Balloon Working Group Meeting
The NASA Ultra Long Duration Balloon Vehicle

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Discussion Topics

- ULDB Vehicle Requirements
- Brief Overview of ULDB Vehicle Development
  - Phase III Flight
  - Australia 2001 Flights
- Developments and Test Flights Since Last BWG Meeting
  - Ground and Model Testing
  - Ft. Sumner/Palestine 2002 Test Flight
  - Australia 2003 Test Flight
- Next Steps

Vehicle Performance Design Requirements

- Duration up to 100 days
- Global flight capability
- Total suspended weight
  - CREAM requirement 2,720 kg (6,000 lbs.)
    - Includes 340 kg (750 lbs) of ballast
- Desired float altitude targeted 33.5 km (110,000 ft)
  - CREAM requirement is 33.0 km (108,000 ft)
- Stability – -1.5 km (-5,000 ft) and +

ULDB Test Flights

- 09/1997 ULDB Project team assigned
- 10/1998 Phase I: Fabric-film spherical balloons - 16.5 meter diameter
- 10/23/1999 Phase II: 1.817 MCF fabric-film pumpkin – Flight 474NT
- 6/4/2000 Phase III: 2.421 MCF co-extruded pumpkin – Flight 485NT
- 2/24/2001 Phase IV: 18.38 MCF co-extruded pumpkin – Flight 495NT
- 3/9/2001 Phase IV: 18.38 MCF co-extruded pumpkin – Flight 496NT
- 7/6/2002 Phase IVA: 21.56 MCF modified co-extruded film pumpkin Flight 1580PT
- 3/16/2003 Phase IVA: 21.56 MCF modified co-extruded film pumpkin Flight 517NT

Phase III Flight

- The Phase III flight was an unmitigated success
  - All minimum and comprehensive success criteria were met
- All systems worked as designed
- Nominal Desired Float Altitude ~28,350 m (93,000 ft)
- Balloon was stable to within < - 1% (-272 m, -890 ft) and ~ +1.7% (+491m, +1,611 ft) of the float altitude
- Balloon was pressurized during entire flight (>200 Pa max DP)
- Flight time of over 30 hours
- This balloon flew over a very bad thunder storm at night (worst case cold condition) and maintained a stable altitude for the duration of the flight
- Balloon was ready to be scaled up to the "full size" balloon

Phase III to Phase IV Flights

	Phase III	Phase IV
Volume	68,554 m^3 (2.42 MCF)	520,483 m^3 (18.38 MCF)
Material weight	37.7 g/m^2	37.7 g/m^2
Number of gores	150	290
Gore length	78.34 m (256.9 ft)	152.7 m (501 ft)
Weight	637 kg (1404 lb)	2,155 kg (4,740 lb)
Inflated height	35 m (115 ft)	68.9 m (226 ft)
Inflated diameter	58.5 m (192 ft)	144.9 m (377 ft)
Float Altitude	~28,350 m (93,000 ft)	~34,110 m (111,900 ft)
Suspended Load	53 kg (1,660 lbs)	2,045 kg (4,500 lbs)

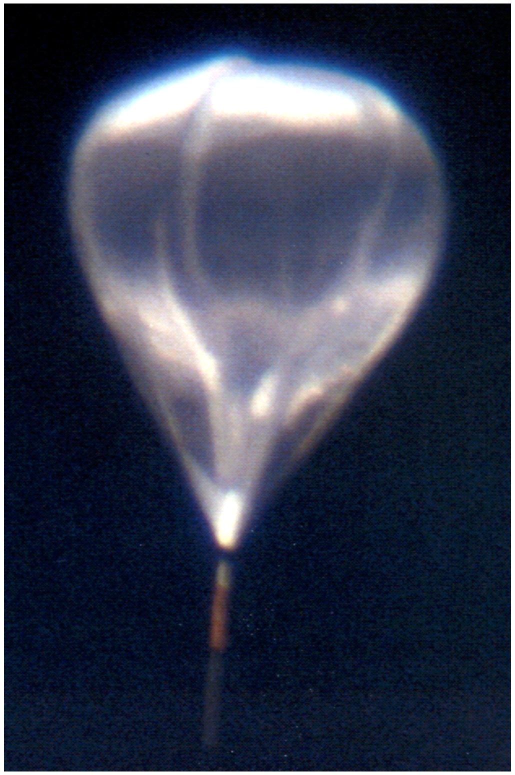
Phase IV Australia

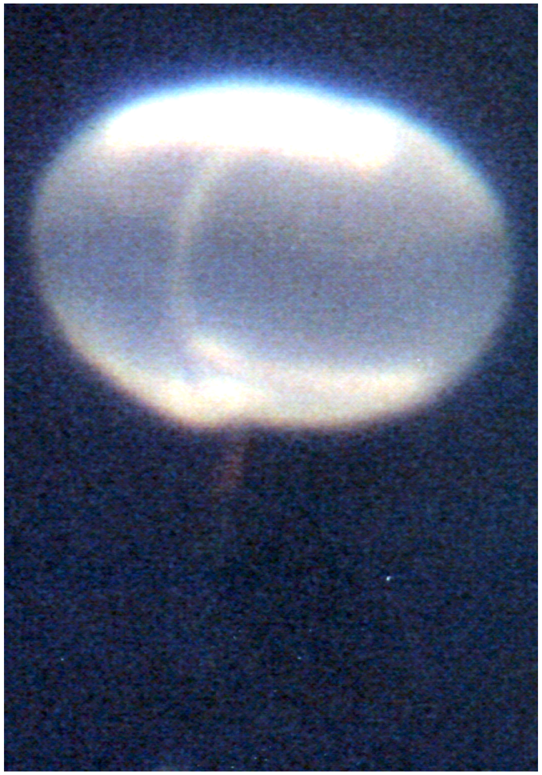
- Phase IV Flight #1 – 495NT
  - Ascent very close to predicted ascent
  - Balloon failed to pressurize
  - Maximum altitude of ~26 km (~85,000 ft)
  - Release of collar at launch tore a hole in the balloon shell under the cap
- Program made decision to fly second balloon
- Phase IV Flight #2 – 496NT
  - Balloon launch and ascent were nominal
  - Ascent rate
    - Slightly slower than predicted before entering the tropopause
    - Averaged near predicted ascent rate after the tropopause
  - Balloon pressurized as predicted

Phase IV Australia

- Balloon pressurization and stable altitude occurred at 32.8 km (107,500 ft) (GPS altitude 33.8 km or 111,000 ft)
- Maximum daytime pressurization 120 Pa
- Observations and decision
  - Telescope observation showed shape discontinuity in the balloon
  - Flight continued through the day with minor variations in pressure observed
  - Altitude was very stable, holding at 32.8 km (107,500 ft) plus or minus 120 m (400 ft.)
- The decision was made to continue with the flight because performance was very close to that predicted and the pressure and altitude were very stable.

