Throttles-Only Control and Propulsion-Controlled Aircraft

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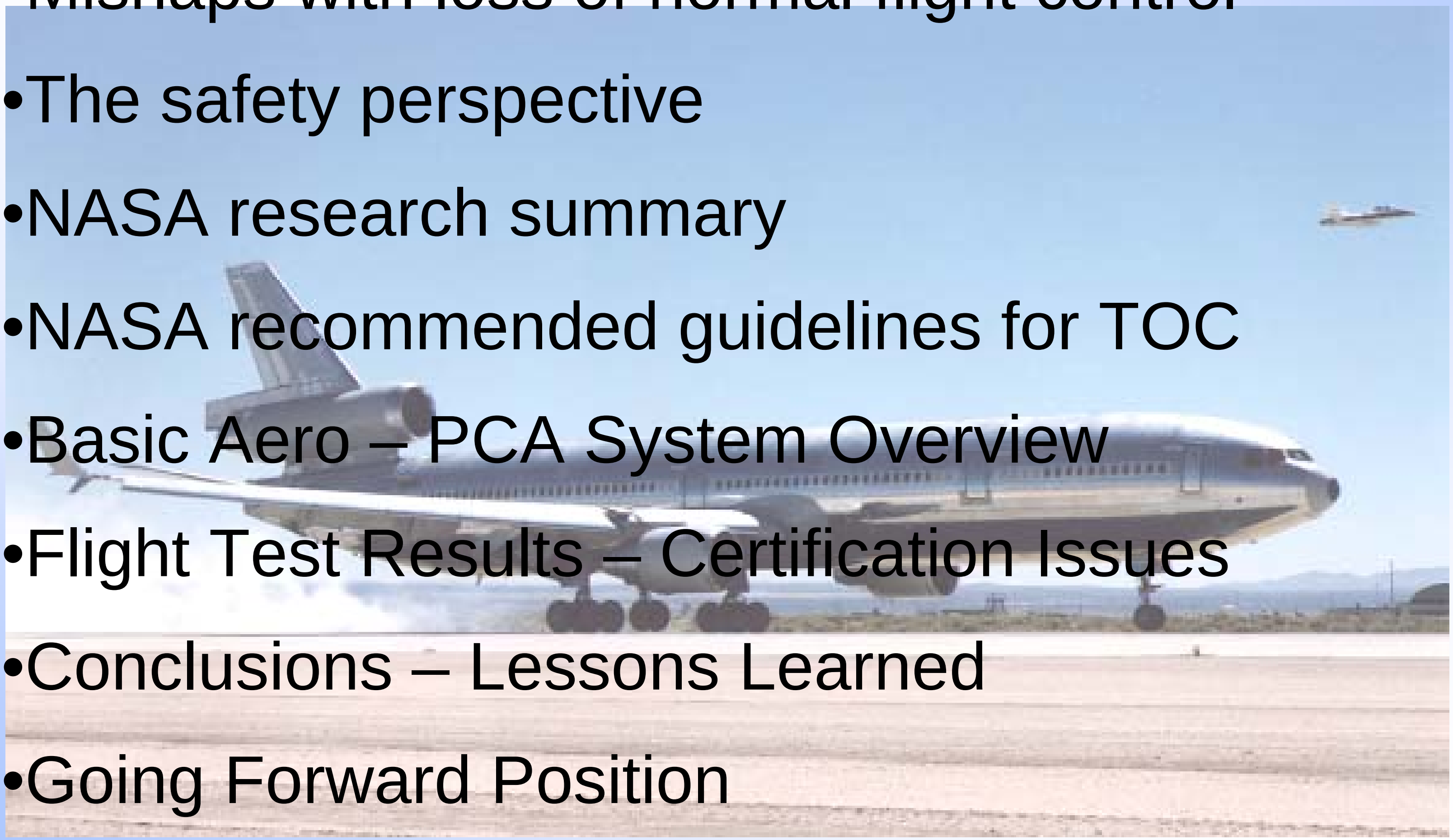
Overview



- Mishaps with loss of normal flight control
- The safety perspective
- NASA research summary
- NASA recommended guidelines for TOC
- Basic Aero – PCA System Overview
- Flight Test Results – Certification Issues
- Conclusions – Lessons Learned
- Going Forward Position

- Very few accidents have occurred where there was *loss of normal flight control*

- Modern flight control systems are exceptionally well designed
  - Redundancy in electric and hydraulic systems
  - Failure analysis assures 10^{-9} reliability

- If *loss of normal flight control* does occur:
  - Pilot techniques are available to regain control
  - Design features have been identified to allow propulsion control through the autopilot

Accident/Incident History with Loss of Normal Flight Control

- Mar 74 – Turkish Airlines DC-10
  - Rear cargo door failure
    - *No knowledge of TOC, crashed at high speed*
- Apr 75 – USAF C-5A "Operation Babylift"
  - Rear pressure door failure
    - *Used TOC + wing controls for 30 minutes, crashed*
- Apr 77 – Delta Airlines L-1011
  - One elevator jammed full-up
    - *Used bank angle, then TOC and load shift to gain control*

Accident/Incident History cont'd

- Aug 85 – Japan Air Lines B747
  - Rear pressure bulkhead failure
    - *Marginal TOC achieved, crashed into a mountain*
- Jul 89 – United Air Lines DC-10
  - Fan disk failure, lost all hydraulics
    - *Taught themselves TOC, used excellent CRM, landed*
- Nov 03 – DHL A-310
  - Damaged in missile attack
    - *Remembered UAL 232, achieved full TOC, safe landing*
- Other MANPADS / Surface to Air Attacks

Safety Perspective

- 600M flights from 1974 to 2004
- Total commercial events: 5
  - Rate: .0083 / 1M flights
  - Current Accident Rate .67 / 1M flights
- Total lives lost: 1098
- Of 3447 airplanes among U.S. carriers, 1607, or 46.6% have no mechanical back-up flight controls

Summary of NASA Research

- Tested 7 different airplanes in flight
  - Transports: B747, B777, MD11
  - Fighter/trainer: F-15, F/A-18, T-38
  - Propeller: PA-30
- Results:
  - *Gross flight path and heading control possible in all types tested*
  - *Safe runway landings exceedingly difficult*

