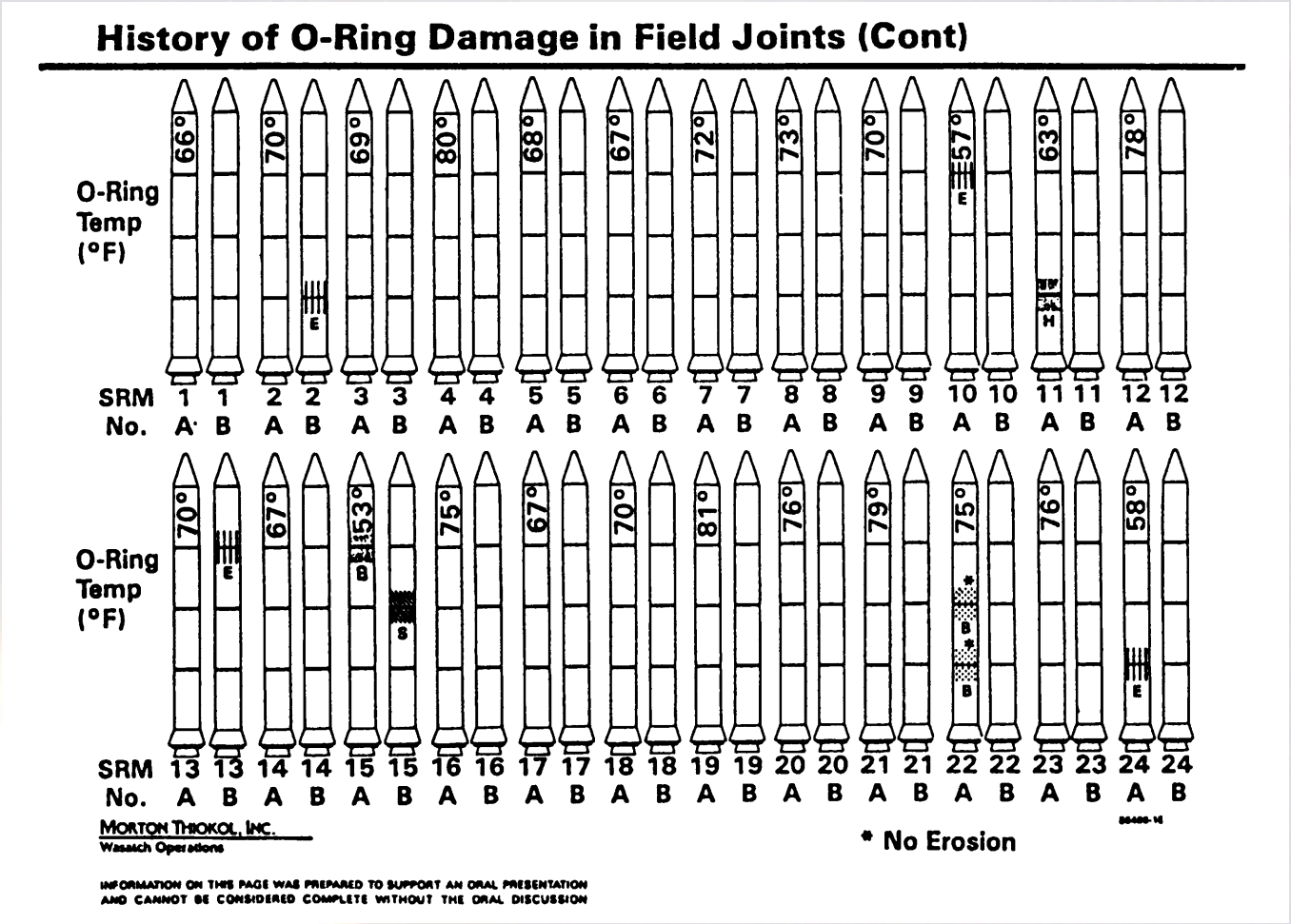
# Launch and Entry Failures

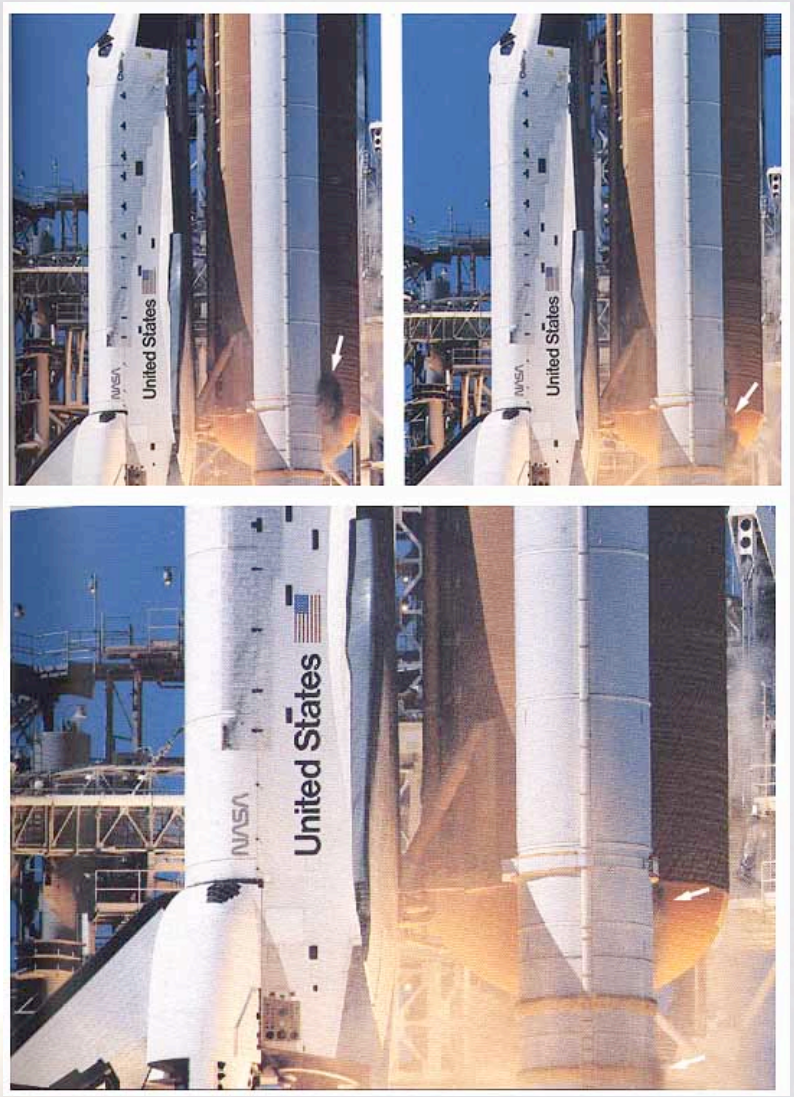
- Atlas ICBM
- STS 51-L - Challenger
- STS 107 - Columbia
- AMROC SET-1

# Review Slide - STS-51L L-1 FRR

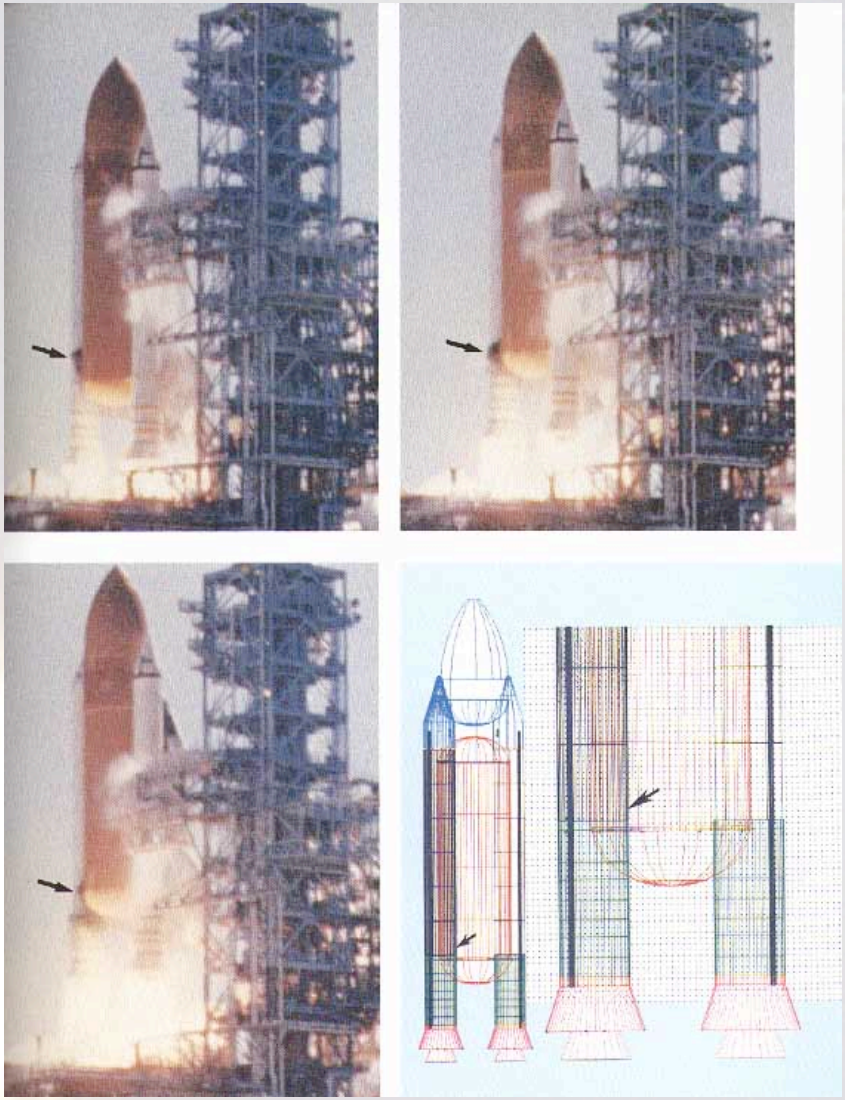



From Edward R. Tufte, Visual and Statistical Thinking: Displays of Evidence for Making Decisions Graphics Press, 1997

