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VMCA Flight Test of the Carrier-Landin', Mail-Hauling' C-2A

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14. ABSTRACT

The C-2A is a Navy, carrier-based aircraft used for the Carrier On-Board Delivery (COD) mission. The aircraft was recently equipped with an L-Probe pitot-static system. Comparison of L-Probe data with previous pitot-static data suggested that approach speeds might be below published Vmc. Analysis of original Vmc flight test suggested that actual Vmc had not been reached. Also, more mission representative Vmc techniques developed in recent years, could provide a more accurate Vmc number. Flight tests were conducted to reassess Vmc using the L-probes as the primary pitot-static source. Vmc tests were conducted in 10 flights, 23 hours and included over 40 actual engine shutdowns. Both the Classic (FTM-103) and Waveoff techniques were used during the flight test. The techniques were conducted at intermediate airspeed ranges for comparative purposes. Both techniques required additional analysis and clarification to ensure minimal airspeed change from the time the engine was secured to the time initial control inputs were made and subsequent. Several other techniques/test conditions were employed to ensure a more conservative Vmc number and proper mission relation. Finally, new airspeed data evaluation considerations helped provide final Vmc numbers for fleet use. The lower Vmc number will permit approach to landings over a broader weight range. The C-2A Vmc test effort not only yielded new, more accurate Vmc numbers for the C-2A aircraft, it also yielded many lessons learned that will be of assistance to future Vmc testers.

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EXHIBIT ONE
[Set of PowerPoint slides to be presented at the Test Pilot School Technical Symposium on 4/14/00, titled, "V_{MCA} Flight Test of the Carrier-Landin', Mail-Haulin' C-2A]

EXHIBIT TWO
[Use – Included in the agenda of topics to be handed out by the Test Pilot School the day of the Symposium on 4/14/00]

Abstract - V_{MCA} Flight Test Of The Carrier-Landin', Mail-Haulin' C-2A

The C-2A is a Navy, carrier-based aircraft used for the Carrier On-board Delivery (COD) mission. The aircraft was recently equipped with an L-Probe pitot-static system. Comparison of L-Probe data with previous pitot-static data suggested that approach speeds might be below published Vmc. Analysis of original Vmc flight test suggested that actual Vmc had not been reached. Also, more mission representative Vmc techniques developed in recent years, could provide a more accurate Vmc number. Flight tests were conducted to reassess Vmc using the L-probes as the primary pitot-static source. Vmc tests were conducted in 10 flights, 23 hours and included over 40 actual engine shutdowns. Both the Classic (FTM-103) and Waveoff techniques were used during the flight test. The techniques were conducted at intermediate airspeed ranges for comparative purposes. Both techniques required additional analysis and clarification to ensure minimal airspeed change from the time the engine was secured to the time initial control inputs were made and subsequent. Several other techniques/test conditions were employed to ensure a more conservative Vmc number and proper mission relation. Finally, new airspeed data evaluation considerations helped provide final Vmc numbers for fleet use. The lower Vmc number will permit approach to landings over a broader weight range. , The C-2A Vmc test effort not only yielded new, more accurate Vmc numbers for the C-2A aircraft, it also yielded many lessons learned that will be of assistance to future Vmc testers.

V_{MCA} Flight Test of the Carrier-Landin', Mail-Haulin' C-2A

Michael J. Wagner (5.5)

Chuck Webb (4.11)