Phase IV Australia – Anomalous Shape





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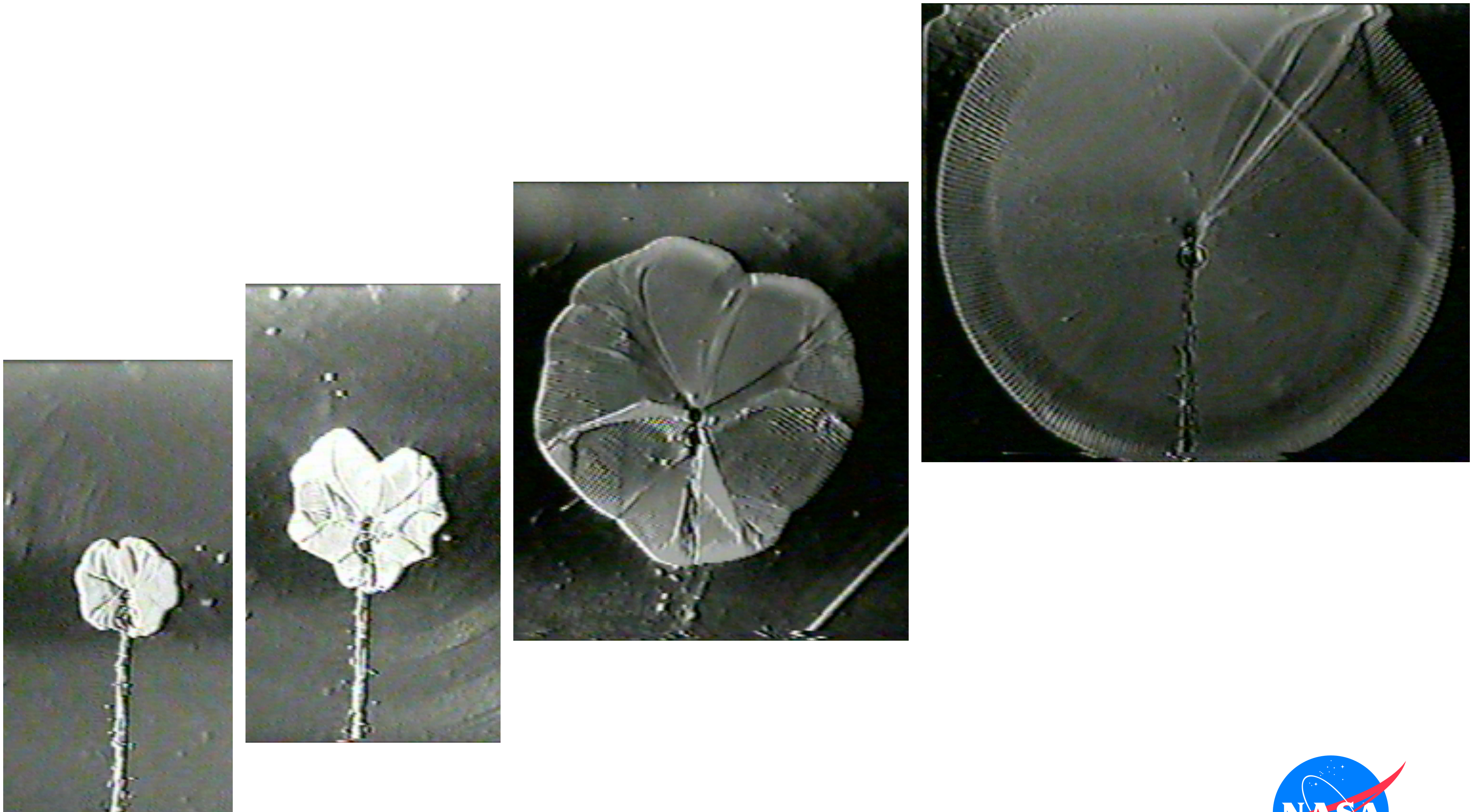
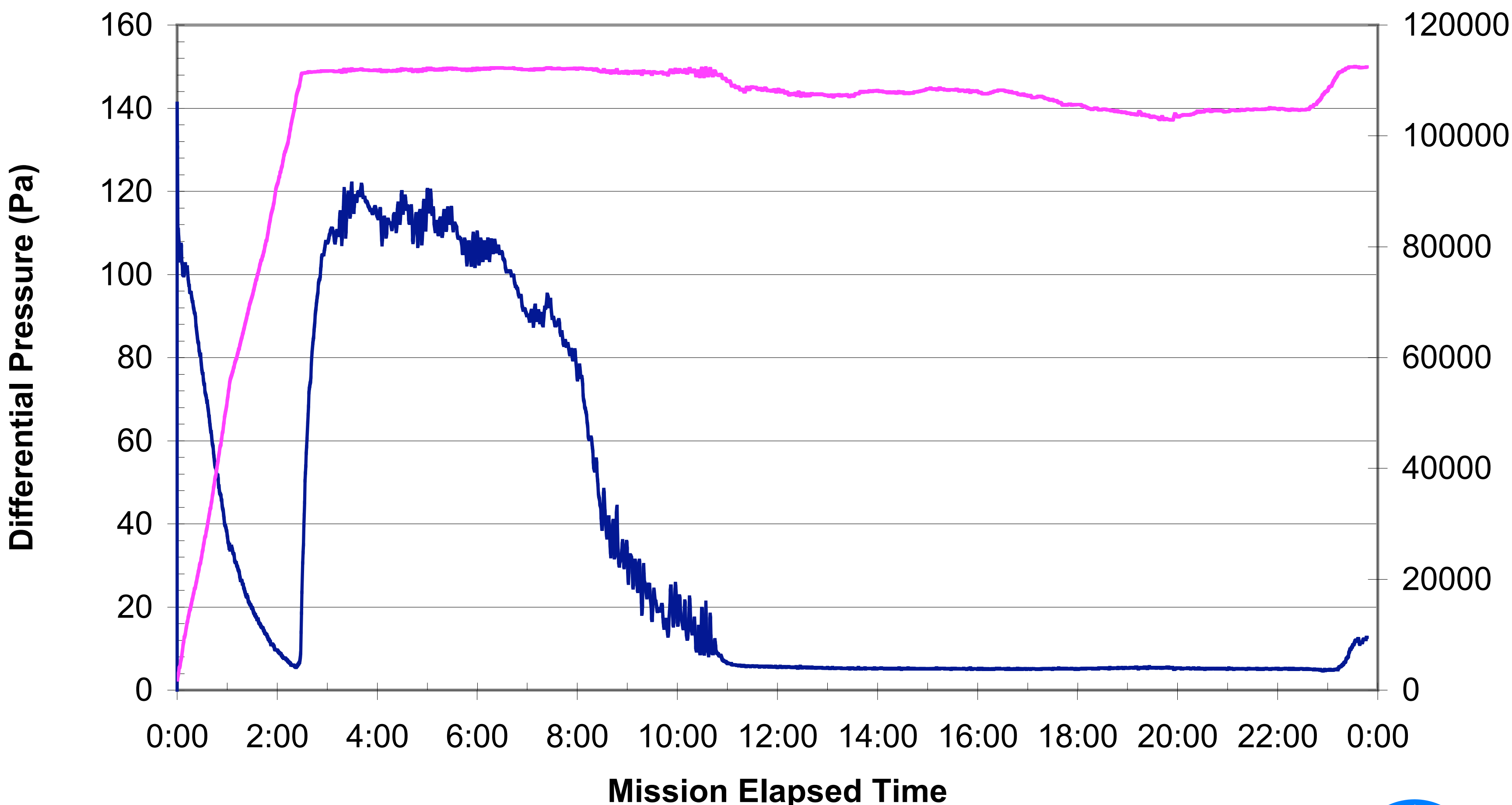
Up-Looking Video



Phase IV Australia

- As the sun set, the pressure in the balloon fell off as expected
  - Balloon flew over thunderstorm
  - Ballast drops at night
    - To maintain altitude
    - Much greater quantity of ballast dropped than predicted
- After sunrise the MKS altitude returned to 32.6 km (107,000 ft)
- Differential pressure barely moved above the nighttime pressure
- As soon as the discovery of this was made, it was reported to operations personnel who executed flight termination
- Determined that the balloon developed a leak at some point during the flight

