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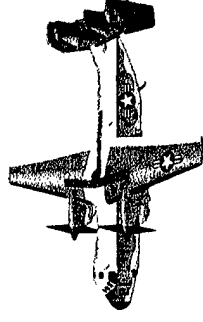
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V_{MCA} Flight Test of the

C-2A



Michael J. Wagner

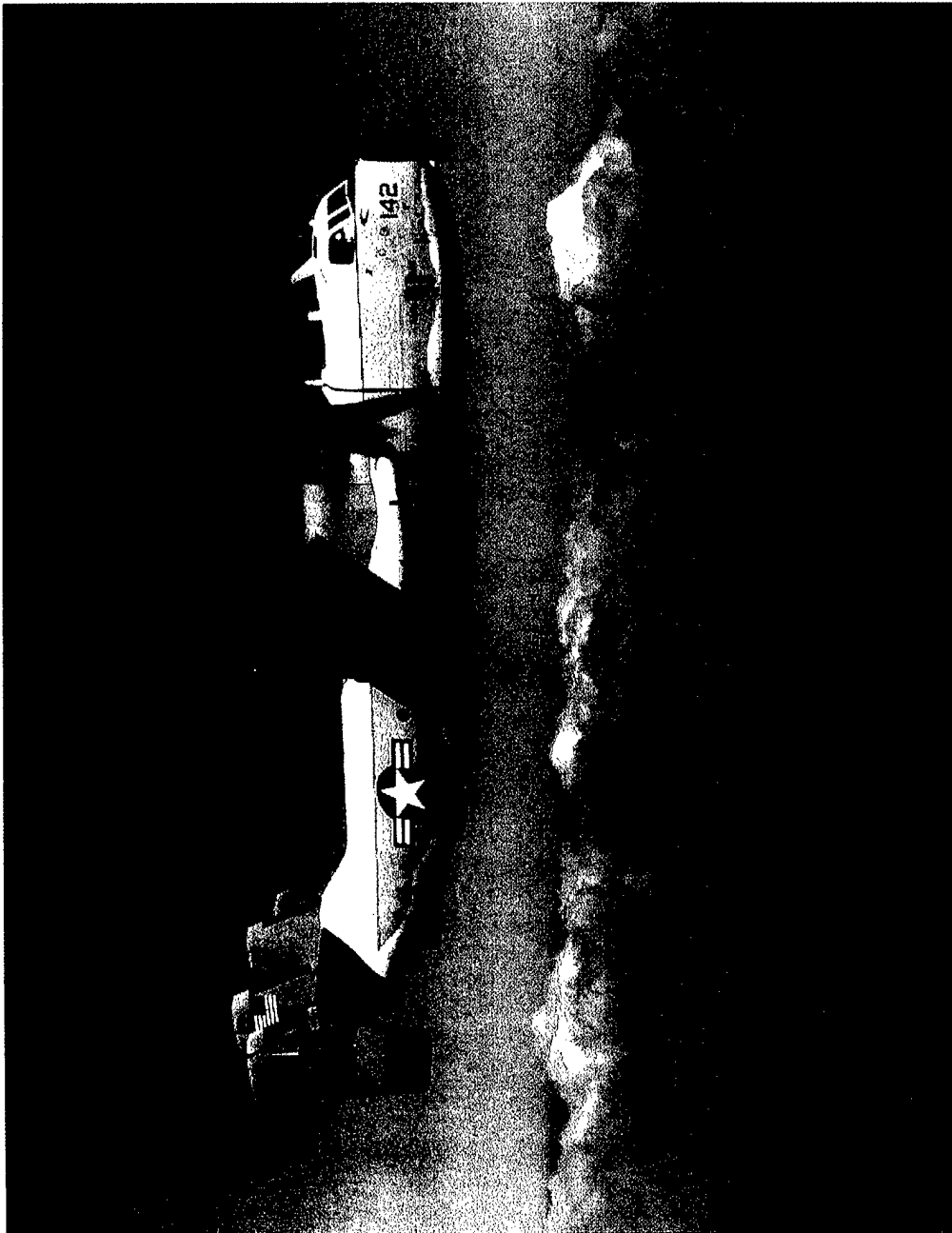
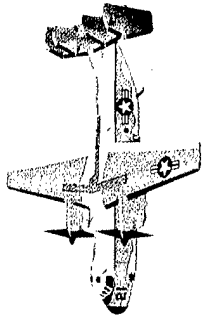
Charles E. Webb

Naval Air Warfare Center-Aircraft Division
Patuxent River, MD

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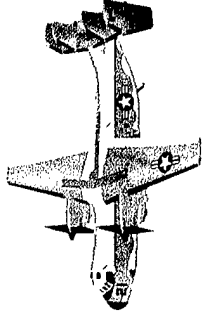
30 Mar 2001