14 Apr 2000
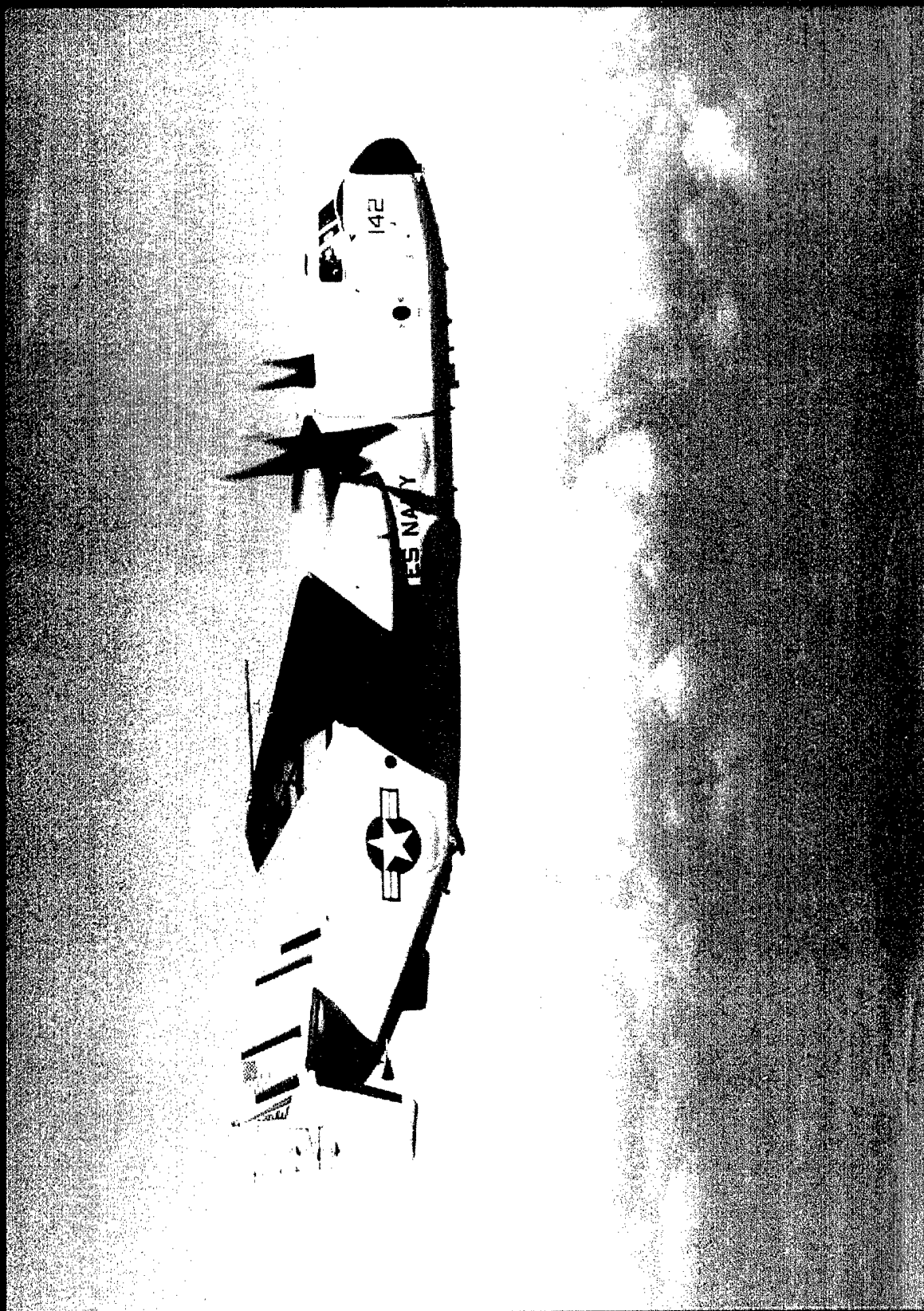
V_{MCA} - Background

- Installed and tested L-shaped pitot-static probes

- Test results showed approach speeds below some historical approach speeds and those published in Aircraft Recovery Bulletins. Also below V_{MCA} for nearly all landing weights.

