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The Deployment Dynamics: Analysis of the 81MM Illumination Mortar Cartridges

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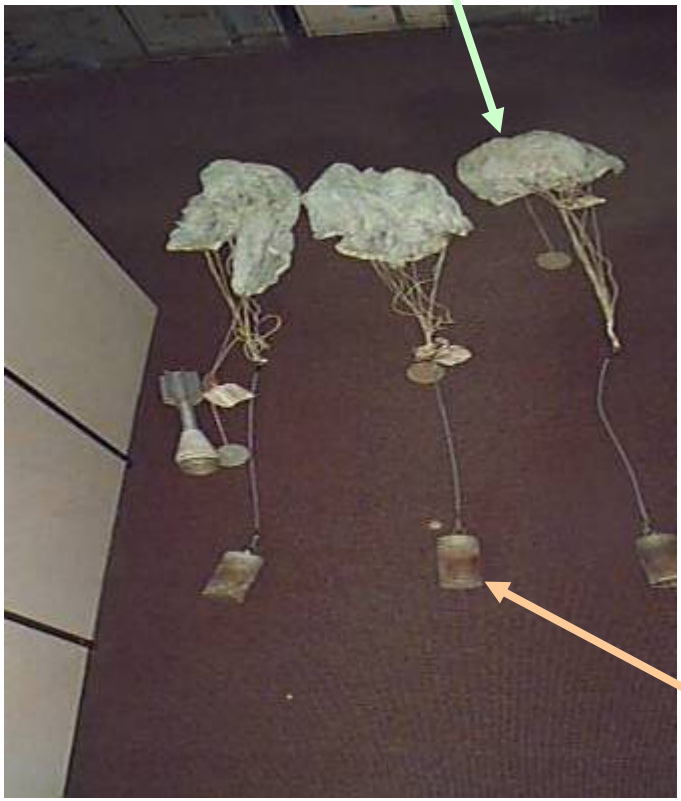
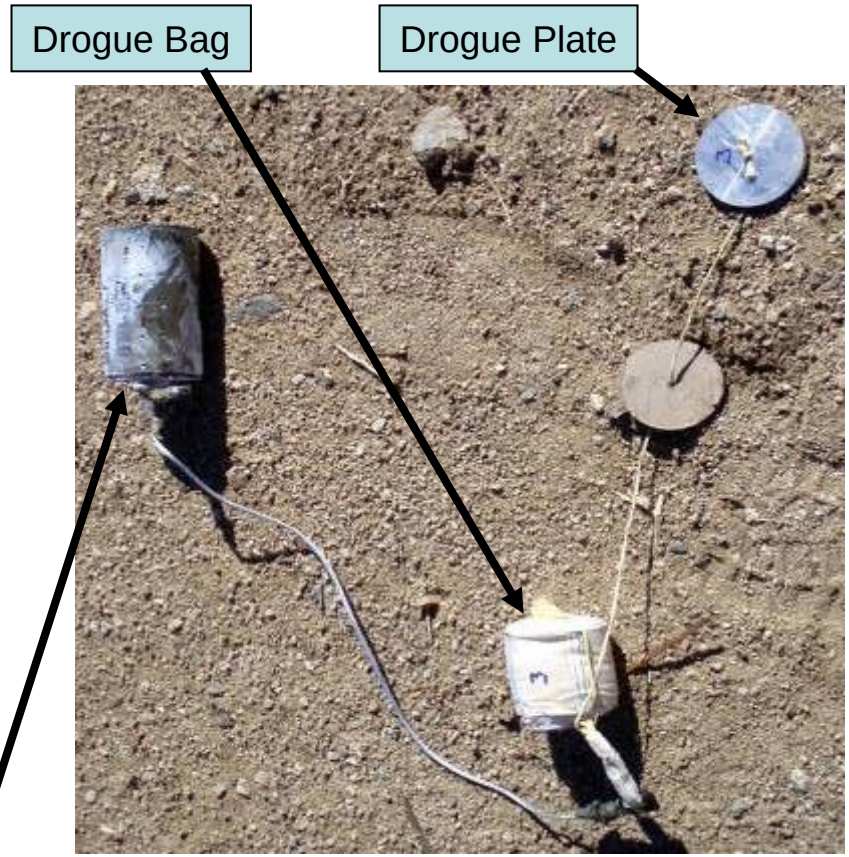
BACKGROUND