Flight 496- Flight Profile



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Addressing the Issues

- Material Deficiency in Shell Film
- Study Shape Anomaly
  - Removed “excess film” from the design

- Material Redesign
- Model Balloon Tests
- Payload Requirement Increase (2,720 kg or 6,000 lbs)

Post Australia Flight Development Steps

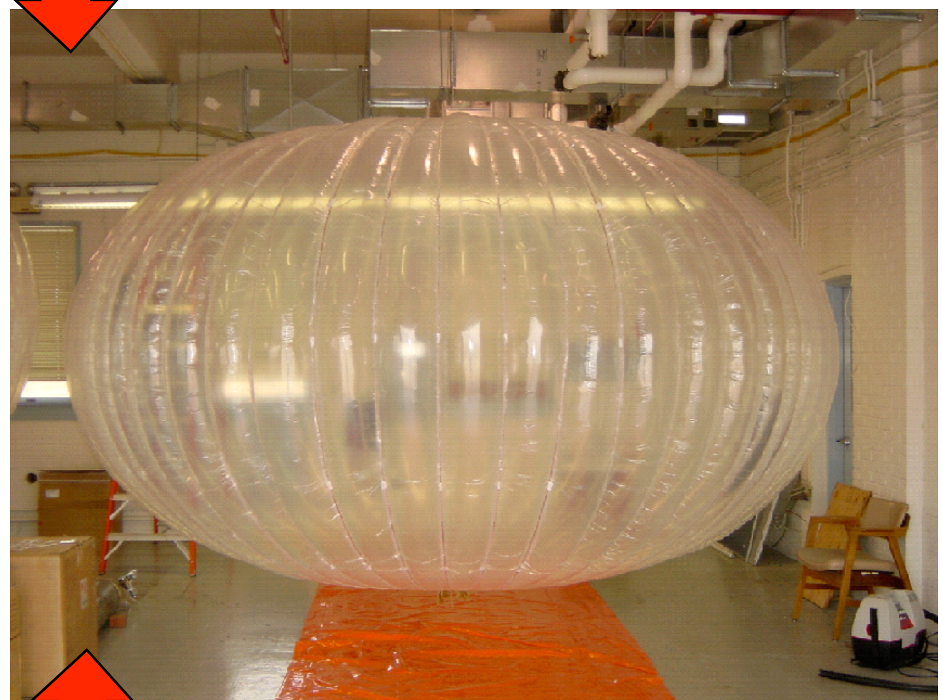
- Two areas required improvements – Materials and Deployment
- Materials
  - Very high rate (“snatch testing”) and very low rate (creep testing) loading requirements
  - Developed and selected new material
  - New material meets existing proven standards and improved “dart impact” characteristics, high strain rate characteristics, and acceptable long term creep
- Structural
  - Deployment issue studied
  - New design criteria developed and documented – includes material requirements, service life considerations, factors of safety, and more
  - Deployment test structures fabricated and tested

Model Test Balloons

FLT 496NT Shape Anomaly

Scaled Hangar Test Structure

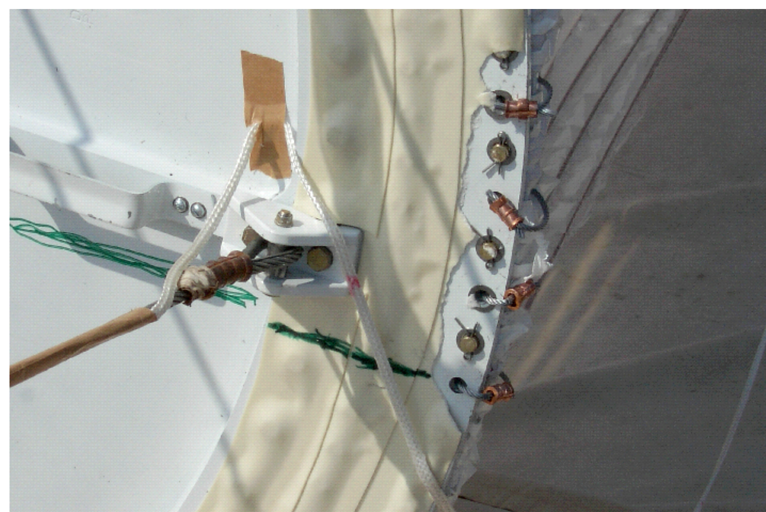
Remove Excess Material for Proper Deployment



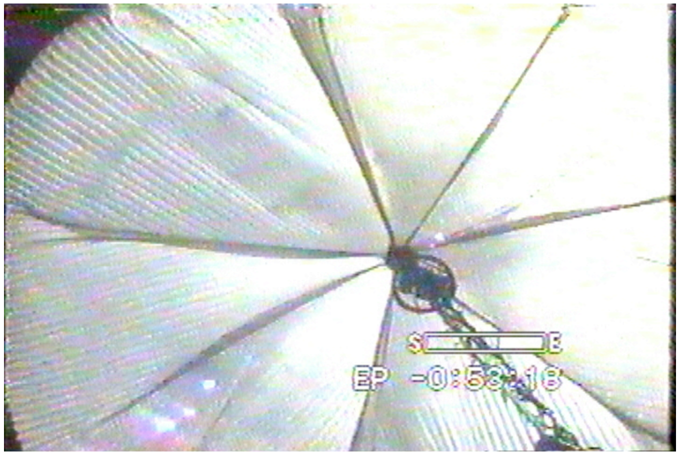
Balloon Design

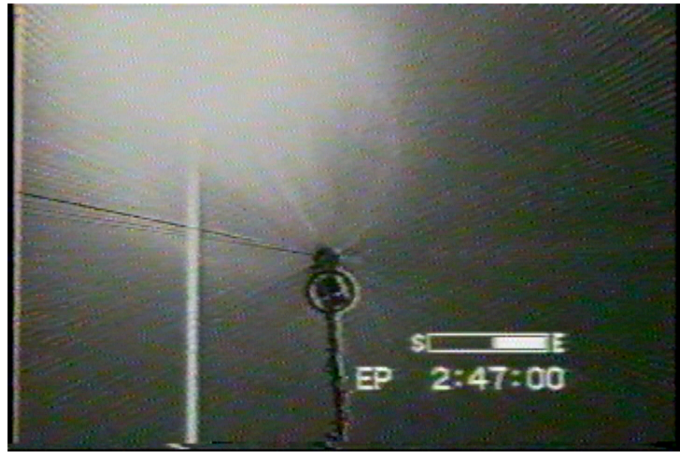
	Phase IV	Phase IVA
Volume	520,483 m^3 (18.38 MCF)	610,533 m^3 (21.56 MCF)
Material weight	37.7 g/m^2	37.7 g/m^2
Number of gores	290	290
Gore length	152.7 m (501 ft)	160.3 m (526 ft)
Weight	2,155 kg (4,740 lb)	2,578 kg (5,692 lb)
Inflated height	68.9 m (226 ft)	71.6 m (235 ft)
Inflated diameter	144.9 m (377 ft)	121.0 m (397 ft)
Float Altitude	~34,110 m (111,900 ft)	~33,600 m (110,200 ft)
Suspended Load	2,045 kg (4,500 lbs)	2,720 kg (6,000 lbs)
LSI	~1780 psi	~1560 psi