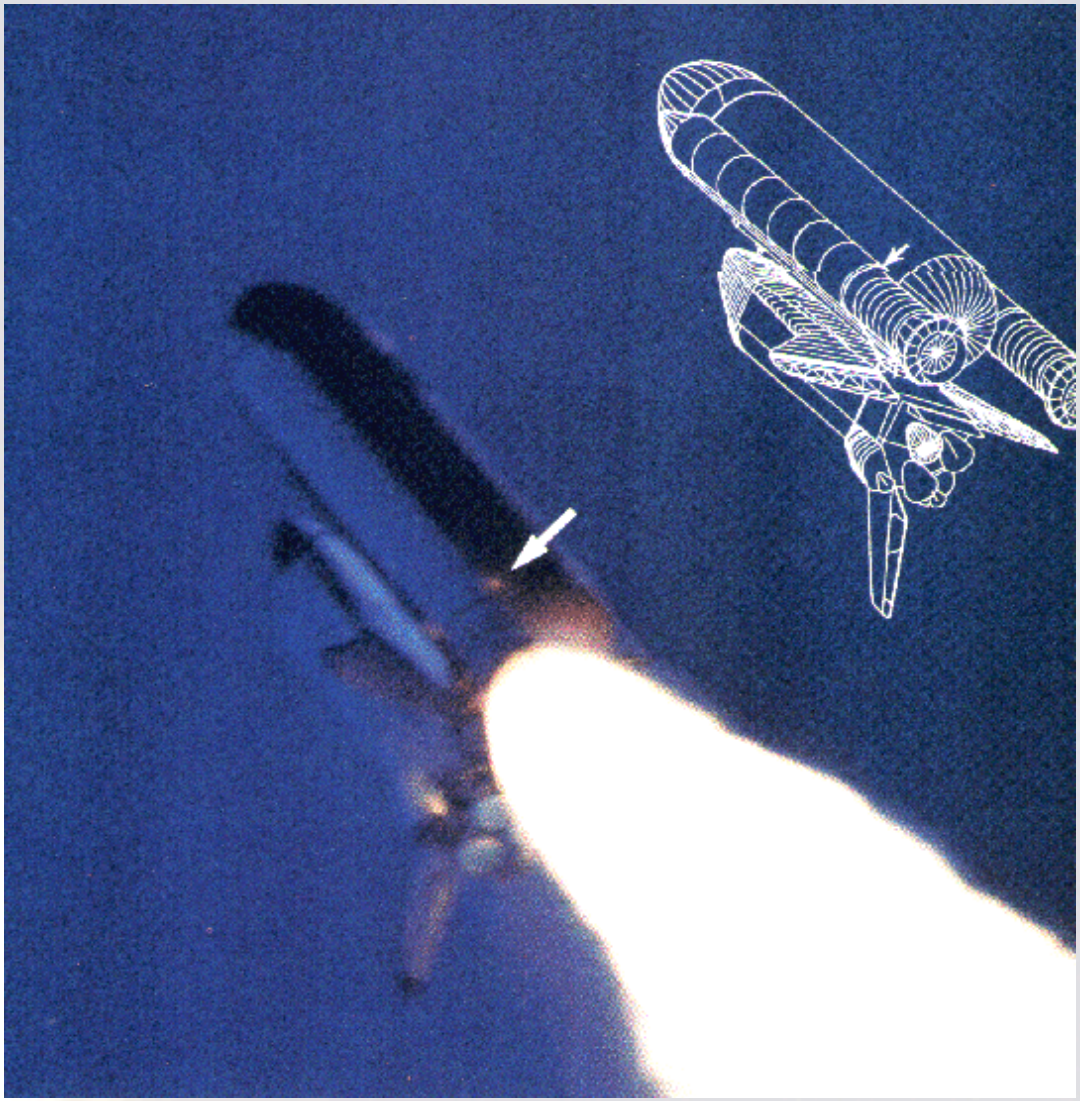
# Black Smoke Plumes from Aft Field Joint