Achieving Throttles-Only Control

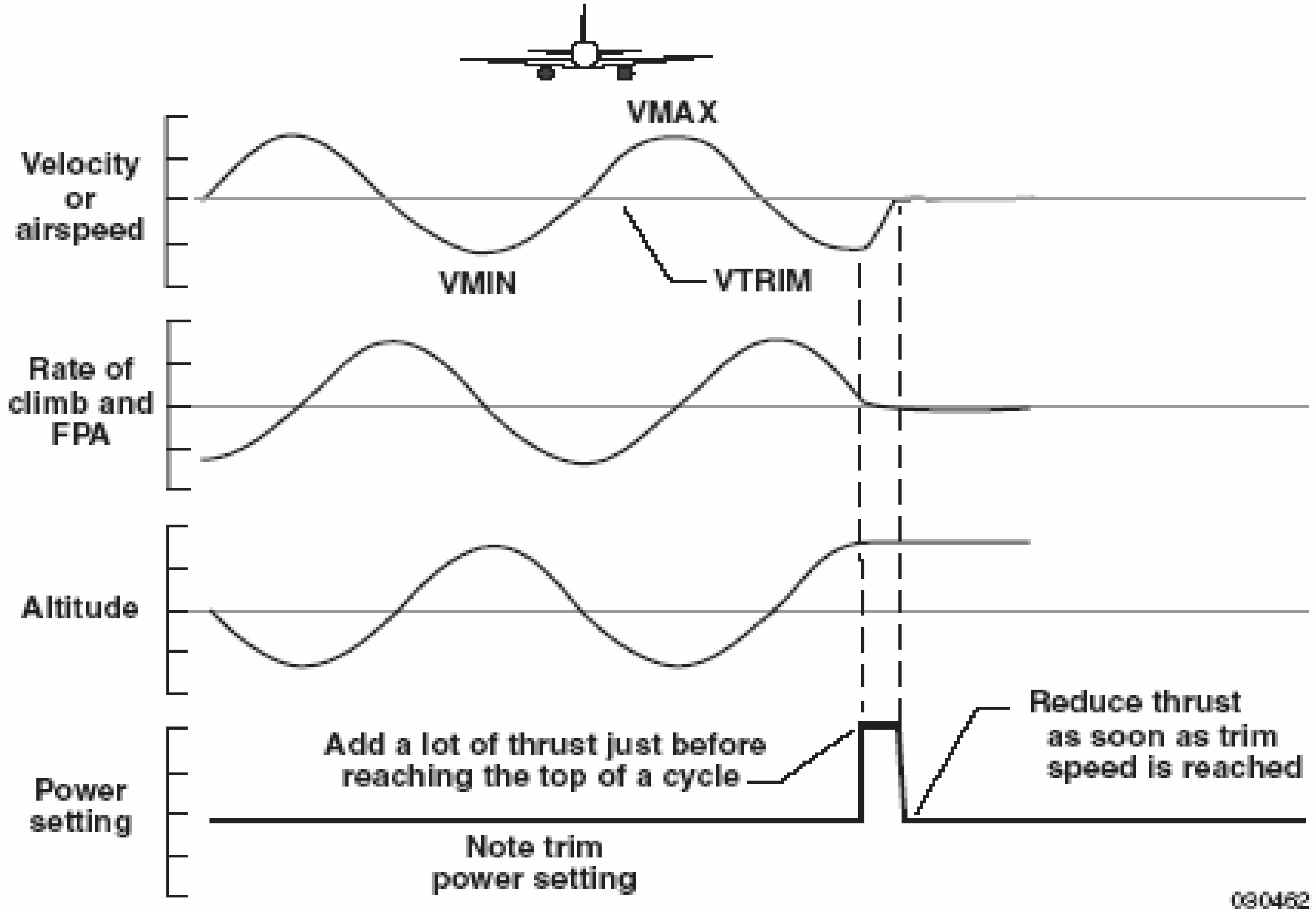
- Motions are affected by trim position, center of gravity, and fuel slosh
- Thrust alone must be used to return to straight and level flight
- Two motions present with loss of normal flight controls:
  - Long period, or *Phugoid*
  - Lateral/directional, or *Dutch Roll*

Solve the lateral/directional Problem

- Use asymmetric thrust to return to straight flight:
  - Add thrust to generate sideslip, which generates roll rate
    - Thrust increase lags thrust lever inputs
    - Sideslip lags thrust increase
    - Roll rate lags sideslip
    - Slow inputs avoid fuel slosh
  - In straight flight, some oscillations may remain

Then Solve the Pitch Problem

- Phugoid oscillations may be 1min or longer
- Avg the high/low speeds to get trim speed
- Add thrust with speed decreasing and the nose near level flight
- Decrease thrust with speed increasing and the nose near level flight
- Continue until oscillations cease, then aggressively maintain airspeed +/- 2 kts



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- Pitch and roll are now both under control
- Now, you can *think*
  - Fly the airplane, and use CRM to divide up all the tasks you face
  - Look at all the EICAS or ECAM messages and determine the exact status of the airplane
    - Use good systems knowledge to determine what you available for additional flight control
  - Begin thinking about where you want to land
    - Trim speed will change with fuel burn or configuration change
    - Make any changes *slowly and incrementally*

Ten Steps to a Survivable Landing Using Only Throttles

NASA's suggested techniques (contained in its report on TOC) have been summarized in the (condensed) list below:

1. If a wing is low, push that wing's throttle(s) up until wings are level. Continue to use asymmetric thrust as required to control bank angle and heading.

2. If the pitch attitude and airspeed continually oscillate, determine the approximate steady state trim airspeed by averaging the high and low speeds seen and set a reference bug or mark at that speed.

3. Damp the pitch oscillation using aggressive throttle inputs to force the airspeed to the steady state trim airspeed as the nose approaches a level attitude.

4. Continue this process until all pitch oscillations are stopped. Constant, precise control of airspeed is the key to prevent oscillations from beginning anew.

5. Gentle climbs and descents can be initiated with a thrust change and then repeating the damping process of step 4. The steady state trim airspeed may change slightly in a climb or descent.

6. Select a suitable landing site: the widest, longest and smoothest landing area with good weather within reach. Emergency services and ILS are also desirable.

7. Well before a landing attempt, configure for landing. Expect a pitch upset and a corresponding trim airspeed change when landing gear are lowered. Flaps, if available, should be lowered in very small increments.

8. Make a very long, flat, straight-in approach with no configuration changes.

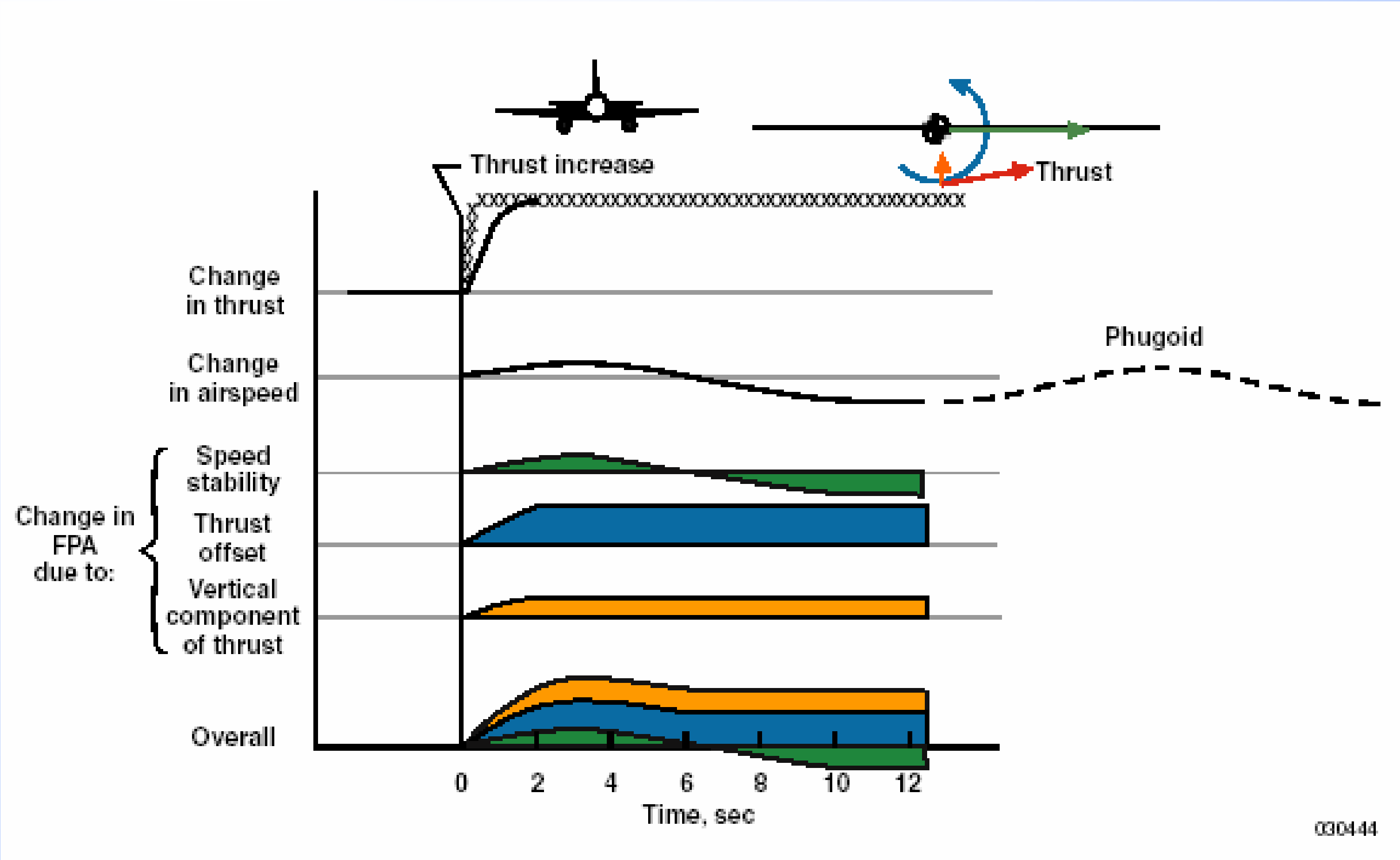
9. Hold a flat approach all the way to the ground; do not reduce thrust before touchdown unless floating just above the ground.

