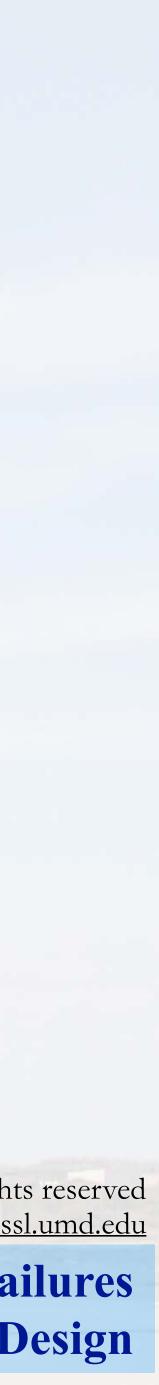
# "Failure is Always an Option"

- Various launch vehicle failures (video only)
- STS 51-L Challenger
- STS 107 Columbia
- AMROC SET-1



# ption" es (video only)

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### **Atlas Launch Failure**

### AtomCentral.com







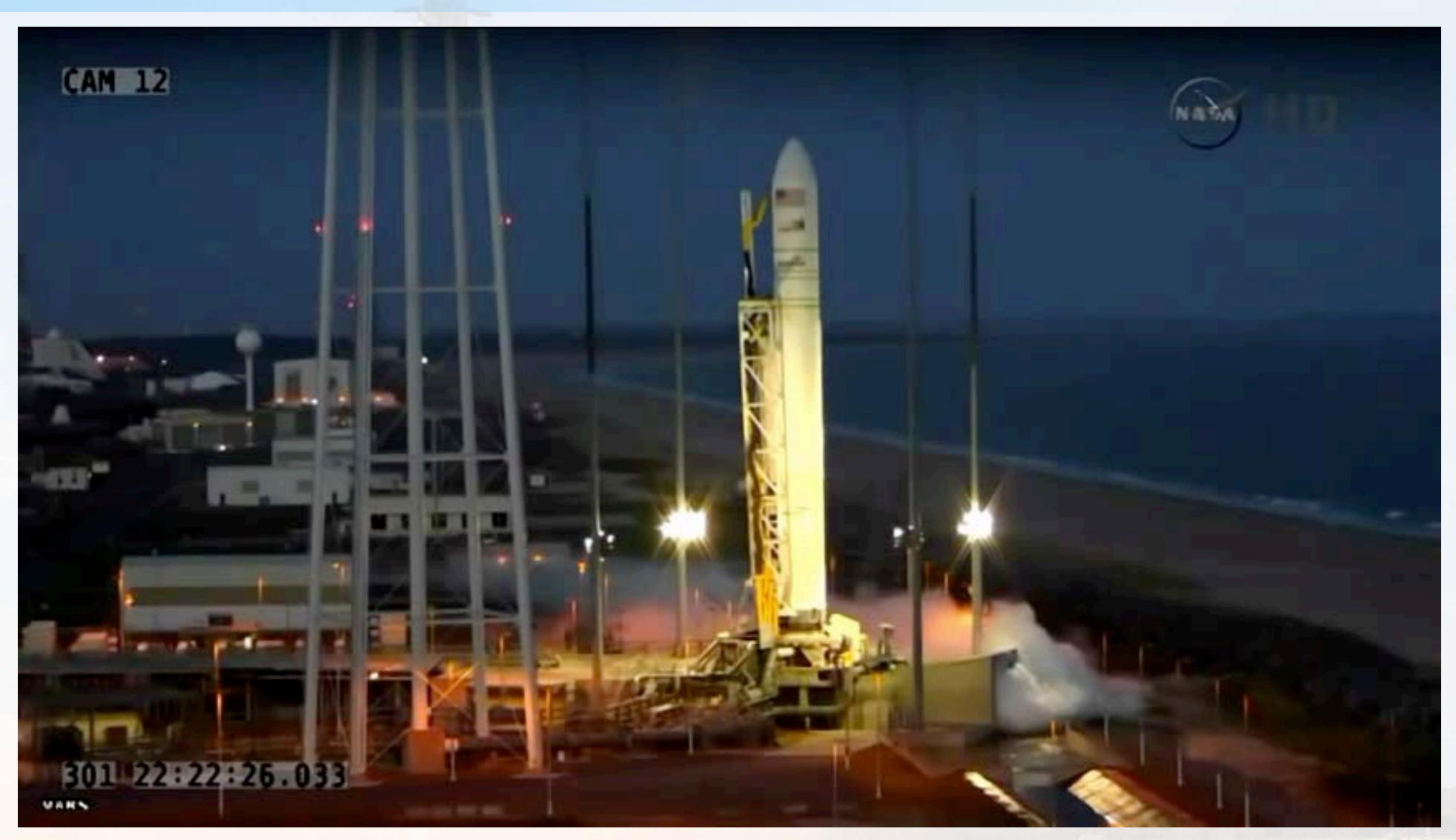
