777 Review of a Lateral Stability Event From a Threat and Error Perspective

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717 737 747 757 767 777 MD11 MD80 MD90

General Overview

- Purpose of test
- Definition of "Threat and Error" terms
- Test Item Planning (TIP Sheet)
- History
- Analysis from a "Threat & Error Perspective"
- Lessons learned
- Conclusion

Definition of TEM Terms

Threats: Are situations external to the flight deck, that must be managed by the cockpit crew during normal, everyday flights. Such events increase the operational complexity of flight and pose a safety risk to the flight at some level.

Error: are ***actions*** or ***inactions*** by the crew that lead to deviations from organisational or flight crew intentions or expectations. Errors in the operational context tend to reduce the margin of safety and increase the probability of accidents or incidents.

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Definition of TEM Terms

Undesired Aircraft State: **Occurs when the flight crew places the aircraft in a situation of unnecessary risk <u>or area of known risk with an unanticipated consequence!</u>**

Managed: An **active crew response in which a threat, error, or undesired aircraft state is detected and mitigated to an inconsequential outcome.**

Mismanaged: **A crew response in which a threat, error or undesired aircraft state is detected but the crew action or inaction allows it to induce and error, additional error, undesired aircraft state, incident or accident; OR; a lack of crew response to a threat, error or undesired aircraft state because it was either ignored or undetected.**

Threats & Errors

Threats

Mitigated Threats:

Trapped Errors

Error

Purpose Of Test

- To verify acceptable static lateral/directional stability characteristics of the 777-300ER prior to certification

- Test considered “Medium” risk

Test Item Planning, (TIP SHEET)

- All maneuvers flown at the aft CG limit, low to mid Weights (worst case scenario).

- Airplane equipped with GE 90-115B engines

- Airplane equipped with LADS which stands for: Labview Analysis Display System.
- Provides
  - Actual flight test speed/Trailing cone airspeed
  - Beta
  - Q-beta
  - Rudder pedal position in inches

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TIP Sheet-Risk Alleviation

•Test pilots familiar with the lateral stability and control characteristics of the 777 will fly these conditions.

•Conditions must be performed in VMC with a clear discernable horizon. Any conditions flown below 10,000 feet AGL must be conducted with constant visual ground contact. Note: Discussion about conducting test at 5,000 feet AGL.

•Empennage loads will be monitored using CALMS: Complex Amplitude Loads Monitoring System (monitors tail loads via cockpit/cabin displays).

•The maneuvers will be monitored real time by engineering test crew in cabin using ADAMS: Airborne Data Analysis System (engineering equipment in the cabin)

Test Item Planning, (TIP SHEET-continued)

Procedure:

1. Trim the airplane with zero sideslip and symmetric thrust for level flight
2. Using Normal Flight Control mode: Conduct a steady heading sideslip using full rudder pedal deflection while maintaining heading by banking the aircraft as required using lateral control, and steady thrust.
3. Original test plan discussion to conduct test at 5,000 feet, at V_{FE}-5 knots for Flaps 30, with gear down (175 knots).
   Note: Crew elected to do test at 10,000-12,000 feet.
1. Stabilize trim for several seconds.

History

•In initial 777-200 certification, (1994-1995), similar testing occurred with different results.

•Informal Lessons Learned Program: (No process guarantee that critical information passed on to subsequent program). Some people were aware of short term lesson learned, however not captured in later programs/future tests.

•Informal Flight Safety Program in Flight Test.