- The M853A1, 81mm Illuminating, Mortar Cartridges experienced 11 streamers during the ballistic LAT at Yuma Proving Ground on July 25, 2006.
- Nine(9) of eleven(11) streamers were reported as the non-deployment (the canopy and suspension lines still inside the bag).
- FMEA narrowed to three possible causes: frozen bag, insufficient drogue plate, or jammed main canopy.
- Pull tests and wind tunnel test had been conducted to verify the root cause.

SYSTEM DESCRIPTION

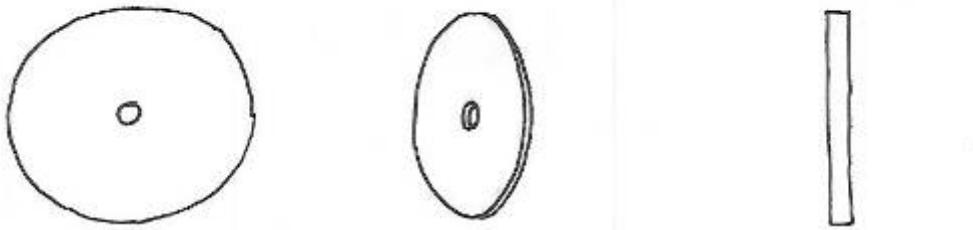


Deployed Canopy



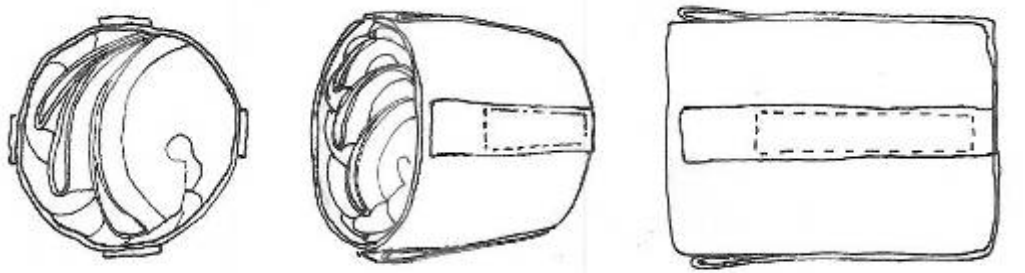
Non-Deployed (Streamer)