### **Titan 34D Failure**







### Antares OA-3 Launch







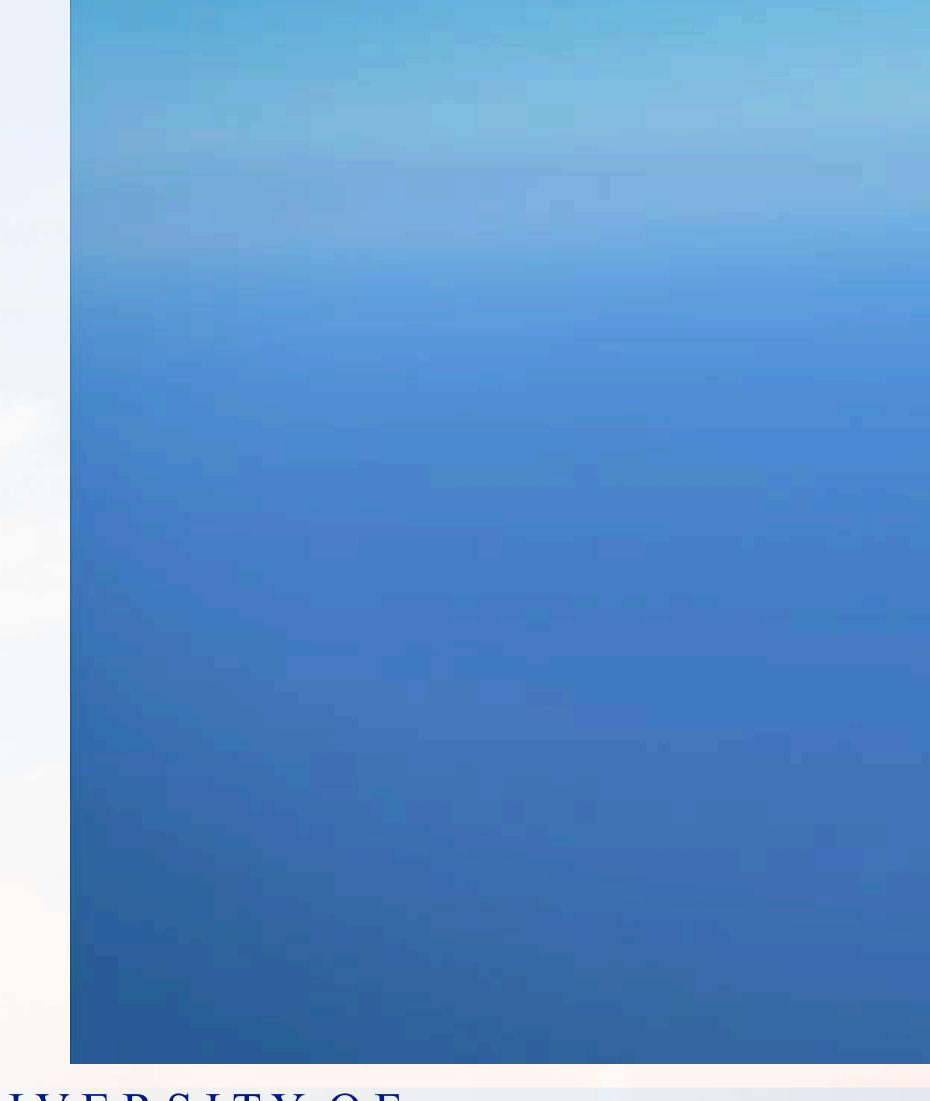
# **SpaceX AMOS-6 Static Test Fire**







### "How Not to Land an Orbital Rocket"







### January 28, 1986

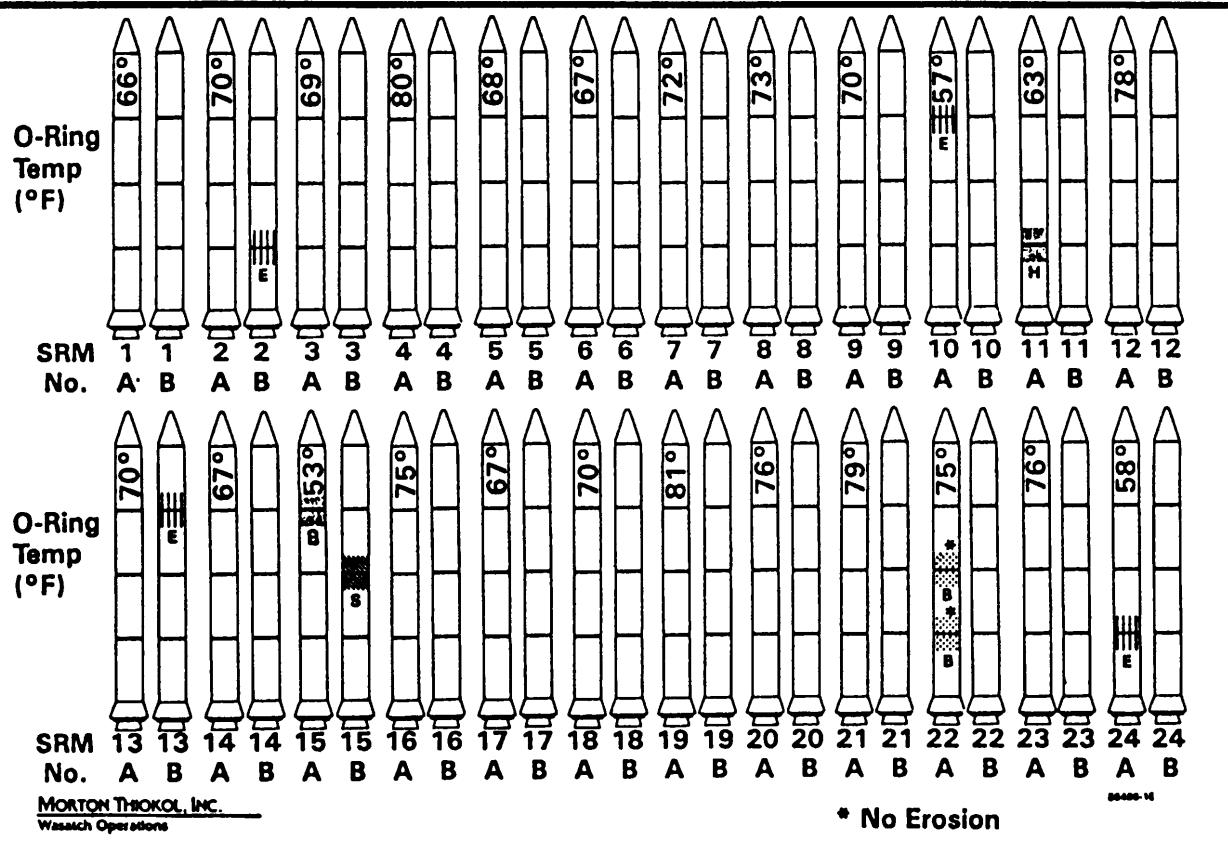