•Same failure event, with a much better outcome. No sense of urgency after this event to document and identify future problems

•No exceedances

Rudder Command Limiting
Rudder Ratio Changing

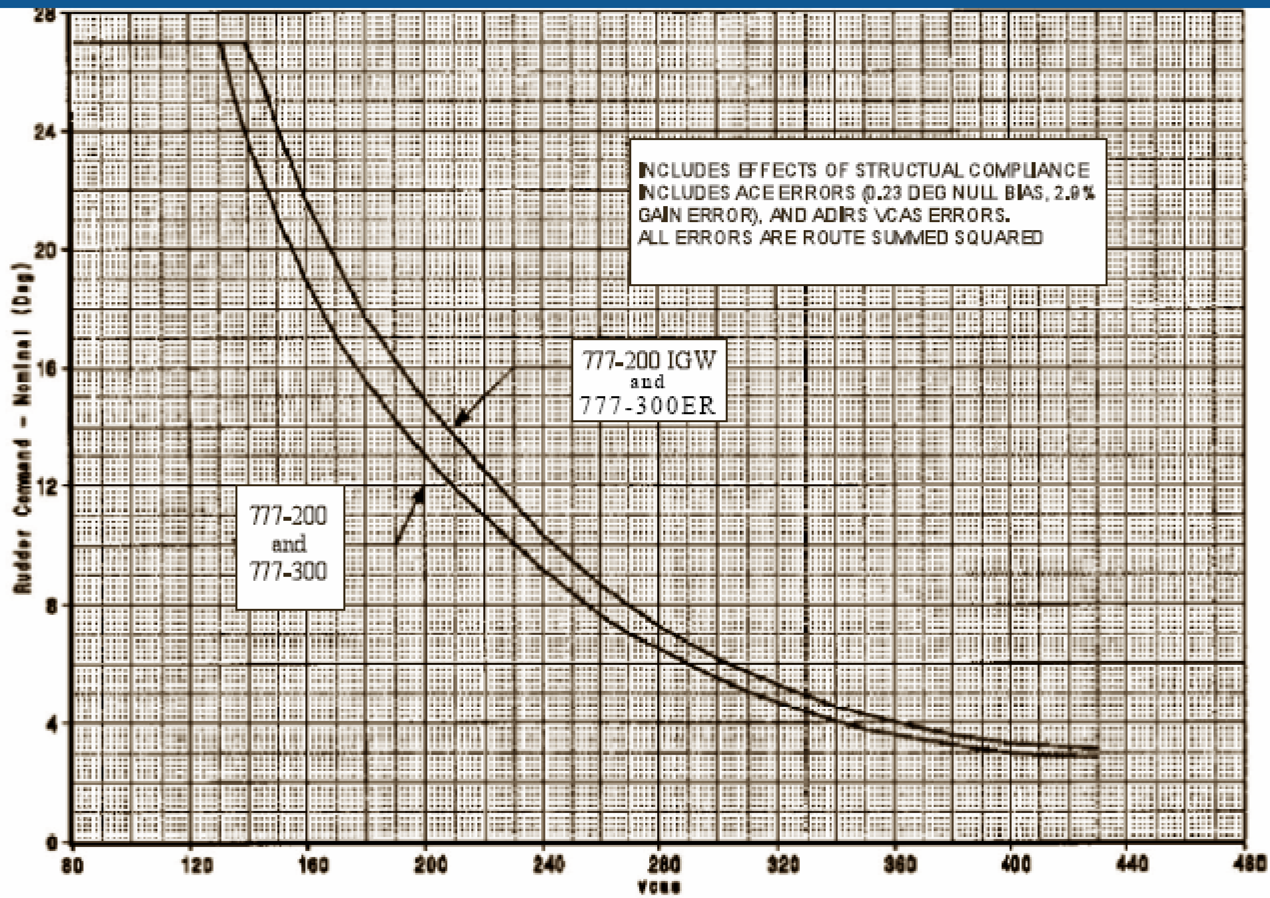
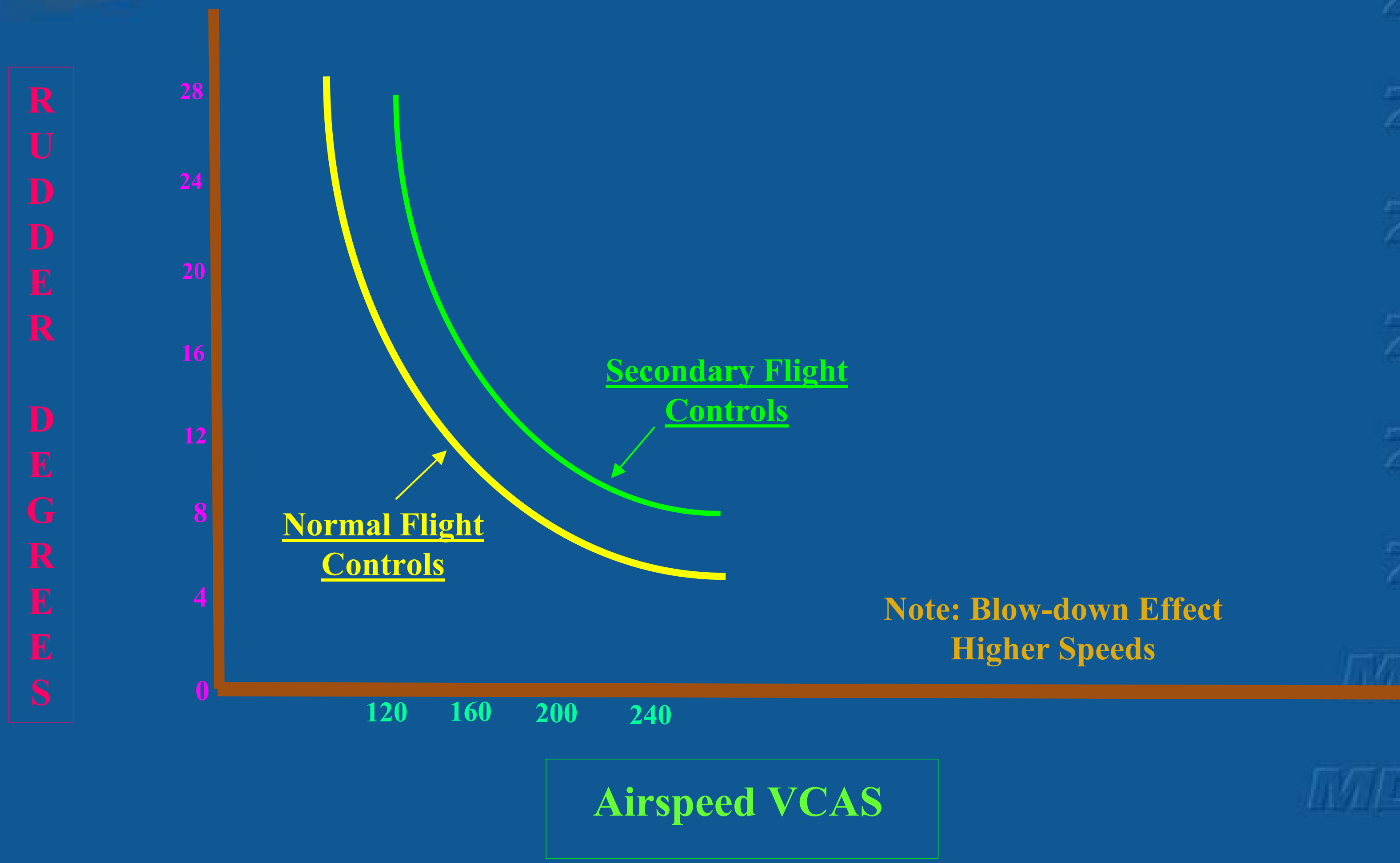
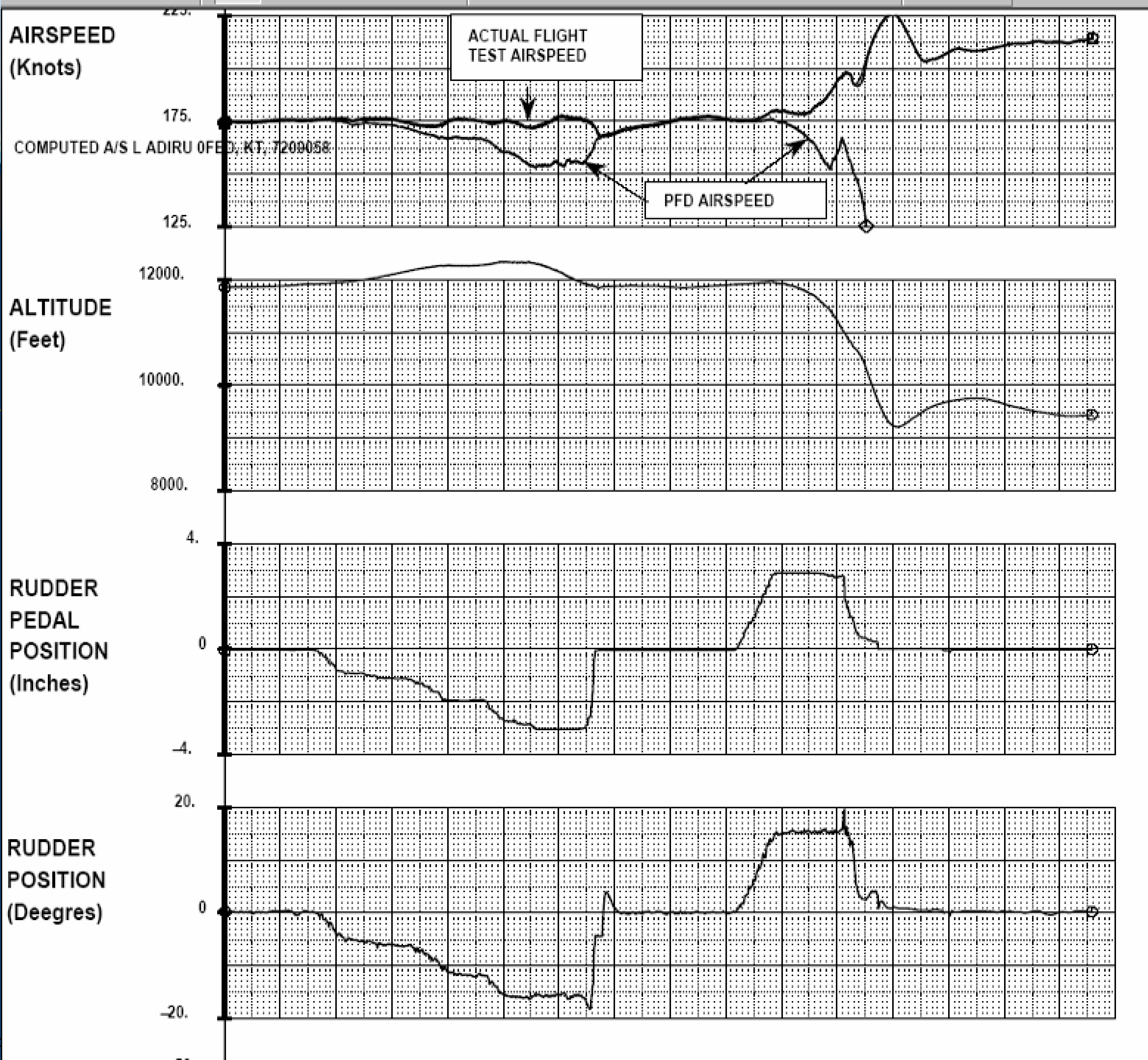


