Parachute Testing

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Parachute Seminar

3rd International Planetary Probe Workshop

Introduction

- **Historically, testing has always been a part of parachute design**
  - Cut and try
- **Design codes are now in widespread use, but testing is still required**
  - Proof testing of actual hardware
  - Validate the design codes

Introduction (Continued)

- **Parachute systems are presently used in applications that were not considered before**
  - Defining tests to qualify parachute systems becomes difficult
  - May require the total system for realistic tests
- **Test costs are becoming a significant portion of program budgets**
- **Some test facilities are closing**

General Categories of Tests

- **Functional**
  - Demonstrate system or component will operate under known conditions
  - “Yes” or “no” test
- **Performance**
  - Obtain and evaluate specific performance characteristics of a system over a wide range of test conditions
  - Record data on test conditions and performance

Types of Tests

- **Infinite Mass**
  - No velocity change of the system during the deployment and inflation of the parachute
- **Finite Mass**
  - Velocity of the system changes significantly during the deployment and inflation of the parachute
- **Large difference in the inflation forces developed by the parachute for infinite and finite mass conditions**

Infinite Mass Tests

- **Wind Tunnel**
- **Laboratory**
- **Captive of tow tests**

Wind Tunnel Tests

- **Parachute performance is determined by a complex interaction of fluid and solid mechanics principles**
- **Parachute performance is a strong function of forebody shape, the resulting wake and the operating conditions**
- **Wind tunnel tests are useful in determining performance**
- **Wind tunnel tests are also useful in accumulating data for empirically based design codes**

Model Scaling

- **Parameters to consider for steady state testing**
  - Model geometry
  - Model elasticity
  - Material permeability
  - Mach number
  - Reynolds number

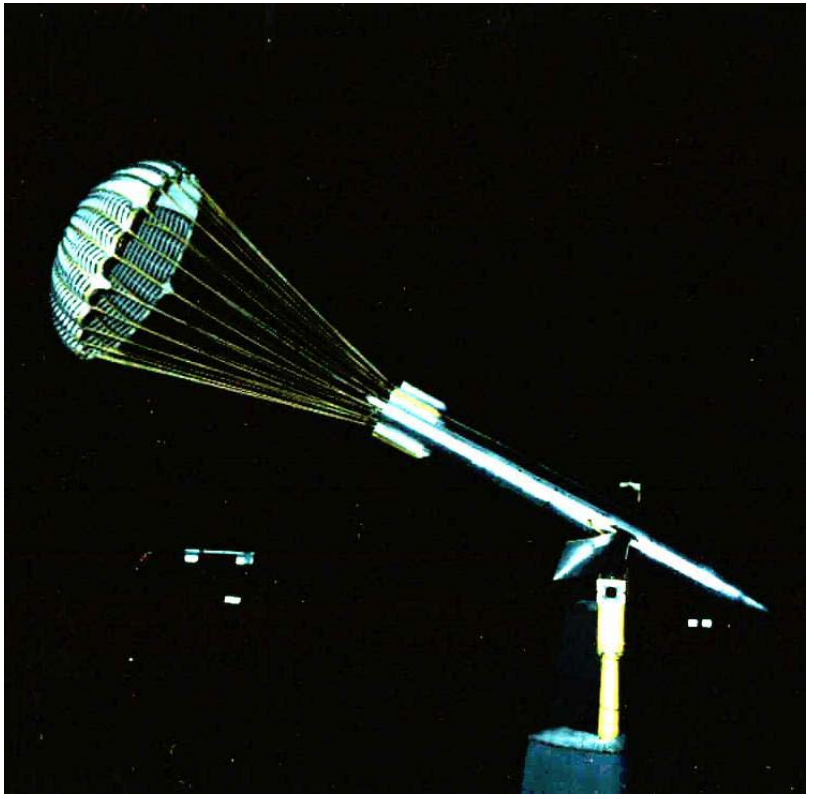
Model Scaling (Continued)

- **Additional parameters to consider for dynamic inflation tests**
  - **Mass ratio**
  - **Model stiffness**
- **Availability of materials makes it difficult to duplicate some of the parameters**