10. Last minute lineup corrections are very difficult, go-arounds are easy. Fuel permitting, a go-around should be accomplished if in doubt about the impending touchdown.

The PCA System is Born

- TOC Effective but Safe Landing Not Assured
- NASA Conceives PCA System
- Near Normal Landings Achieved with PCA
- Software Driven System with Future Adaptability

Propulsion - Controlled Aircraft (PCA)



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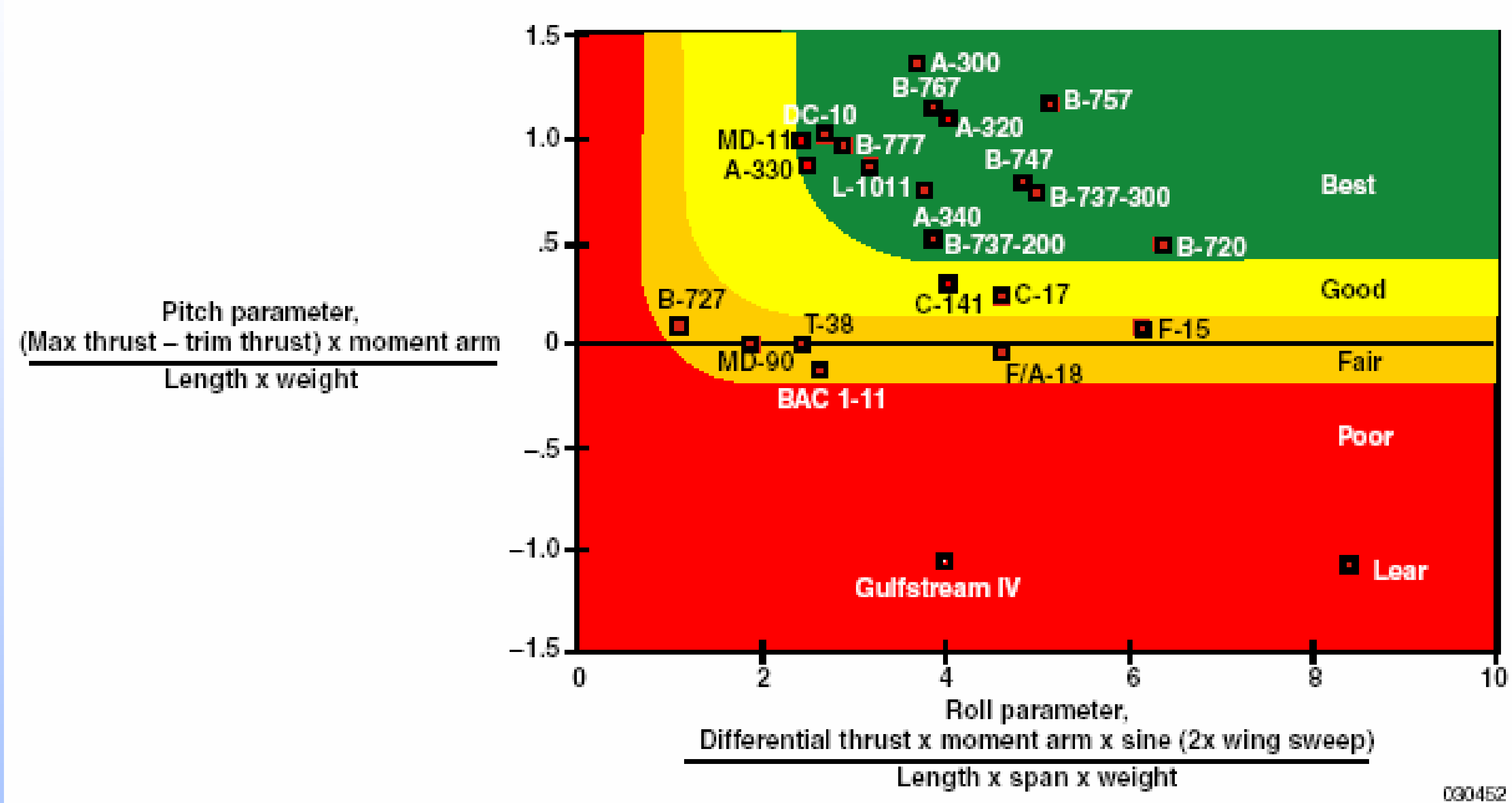

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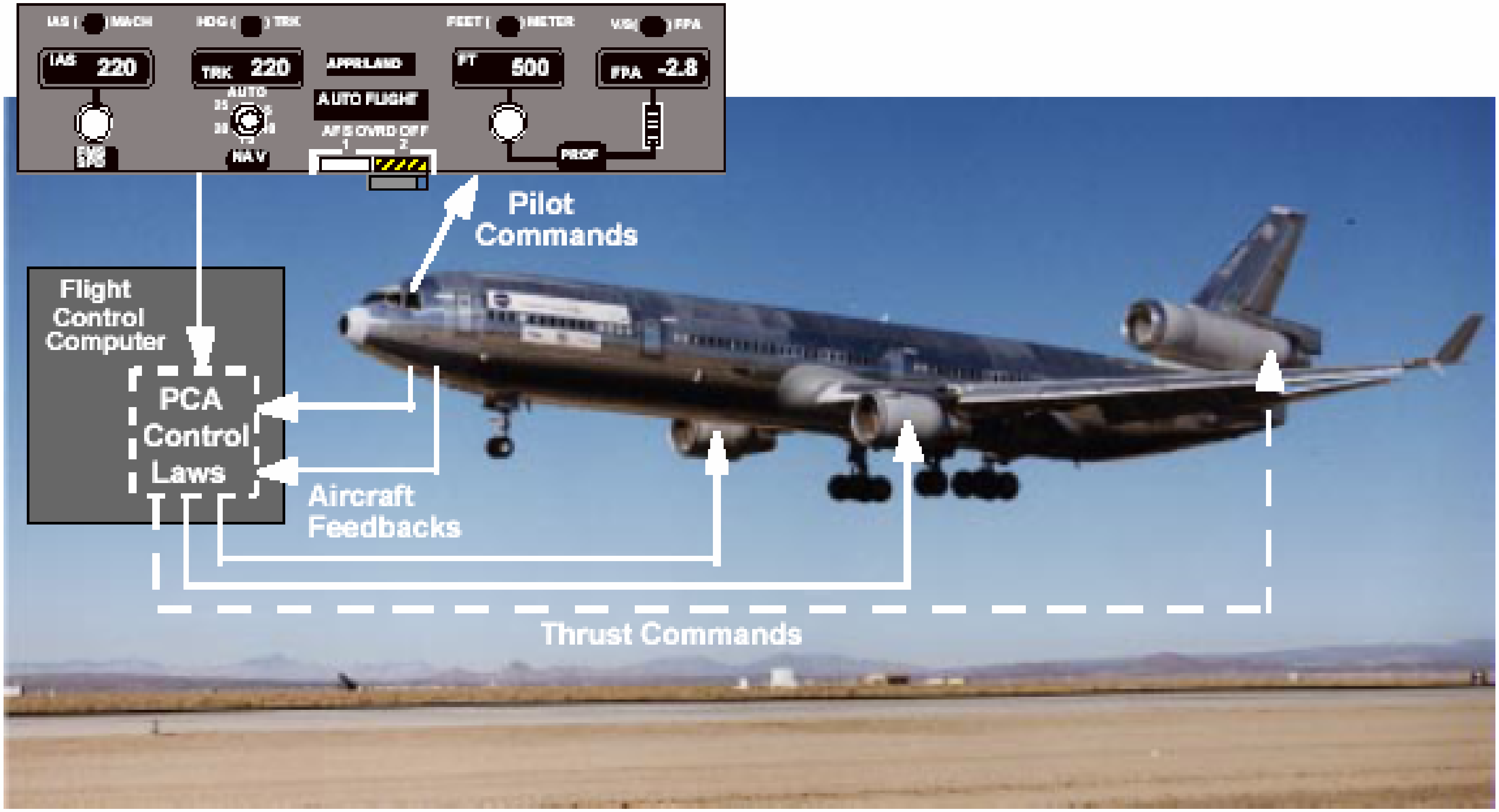