Drogue Plate

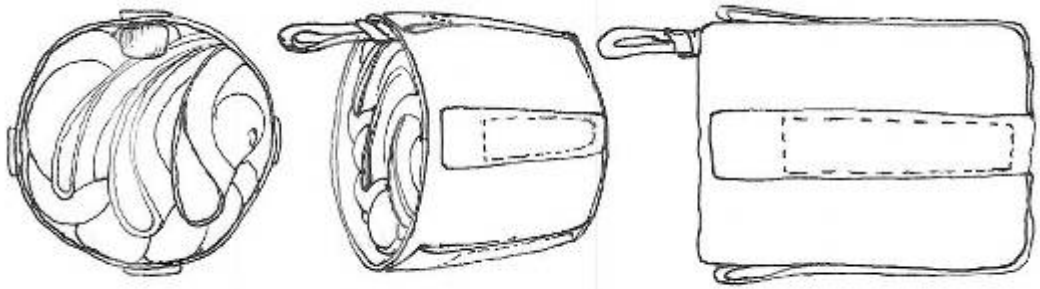


FRONT VIEW | 45 deg ANGLE VIEW | 90 deg SIDE VIEW

Intact Drogue Bag with/without Riser

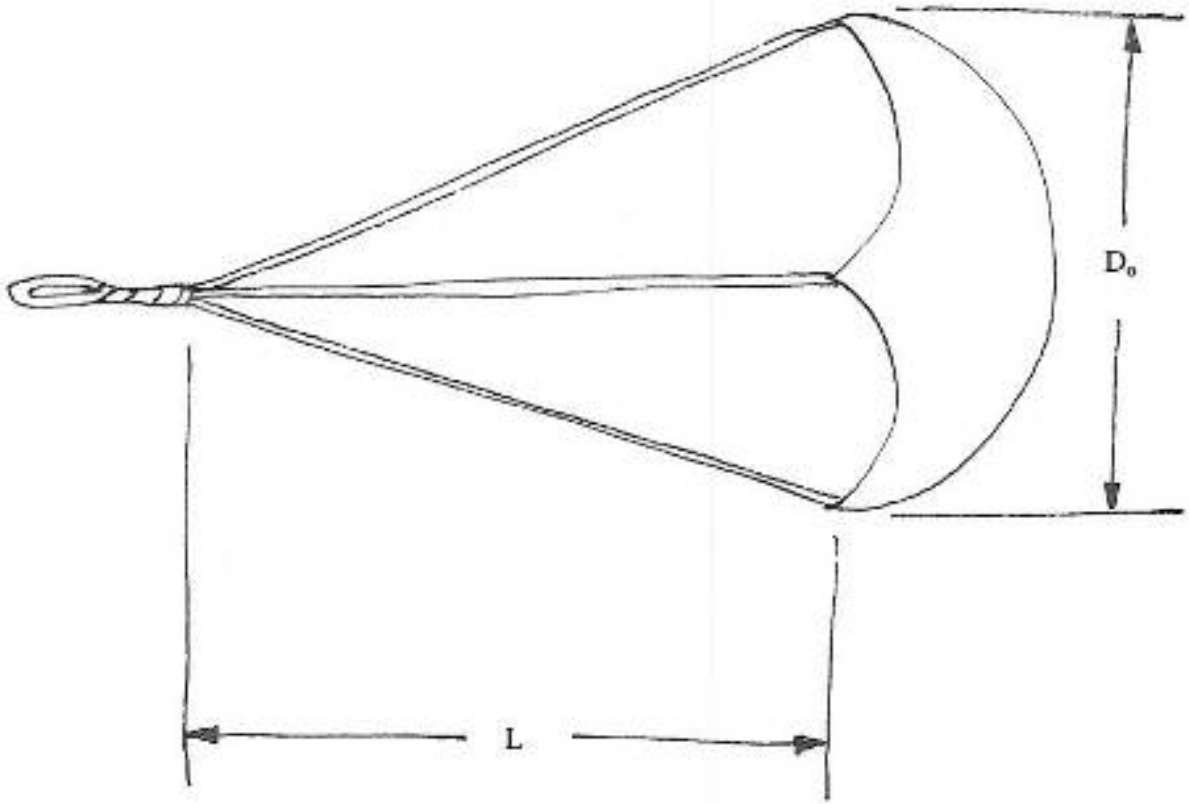


FRONT VIEW 45 deg ANGLE VIEW 90 deg SIDE VIEW



FRONT VIEW 45 deg ANGLE VIEW 90 deg SIDE VIEW

The deployed 9 inch Drogue Chute



$D_o = 0.7 * D_c$, which is inflated canopy diameter
$D_c = 9$ inches, which is constructed canopy diameter

SPECULATIONS

- Frozen Bag: A bag exposed to high humidity then frozen may require more force to deploy the main canopy than the bag stored at ambient condition.