United States
NASA
United States
NASA
United States
NASA

# Photographic Evidence

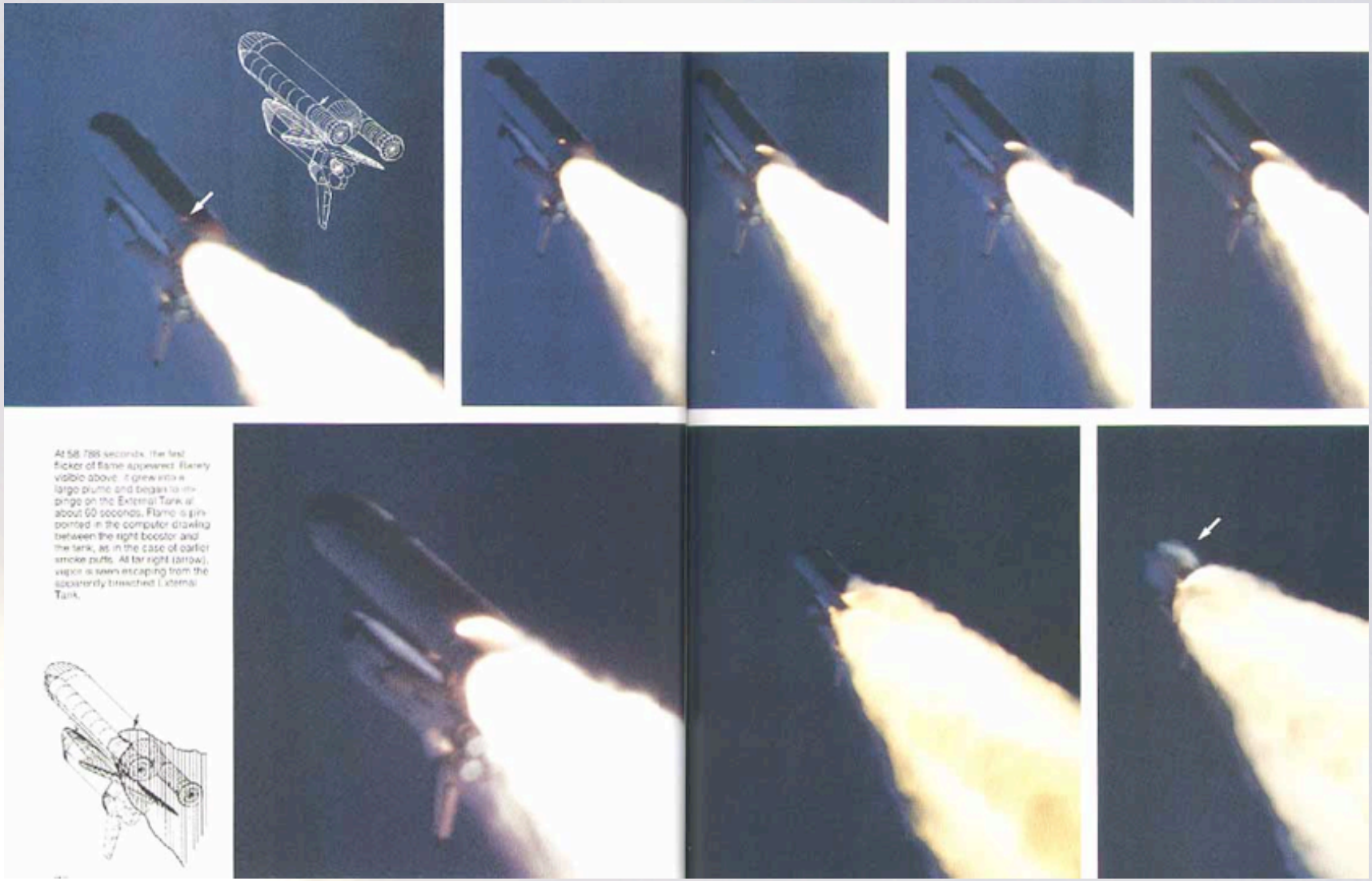


# T+58 sec - Appearance of External



# Flame Hitting Aft Attach Fixture and ET

# Progression of SRB Burn-through



# Original SRB Field Joint Design

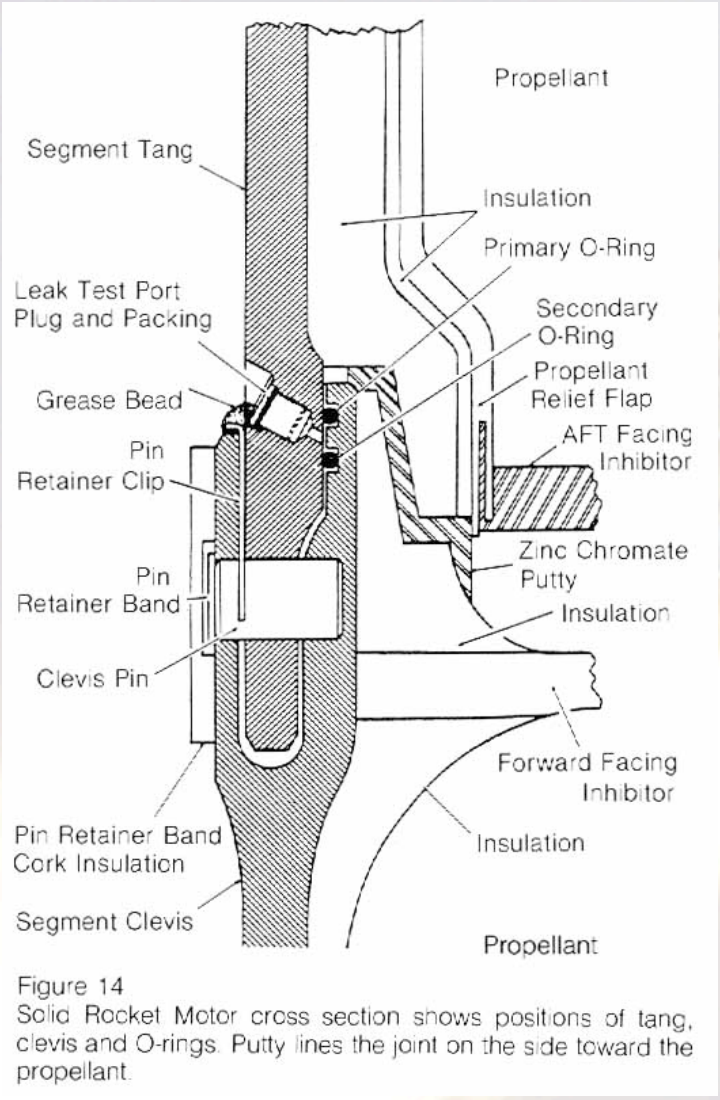
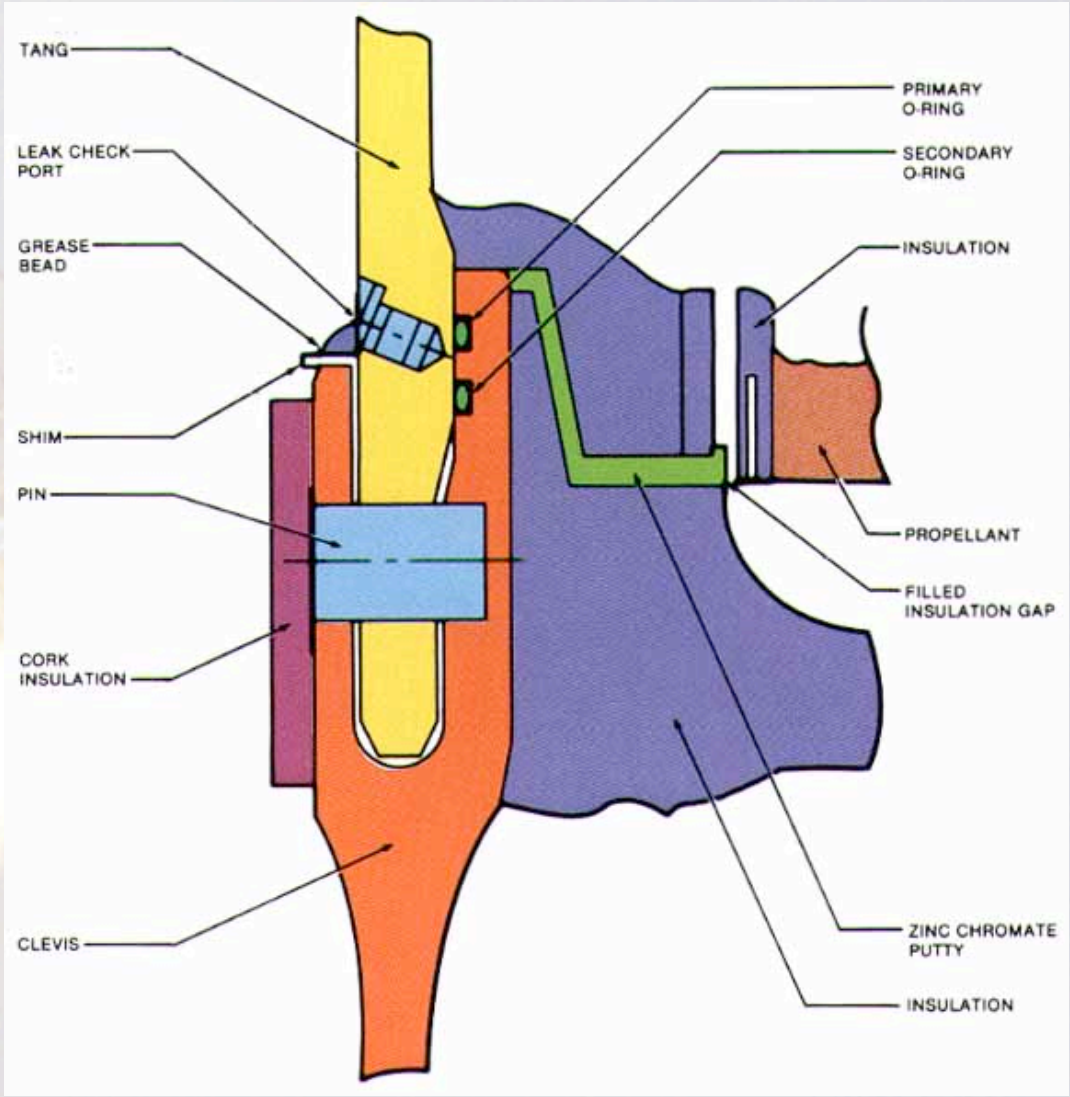
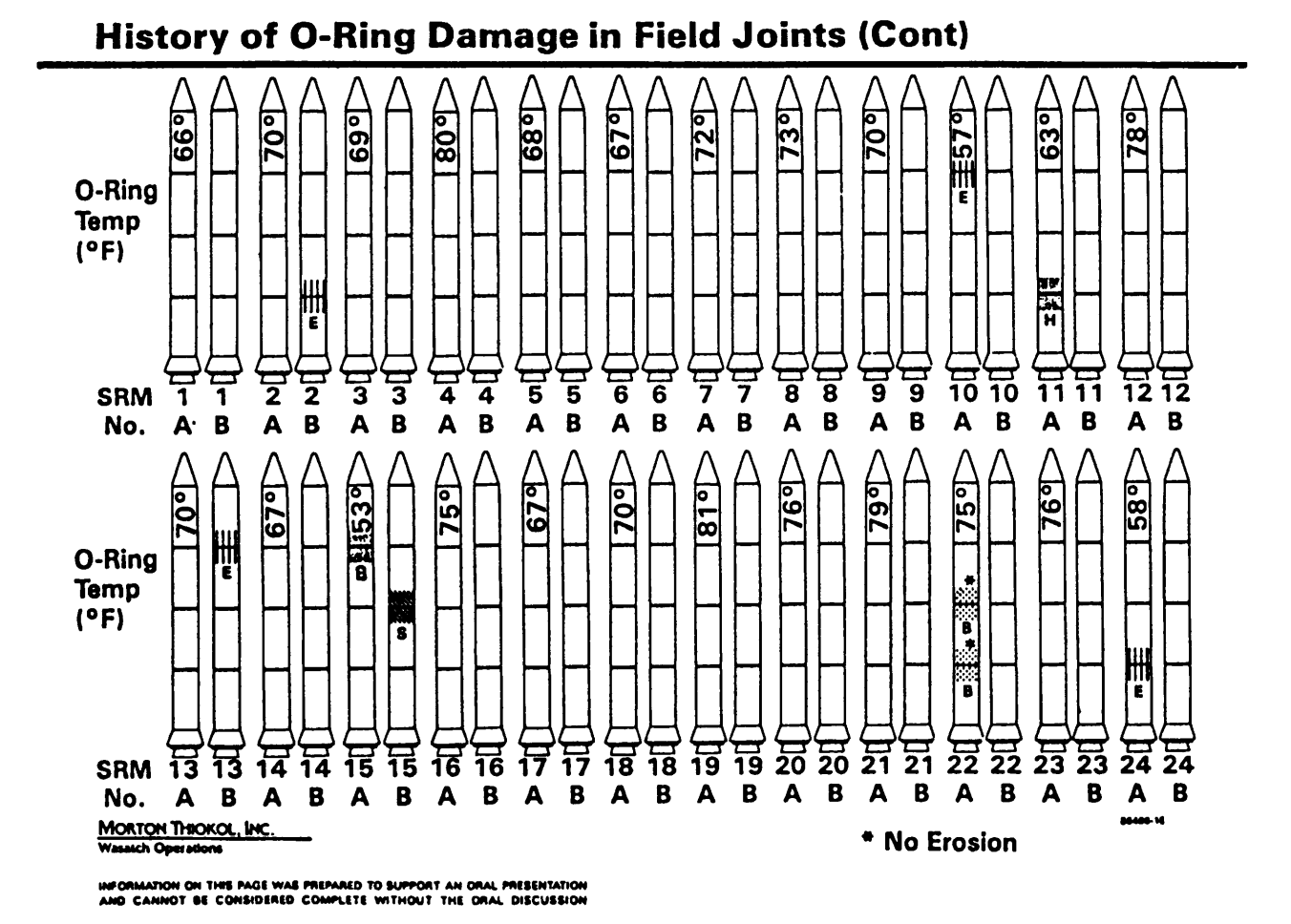



Figure 14
Solid Rocket Motor cross section shows positions of tang, clevis and O-rings. Putty lines the joint on the side toward the propellant.

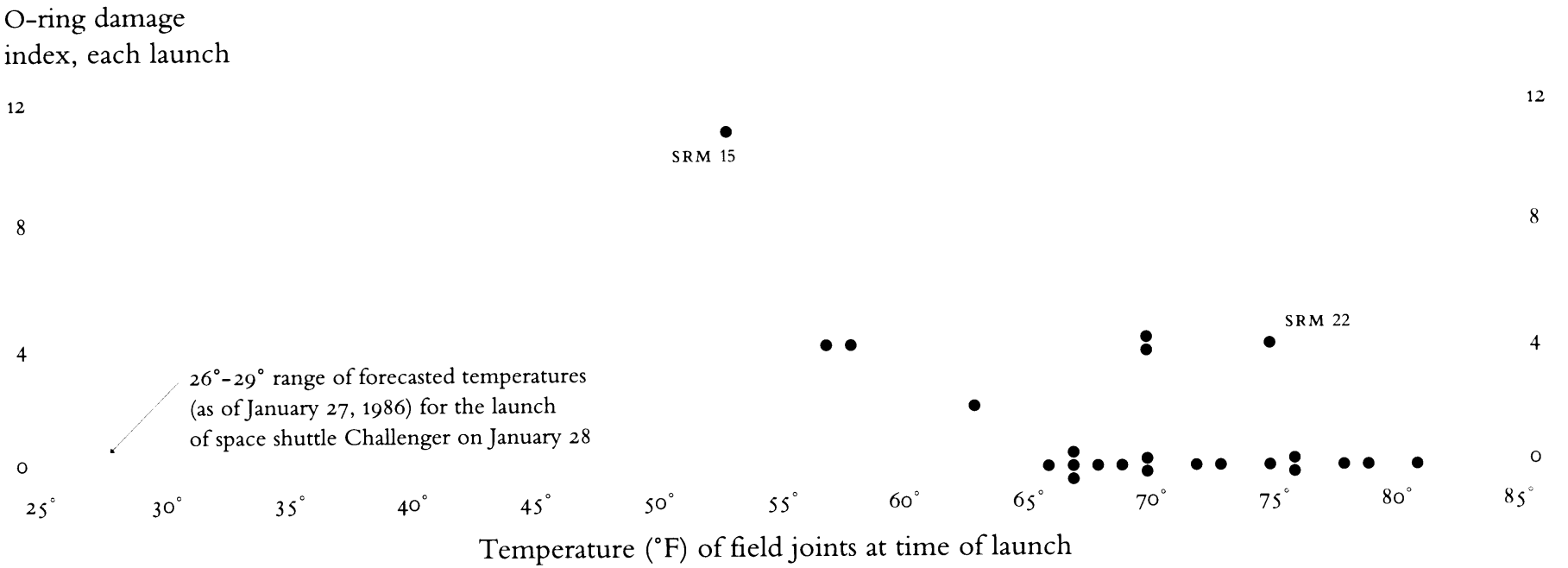


# The Slide That Was Presented




From Edward R. Tufte, Visual and Statistical Thinking: Displays of Evidence for Making Decisions Graphics Press, 1997