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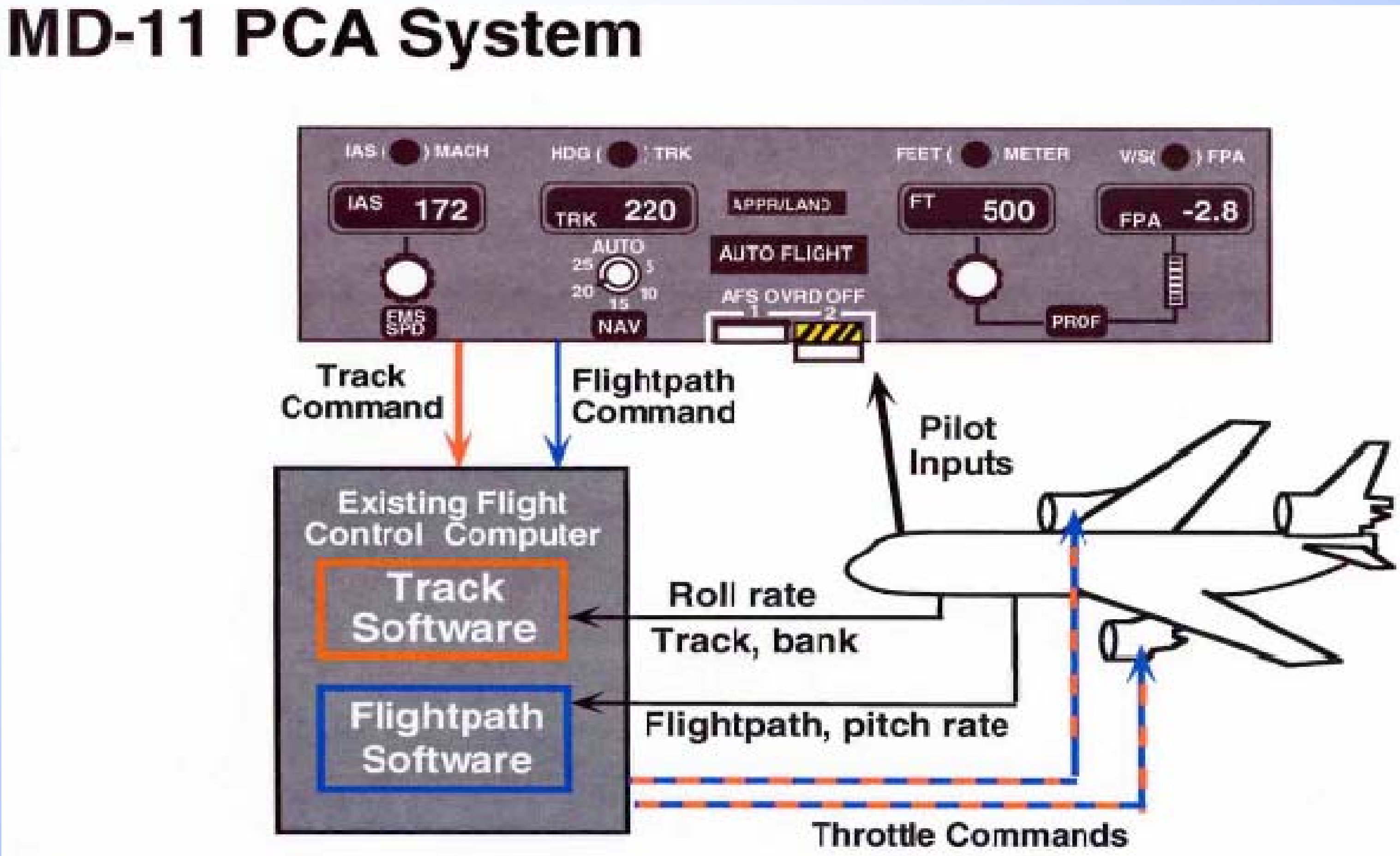