# **Review Slide - STS-51L L-1 FRR**

### **History of O-Ring Damage in Field Joints (Cont)**



INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE DRAL DISCUSSION

Graphics Press, 1997



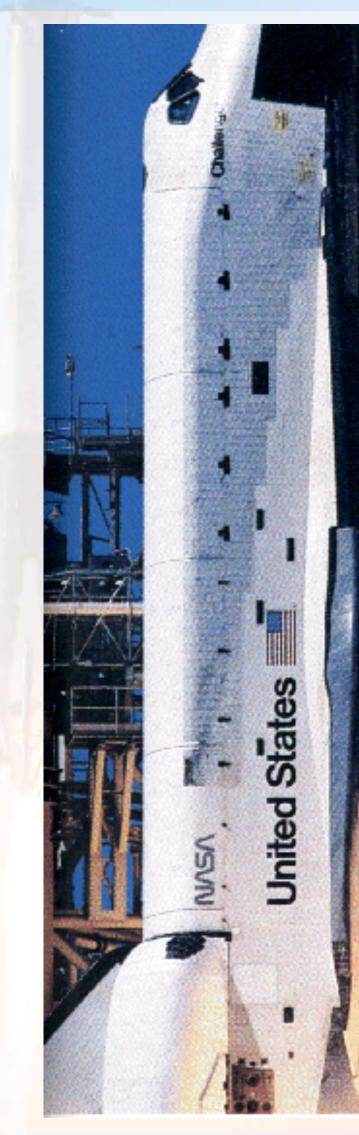
NIVERSITY OF MARYLAND

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