# The Slide That Should Have Been...




From Edward R. Tufte, Visual and Statistical Thinking: Displays of Evidence for Making Decisions
Graphics Press, 1997

# Clearance Effects on O-Ring Seating

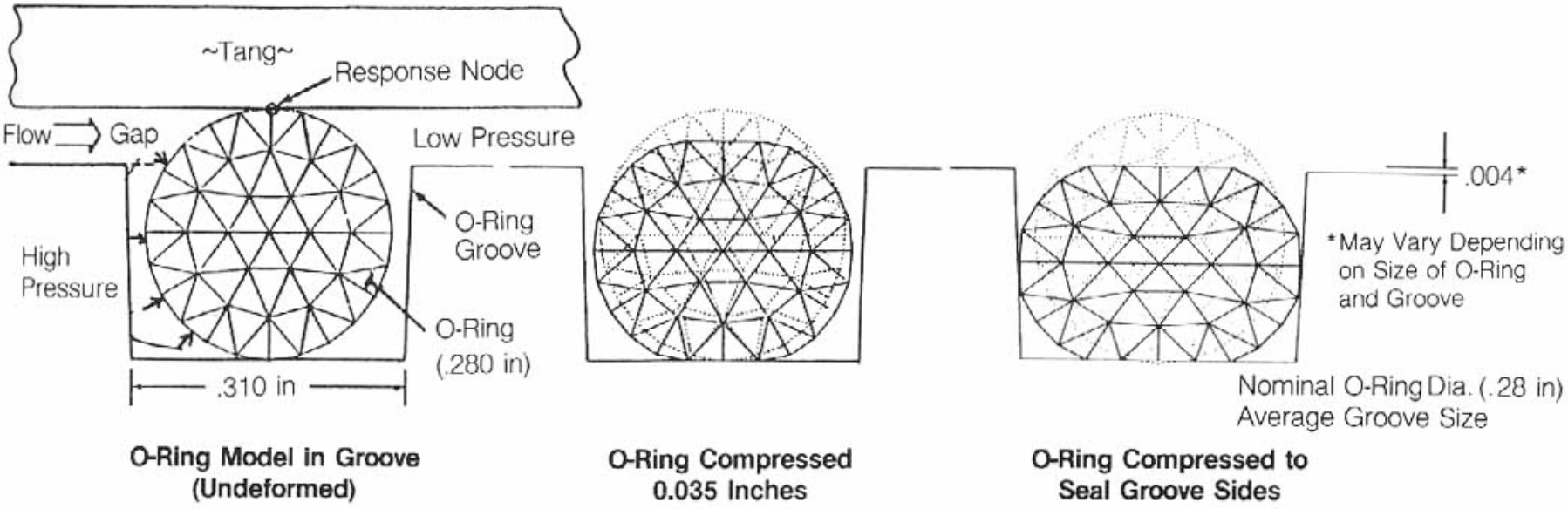



Figure 18
Drawings show how progressive reduction of gap between tang and clevis can inhibit and eventually block motor cavity's high-pressure flow from getting behind O-ring.

# Dynamic Motion of O-Ring Seals

**Pressurized Joint Deflection**

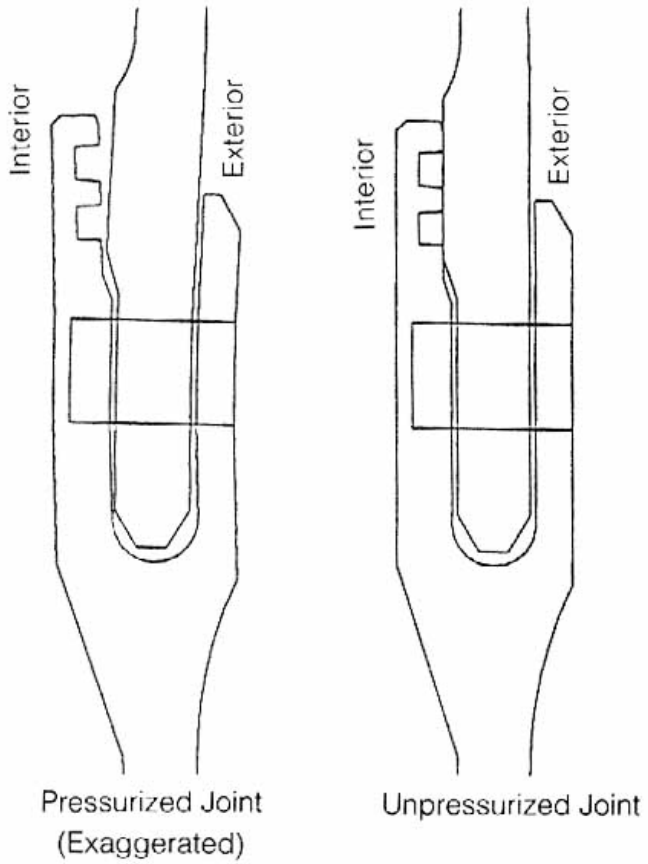



Figure 16
Drawings show how tang/clevis joint deflects during pressurization to open gap at location of O-ring slots. Inside of motor case and propellant are to left in sketches.