VMC 3_5_2001



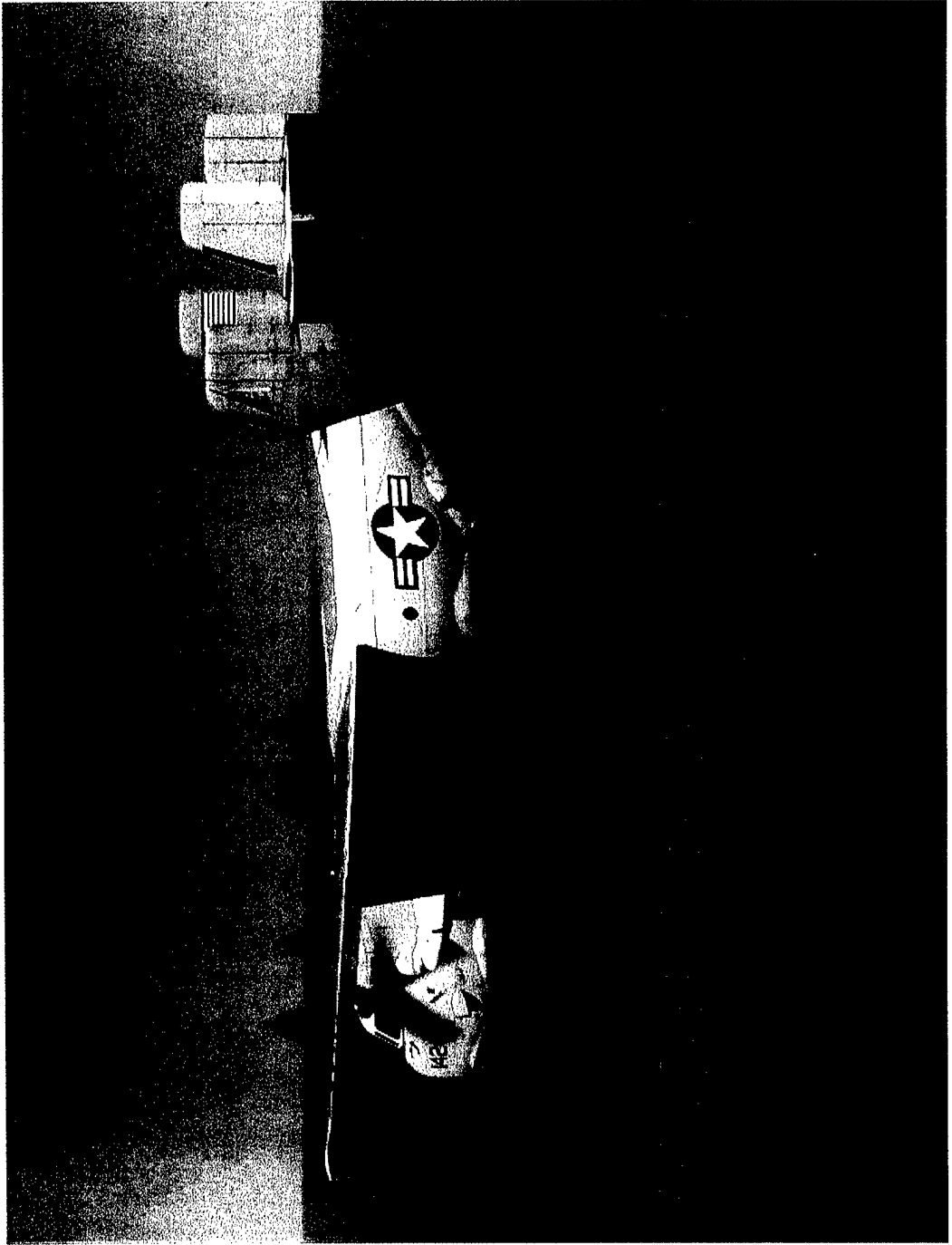
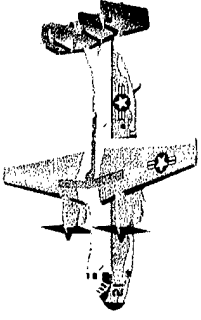


C-2A Greyhound - The



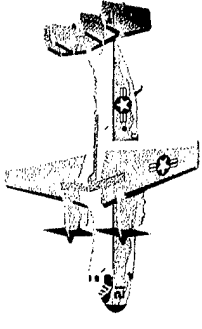
Basics

- Aircraft Carrier-based cargo aircraft built by Grumman. Original design/construction early-mid 60's.
- Twin-engine turboprop producing 4,600 SHP per engine.
- Range - 1200 NM, Basic weight - 38,000 lbs., Max T/O weight - 60,000 lbs.
- Cargo - 10,000 lbs., Pax - 26
- Wingspan - 81 feet, Length - 57 feet