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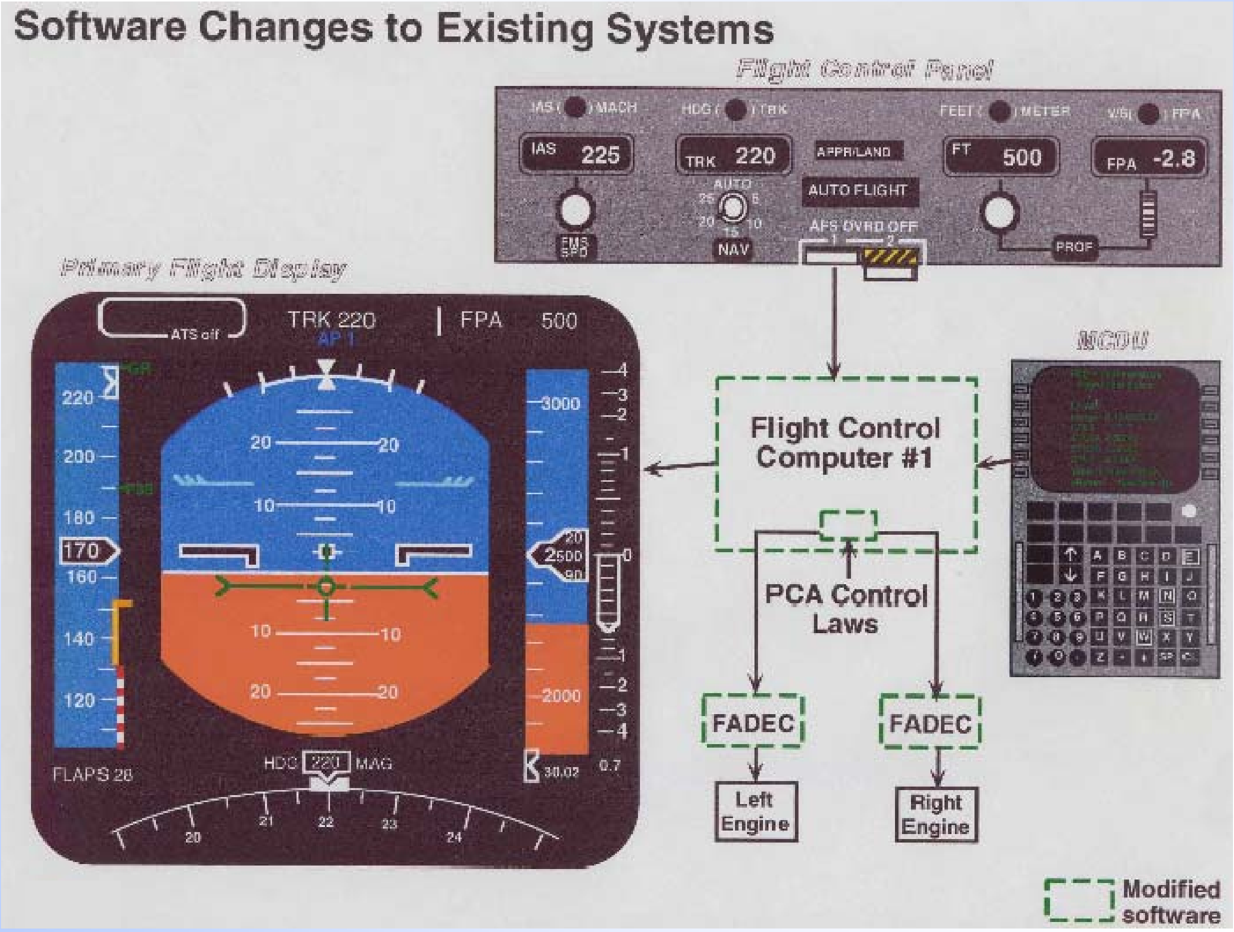

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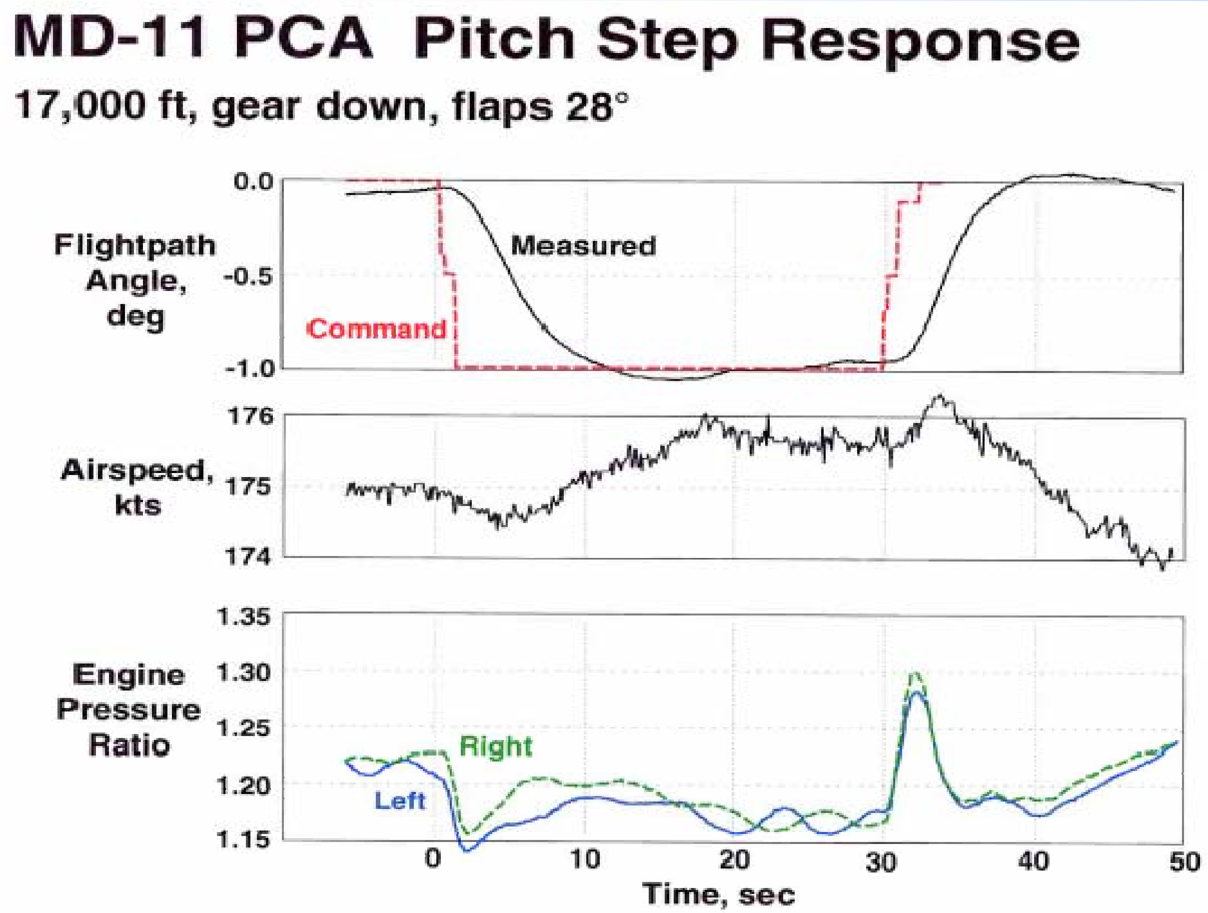

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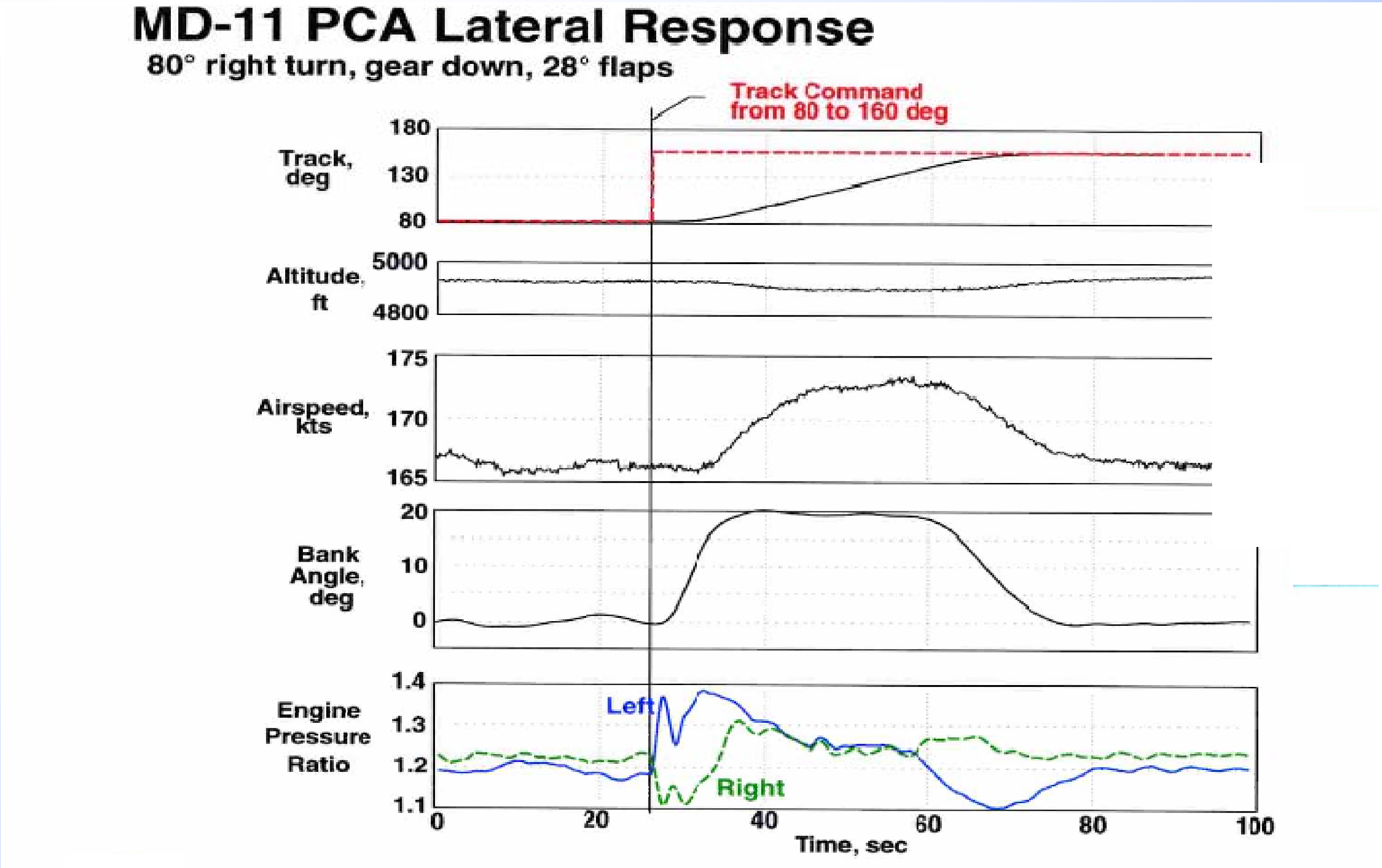