**Right Hand SRM Aft Field Joint Primary And Secondary Delta Gap Opening**

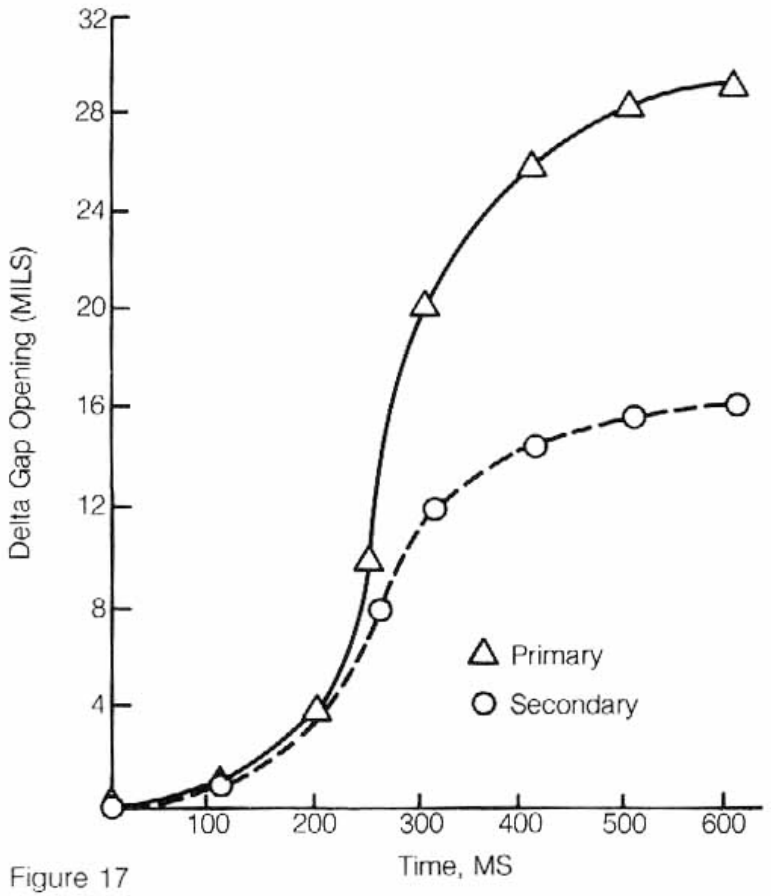
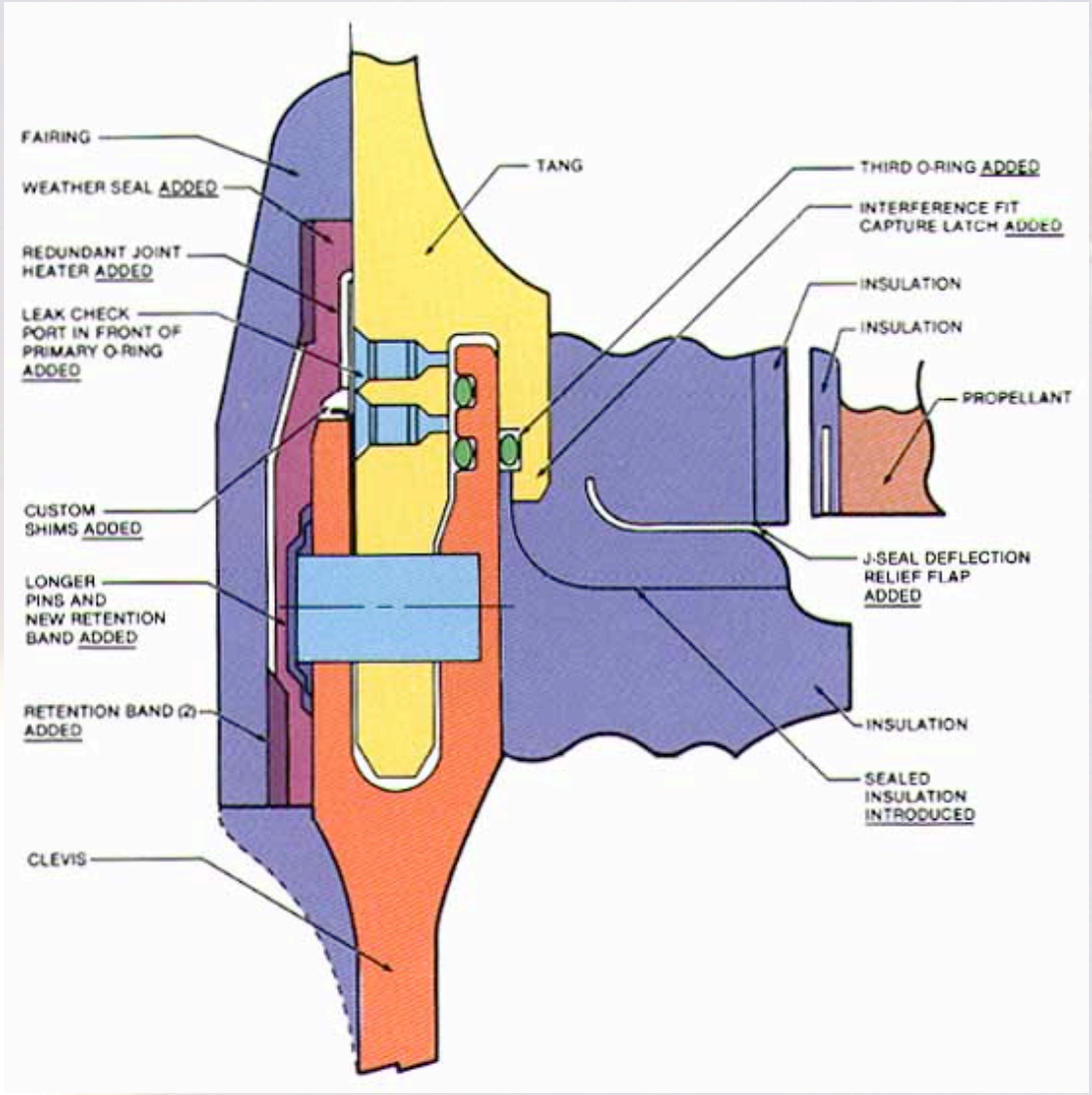
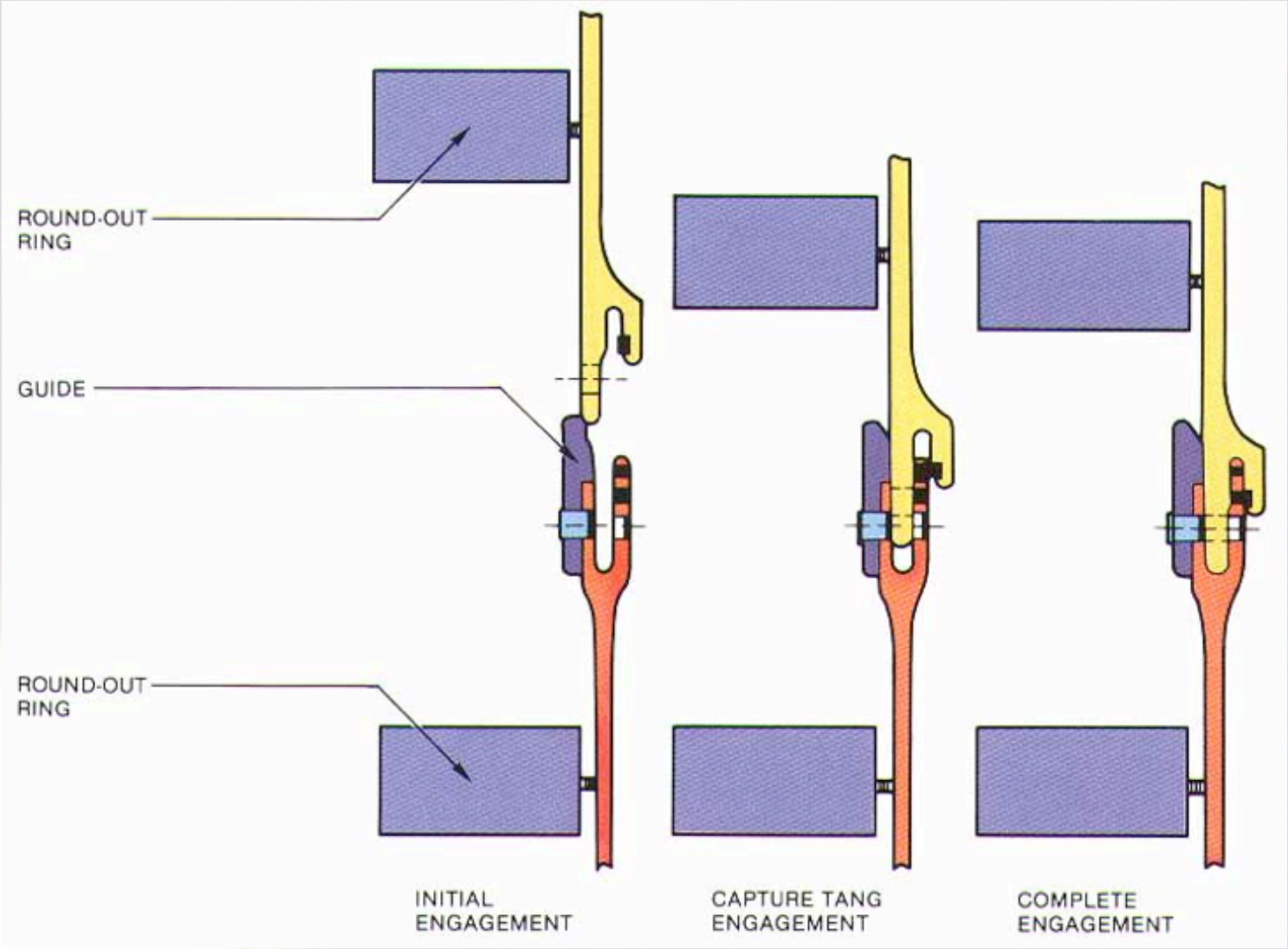



Figure 17
Graph plots changes in right booster's aft field joint primary and secondary gap openings. Horizontal scale is time in milliseconds from ignition.