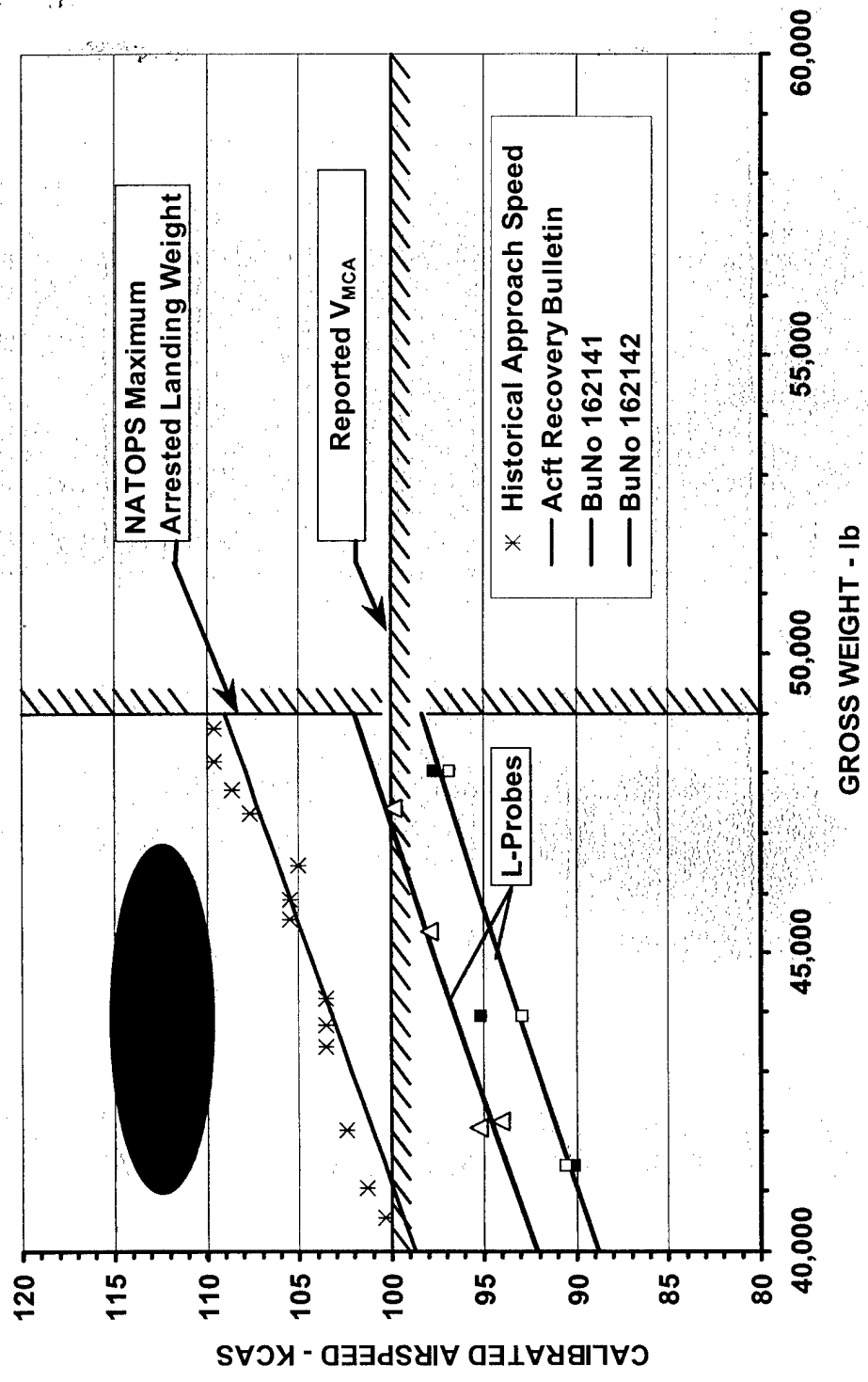
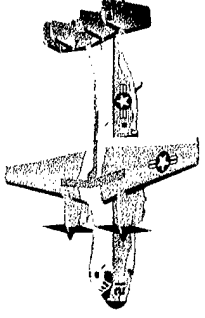


V_{MCA} - Background



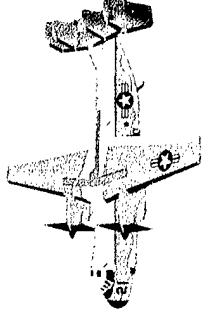
- Original pitot-static system upgraded to L-shaped pitot-static probes
- L-Probe test results showed approach speeds below some historical approach speeds and those published in Aircraft Recovery Bulletin.
- Approach speeds also below then-published V_{MCA} for nearly all landing weights.

Configuration PA(20) Approach Speeds





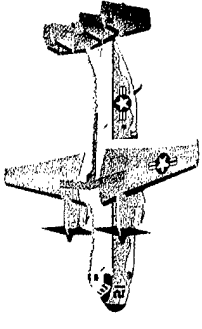
V_{MCA} - Background (2)



- Then-current Flight Manual (NATOPS)
 - V_{MCA}
 - 100 KCAS came from C-2A Increased Gross Weight testing of 1988
 - 100 KCAS transposed to 100 KIAS
 - Report data showed at 100 KCAS additional rudder control power was still available