# **Black Smoke Plumes from Aft Field Joint**

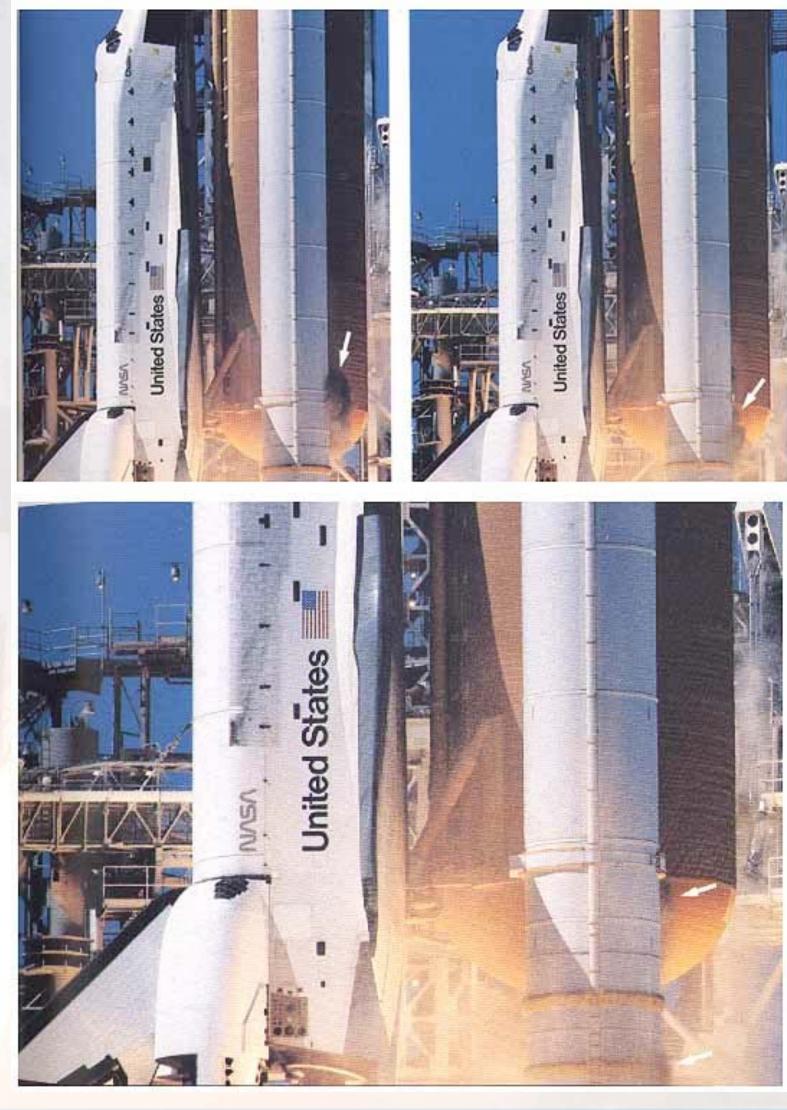


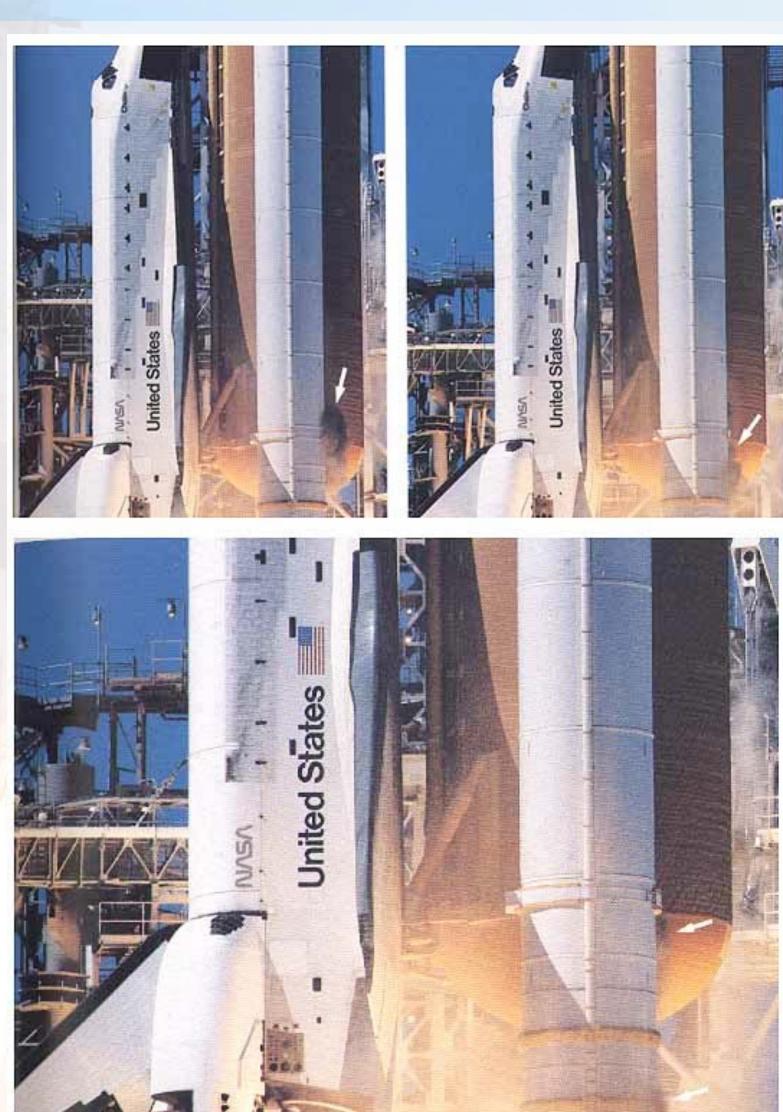














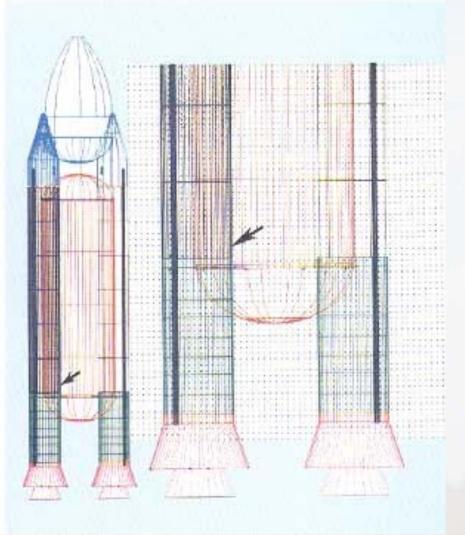
# Photographic Evidence









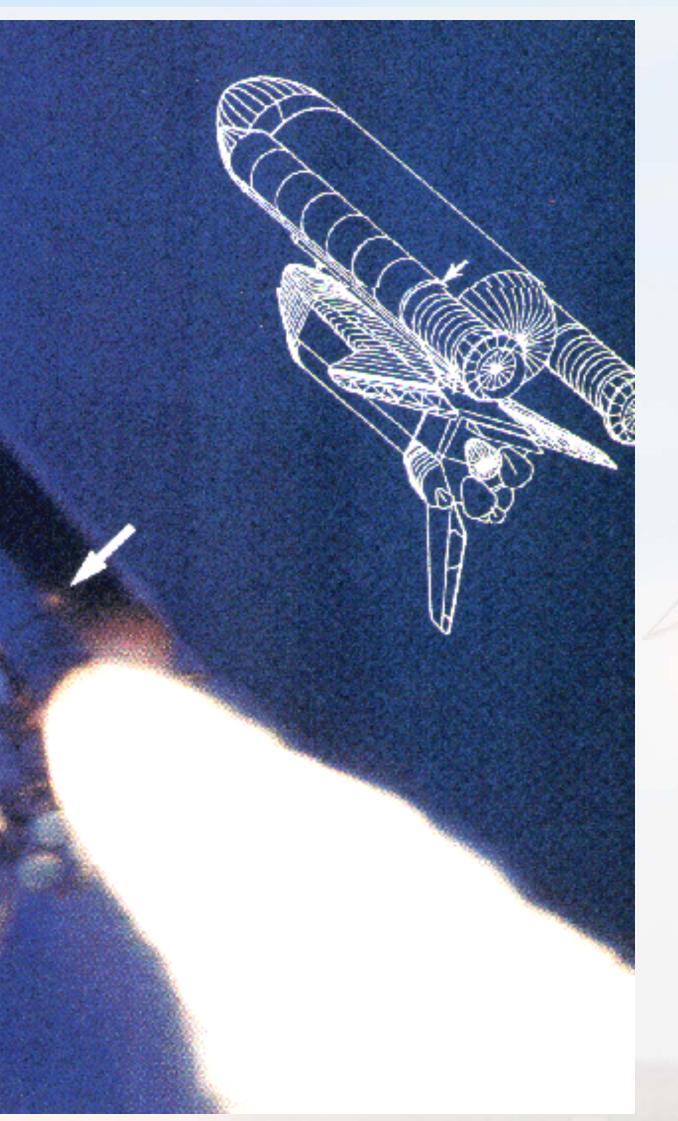


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# **T+58 sec - Appearance of External Flame**