# Redesigned SRB Field Joint

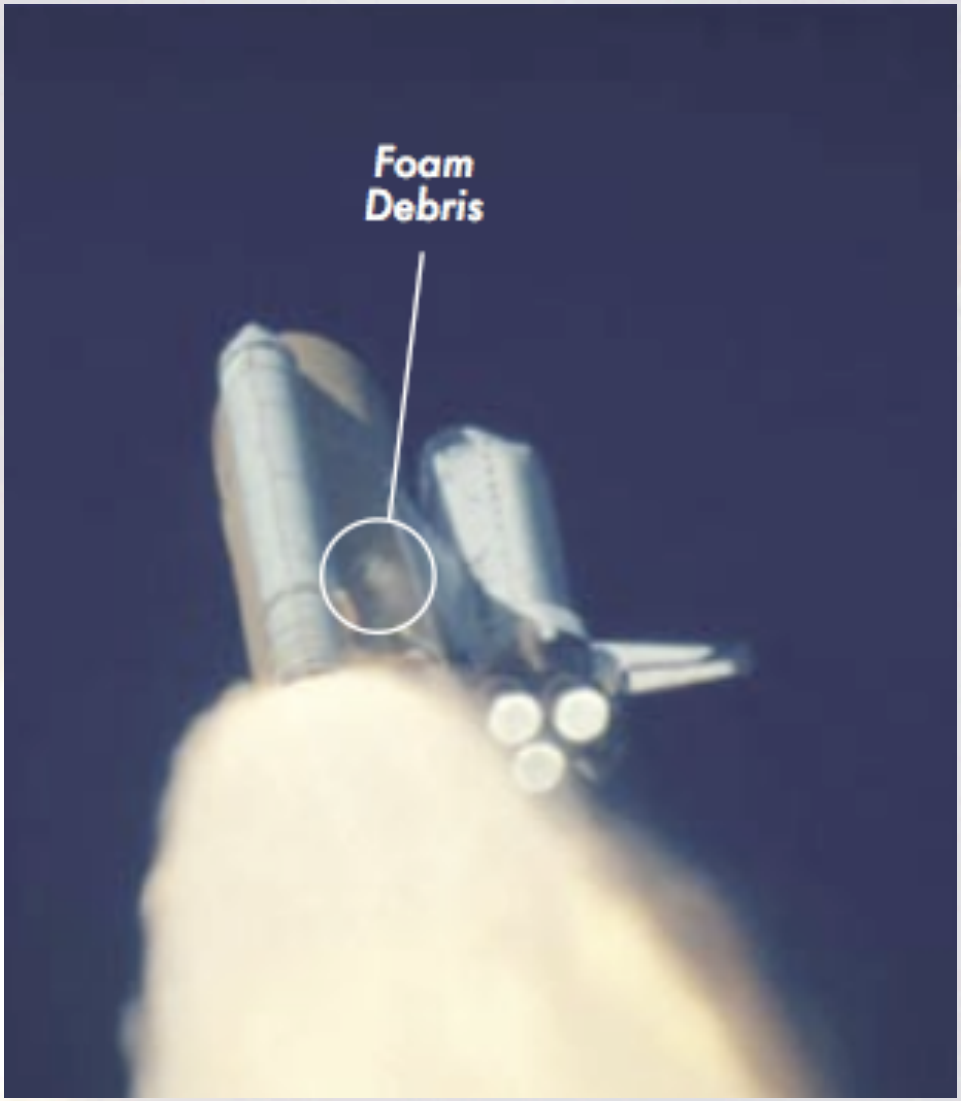


# Revised SRB Assembly Technique

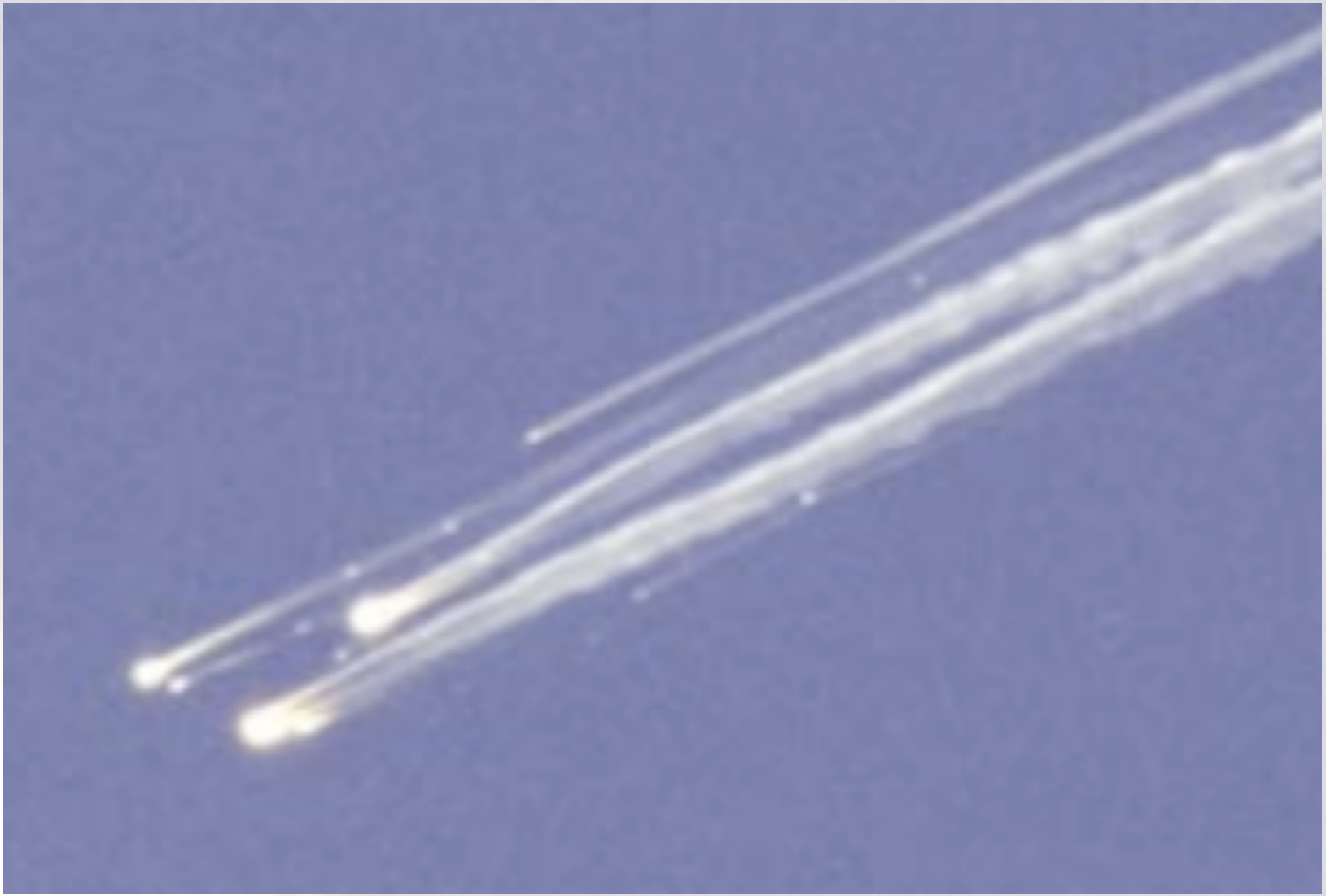


# Columbia Launch - STS-107

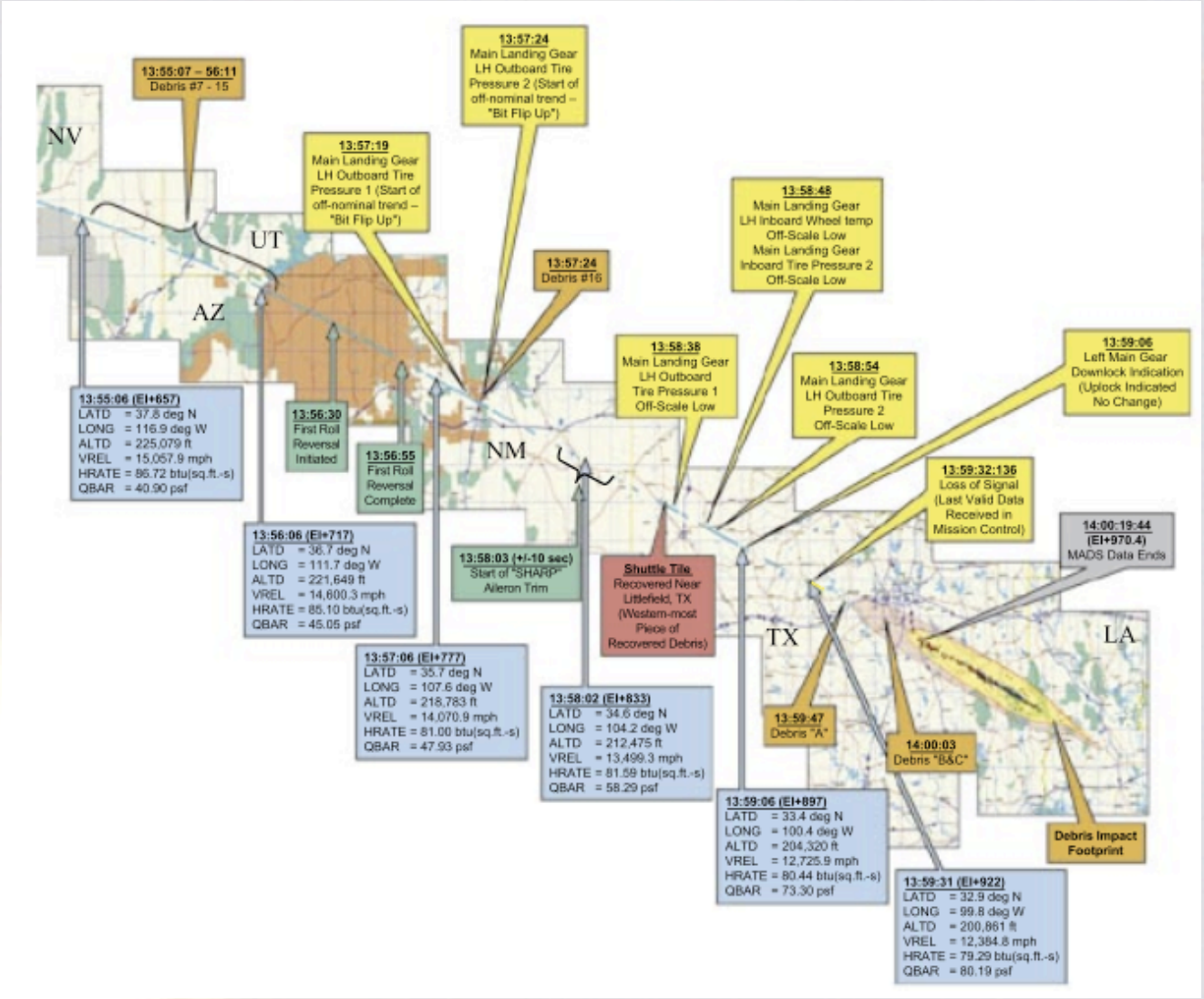
# L+81.9 sec



# In-Flight Breakup

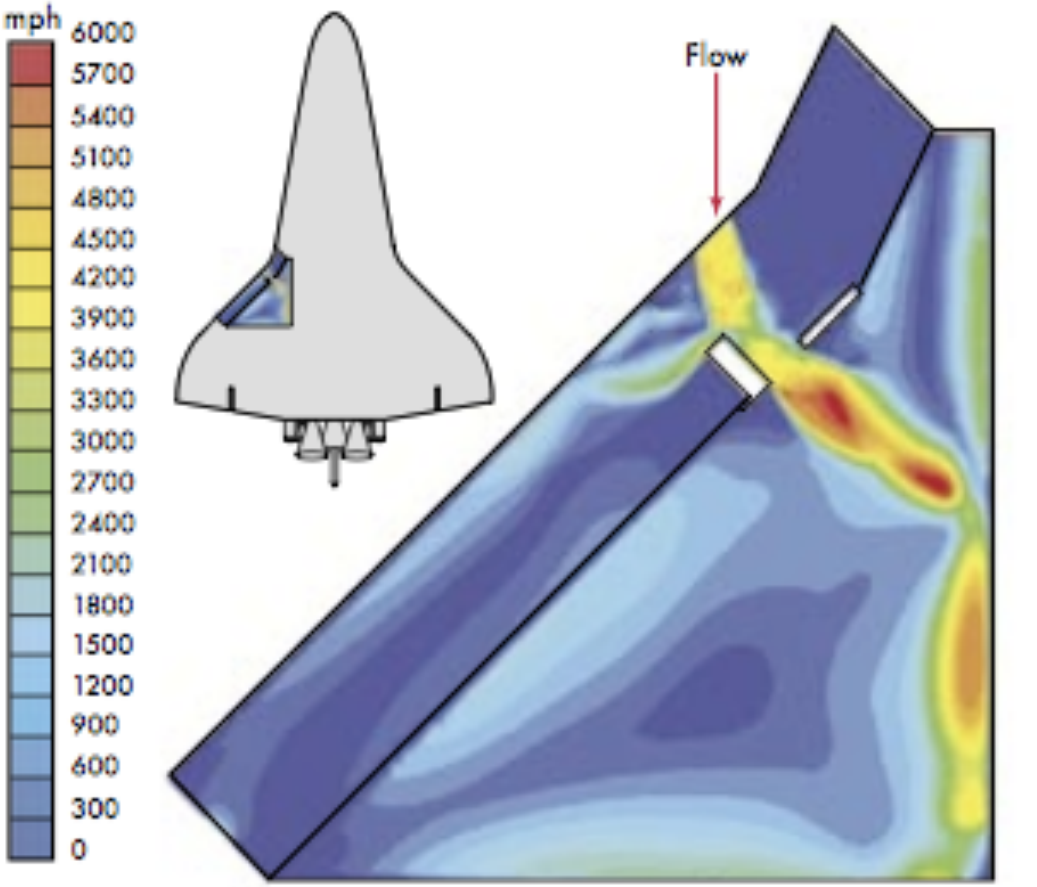