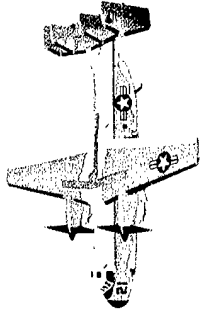
V_{MCA} - Scope of Tests



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



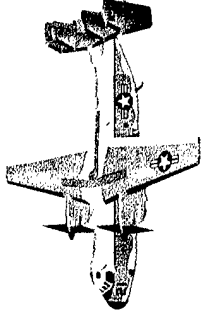
Classic Technique



- 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



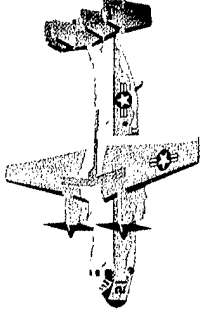
Classic Technique: Pros and Cons



- Pros
 - Repeatable
 - Stable conditions at maximum power
- Cons
 - Nose high attitude
 - Not mission representative
 - Airspeed control following engine failure
 - Large airspeed loss
 - Large longitudinal push-over required to minimize airspeed loss



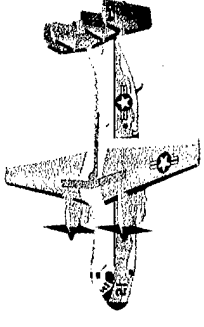
Waveoff Technique



- Establish 500 FPM ROD (simulated approach)
- At target airspeed and altitude, rapidly advance power levers to max
- On power addition, copilot immediately fails desired engine by pulling Condition Lever to FX (simulated - power lever to Flight Idle)
- No inputs for 1 second (except small longitudinal inputs to control airspeed gain)
- Apply recovery inputs as required



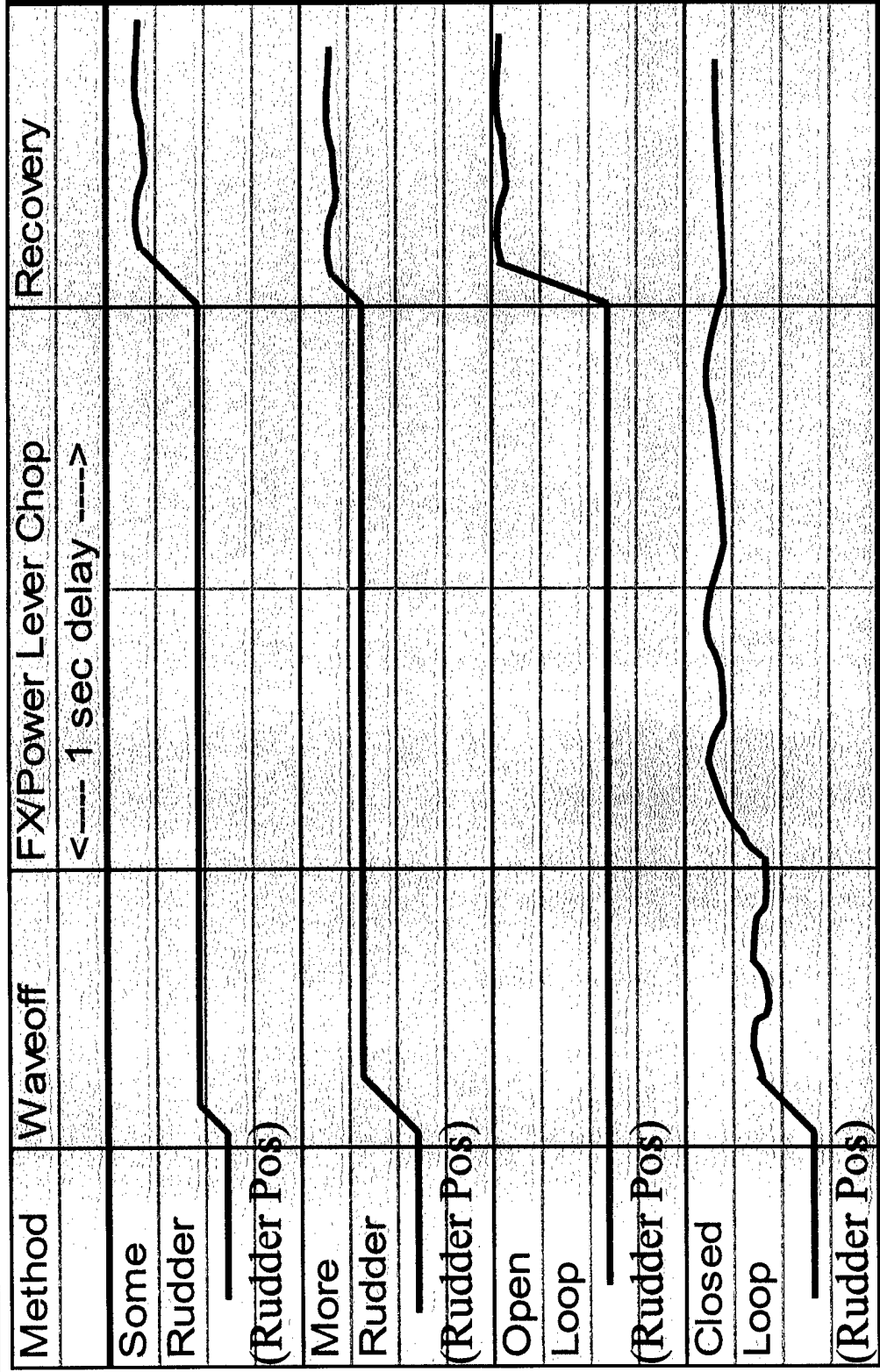
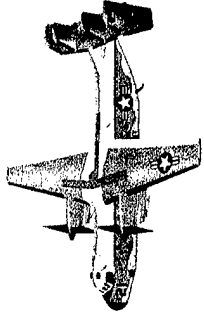
Waveoff Technique: Pros and Cons