- Approach Speed Chart - reveals need to verify V_{MCA}

Config PA(20) Approach Speeds
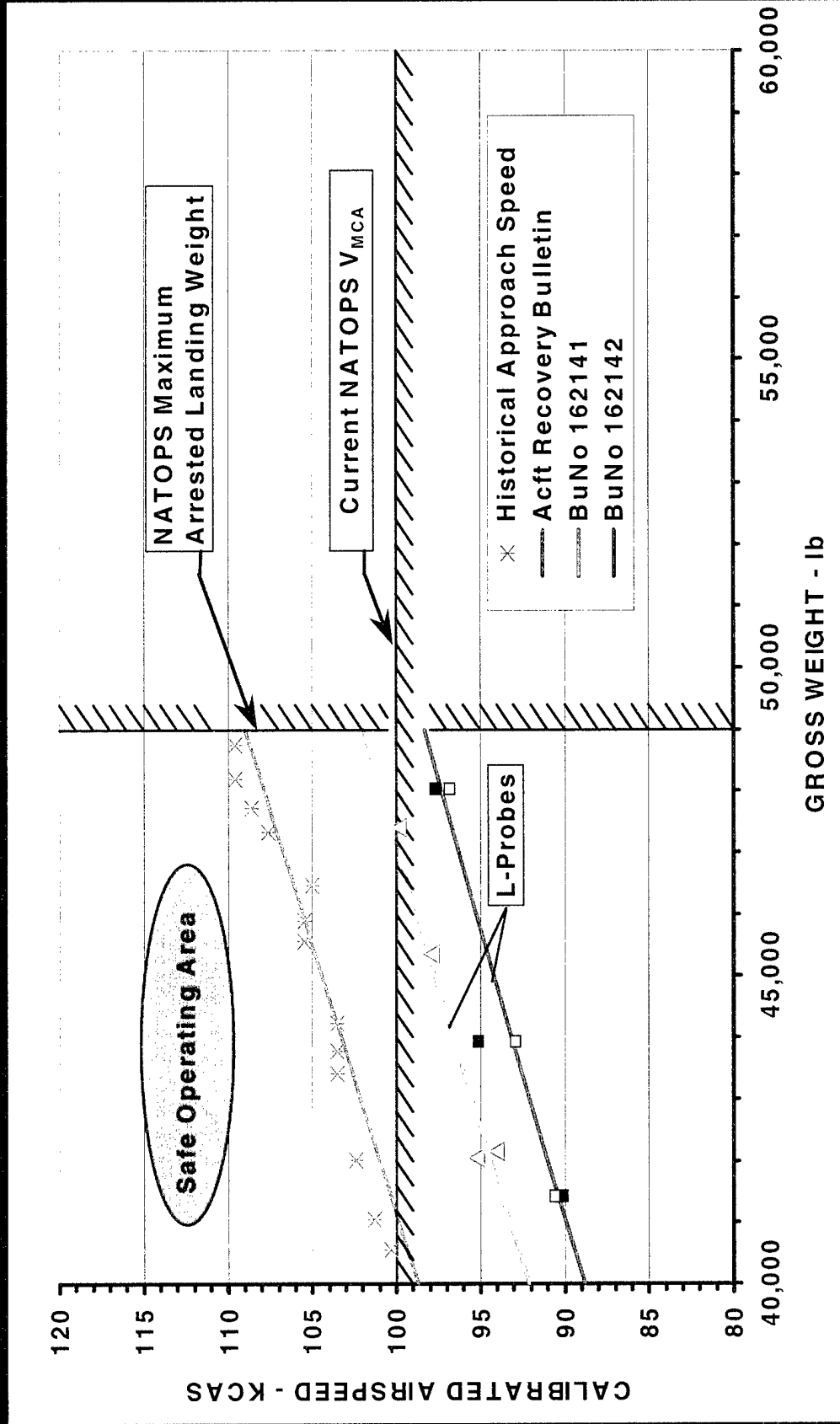
V_{MCA} – Background

- **Current NATOPS V_{MCA} – 100 KIAS**

  – 100 KCAS came from C-2A Increased Gross Weight testing

  – 100 KCAS transposed to 100 KIAS – date unknown

  – Accuracy – According to report data, at 100 KCAS additional rudder control power is still available