# Events Along Flight Path

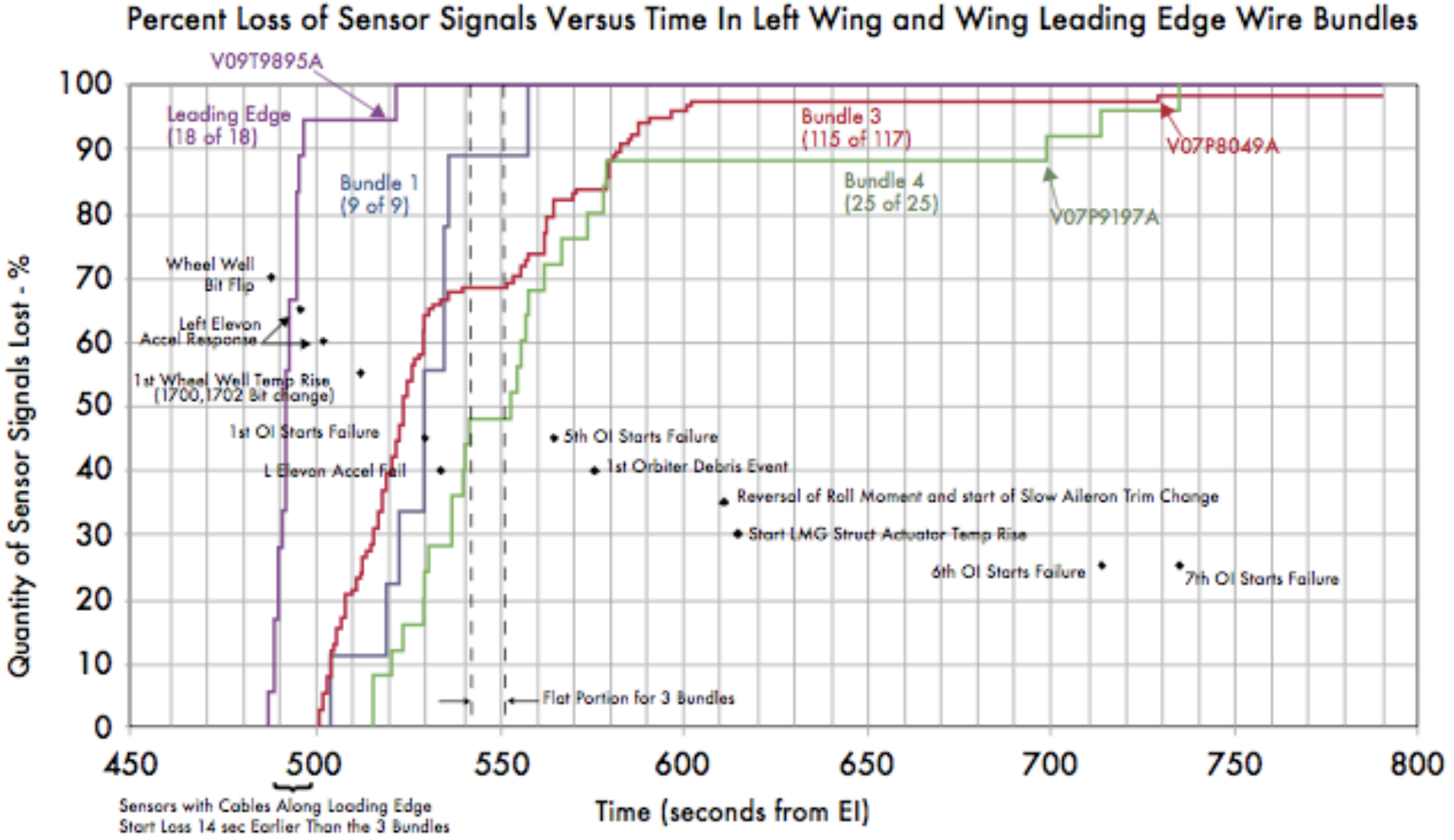


# Columbia Debris Reconstruction

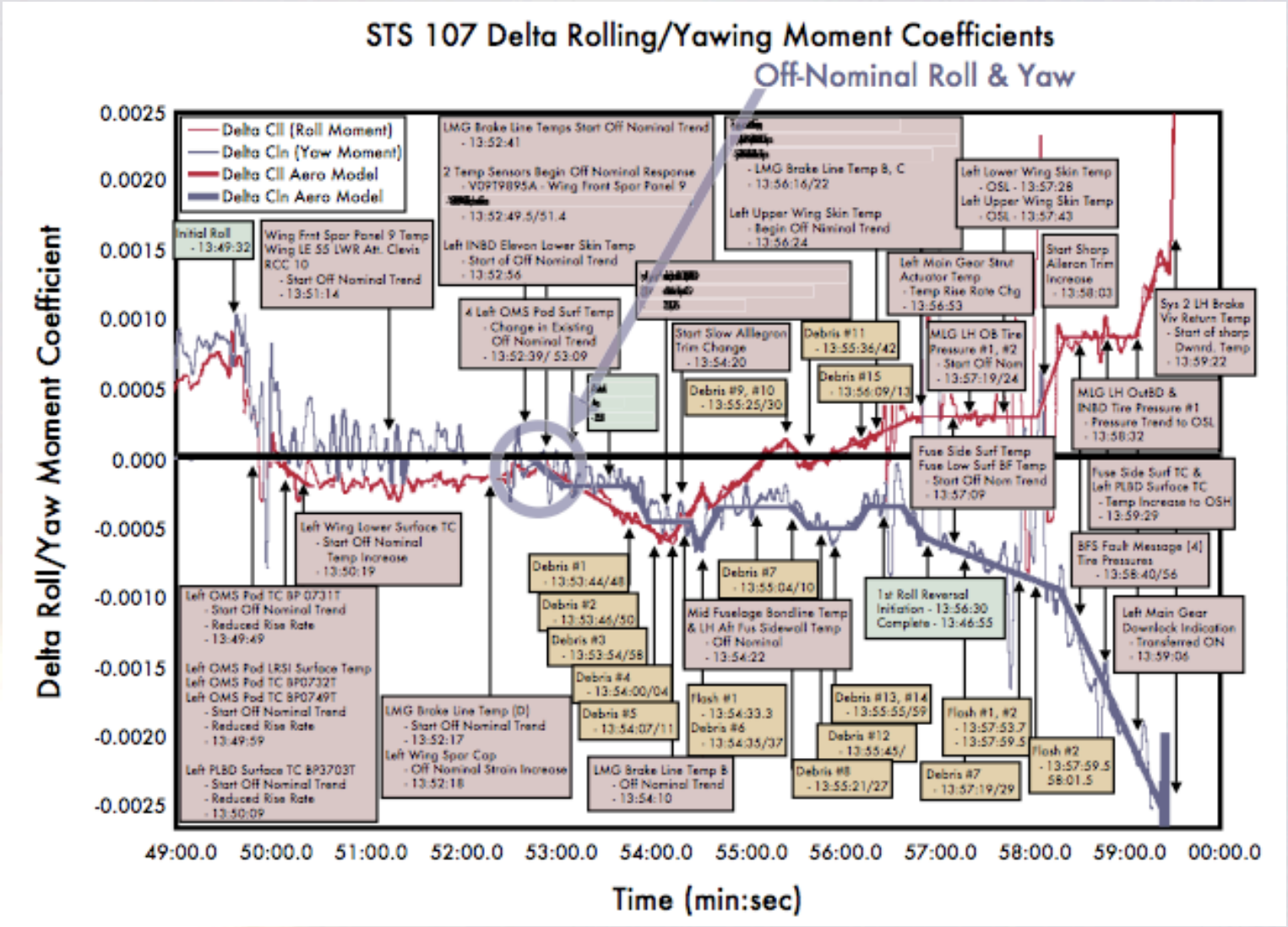
# CFD Analysis of Internal Airflow



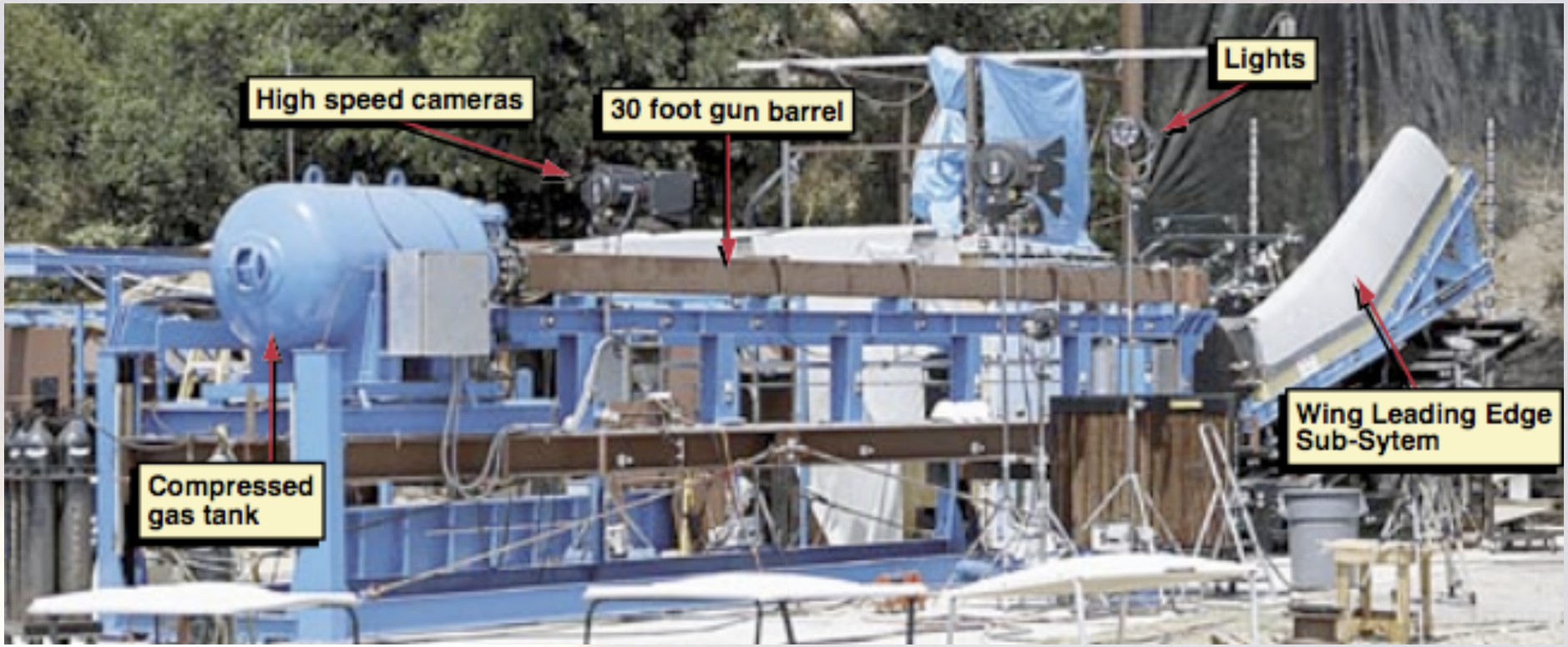
# Failure Rates of Sensor Wiring Bundles



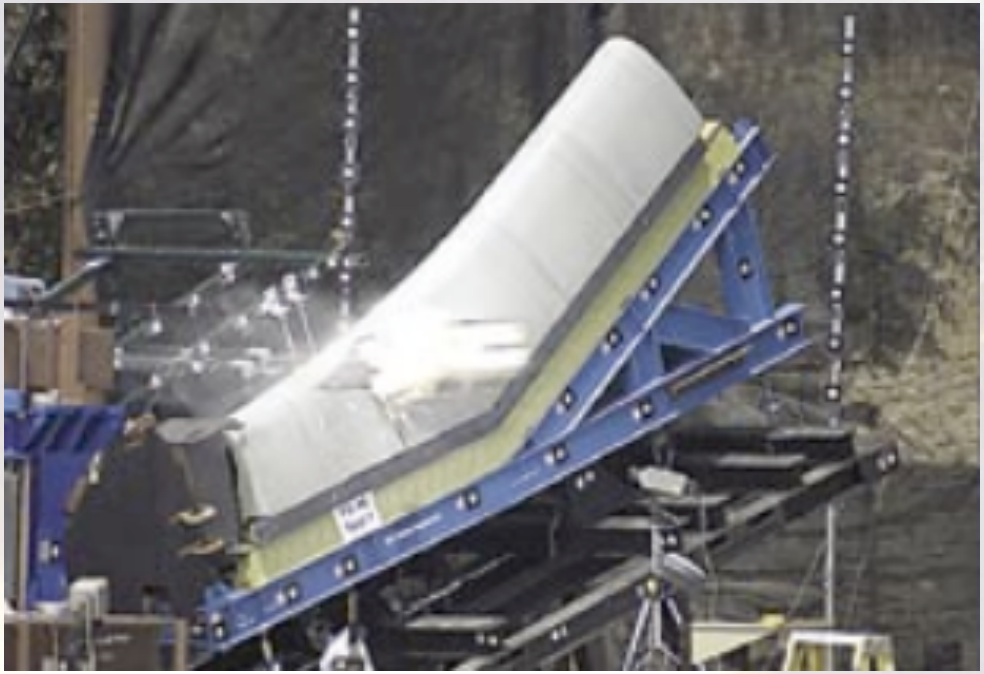