- 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
 - There can be non-repeatable control inputs on waveoff and recovery



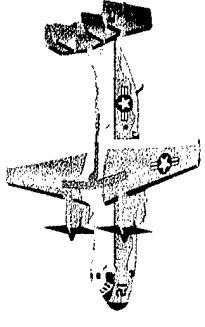
Waveoff Technique Adjustments



Time →



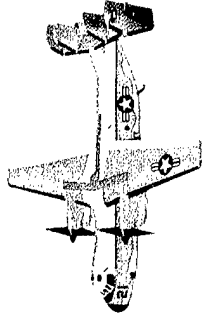
Waveoff Technique: Built-In Conservatism



- Very rapid power addition
 - Power for Glide Slope to max power in ~ 0.2 seconds
 - Mechanical Power Lever Stop - adjustable for test day conditions. Allowed rapid power addition while preventing engine over-torque or over-temp
- Minimized airspeed acceleration
 - Simultaneously failed target engine while adding power on other
 - Permitted nose to rise slightly on power addition



Waveoff Technique: Built-In Conservatism (2)

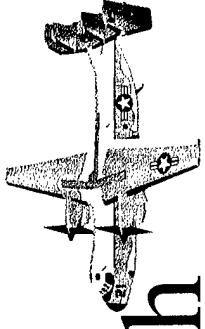


- Aft CG
- 1 second delay from engine failure to initial recovery inputs
- Different test pilot used for end points



Waveoff Technique:

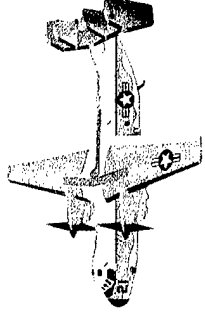
Another Possible Approach



- 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 may minimize airspeed change on engine failure
 - Net change of 0 thrust
- Not tested here



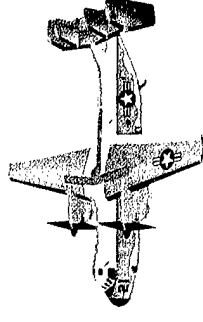
V_{MCA} Criteria:



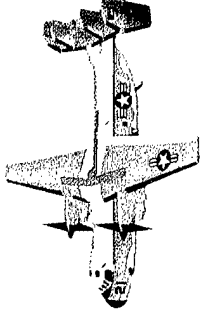
- Angular acceleration fails to reverse immediately at control input
- Time from initiation of rudder input to 0 yaw rate is greater than 2 sec
- 23 ½ units AOA (artificial stall warning)
- > 15 deg sideslip



V_{MCA} Criteria (2):