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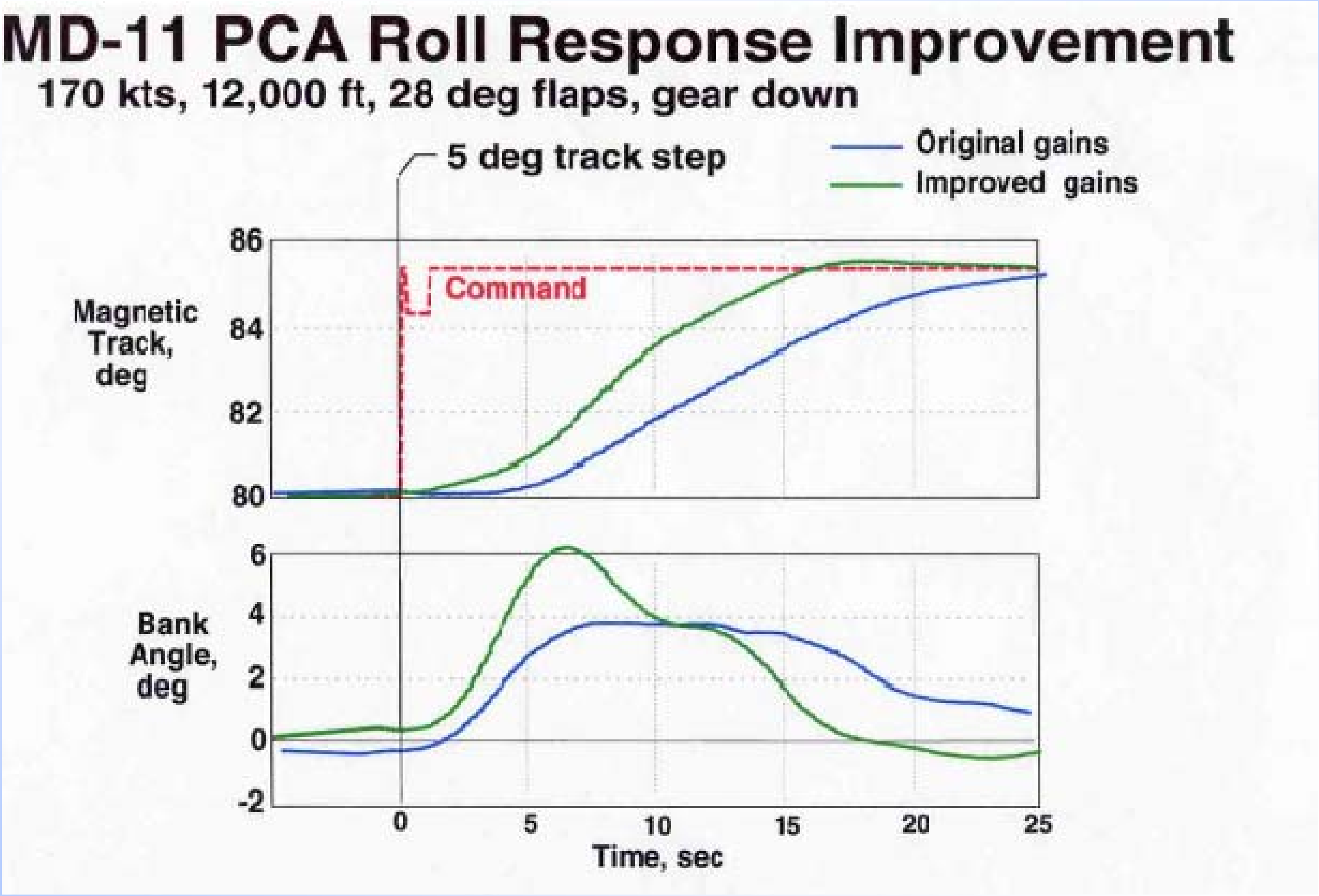

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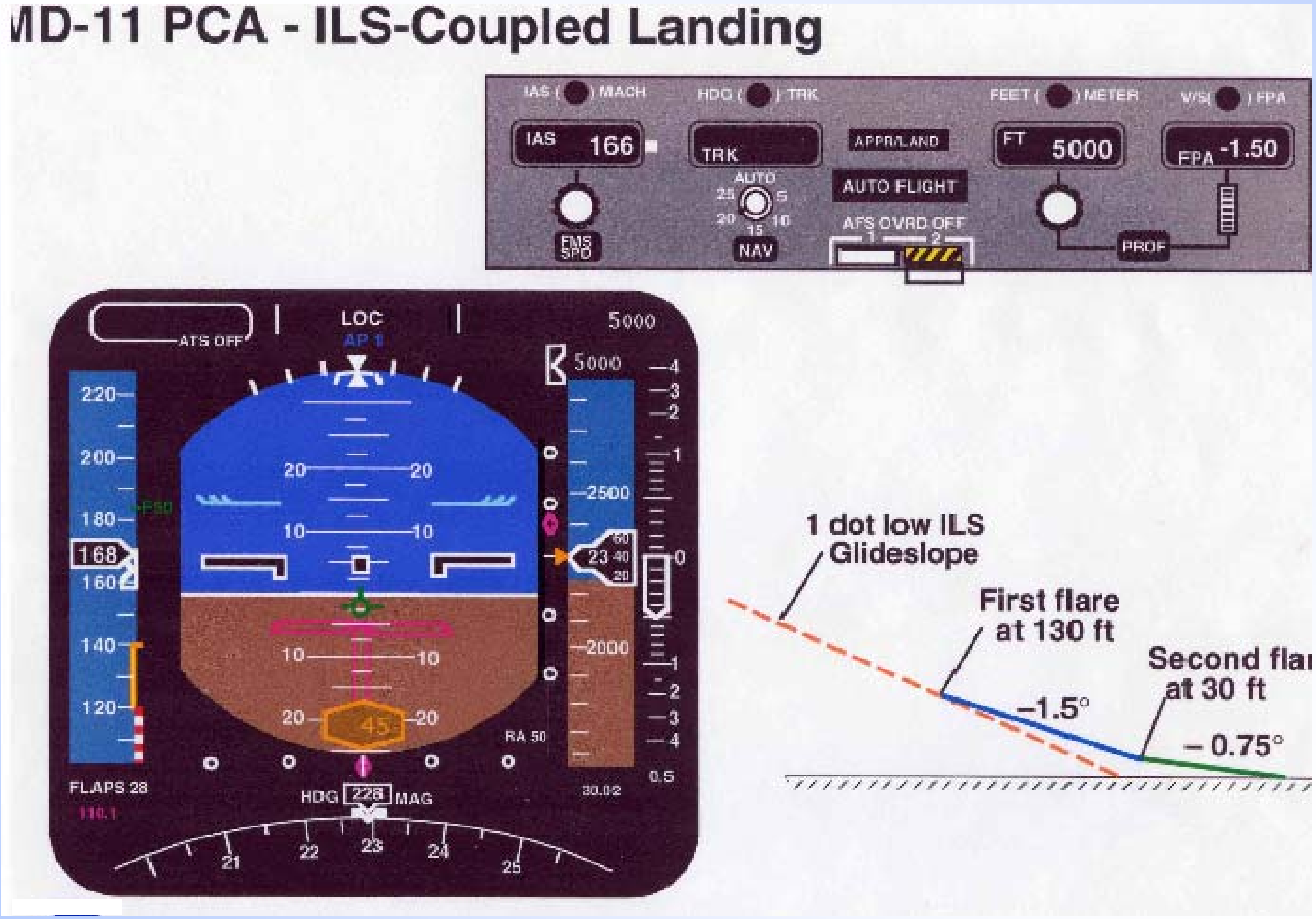