Model Support

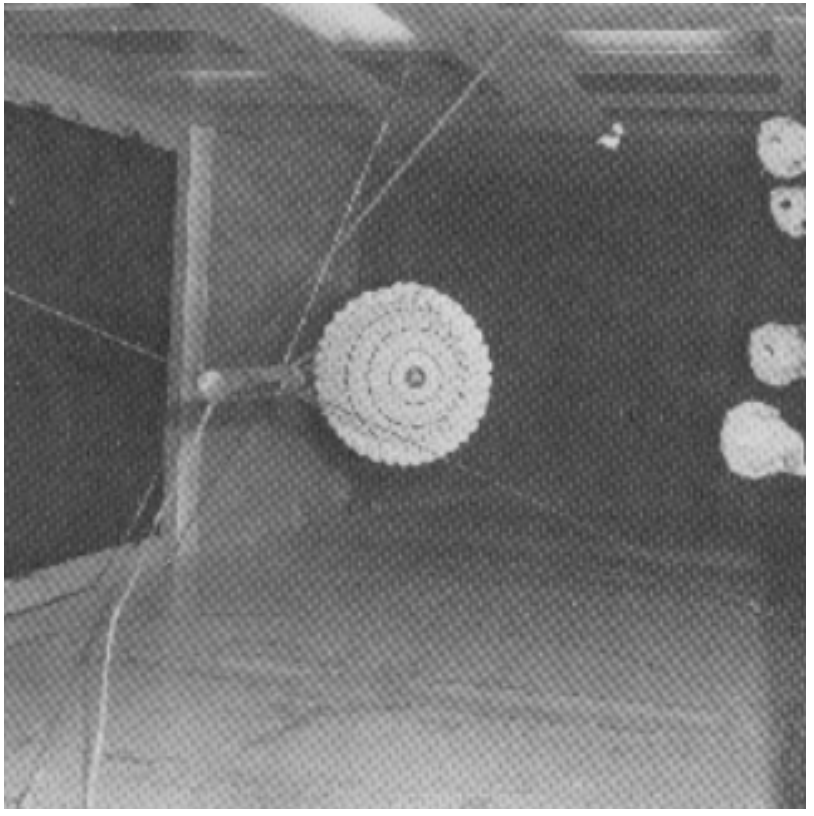
- **Forebody with parachute**
  - Strut
  - Cables
  - Rear mounted sting
- **Parachute only**
  - Requires a small forebody
- **Supersonic tests**
  - Support very difficult without changing the flow field

Sandia Lifting Chute in 40 by 80 ft



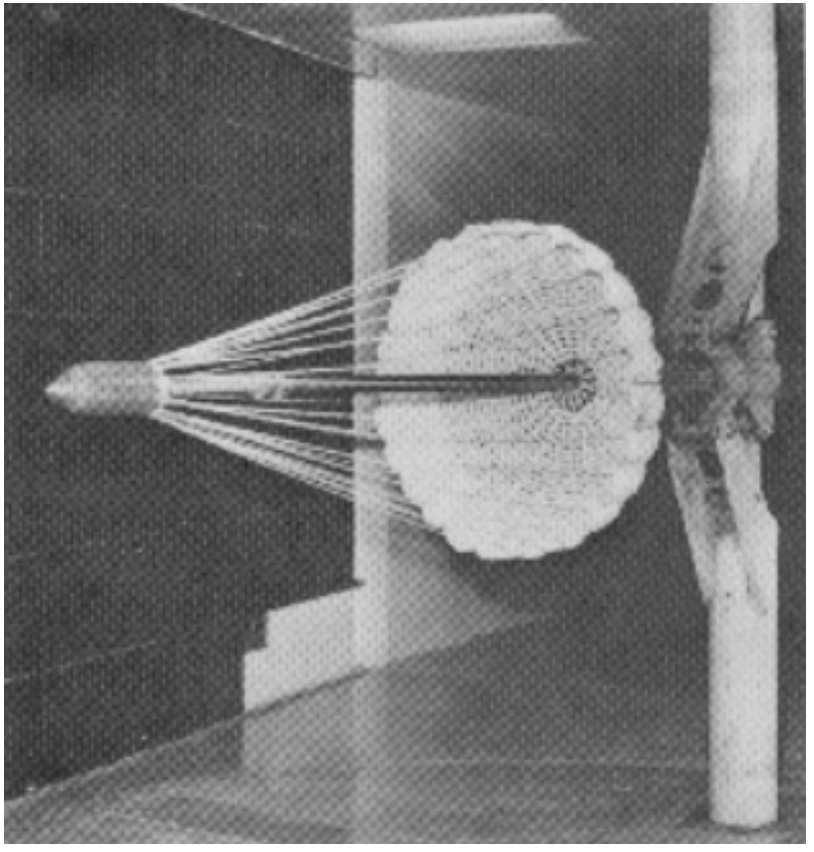
- **Bomb mockup**
- **Flight hardware tested**
- **Force measurements**
- **Trim angle of attack**
- **Dynamic stability**