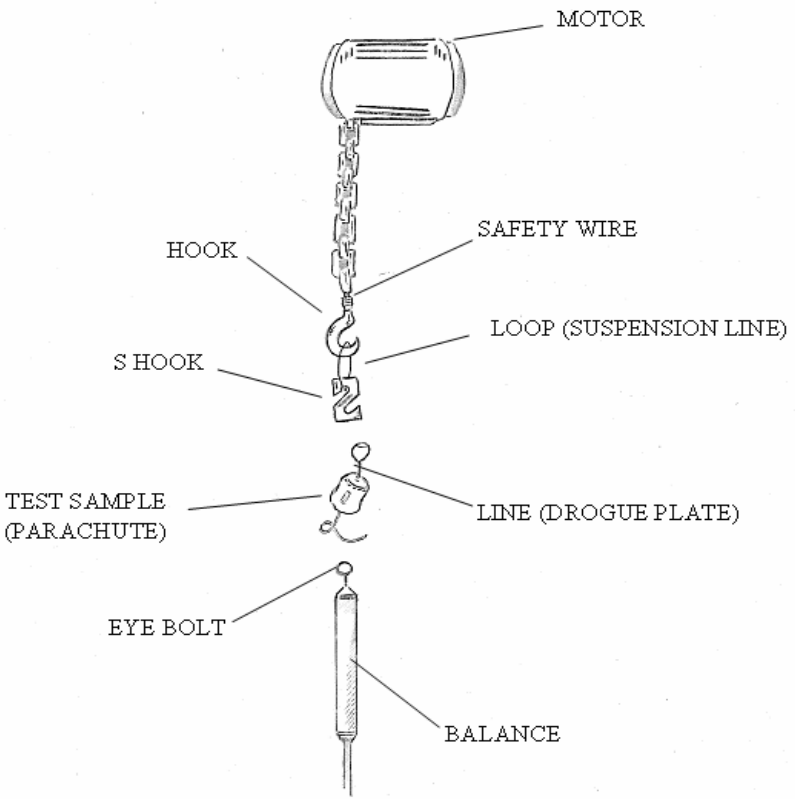
- Insufficient Drogue Plate: Drogue plate may not generate adequate drag force to deploy the main canopy.

- Jammed Main Canopy: Canopy may be jammed inside the drogue bag due to one of these phenomenon:
  - Chinese Finger-cuff Effect: due to the fiber orientation of the bag, the bag may constrict as it is pulled.
  - Piston (Vacuum) Effect: due to the vacuum inside the bag, the canopy may be difficult to deploy from the bag.

PROCEDURES

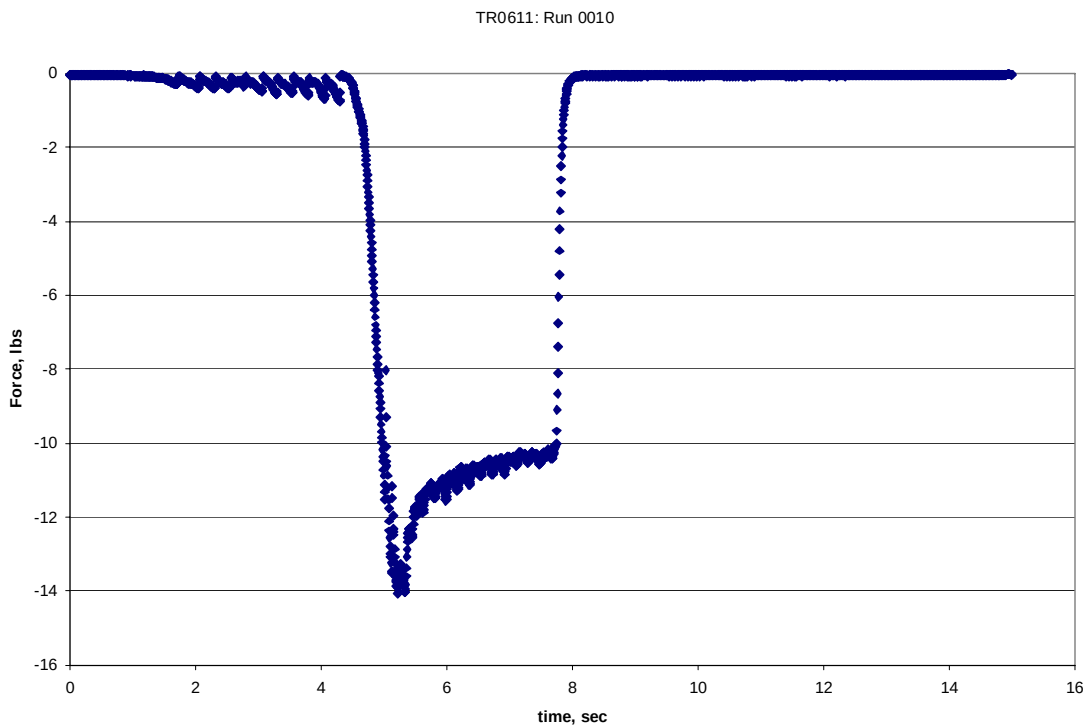
- Laboratory Tests were completed to validate FMEA alternatives
  - Pull Tests
    1. Steady Pull Test
    2. Dynamic Pull Test
  - Wind Tunnel Tests
    3. Aerodynamic Characterization Test
    4. Drag Force Comparison Test
- This test data was evaluated to determine FMEA and propose design alternatives