V_{MCA} – Scope of Tests

- Conditions
  - WO(20) – gear down, flaps 20
  - WO(30) – gear down, flaps 30
  - Power – defined by test technique
  - Altitude – 4000 ft
- 10 flights, 23 hours, V_{MCA} Static and Dynamic
- Techniques Used
  - Classic (method used to obtain current V_{MCA})
  - Waveoff (method used in E-2C PLUS tests, considered more mission representative, yielded ultimate results)

Classic Technique

- Stabilize in climb at target airspeed with max power (4600 ISHP/engine)

- At target altitude copilot fails desired engine by rapidly pulling Condition Lever to FX (simulated – power lever to Flight Idle)

- No inputs for 1 second (except longitudinal inputs to control airspeed loss if desired)

- Apply recovery inputs as required

Classic Technique:
Pros and Cons

- Pros
  - Repeatable
  - Stable conditions at maximum power
- Cons
  - Not mission representative
  - Airspeed control following engine failure
    - large airspeed loss
    - large longitudinal push over required in an attempt to minimize airspeed loss
  - Extremely nose high attitude

Waveoff Technique

- Establish 500 FPM ROD

- At target airspeed and altitude, rapidly advance power levers to max

- On power addition, copilot immediately fails FX (simulated – power lever to Flight Idle)

- No inputs for 1 second (except small desired engine by pulling Condition Lever to longitudinal inputs to control airspeed gain)

- Apply recovery inputs as required

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Waveoff Technique: Pros and Cons

- Pros
  - Very mission representative (engine failure on waveoff)
  - Better airspeed control than Classic following engine failure

- Cons
  - Airspeed control following engine failure
    - acceleration during power addition
  - Dynamic engine response with power addition
  - Can be non-repeatable inputs on waveoff and recovery

Waveoff Technique Adjustments

Method	Waveoff	FX/PL Chop <---- 1 sec delay ---->	Recovery
Some Rudder			
More Rudder			
Open Loop			
Closed Loop			

Waveoff Technique: Built-In Conservatism

- Very rapid power addition (PGS to max power in ~0.2 seconds)
  - Mechanical Power Lever Stop - adjustable for test day conditions. Prevent engine over-torque or over-temp on rapid power addition
- Minimized airspeed acceleration
  - Adding power on one engine while failing other
  - Permitted nose to rise slightly on power addition

Waveoff Technique:
Built-In Conservatism (cont'd)

- Aft CG
- 1 second delay from engine failure to initial recovery inputs
- Different test pilot used for end points

V$_{MCA}$ Criteria:

- Angular acceleration fails to reverse immediately at control input

- The time from initiation of rudder input to 0 yaw rate is greater than 2 sec

- 23 ½ units AOA
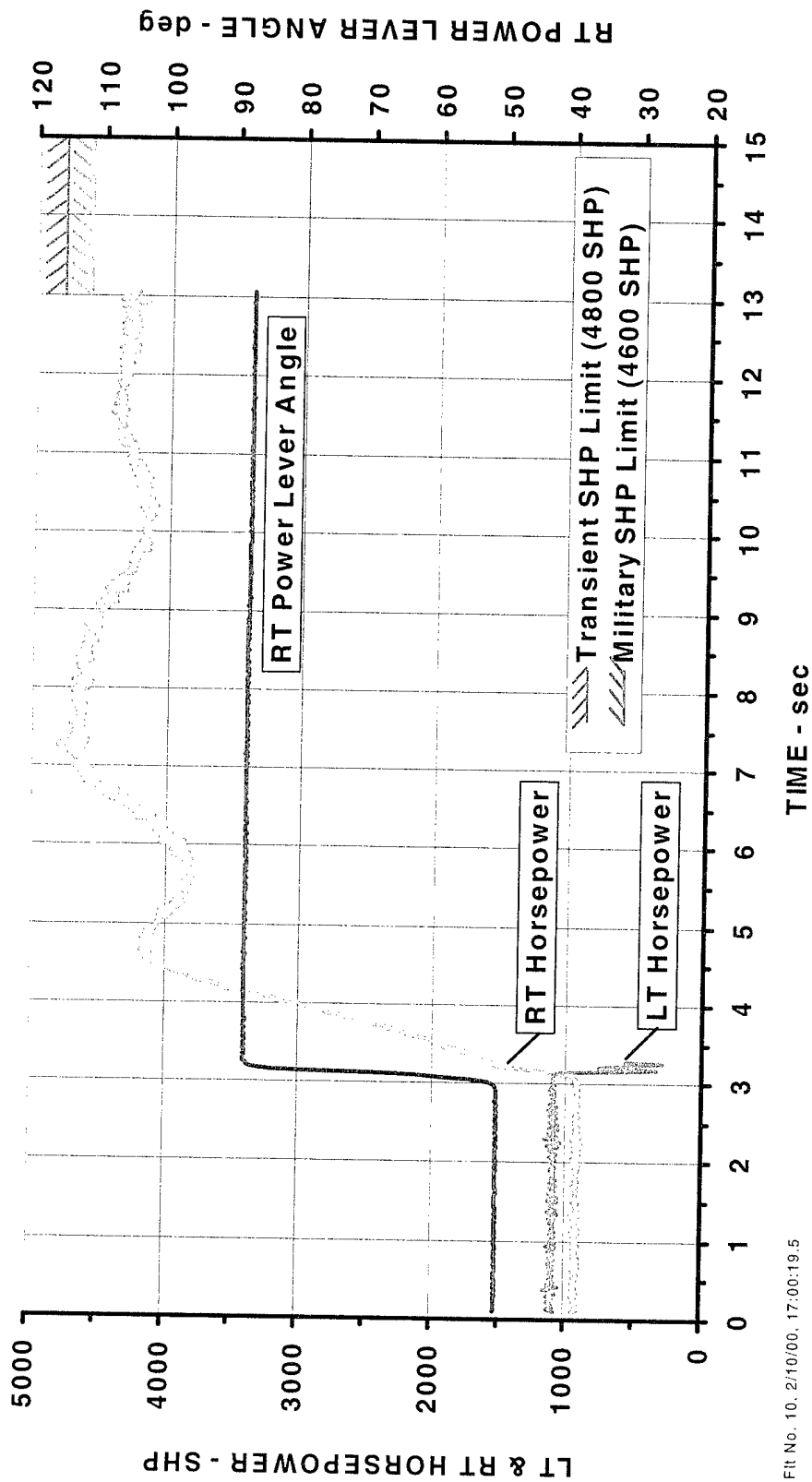
- Greater than 15 deg sideslip

V_{MCA} Criteria (cont'd):