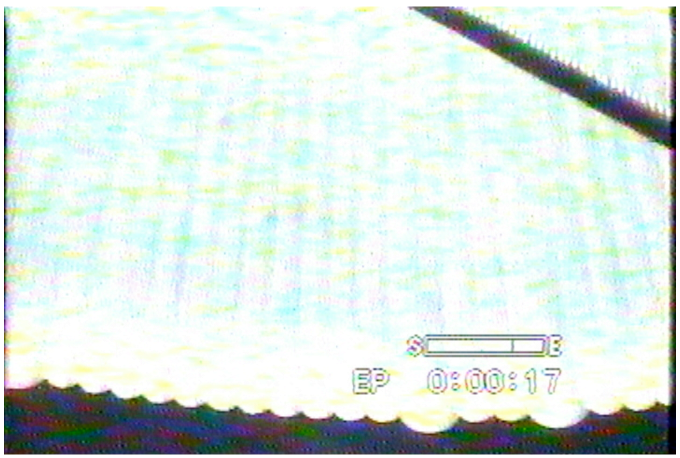
Flight 1580PT – Flight Line Issue

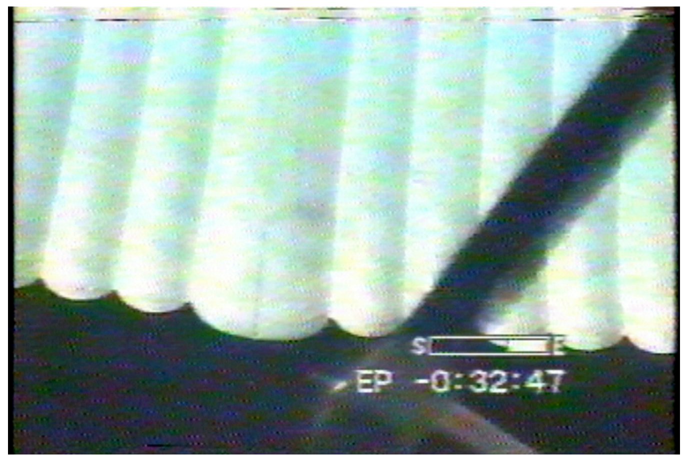


In Flight Video Captures



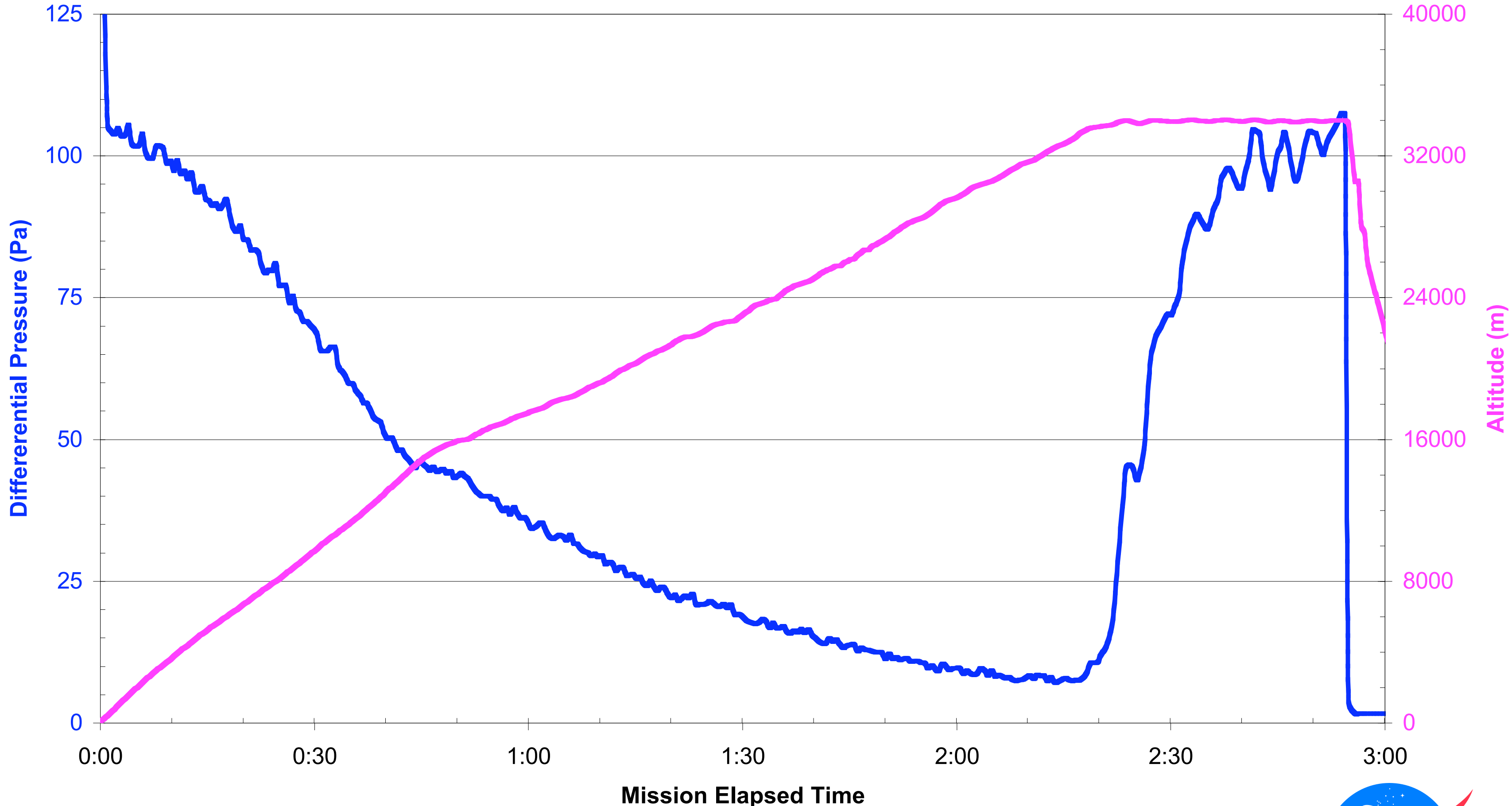




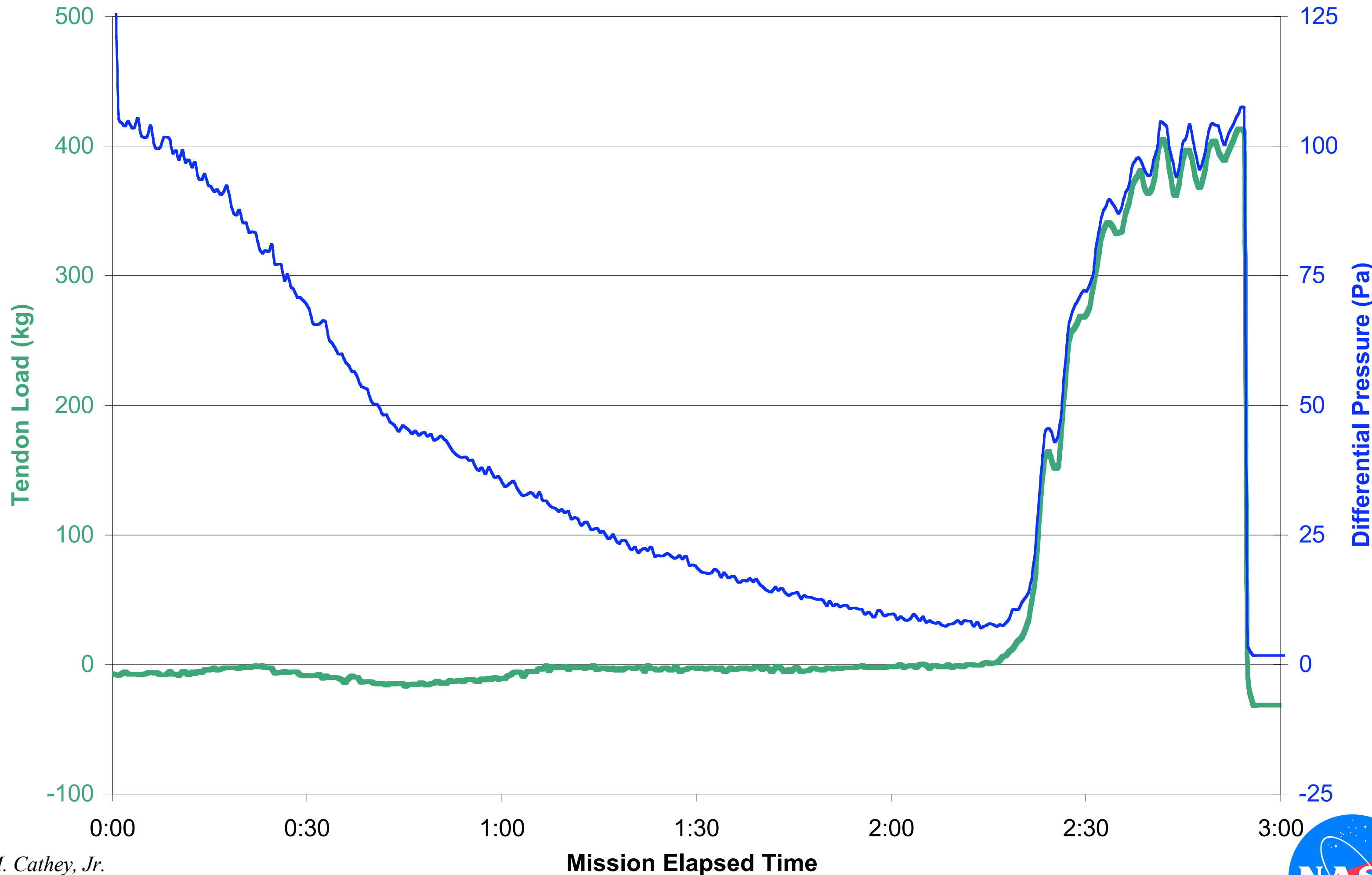


Balloon Recovery

Flight 1580PT – Flight Profile



Flight 1580PT – Differential Pressure



Flight 1580PT – Conclusions

- Break down in manufacturing process
- Tendon attachment was a “blind” process
- Inspection of tendon attachment difficult - also a “blind” process
- Punctured tendons were inherent problem
- NSBF QA observed rather than inspected for this balloon
- Numerous recommendations made to BPO
- Full review and revision of production documentation completed – Material Specifications, Fabrication Procedures, and Quality Procedures
- Additional inspections with sign-off’s added

Australia 2003 Mission Success Criteria

- This was a Test Flight
- Synopsis of balloon minimum mission success criteria
  - Successful Launch
  - Successful Deployment
  - Pressurization
  - Altitude Stability During Flight
  - One Circumnavigation (Australia to Australia precluding Safety required termination)

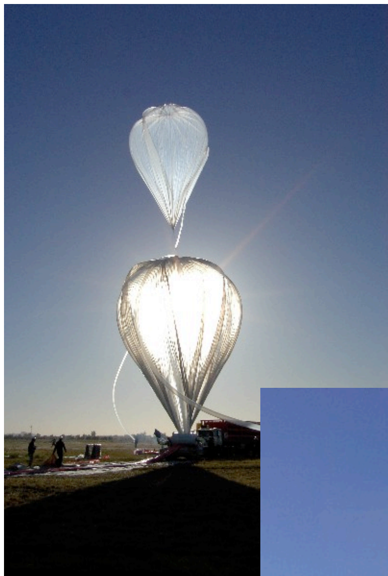
Test Flight 517NT