Figure 6.4-5 Rudder Command Limiting (Rudder Ratio Changing)

777 RUDDER COMMAND LIMITING CHART
Rudder Ratio Changing (Full Pedal)



Airspeed Rudder Data Plot



Analysis of Edwards AFB Flight Threat and Error Perspective

Winds were out of limits for takeoff performance testing so the airplane was de-fueled and re-ballasted for a light-weight aft CG stability and control flight. This was a long test program with weather issues. Fatigue was a factor!

A thrust asymmetry compensation condition was done on takeoff, followed by transit into W-291 test area. An all engine trim and three simulated engine-out trim conditions were done at low altitude. Left and right side slips were then done at Flaps 30.

Previous 777 lateral stability test in mid-1990's were conducted noting similar blanking of the left and right pitot systems causing reversion from normal flight controls mode to secondary flight control mode. Crew reaction kept aircraft within flight limitations.

Relied on program pilots and certain test engineers for experience & knowledge for preparation for flight test, (Human Memory Based System). Lessons Learned program not formal.

The first condition was a 1/3, 2/3/ and full right pedal input at 175 kts with flaps at 30 degrees, (BUILDUP). The condition was satisfactorily completed. At this time the one ADIRU experienced a latched fault due to pitot asymmetries, which provided no flight deck affect other than a status message.

The status message was not identified to the pilots.

Analysis From a Threat and Error Perspective-Continued

During second sequence of testing, left rudder and right aileron applied. As full pedal was reached the pilots' airspeed began to decrease. A second ADIRU had latched and pilot's airspeed indication was erroneous.

No crew member on board noted any failures to the pilots or test director.

To maintain airspeed the pilot reduced pitch from 1 degree to -10 degrees. While holding full left pedal, the pilot was adjusting for speed and heading when the Primary Flight Controls went into secondary mode and the rudder delivered 4 degrees of additional movement.

This occurred because the loss of Normal Flight Control Mode caused the rudder system to revert to a mode with increased rudder at low speeds and less rudder authority at high speeds.

Initially pilot increased back pressure and held rudder.

As airspeed increased flaps overspeed by 46 knots.

Analysis From a Threat and Error Perspective-Continued

As airspeed increased the Pilot Monitoring attempted to bring the flaps to 25.

Aileron was immediately used to oppose the roll, however rudder did not return to symmetric flight for approximately 15 seconds. *"Step on Brake Syndrome?"*

Aircraft was recovered from jet upset condition with limited increased "G" until wings were level.

Post-recovery crew elected to RTB to Edwards. Flaps and secondary structure mandatory inspection. No damage was found.

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TIP Sheet-Risk Alleviation & Lessons Learned

- Test pilots familiar with the lateral stability and control characteristics of the 777 will fly these conditions. Familiarity will include training in the Engineering cab/simulator.
- Lateral Stability Test is now considered "Medium" to "High" Risk.
- Testing needs to be done at sufficient altitude for recovery from unexpected upsets. Minimum declared altitude for symmetric thrust steady heading side slip should be 10,000 feet AGL. Test will normally be conducted at 10-15K ft.
- Important that wheel and rudder are both removed slowly and simultaneously when terminating condition.
- Both flight test and ship system airspeeds must be monitored to prevent chasing erroneous airspeed.
- Electronic flight control functions need to be monitored in real time to determine there are no latent failures prior to condition.
- Crew coordination for who is responsible for each of the critical parameters should be discussed in the preflight.
- Load relief is not available when in secondary flight control modes. Although this is known information, putting it on the TIP sheet increases situational awareness for potential failures to other than normal flight control mode.
- Monitor with timing….beat the comparator. Limiting the time the airplane is in excessive side slip can eliminate exposure to reversion from Normal to Secondary Flight Control Mode, which reduces potential for airplane jet upset.

Summary

- Current Boeing "Lessons Learned" process is integral to future accident & incident prevention.
- During test, when anomalies & latched failures occur, immediate crew feedback to the flight deck is critical & essential.
- For those crew members unfamiliar with specific high risk test, appropriate training in engineering cabs and simulators prior to applicable flight test is essential with appropriate system failures experienced. Note: If not possible to replicate potential anomaly in the simulator, crews must be full aware of potential failures and optimum solutions.
- Threat and Error tools can be utilized to identify and structure risk analysis. Threat and Error management, as a Crew Resource Management tool, will play a part in Boeing's future threat mitigation and error management strategy.

Questions For Further Discussion At This Conference

•Can TEM be utilized for more than flight test accident and investigation?

•Can TEM be used as part of risk and error mitigation strategy in flight test operations?

•Can TEM be used to improve flight test operations crew resource management?

•Can TEM be used to improve the quality and safety of each test flight?

Answer: Yes

ANY QUESTIONS?