STEADY PULL TEST APPARATUS

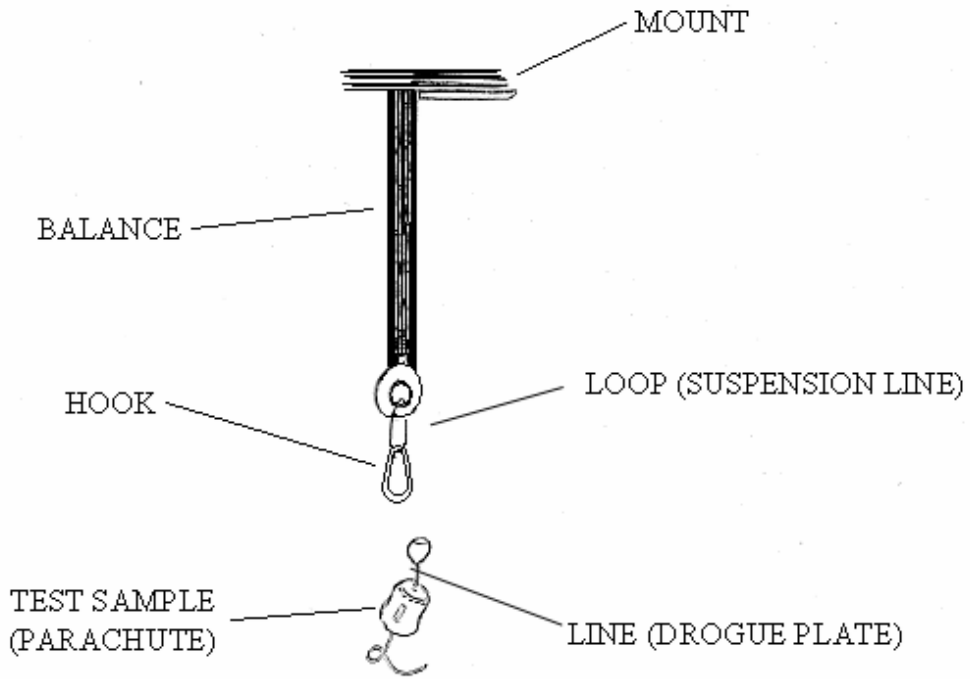


STEADY PULL TEST

- Alternative configurations were tested.
- Ten baseline configurations were temperature conditioned at –30°F for a minimum of 5 hours, then tested.
- The drogue plate suspension line was tied to an eye bolt connected to the 1.23” balance.
- The test samples were pulled at a constant rate of 1.6”/sec until the main chute is fully deployed from the drogue bag. The data acquisition system tracks the force history.