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

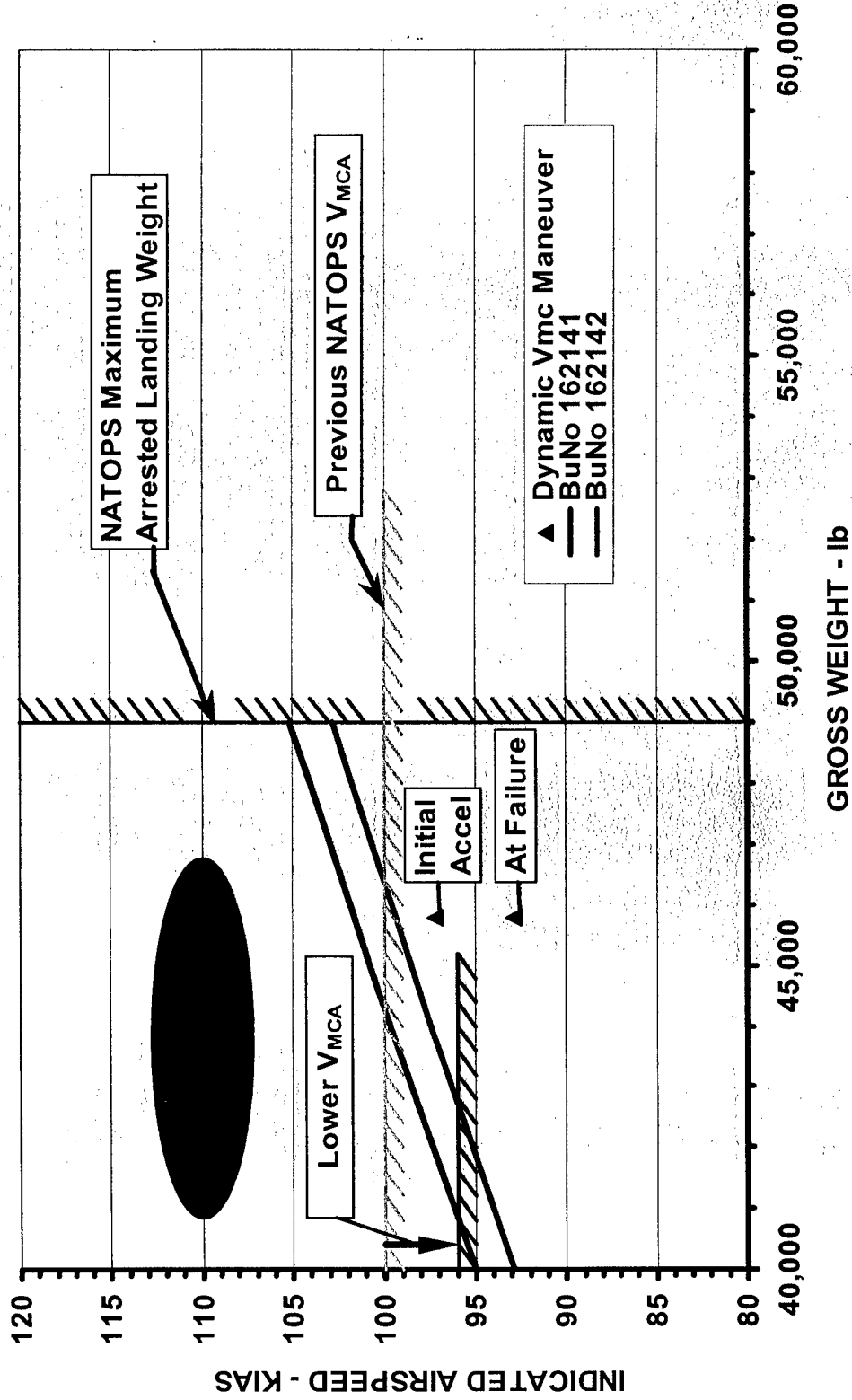
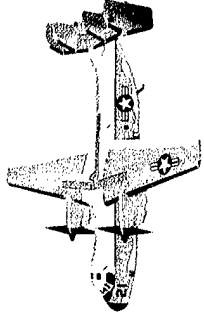


Results

- 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 (excessive workload)
 - V_{MCA} flaps 30 - 96 KIAS (V_{MC} Static)
- Although controllable above V_{MCA} , adequate SERC performance is not assured