## Flame Hitting Aft Attach Fixture and ET



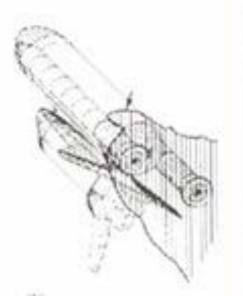


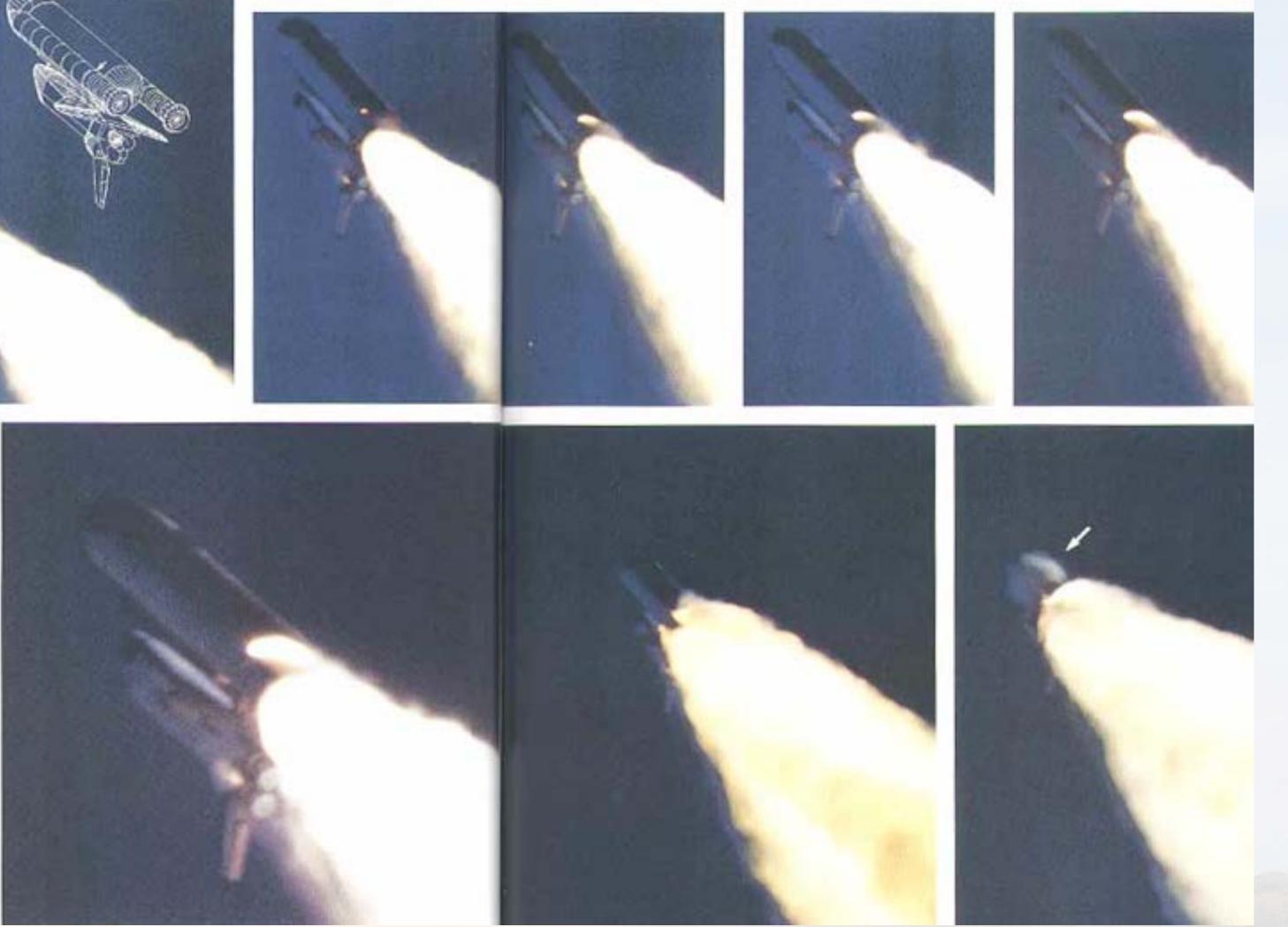


# **Progression of SRB Burn-through**



At 58 781 seconds, the feet ficker of fame appeared, flatery visible above, it grew end a large plume and becaus is impinge on the External Tark at about 60 seconds. Flame is give ported in the computer drawing between the sight boostor and the tark, as in the case of particisincke public. At far sight larged, sight is seen escaping from the according towershell become Tark.