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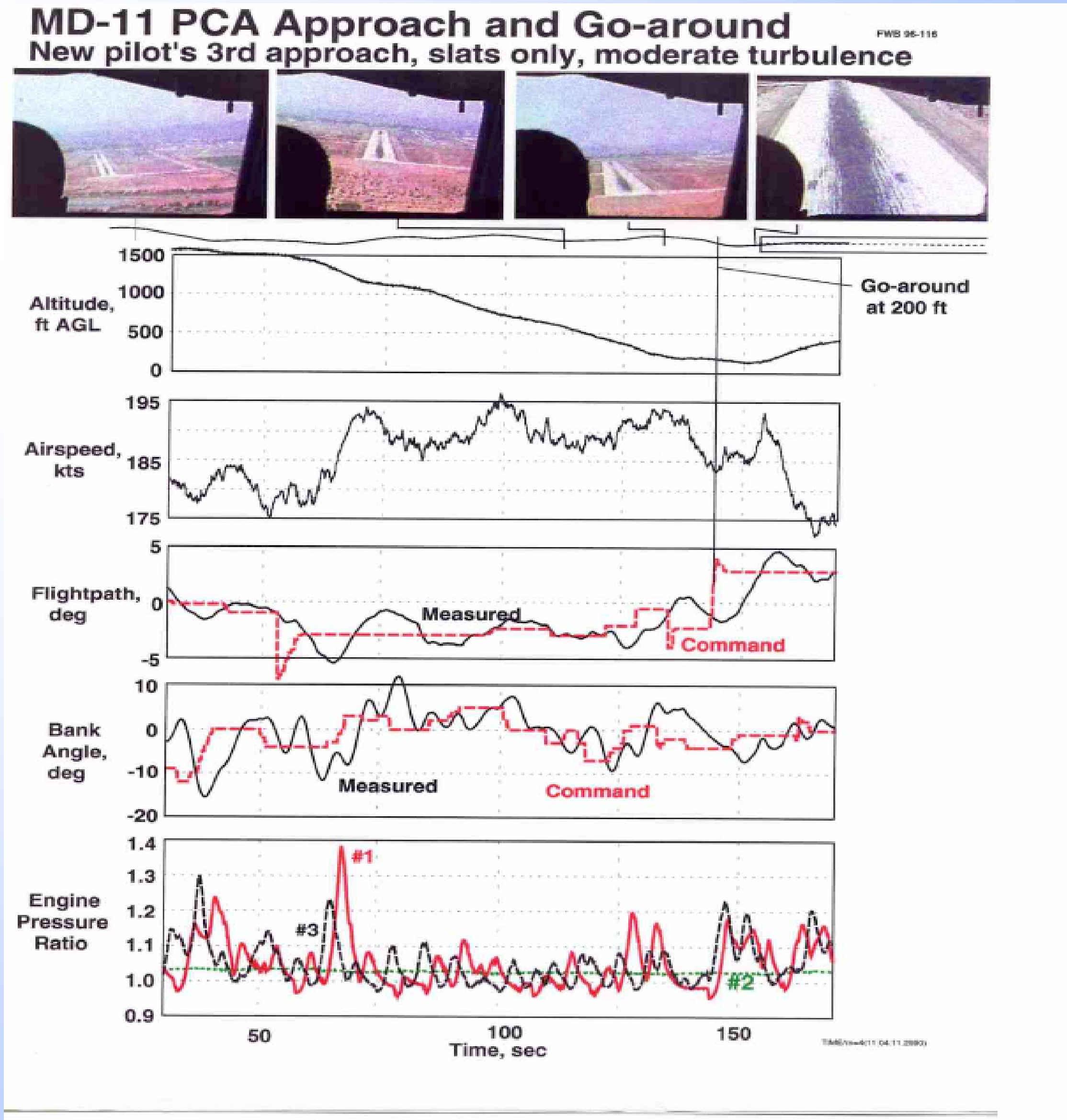

