III. "Road Map" for Understanding Possible Causes

Section II described how the accident scenario began when Flight 427 intercepted the wake vortex of a 727 flying ahead of it. This unusually severe wake encounter was followed by exclamations of surprise by the flight crew; roll accelerations caused by the wake, autopilot, and crew; a rudder deflection to its blowdown limit; and a full-aft column input.

The investigation initially focused on possible aircraft failures that might have contributed to the lateral/directional upset observed on the DFDR. Evaluation of these possible failures—by examination of the airplane structure or by determination of the aerodynamic effects of the potential failure—led all investigators to the conclusion that only a large rudder deflection, in the direction to contribute to the left roll, could have caused the heading trace recorded by the DFDR. Appendix B contains a list of all aircraft scenarios considered and ruled out during the course of the investigation.

One of the main issues of the investigation is what caused the rudder to go to its blowdown limit, since this played a key role in the chain of events leading to the accident. During the course of the investigation, various hypothetical scenarios were put forth as the cause. These fall into three main categories: the rudder went to blowdown due to an atmospheric disturbance, a rudder system failure, or a flight crew input. Figure 4 shows the various rudder time histories determined by the kinematic analysis described in Section II. Figure 5 shows the different scenarios that have been proposed. This section discusses these possibilities and then lays out the plan for reviewing the evidence as to whether these hypothetical scenarios could have occurred on the accident flight.

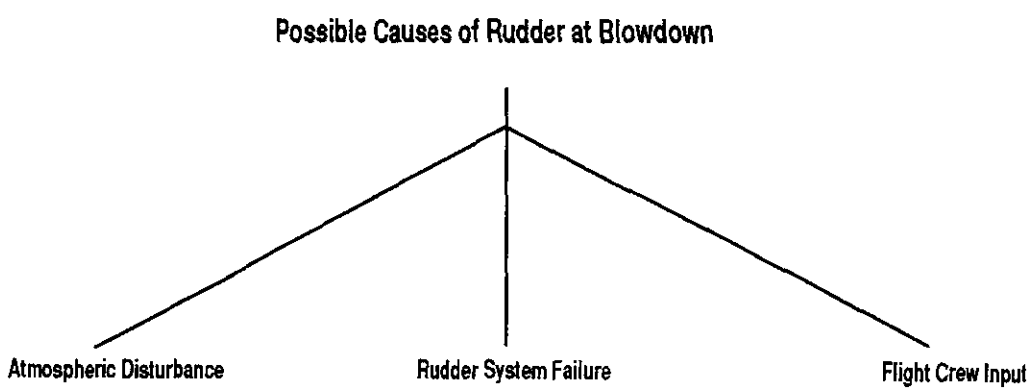

Figure 5: "Road Map" for Understanding Possible Scenarios

A. Hypothetical Scenarios Causing Rudder to Go to Blowdown

Atmospheric Disturbance Scenarios

While the accident event began when the airplane encountered the wake vortex, there is no evidence of any rudder control anomaly being associated with an atmospheric disturbance. Although there are documented cases in which pilots have been startled by unexpected wake encounters and used the rudder, there are no documented cases where the rudder has moved by itself due to atmospheric conditions, such as a wake encounter or turbulence. In addition, under the auspices of the NTSB, both flight testing[7] and lab testing[8] were conducted that demonstrated no anomalies for all combinations of air loads, yaw damper inputs, and pilot inputs.

[7] *Wake Vortex Flight Test*, NTSB Factual Report, to be issued.
[8] *Addendum, Main Rudder PCU Dynamic Testing*, Apr. 18, 1997.

Rudder System Failure Scenarios

These scenarios, all of which involve the rudder power control unit (PCU), are those in which the system could theoretically fail and drive the rudder to its blowdown limit:

- Dual slide jam.
- Secondary slide jam and primary slide overtravel.
- Input linkage jam

Flight Crew Input Scenarios

These scenarios are those in which the flight crew commands the rudder to blowdown, without any system failure.

As a result of the above discussion, Figure 5 can be updated as shown in Figure 6. The atmospheric disturbance branch has been dropped, and the various rudder failure modes have been added.