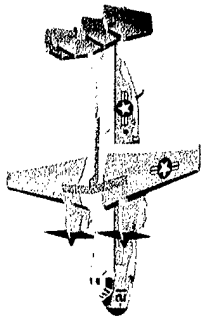


Dynamic Vmc Results, 20 Flaps

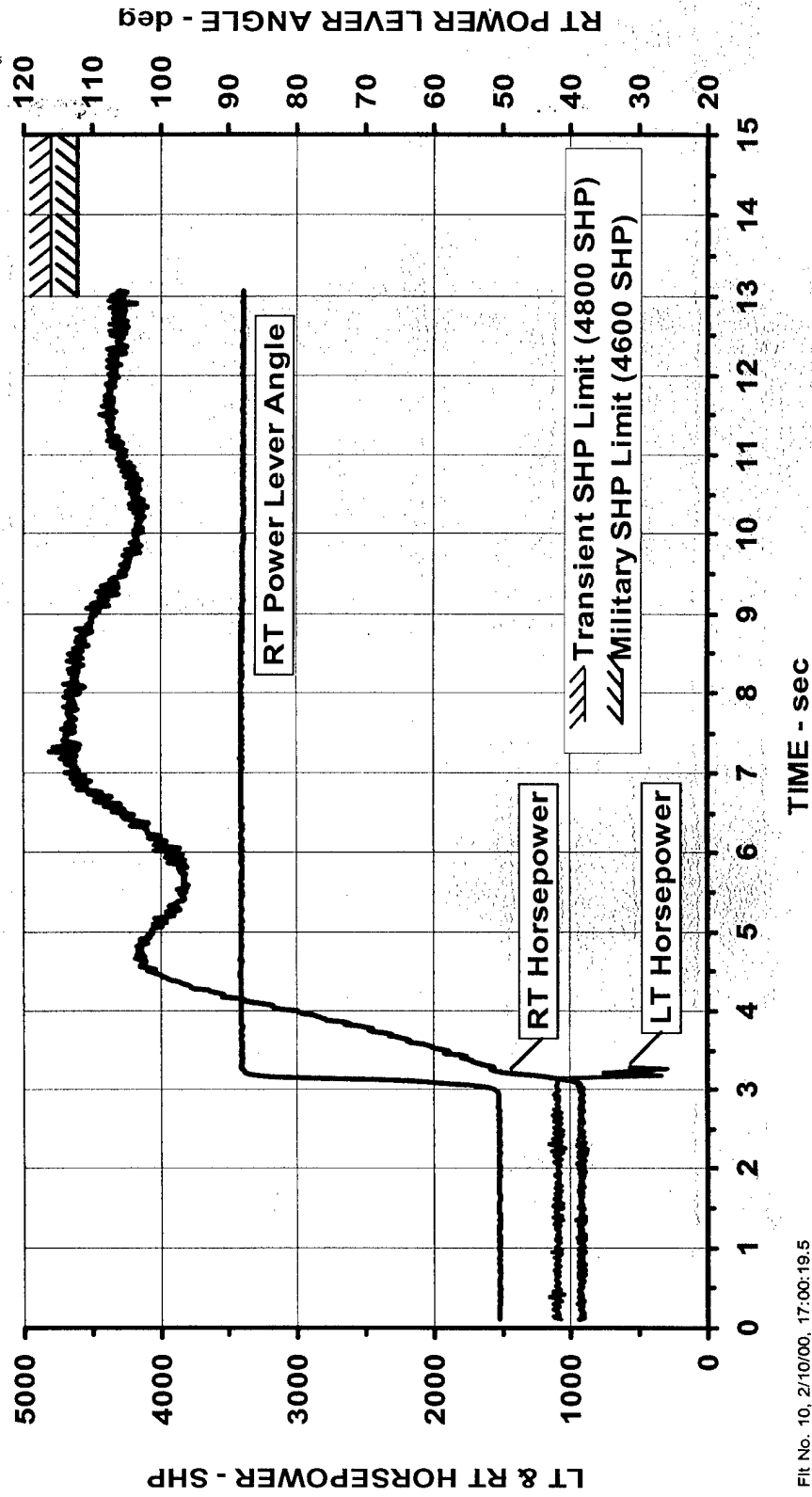




Engine Response

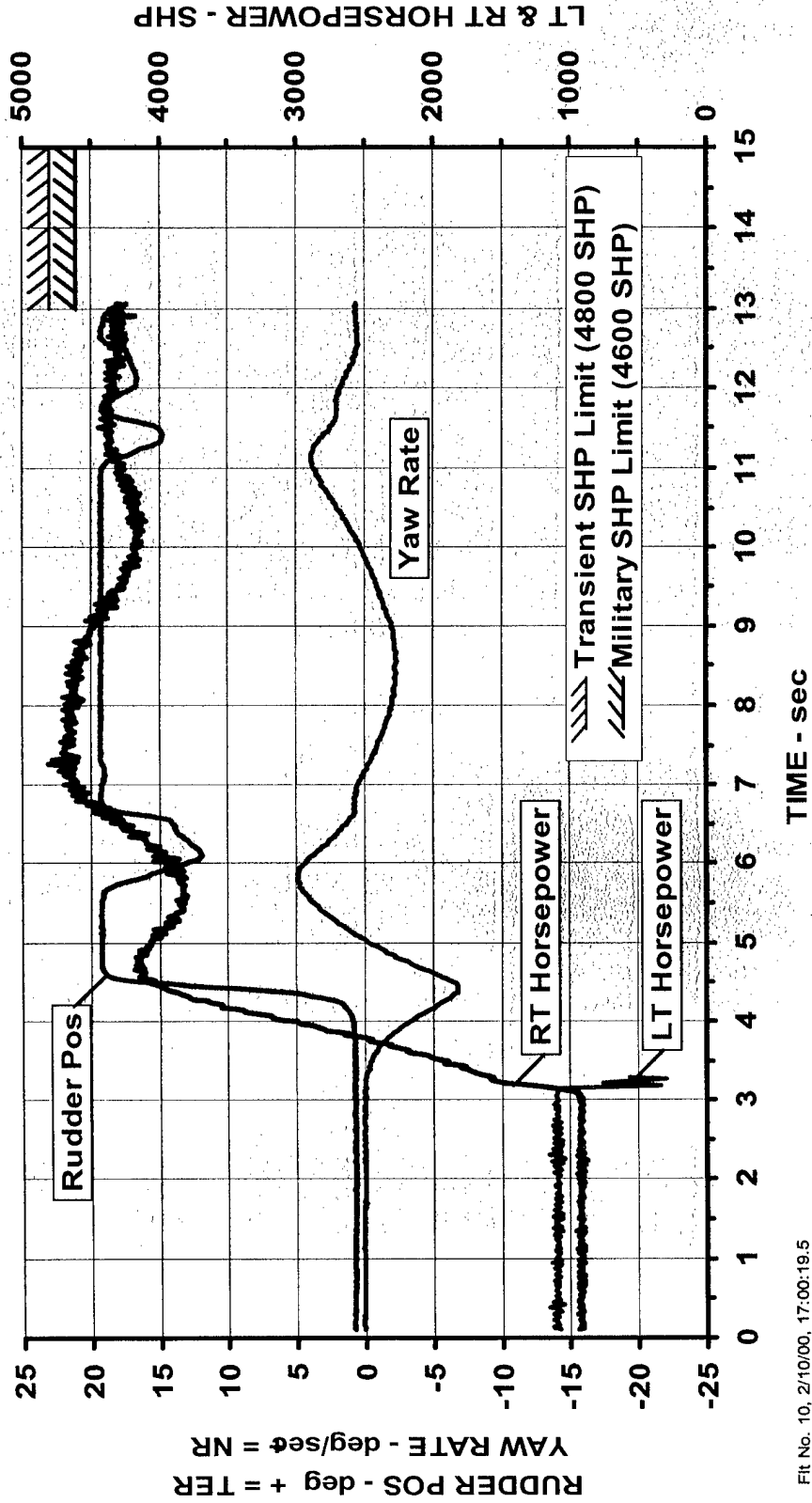
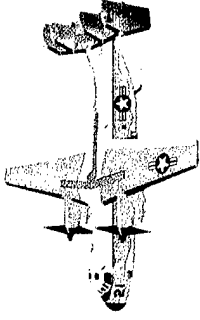