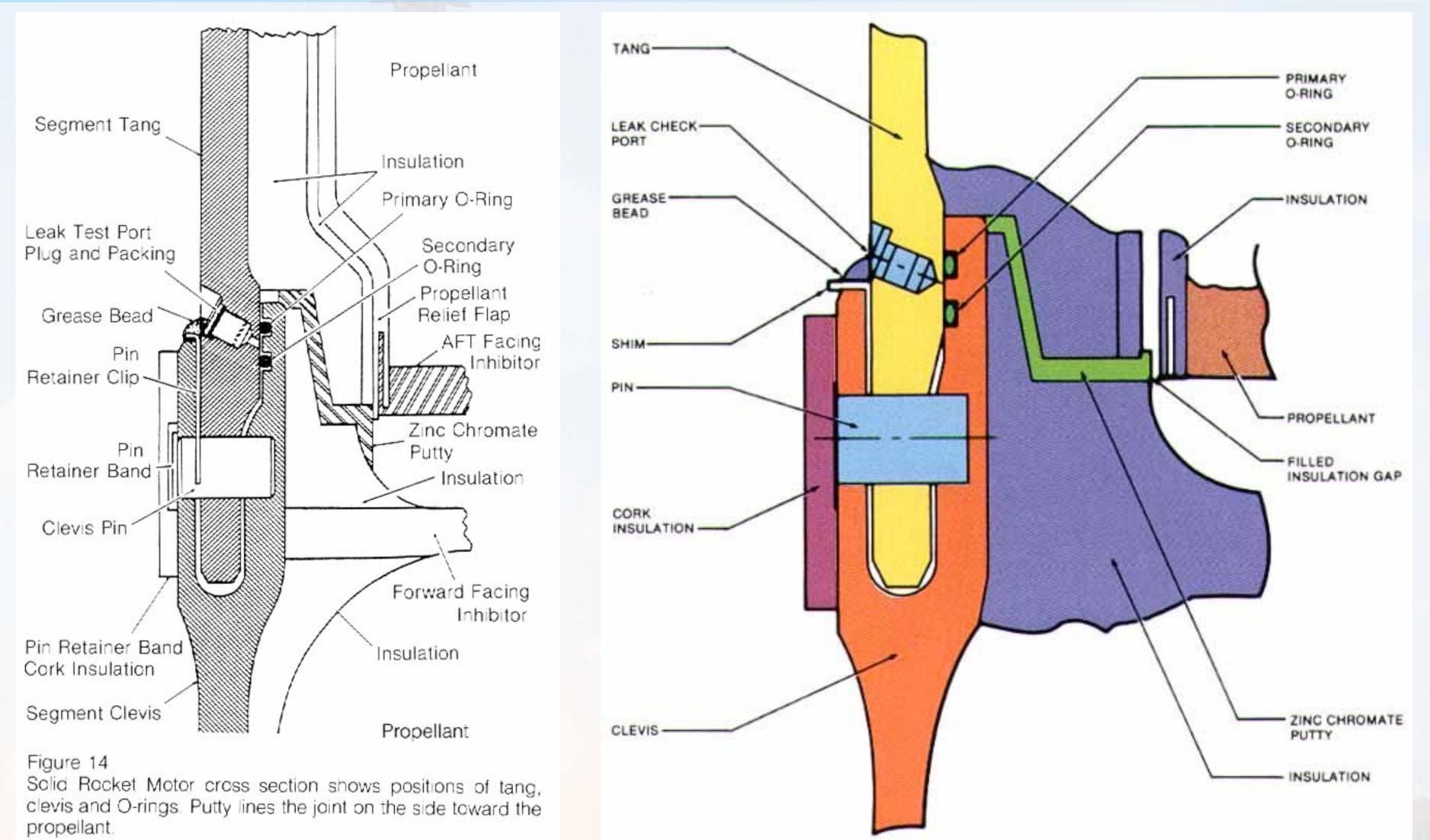








# **Original SRB Field Joint Design**

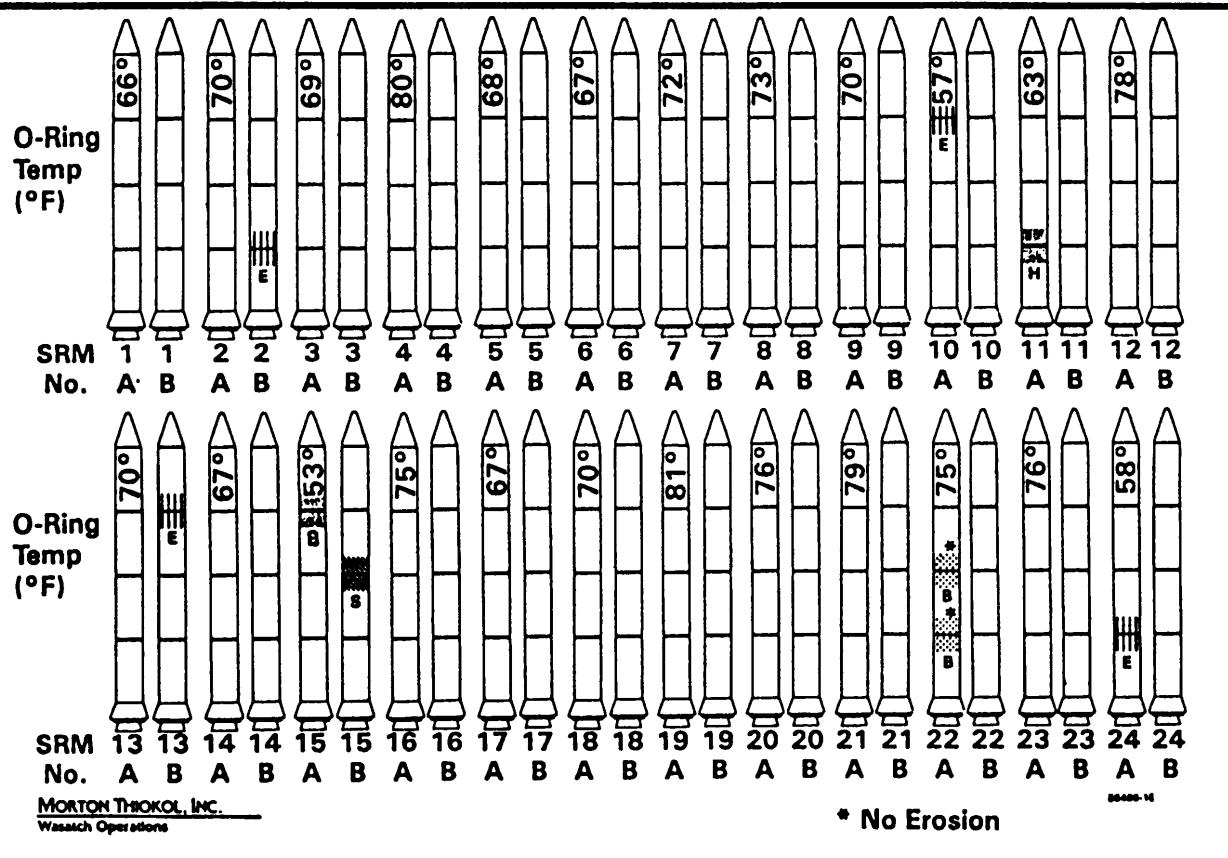






## The Slide That Was Presented

### **History of O-Ring Damage in Field Joints (Cont)**



INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE DRAL DISCUSSION

Graphics Press, 1997 NIVERSITY OF MARYLAND

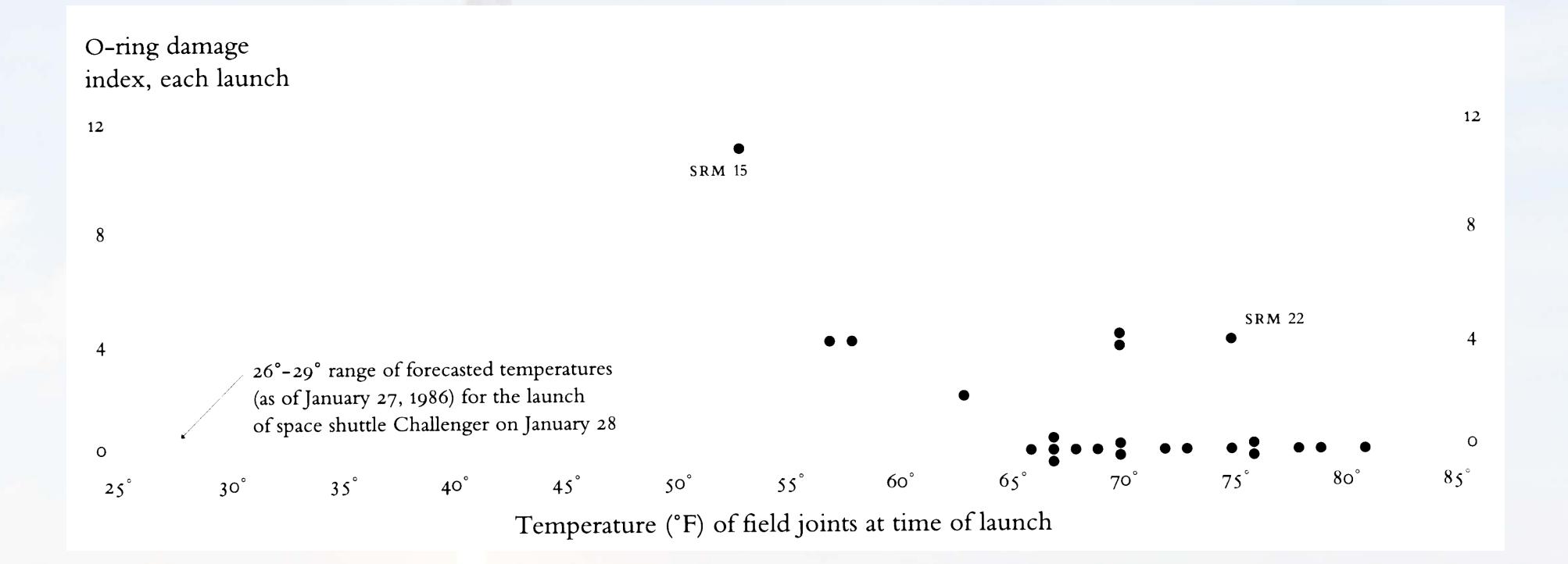


16

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### The Slide That Should Have Been...