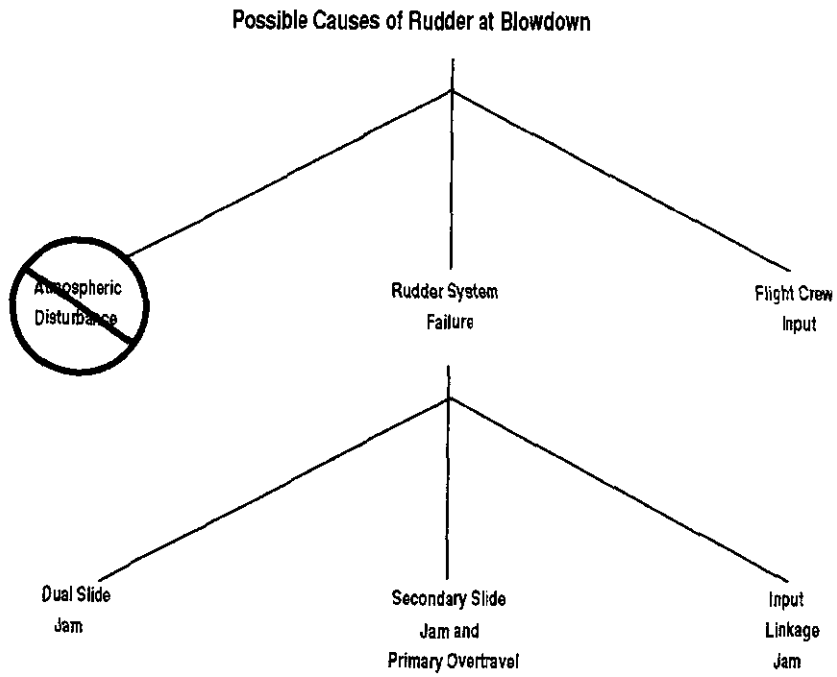

Figure 6: Revised "Road Map" for Understanding Possible Scenarios

B. Plan to Review Evidence in the Following Sections

In the remainder of this submission document, we will examine each of the scenarios on the road map. Section IV of this document identifies, describes, and evaluates the possible rudder system failures that could lead to the rudder going to its blowdown limit, and provides an overview of the investigations conducted relative to the rudder system. That section examines the various hypothetical scenarios involving failures of the rudder system by discussing what they are, cues these failures would give the pilots, and evidence for or against their occurrence. Relevant factual data, analysis, and in-service experience are examined for any evidence that a system malfunction could have caused the rudder deflection encountered by Flight 427. Other rudder system failure scenarios that do not fit the kinematic analysis, but have been discussed in the industry at large, are discussed in Subsection B of Section IV.

Section V provides a detailed discussion of the human factors and operational issues that relate to the accident. It considers scenarios in which the flight crew could have induced the rudder to go to blowdown. Relevant factual data, analysis, and in-service experience are examined for evidence that the crew might have caused the rudder deflection experienced by Flight 427.

Section VI then summarizes these system and flight crew scenarios. Based on facts and data, it indicates which scenarios cannot be considered as a possible cause of the accident.

Summary Table

The following table shows the scenarios that will be considered in greater detail in the following sections. Each scenario can be made to fit one of the kinematic analysis profiles, which then constitutes the initial evidence for it having caused the rudder to go to blowdown. The table will be updated in Sections IV and V with the available evidence supporting or contradicting the various scenarios. In Section VI, a final evaluation will be made of which scenarios can be considered a possible cause of the accident.

Hypothetical Scenario for Full Rudder Deflection	Indications For	Indications Against	Comments
1. Dual slide jam	Potentially fits a kinematic analysis *	*	*
2. Secondary slide jam and primary slide overtravel	Potentially fits a kinematic analysis *	*	*
3. Input linkage jam	Potentially fits a kinematic analysis *	*	*
4. Fight crew input, no aircraft malfunction.	Potentially fits a kinematic analysis *	*	*

*To be filled in further in Sections IV, V, and VI

Table 1: Hypothetical Scenarios Causing Rudder to Go to Blowdown