. R. L. Helmreich. Cockpit Management Attitudes. *Human Factors*, Vol. 26, 1984, pp. 583–89.
10. J. R. Hackman. Group Level Issues in the Design and Training of Cockpit Crews. In *Cockpit Resource Management Training: Proceedings of the NASA/MAC Workshop* (H. W. Orlady and H. C. Foushee, eds.), NASA CP-2455. NASA-Ames Research Center, Moffett Field, Calif., 1987, pp. 23–39.
11. *Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment*. Office of Technology Assessment, OTA-SET-381. Washington, D.C., July 1988.
12. R. S. Billings, T. W. Milburn, and M. L. Schaalman. Crisis Perception: A Theoretical and Empirical Analysis. *Administrative Science Quarterly*, Vol. 25, 1980, pp. 300–15.
13. C. F. Hermann. *Crisis in Foreign Policy*. Bobbs-Merrill, Indianapolis, Ind. 1969.
14. T. W. Milburn. The Management of Crisis. In *International Crisis: Insights from Human Behavioral Research*. (C. F. Hermann, ed.), The Free Press, New York, N.Y., 1972, pp. 257–277.
15. J. A. Robinson. Crisis: An Appraisal of Concepts and Theories. In *International Crisis: Insights from Human Behavioral Research*. (C. F. Hermann, ed.), The Free Press, New York, N.Y., 1972, pp. 18–35.
16. B. M. Straw, L. E. Sanderlands, and J. E. Dutton. Threat-Rigidity Effects in Organizational Behavior: A Multi-Level Analysis. *Administrative Science Quarterly*, Vol. 26, 1981, pp. 640–657.
17. T. C. Wiegele. Decision Making in an International Crisis: Some Biological Factors. *International Studies Quarterly*, Vol. 17, 1973, pp. 295–336.
18. J. E. McGrath. Stress and Behavior in Organizations. In *Handbook of Industrial and Organizational Psychology*, (M. D. Dunnette, ed.), Rand-McNally, Chicago, Ill., 1976, pp. 1351–1395.

19. S. Fink, J. Beak, and K. Taddeo. Organizational Crisis and Change. *Journal of Applied Behavioral Science*, Vol. 7, 1971, pp. 15–37.
20. L. R. Hoffman. Improving the Problem-Solving Process in Managerial Groups. In *Improving Group Decision Making in Organizations: Approaches from Theory and Research*. (R. A. Guzzo, ed.), Academic Press, Orlando, Fla., 1982, pp. 95–126.
21. H. A. Simon. *The New Science of Management Decision*, rev. ed. Prentice-Hall, Englewood Cliffs, N.J., 1977.
22. I. L. Janis and L. Mann. *Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment*. The Free Press, New York, N.Y., 1977.
23. D. C. Nagel. Human Error in Aviation Operations. In *Human Factors in Aviation*. (E. L. Weiner and D. C. Nagel, eds.), Academic Press, San Diego, Calif., 1988, pp. 263–303.
24. E. P. Torrance. A Theory of Leadership and Interpersonal Behavior Under Stress. In *Leadership and Interpersonal Behavior*. (L. Petrullo and B. M. Bass, eds.), Holt, Rinehart & Winston, New York, N.Y., 1961, pp. 100–117.
25. L. Berkowitz. Sharing Leadership in Small, Decision-Making Groups. In *Small Groups: Studies in Social Interaction*, (A. P. Hare, E. F. Borgatta and R. F. Bales, eds.), Knopf, New York, N.Y., 1966, pp. 675–687.
26. M. Mulder, J. R. Ritsema, and R. deJong. An Organization in Crisis and Non-Crisis Situations. *Human Relations*, Vol. 24, 1971, pp. 19–41.
27. C. T. Kerchner and J. H. Schuster. The Uses of Crisis: Taking the Tide at the Flood. *The Review of Higher Education*, Vol. 5, 1982, pp. 121–141.
28. J. E. Dutton. The Processing of Crisis and Non-Crisis Strategic Issues. *Journal of Management Studies*, Vol. 23, 1986, pp. 501–517.
29. C. Smart and I. Vertinsky. Designs for Crisis Decision Units. *Administrative Science Quarterly*, Vol. 22, 1977, pp. 640–57.
30. E. L. Weiner. Cockpit Automation. In *Human Factors in Aviation*. (E. L. Weiner and D. C. Nagel, eds.), Academic Press, San Diego, Calif., 1988, pp. 433–461.