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

Mike Wagner        Chuck Webb

Naval Air Warfare Center Aircraft Division
22347 Cedar Point Road, Unit #6
Patuxent River, Maryland 20670-1161

Naval Air Systems Command
47123 Buse Road Unit IPT
Patuxent River, Maryland 20670-1547

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 (PTM-103) and Wavescant 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.
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 V_{mca}. Analysis of original V_{mca} flight test suggested that actual V_{mca} had not been reached. Also, more mission representative V_{mca} techniques developed in recent years, could provide a more accurate V_{mca} number. Flight tests were conducted to reassess V_{mca} using the L-probes as the primary pitot-static source. V_{mca} 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 V_{mca} number and proper mission relation. Finally, new airspeed data evaluation considerations helped provide final V_{mca} numbers for fleet use. The lower V_{mca} number will permit approach to landings over a broader weight range. The C-2A V_{mca} test effort not only yielded new, more accurate V_{mca} numbers for the C-2A aircraft, it also yielded many lessons learned that will be of assistance to future V_{mca} testers.
$V_{MCA}$ Flight Test of the Carrier-Landin’, Mail-Haulin’ C-2A

Michael J. Wagner (5.5)
Chuck Webb (4.11)

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\( V_{MCA} \) - 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

- Safe Operating Area
- NATOPS Maximum Arrested Landing Weight
- Current NATOPS $V_{MCA}$
- Historical Approach Speed
  - Acft Recovery Bulletin
  - BuNo 162141
  - BuNo 162142

CALIBRATED AIRSPEED - KCAS

GROSS WEIGHT - lb
$V_{MCA}$ - 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
Pros and Cons Classic Technique:

- Extremely nose high attitude
- Minimize airspeed loss
- Large longitudinal push over required in an attempt to
- Large airspeed loss
- Airspeed control following engine failure
- Not mission representative

Cons

- Stable conditions at maximum power
- Repeatable
Waveoff Technique

- Apply recovery inputs as required
- No inputs for 1 second (except small longitudinal inputs to control airspeed gain)
- FX (simulated - power lever to Flight Idle)
- On power addition, copilot immediately fails desired engine by pulling Condition Lever to advance power levers to max
- At target airspeed and altitude, rapidly establish 500 FPM ROD
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 $\frac{1}{2}$ 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

- LT & RT Horsepower - SHP
- RT Power Lever Angle
- Transient SHP Limit (4800 SHP)
- Military SHP Limit (4600 SHP)
Recovery
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