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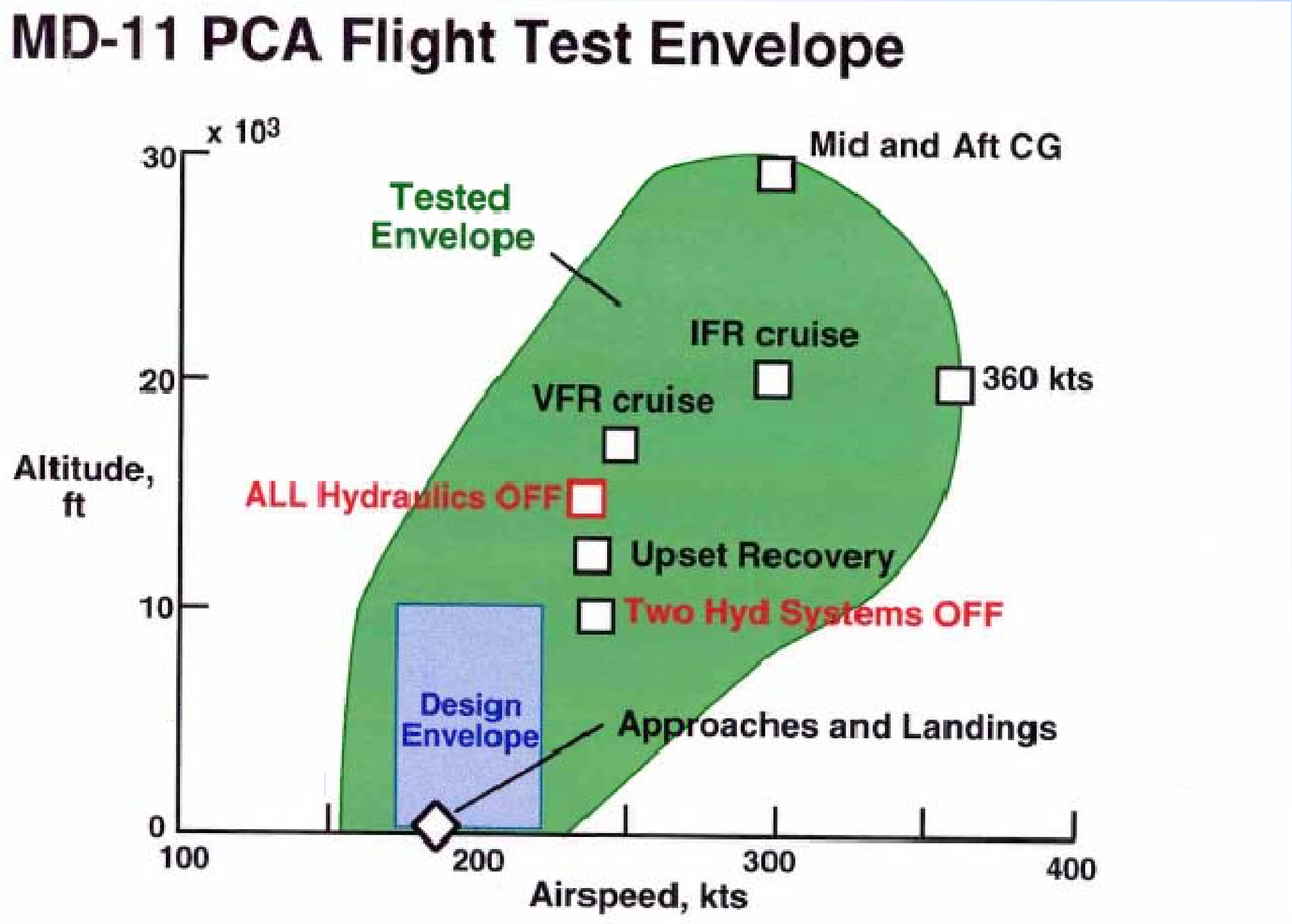
Propulsion - Controlled Aircraft (PCA)

ILS Coupled Video

Propulsion - Controlled Aircraft (PCA)



Propulsion - Controlled Aircraft (PCA)

All Hydraulics Off Test

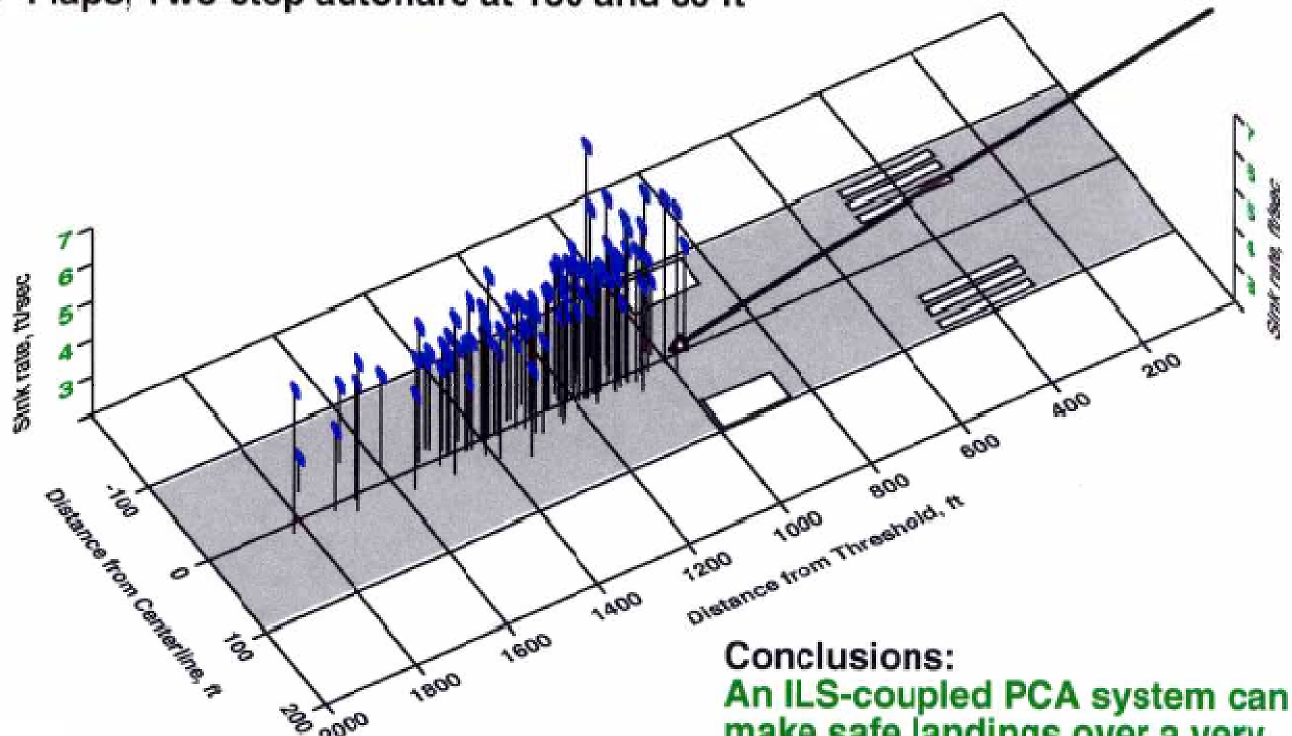
- Stabilizer remains fixed
- Rudder, elevator float near trim position
- Ailerons float up, mild nose-up trim change
- Alternate gear extension, small nose up trim change
- Flew 25 minutes, PCA control like normal autopilot

Propulsion - Controlled Aircraft (PCA)

MD-11 Simulation, PCA ILS-Coupled Landing Dispersion

Hands-off landings, range of weather, weight, and CG, 100 landings

28° Flaps, Two-step autoflare at 130 and 30 ft



Conclusions:
An ILS-coupled PCA system can make safe landings over a very wide range of conditions

Propulsion - Controlled Aircraft (PCA)

Flight Test Results

- No Additional Hardware Required
- Excellent Control – Like Normal Autopilot
- Near Normal Landing Demonstrated
- Manual Pitch/Lateral Inputs Requires Some Practice
  - Coupled Approach/Touchdown Successful on First Attempt
  - Demo for 21 Pilots, Airlines, FAA, DoD, Airbus and Boeing

Propulsion - Controlled Aircraft (PCA)

Certification Issues

- Remote - Extremely Remote - Extremely Improbable
- NTSB – Emergency Flight Control System
- Total Safety Picture
  - System Failure events

    PLUS

  - Ground to Air Attacks

Propulsion - Controlled Aircraft (PCA)

Conclusions / Lessons Learned

- Works Well
  - Like Normal Autopilot
  - Near Normal Landings
- No New Hardware
- Cost Effective
- Certifiable in the short term

Propulsion - Controlled Aircraft (PCA)

Go-Forward Position

- Regulators
    - Continue to advocate Certification Requirement
- Security Interests
    - DHS and TSA have expressed interest
- IFALPA and ICAO
- Educate the Membership and Public
- Manufacturers – Aircraft and Engine OEMs
    - Continue to advocate PCA Development and Incorporation

Throttle Only Control (TOC) Propulsion - Controlled Aircraft (PCA)

Questions?

Acknowledgements

Gordon Fullerton – Chief Pilot NASA DFRC

NASA TM-2004-212045 Manual Manipulation of Engine Throttles for Emergency Flight Control

NASA TP-97-206217 Development and Flight Test of an Emergency Flight Control System Using Only Engine Thrust on an MD-11 Transport Airplane

NASA reports www.ifalpa.intranets.com/ members only section

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