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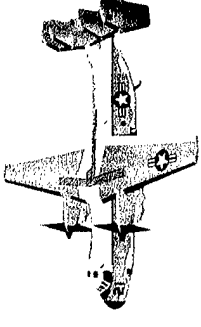
Recovery



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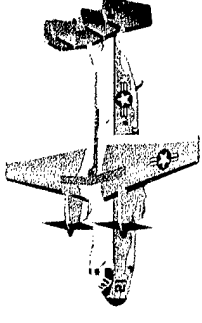
Recommendations



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



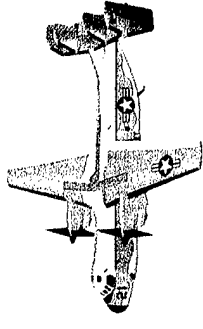
Lessons Learned



- Test Planning:
 - Consider normal dual-engine waveoff control input profiles and assess their impact on control inputs during V_{MCA} tests
 - Consider different methods of securing engine/FX prop (Auto FX, Condition Lever, T-handle)



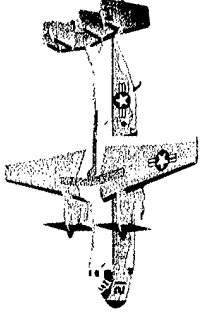
Lessons Learned (2)



- Testing:
 - Minimize airspeed change from engine failure to recovery inputs.
 - Consider impact of airspeed changes in data reduction.
 - Waveoff technique - Operating engine may not be at maximum power when making recovery inputs (depends on engine response)

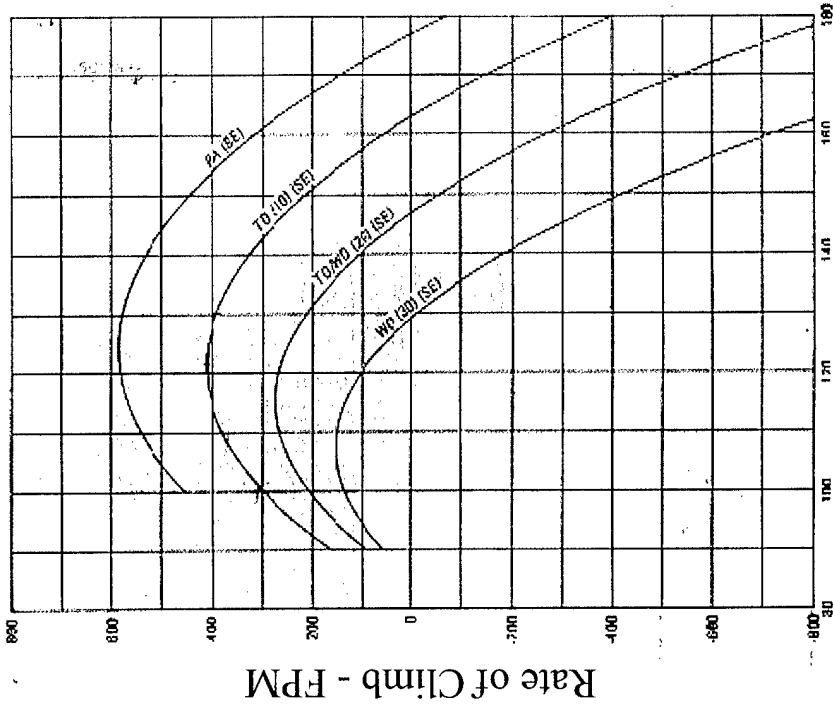


Lessons Learned (3)



GROSS WEIGHT: 61,960 LB
PRESSURE ALTITUDE: SEA LEVEL
AMBIENT AIR TEMPERATURE: STANDARD DAY (59°F)
NOTE: RATE OF CLIMB CALCULATED FROM FLIGHT TEST DRAG POLAR AND SPECIFICATION ENGINE DECK

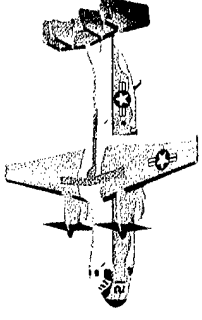
LEFT ENGINE FEATHERED
MILITARY RATED POWER
LANDING GEAR DOWN



Calibrated Airspeed - KCAS

CC-SINGLE-ENGINE CLIMB PERFORMANCE
Reproduced C-2A Airplane, Buks 162110

- V_{MCA} Ramification
 - Adequate single engine performance may not be assured at V_{MCA}
 - Example: Rate of climb



?? Questions ??