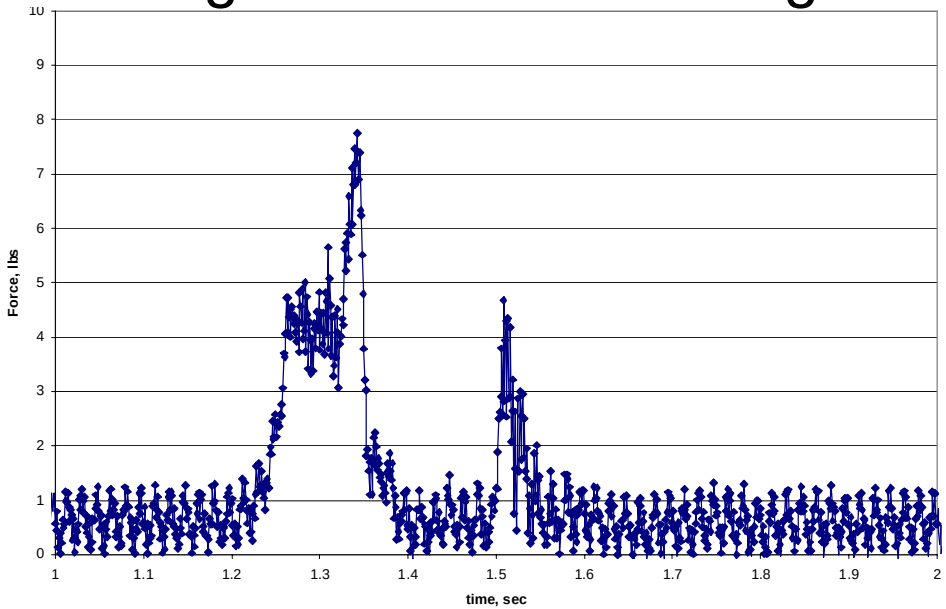


DYNAMIC PULL TEST APPARATUS



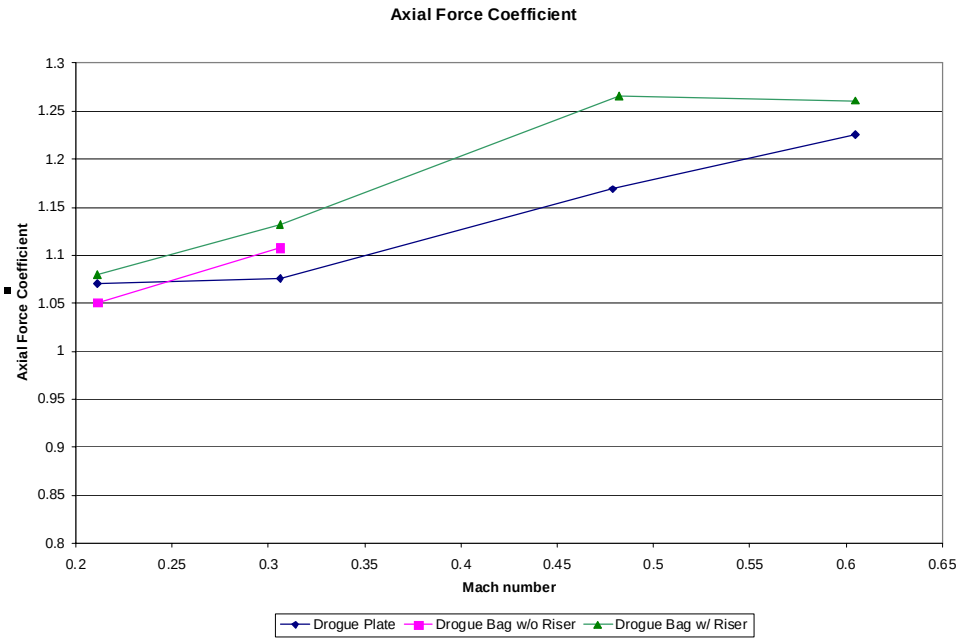
DYNAMIC PULL TEST

- A balance was mounted to an A-frame in a high bay area.
- The safety to protect the balance was 80 lbs.
- A ballast of 4 lbs was dropped at two predetermined heights (29 inches and 78 inches from the ground).
- The data acquisition system tracks the force history transmitted through the balance during the entire testing.