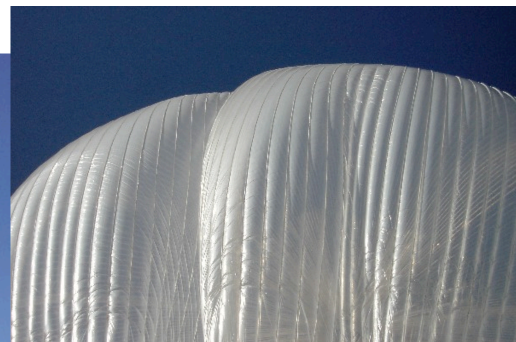
- ULDB Test Flight 517NT on March 16, 2003
- ULDB Test Flight Preparations
  - Balloon “unpacking” and prep for flight was very smooth and efficient
  - Checklist procedures previously developed allowed flight preps to be completed in about half the time
- Long Wait for Acceptable Launch Conditions
- Launch Operations
  - Followed previously established procedures and checklists
  - Launch went like “clockwork” – no issues, surprises, or delays
  - Tow balloon and inflation tube releases with primary squibs – no issues
  - Usual “vacuum” at base fitting indicating a sealed balloon
  - Stand-up and launch were very smooth (“Best to date” for ULDB)

Notes on the Balloon Vehicle

- Flanges on red wrap worked very well
  - Easier unloading and handling on flight line
  - No damage found on balloon on flight line (significant improvement)
  - Improvement recommended to be instituted on ZP balloons
- No swirl in apex or base where balloon attaches to the fittings
- Balloon deployment through spool was as expected
  - Balloon carefully stacked and packaged for inflation deployment
  - Better than previous balloons
- Base fitting cart worked as designed