Model Chute in Vought 7 by 10 ft



- Cable support
- Balance in forebody
- Drag force measurements
- Stable parachute

Model Chute in Vought 7 by 10 ft



- Sting support
- Balance in sting
- Force and moment measurements
- Some parachute instability OK

Force Measurement

- **External balance**
  - Measures forces on a set of balances outside the test section
  - Usually heavily damped with low natural frequencies
- **Internal balance**
  - Requires forebody for mounting
  - Simple drag link to multi-component

Pressure Distributions

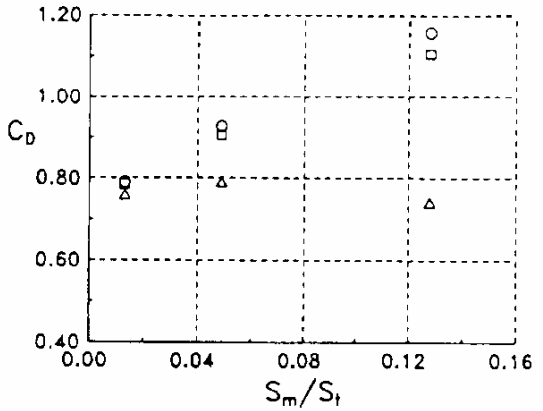
- **Steady pressure distributions for reefed and full open ribbon parachute models have been measured**
  - Plastic tubing attached to radials of ribbon parachute models recorded pressure at a specific radial locations
  - Recorded pressure distributions provide input for canopy stress analysis models

- **Unsteady pressure distributions have been measured using small differential pressure transducers**
  - Unsteady pressure distributions provide additional input for canopy stress analysis models

Boundary Interference (Blockage)

- **Generally underestimated (?)**
- **Recent study indicates that corrections can be made for blockages as high as 22%**
  - Single parachute
  - Independent of porosity
- **Blockage corrections are based on wind tunnel data only, not on comparison with free flight data**

Wind Tunnel Blockage Correction



Parachute drag coefficient as a function of geometric blockage ratio.

○ - uncorrected
△ - corrected using Eq. (1)
□ - corrected using Eq. (2)

$$\frac{q}{q_u} = 1 + 1.85 \times \frac{C_D S_u}{S_t} \quad \textbf{(1)} \qquad \frac{q}{q_u} = 1 + 0.5 \times \frac{S_m}{S_t} \quad \textbf{(2)}$$

- **Macha AIAA 91-0858**
- **Based on wind tunnel data only**
- **Not validated by comparison with free-flight data**

Laboratory Tests

- **Determine material characteristics**
  - Optimize sewn joint strength
  - Develop proper sequence
  - Check deployment and staging
  - Test deployment initiation
    - Springs
    - Explosives

Types of Captive Tests

- **Truck towed**
- **Rocket powered sled towed**
- **Aircraft towed**
- **Water towing basin**

Captive Tests

- **Advantages**
  - Good control of test conditions
  - Reuse of test vehicle
  - Low cost
- **Disadvantages**
  - Limited freedom of motion
  - Ground effects or vehicle/model support wake effects
  - Near infinite mass test conditions

Finite Mass Tests

- **Test vehicle usually represents actual flight vehicle**
- **Attempts to match actual deployment conditions**
- **Methods of launching the test vehicle**
  - Balloon
  - Aircraft
  - Rocket boosted from ground
  - Ejector sled
  - Whirl tower
  - Aerial cable

Balloon Launched Tests

- **Test vehicle carried to high altitude by balloon**
  - Viking parachute tests
- **Gravity or rocket accelerated to the test conditions**
- **High Mach number – low Q tests**
- **Panetary entry conditions**
  - Mars

