GENERAL DYNAMICS
Armament and Technical Products
APKWS Flight Test Results

Validation of Aerodynamic Coefficients

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April 27, 2005
Agenda

- APKWS Guided Rocket
- F-4 Telemetry Data
- Validation of Aerodynamic Coefficients
- Preprogrammed Flight F-4 Maneuvers
- Inertially Guided Flight F-4
- F-4 Post-flight Analysis
- Guided Flight F-6A
- Lessons Learned
APKWS Guided Rocket

MK 66 MOD 4
2.75-inch Rocket Motor

Guidance Section

M151/M423
Warhead & Fuze

Telemetry Warhead used in DT Flights

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F-4 Telemetry Data

Witness Sensors Provide:
• Axial acceleration
• Lateral acceleration
• Normal acceleration
• Yaw rate
• Pitch rate
• Roll Rate
• Y axis magnetic field strength
• Z axis magnetic field strength

Guidance Section IMU Provides:
• Yaw rate
• Pitch rate
• Roll rate

Other G&C Data:
• Seeker Angle and LOS Rates
• CAS Data
Validation of Aerodynamic Coefficients

Aerodynamic Coefficients – NASA Ames

Guidance Section Autopilot

Pre-programmed IGTV Flight F-4

Post-flight TM Data Analysis

Validated Aero Coefficients

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Preprogrammed Flight F-4 Maneuvers

- Preprogrammed Autopilot Rate Commands
  - Aerodynamic coefficients from NASA Ames Tunnel data
- Flight Path Angle Rate Commands Processed Through Lead Compensation
  - Provides steady trim conditions for validating aerodynamic control derivatives
  - Resulting body rates indicate aerodynamic control power
- Roll, Pitch, and Yaw Fin Test Tones Added to Observe Control Derivatives at Trim Conditions
  - Roll fin tone: 3 degrees at 20 Hz
  - Pitch/Yaw fin tone: 6 degrees at 10 Hz
IGTV Flight Path Angle Rate Commands and Body Attitude Commands

Flight Path Angle Rates (deg/sec)  Body Attitude Commands (deg)

-8 -6 -4 -2 0 2 4 6
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
0 2 4 6 8 10 12 14 16 18 20

-8 -6 -4 -2 0 2 4 6
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
0 2 4 6 8 10 12 14 16 18 20

WqcI  AthCmd (deg)
WrcI  ApsiCmd (deg)

Time From Motor Fire (sec)
Roll Fin Tones

![Graph showing Roll Effective Fin Cmd (deg) vs. Time From Motor Fire (sec)]
IGTV Flight Test F-4

- Inertially Guided Test Vehicle Flight F-4
  - Guidance loop intentionally deactivated
  - Ambient Temperature
  - Ground Launched: Army M260 Launcher
  - Target Range: 5 km
  - Target Board: 15.3% reflectivity
  - Target Remote Laser Designator: 0.8 km

- Test Results
  - Wings deployed and airframe de-rolled
  - Seeker acquired target during limited period
  - Preprogrammed flight maneuvers and tones executed
  - Characterized airframe performance over 38 sec flight
APKWS F-4 Flight Test Video
May 20, 2004 – Site C-7, Eglin AFB
F-4 Post-flight Analysis

- Post-flight Analysis Of F-4 Telemetry Data Revealed Differences In Flight Test vs. NASA Ames Wind Tunnel Aerodynamic Performance
- 6-DOF Model Simulations Were Matched To Flight Test Data To Obtain Corrected Aerodynamic Coefficients
- New Aerodynamic Coefficients Loaded Into Tactical Software
- Updated Tactical Software Flown On Flight F-6A
  - Guidance loop closed to intercept laser designated target
Guided Flight Test F-6A

- Ambient Temperature
- Ground Launch: Army M260 Launcher
- Target Range: 5 km
- Target Board: 31% reflectivity
- Remote Laser Designator: 1.9 km
- Guidance Loop Activated
APKWS F-6A Flight Test Video
September 10, 2004 – Site C-7, Eglin AFB

FLIGHT TEST F-6A

ARMY APKWS

PROJECT UZZE0068

MISSION # 5878

DATE: 09/10/04

SHOT# R0004

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APKWS Flight Test F-6A
Target Impact from 5 km Range

Laser Spot Centroid

0.51 m
Lessons Learned

- Comparison to NASA Ames Wind Tunnel Data
  - Drag match accomplished with small drag increase
    - TM warhead antenna features
  - Roll aerodynamics matched with reduced
    - roll control power
    - roll damping