ULDB Test Flight Photographs

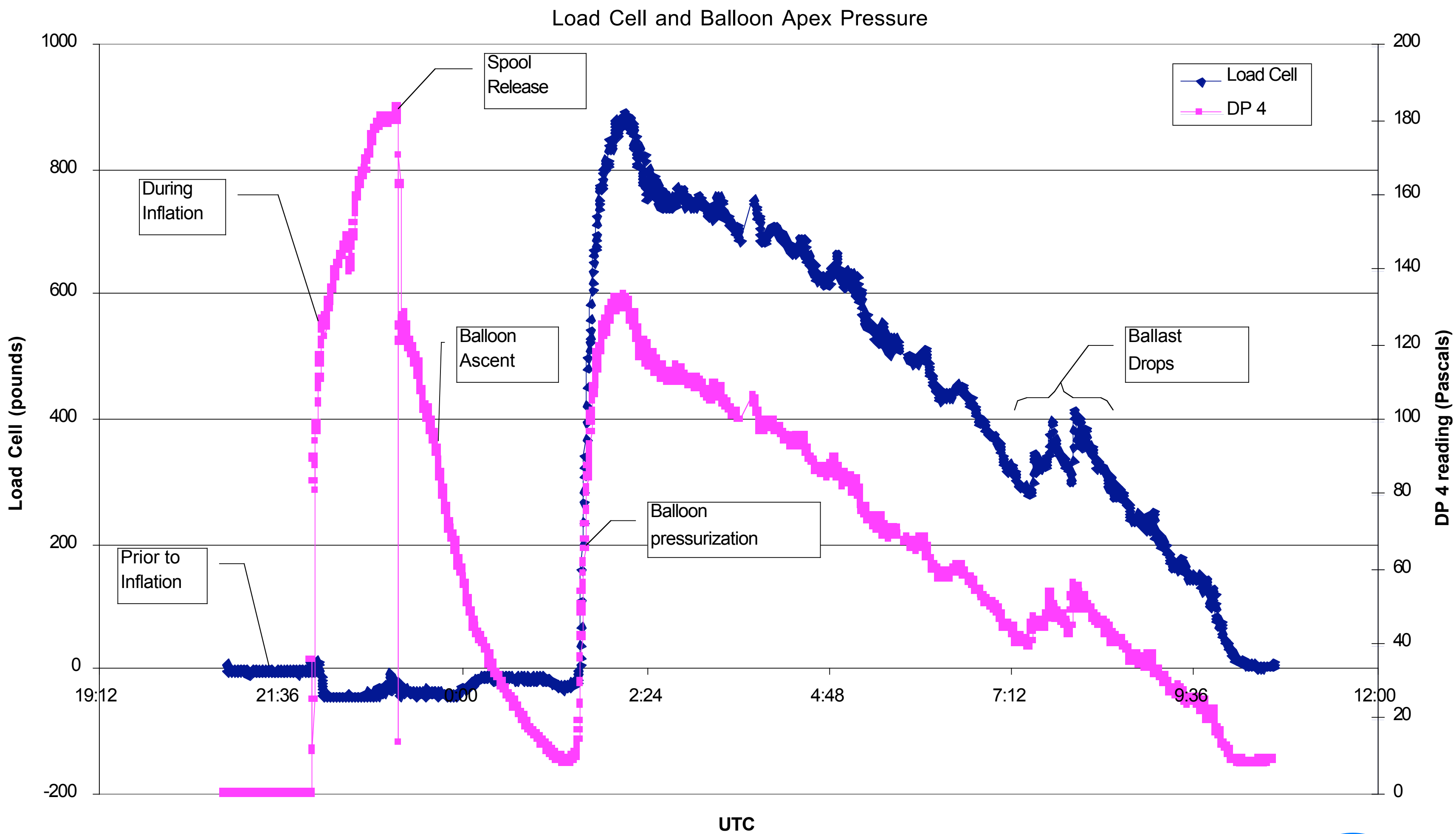




ULDB Test Flight Operations

- Ascent rates were within the expected ranges
- Smoothly transitioned into float.
- Auto-valve function activated to maintain balloon within pre-flight specified differential pressure limits – Auto-valve system worked as designed
- Balloon did not deploy properly (confirmed by up looking videos and telescope)
- Float altitude was a couple hundred feet below designed altitude
- After reviewing undeployed shape and performance data, decision made to terminate flight
- Flight terminated over a remote area on Aboriginal lands “near” a road

Flight Plot



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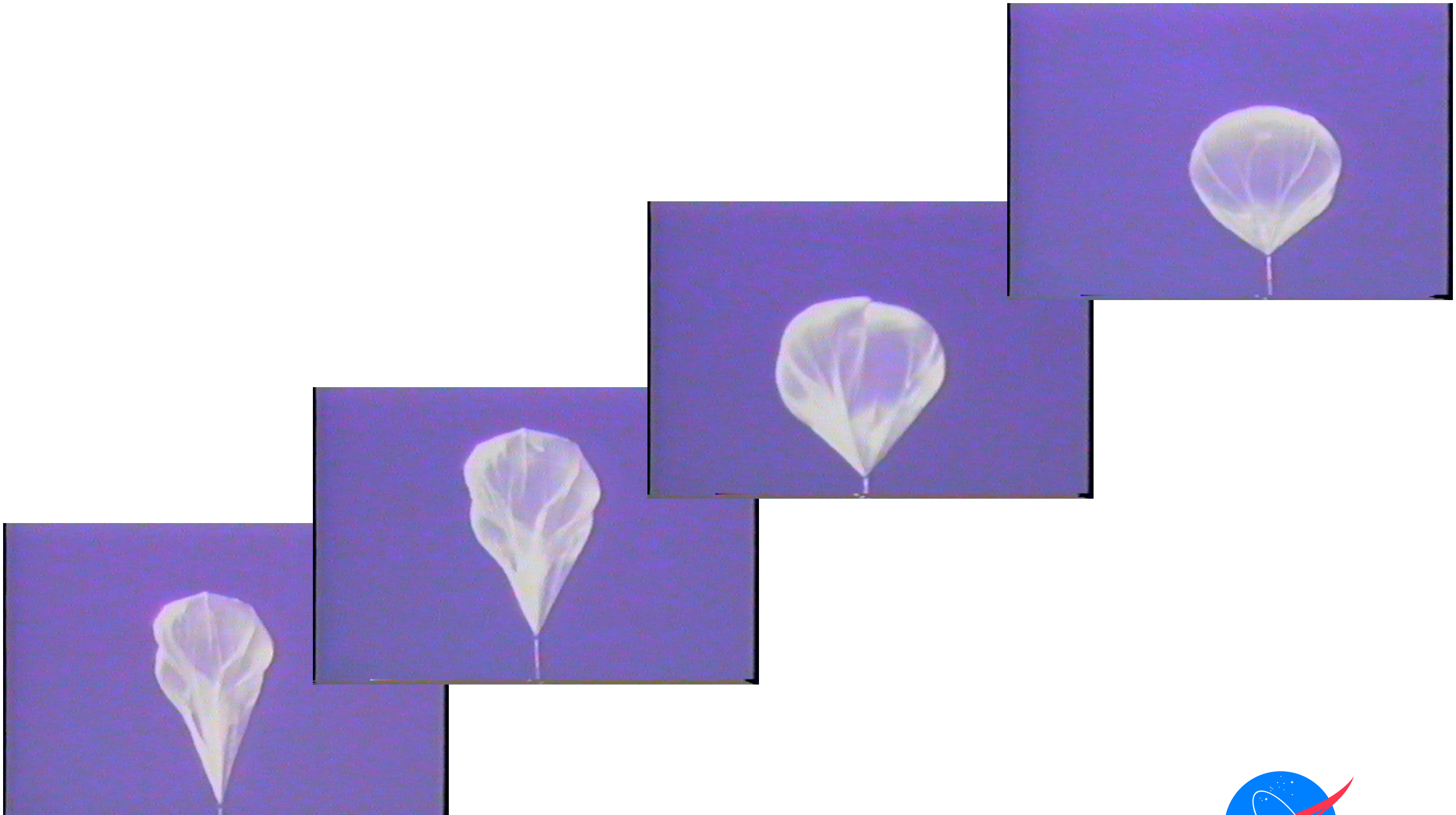
ULDB Test Flight Photographs