# Divergence of Roll/Yaw Angles

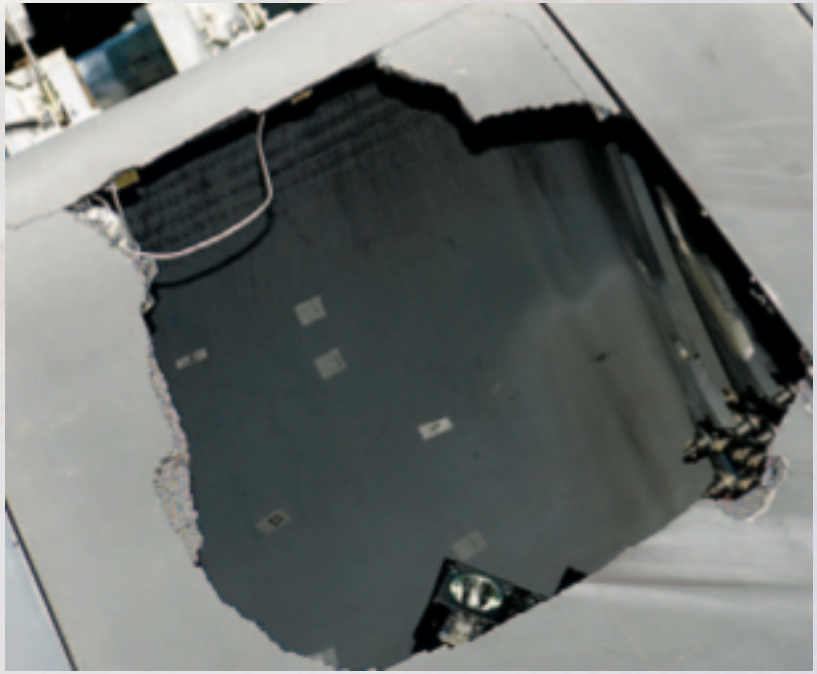


# High-Velocity Impact Testing of RCC

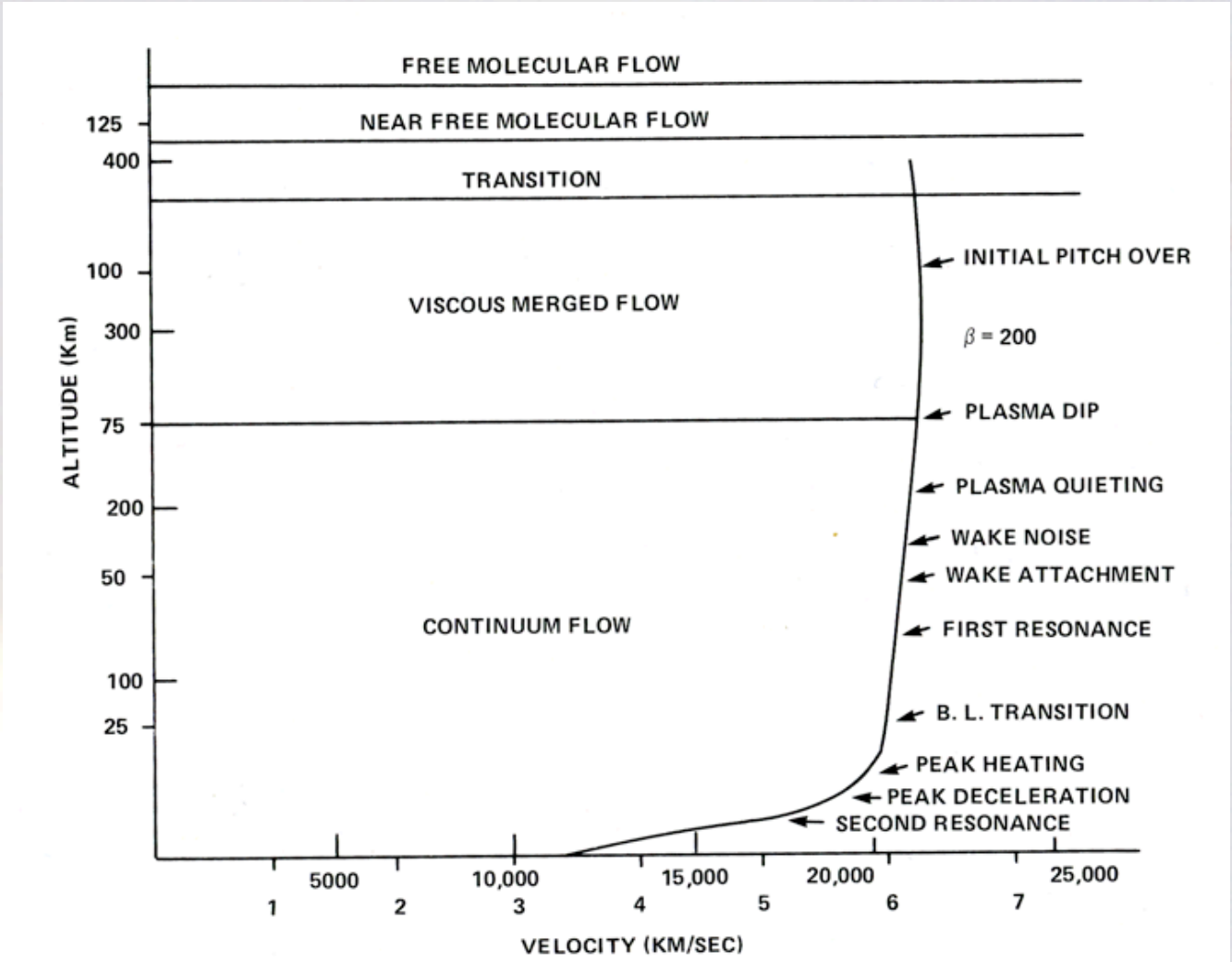


# Results of Impact Tests on RCC





# Entry Flow Regimes




ref: Frank J. Regan, Reentry Vehicle Dynamics AIAA Education Series, NY, NY 1984

# October 5, 1989 - T+2 sec

# October 6, 1989 - Aftermath