Aircraft Launched Tests

- Most common test method in use today
- Nearly any type of aircraft can be used
- Deploy parachute shortly after release
- Delayed parachute deployment after free fall
- Rocket boosted
- Aircraft/aircrew safety
  - Aircraft/test vehicle separation
  - Premature parachute deployment

Aircraft Launched Test

- **Vehicle and parachute subjected to actual flight environment**
- **Vehicle and aircraft compatibility**
- **Parachute trajectory control**

Low Altitude B-52 Release

- **Vehicle and parachute subjected to actual flight environment**
- **Vehicle and aircraft compatibility**
- **Parachute trajectory control**

Ground Launched Rocket Boosted Tests

- **Test to conditions not attainable by normal aircraft drop test**
- **Surplus military rockets used for boosters**
- **Design of hardware can be difficult**

Rocket Boosted Test Vehicle

- **Parachute overtest**
- **Flight hardware tested**
- **Onboard instrumentation**
- **Photometric data**

Rocket Boosted Test Vehicle After Test

- **Test Vehicle Reusable**
- **Parachute inspected for damage**

Other Ground Launched Tests

- **Rocket powered ejector sled**
- **Rocket powered captive sled**
- **Whirl tower**
- **Aerial cable**

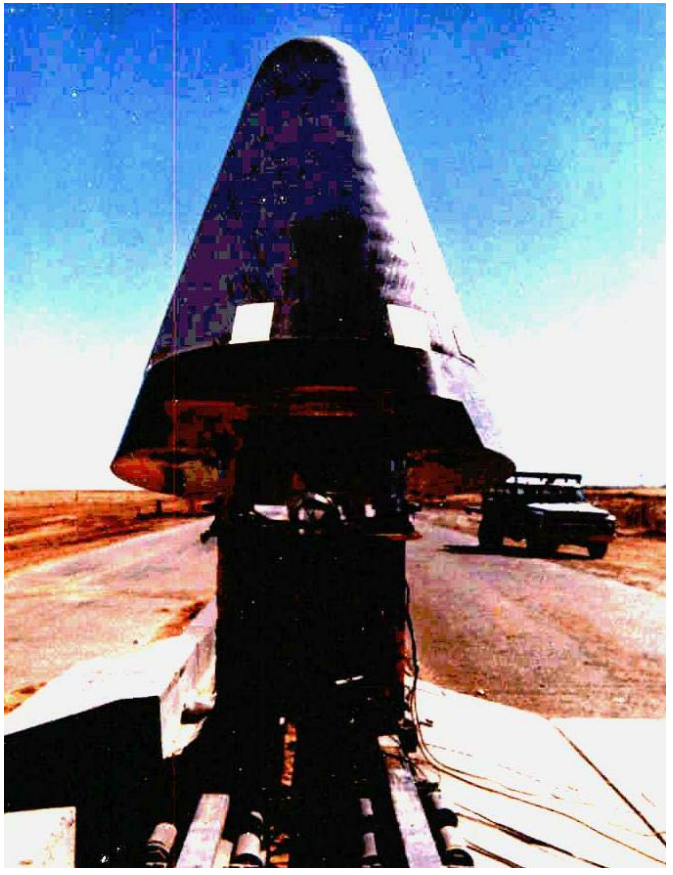
Ejector Sled

- **Test vehicle launched upward by high pressure gas piston**
- **Flight hardware tested at design conditions**
- **Precise test parameter control**