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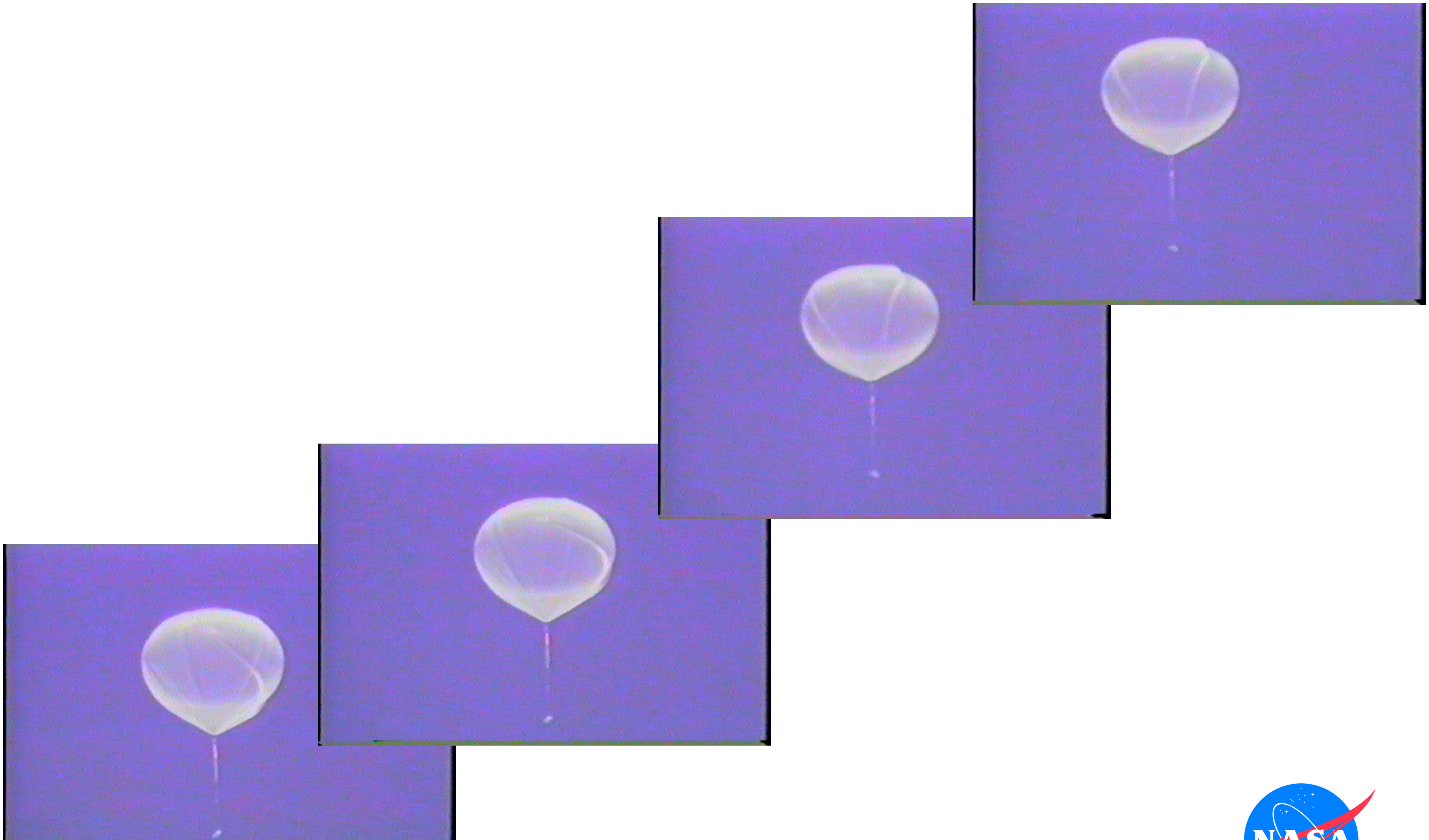

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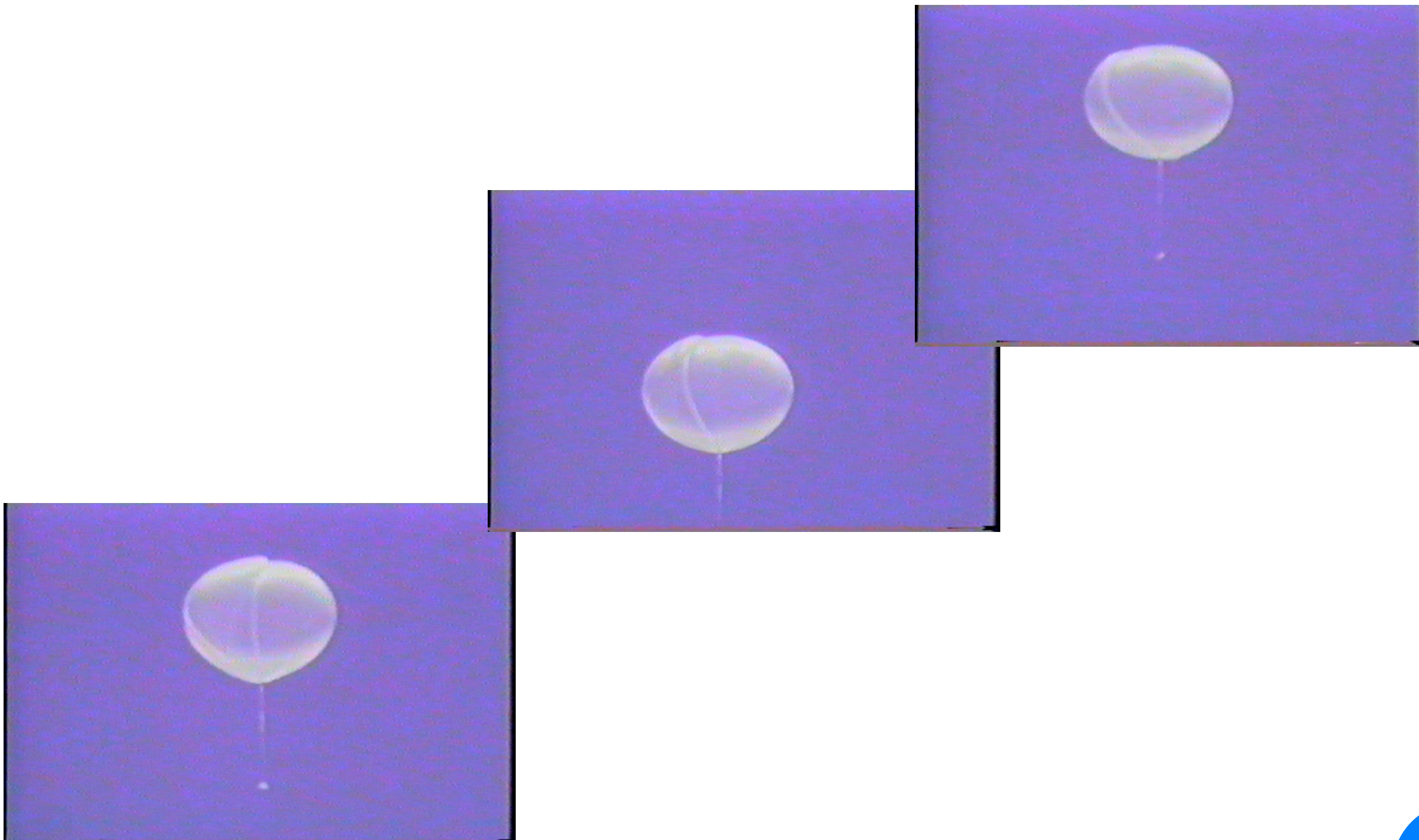