- Greater than 20 deg bank angle
- Greater than 20 deg heading change
- Static single engine control airspeed
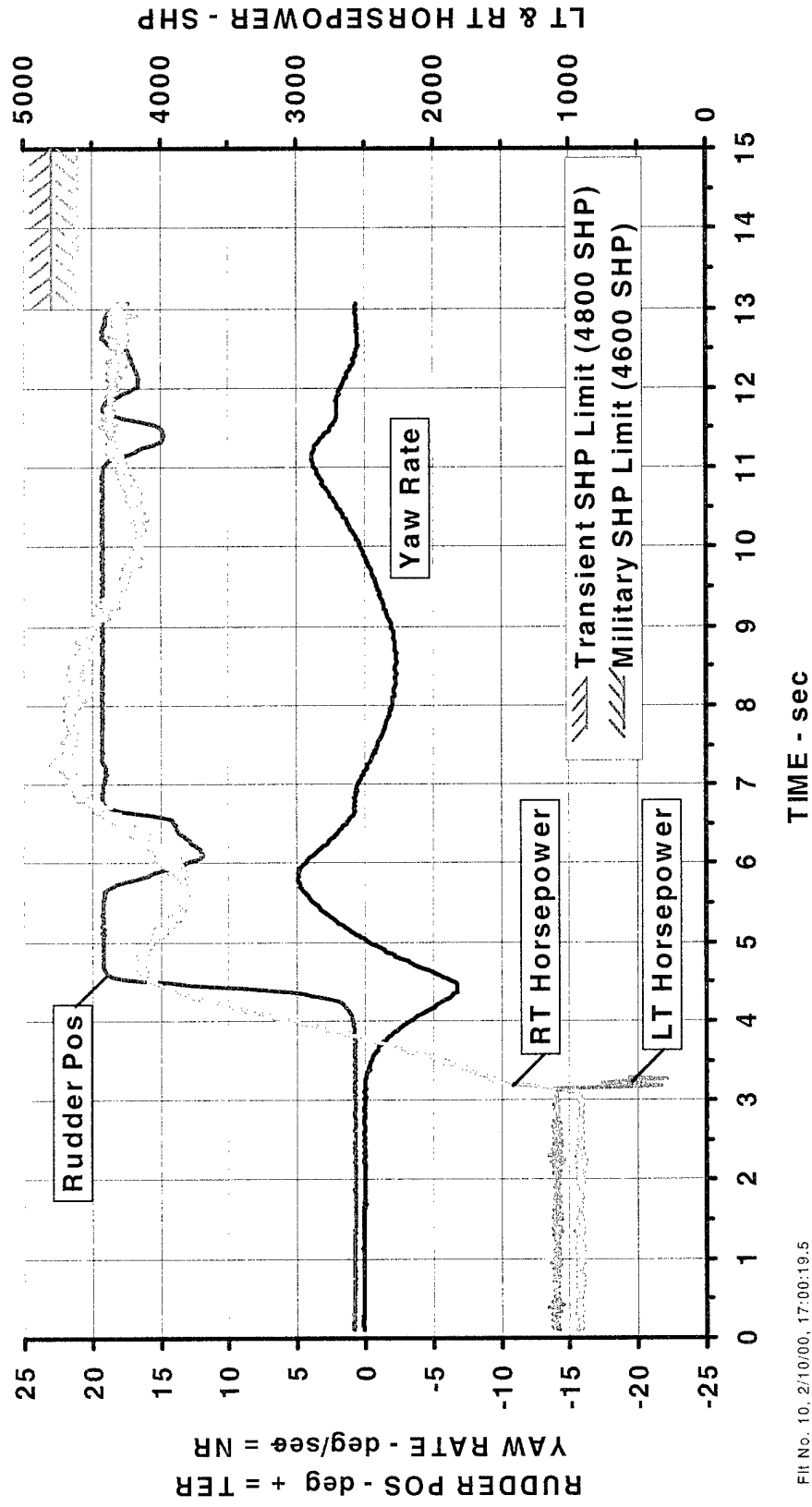- Recovery is unsafe or required excessive workload for the average pilot

Results

- Left engine was determined to be critical from previous testing and V_{mc} Static
- Results indicate a lower V_{MCA} than previously reported
  - V_{MCA} flaps 20 - 95 KIAS
  - V_{MCA} flaps 30 - 96 KIAS
- Although controllable above V_{MCA}, positive SERC performance is not assured

Engine Response

RT POWER LEVER ANGLE - deg

LT & RT HORSEPOWER - SHP

TIME - sec

RT Power Lever Angle

Transient SHP Limit (4800 SHP)
Military SHP Limit (4600 SHP)

RT Horsepower

LT Horsepower

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Recovery

Flt No. 10, 2/10/00, 17:00:19.5

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Waveoff Technique:
Another Possible Approach

- Stabilize on target airspeed with 1/2 max power on each engine
- Concurrently –
  - FX target engine
  - Add Max power on other engine
- Recovery inputs after 1-2 second delay
- Technique minimizes accel – no net change in thrust
- Not tested here

Lessons Learned / Summary

- Plan dual-engine waveoff control input profiles and consider their impact on V_{MCA} control inputs

- Waveoff technique – operating engine may not be at maximum power when attaining V_{MCA} depending on engine response

- Adequate single engine performance may not be assured at V_{MCA} - ex.: rate of climb

Lessons Learned / Summary

- C-2A NATOPS changes
  - New V_{MCA}
  - "Engine Failure During Waveoff" - descriptive paragraph not previously incorporated