Test Vehicle Landing After Ejector Sled Launch

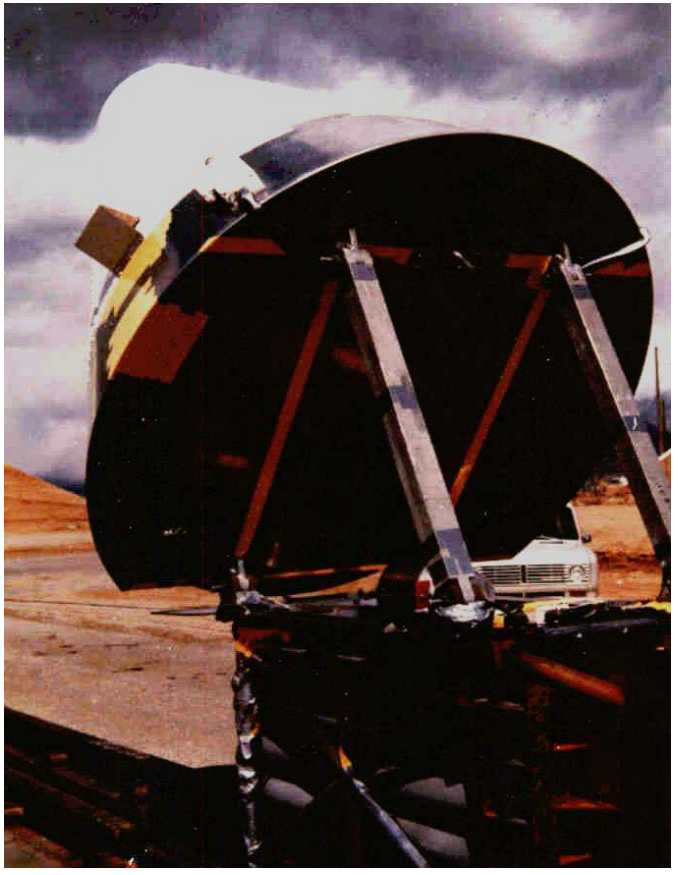
- Test vehicle landing conditions precisely controlled
- Flight hardware subjected to actual landing conditions
- Trajectory recorded using laser tracker

SRB Nose Cap Ejection Sled



- SRB nose mockup
- Flight hardware tested
- Onboard instrumentation
- Photometric data

SRB Nose Cap Ejection Sled



- SRB nose mockup
- Flight hardware tested
- Onboard instrumentation
- Photometric data

Captive Sled

- **Test vehicle attached to sled**
- **Speed range limited by structural capability**
- **Wake and ground proximity effects**

Test Vehicles

- Torso dummies
- Ejection seats
- Crew modules
- Weight platforms
- Cylindrical bomb-like vehicles
- Actual flight vehicles
- Other

Test Data Acquisition

- **Telemetry**
  - FM/FM
  - Digital
- **Onboard Storage**
  - Tape recorder
  - Solid state memory

Test Facilities

- **Facilities must accommodate the test**
  - Permanent test range
- **Data Acquisition**
  - Photographic coverage
  - Trajectory data
    - Cinetheodolites
    - Radar
    - Laser tracking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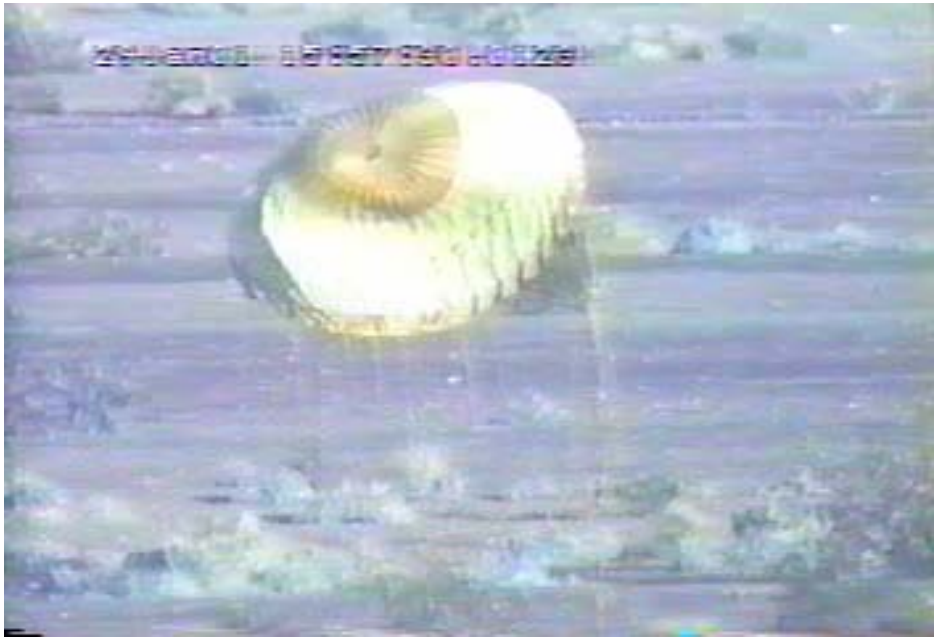


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