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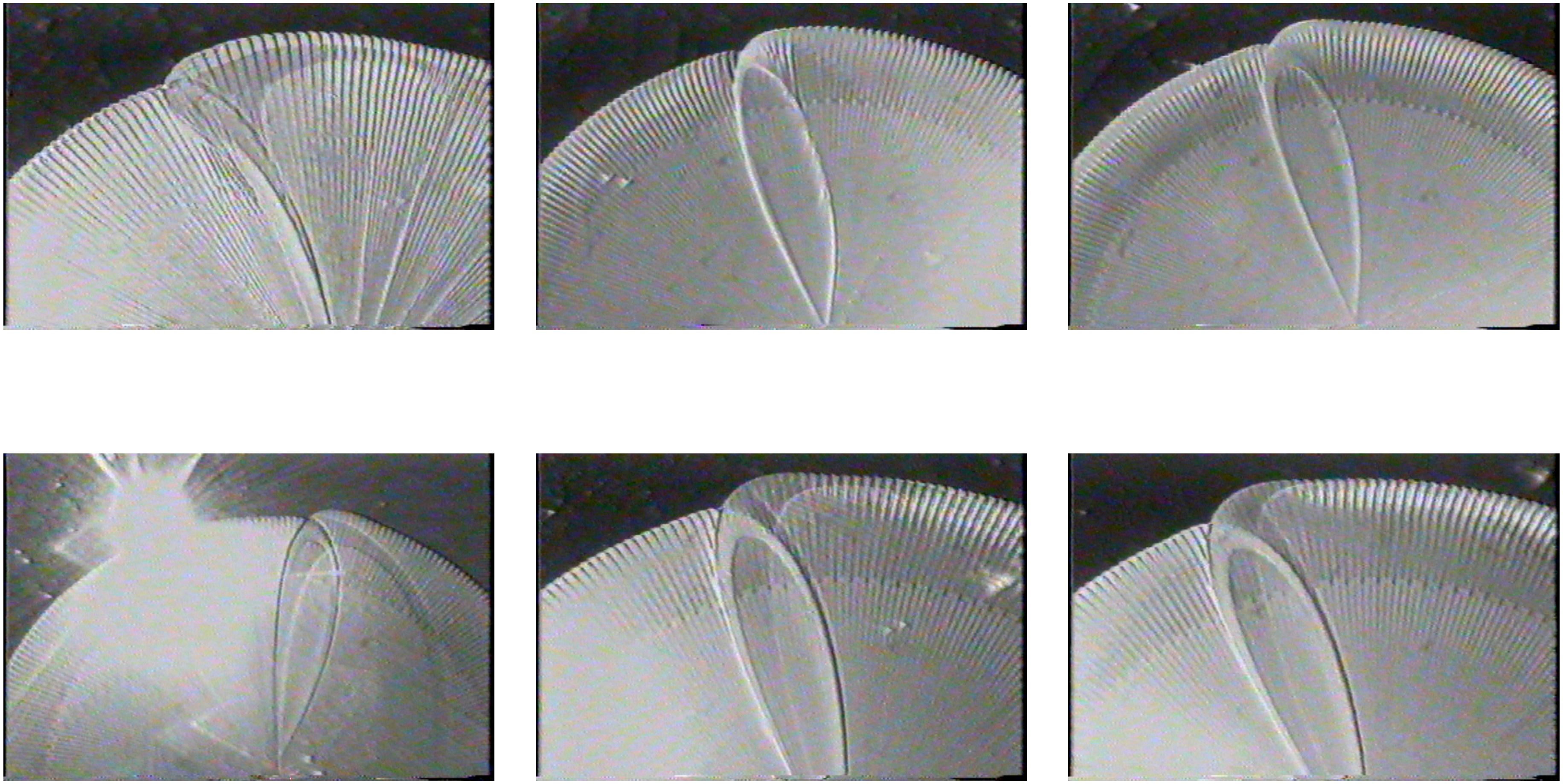

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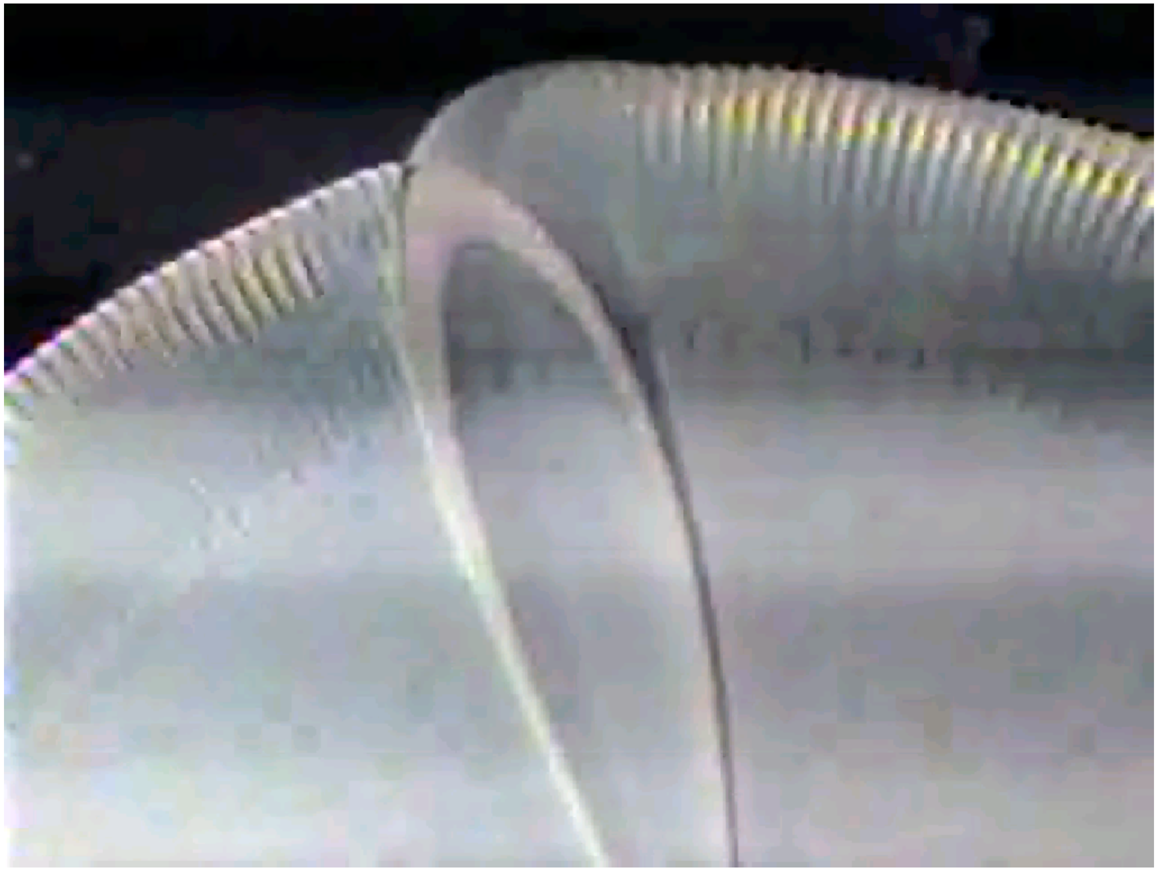

Recovery and Post Flight

- Payload found the only water for 100's of kilometers ("clay pan" Aboriginal Holiday spot)
- Balloon pile was a mess (like all balloons after flight) – damaged on descent
- Impact area measured (~33 ft by ~66 ft)
- Apex and base fittings looked as they did on launch
- All tendons were attached on apex and base
- Three small pieces of the balloon retrieved – final balloon recovery completed
- Balloon returned to the U.S. on June 20

Recovery and Post Flight Photographs

Recovery and Post Flight Photographs

Next Steps

- ARB - Investigating issues identified from “fishbone analysis”
- Balloon has just returned to the NSBF on June 20
- Inspection of balloon and accessories to be done July 7 to 11
- Design and modeling of potential fixes in process
  - Pattern design changes to ensure deployment
  - Approaches to “force” deployment being investigated
- Proposed verification plan to test “fixes” will be presented to BPO
  - All potential “fixes” will require fabrication and testing
  - Will include recommendations for each approach, test structures to be built, proposed test flights, schedule, and cost

Next Steps

- Specific final "fixes" are TBD
  - Pending completion of identified efforts from "fishbone analysis"
  - Pending review and recommendations by investigation committee
  - Pending BPO selection of approaches to be tested
- Next test flight date, location, and success criteria are TBD