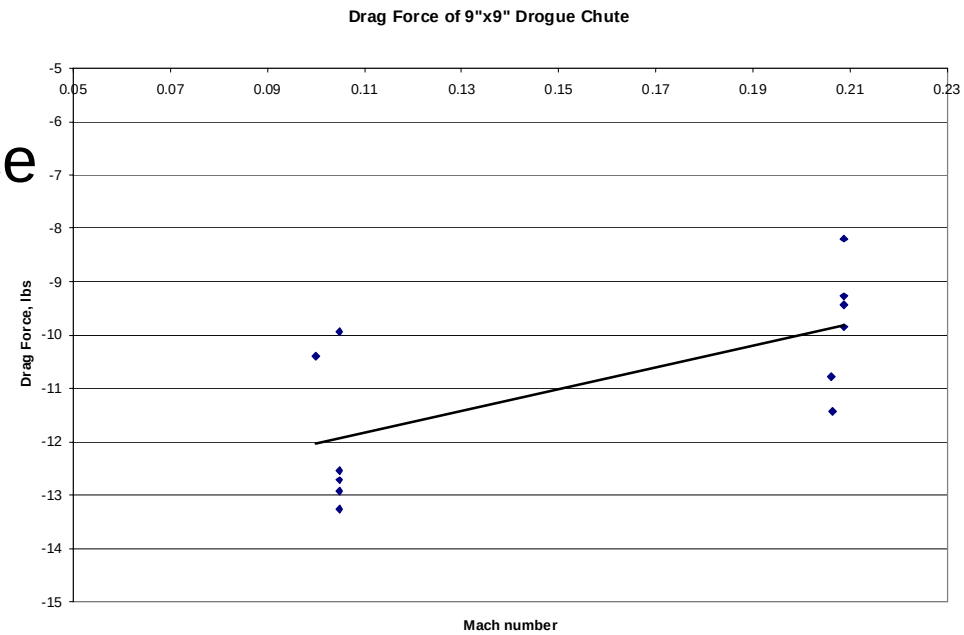
DRAG FORCE COMPARISON TEST

- Three configurations were tested: drogue bag without the riser, the drogue bag with riser, and the drogue plate.
- The 0.88B strain gage balance was used.
- Mach numbers tested include 0.21, 0.30, 0.50, and 0.61 with the angles-of-attack of -4 to +15 degrees.
- The aerodynamic test conditions, axial force, pitching moment, and normal force were recorded.



AERODYNAMIC CHARACTERIZATION TEST

- The drogue chutes were attached to an eyebolt, which was attached to the 0.88B strain gage balance inside the bomb strut assembly located upstream of the test section.
- Mach numbers tested include 0.21, 0.30, 0.50, and 0.61 at zero angle-of-attack.
- The aerodynamic test conditions, and axial force were recorded.



RESULTS

- Steady Pull Tests:
  - Required pull force (2 -4 lbs) agreed with historical data, without any abnormality.

- Dynamic Pull Tests:
  - The required pull force increases as the snatching force increases.
  - The required pull force is not linear over snatching velocity.

AERODYNAMIC CHARACTERIZATION

- No significant differences in drag among the three configurations (the intact bag with/without riser, the drogue plate).
- Due to similar drag and weight between the drogue plate and drogue bag, there is no momentum difference between the two.
- Inversely, this finding raises a question about the successful deployments.

DROGUE CHUTE DEPLOYMENT TESTS

- The 9 inch drogue chute performance is insensitive to the tested suspension line lengths.
- The drag of the 9 inch drogue chute exhibited around 30 lbs (about 8 - 9 times of the drogue plate) at Mach 0.2.

CONCLUSIONS

- The results of the pull test came out as expected and agreed with the previously reported data (no new findings).
- The dynamic pull test showed an increase in the mean pull force but inconclusive due to a trend of nonlinearity.
- The wind tunnel test showed no drag difference between the drogue bag and the drogue plate.
- The successful deployment in the past might be done mechanically and accidentally (by swing motion of the aluminum drogue plate) rather than aerodynamically.
- In order to make the function aerodynamically, the 9” square drogue chute is highly recommended.

RECOMMENDATIONS

- Conduct a horizontal ballistic test to characterize the ADS of the 81mm, M853A1.
- A lab test to simulate and understand the steel cable bending phenomenon.

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