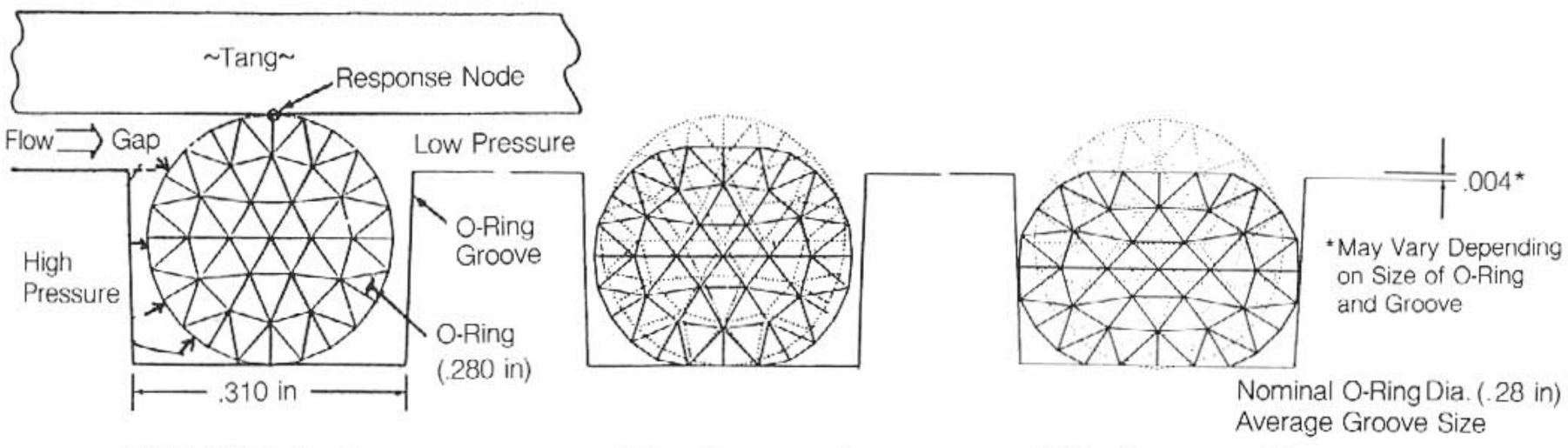


From Edward R. Tufte, Visual and Statistical Thinking: Displays of Evidence for Making Decisions Graphics Press, 1997





# **Clearance Effects on O-Ring Seating**



O-Ring Model in Groove (Undeformed)

O-Ring Compressed 0.035 Inches

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.



O-Ring Compressed to Seal Groove Sides



# **Dynamic Motion of O-Ring Seals**

#### **Pressurized Joint Deflection**

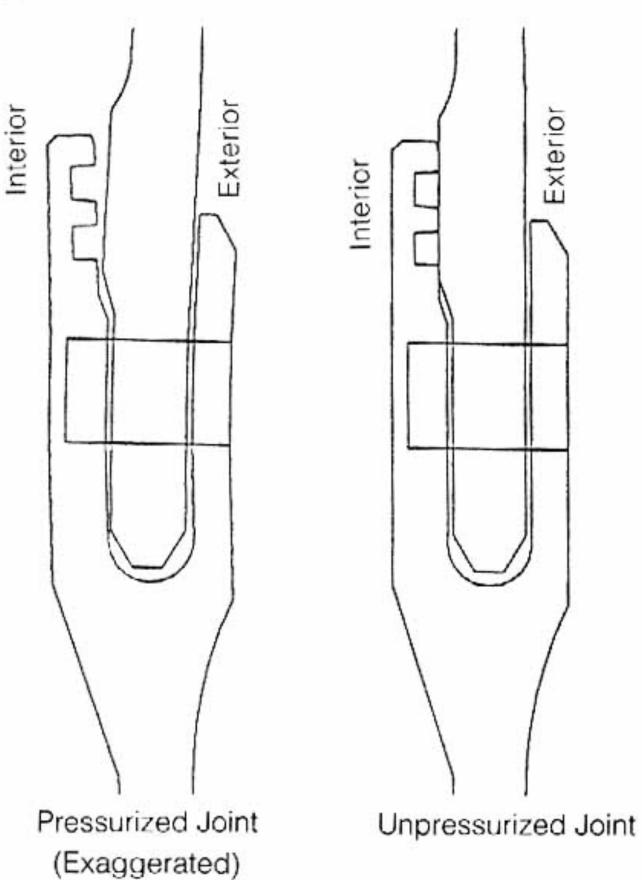
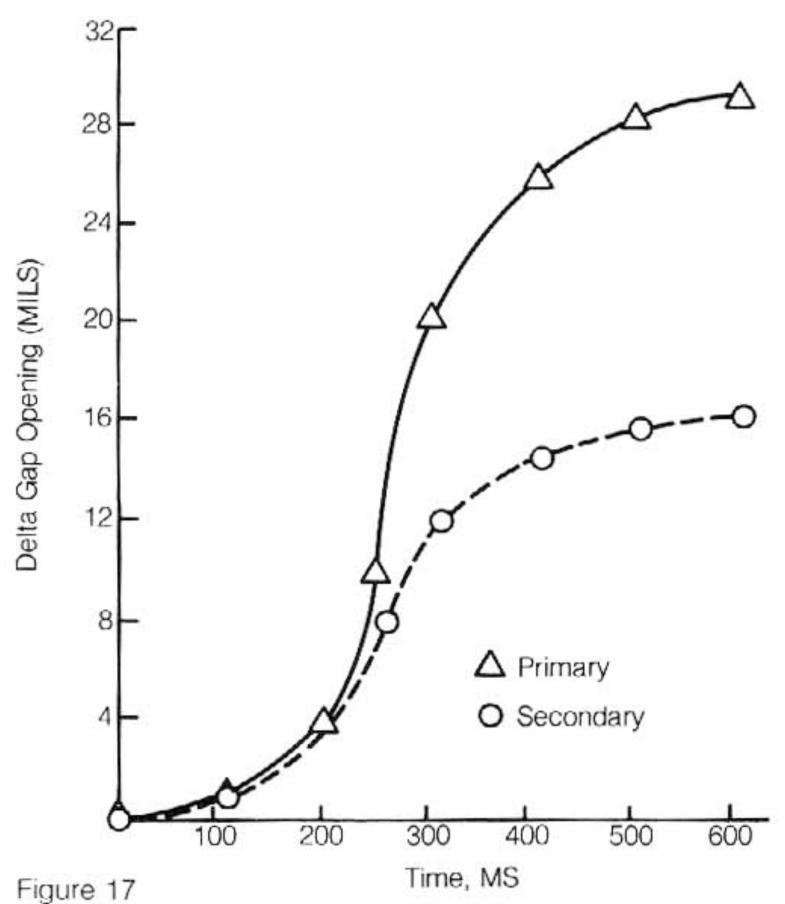


Figure 16

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.



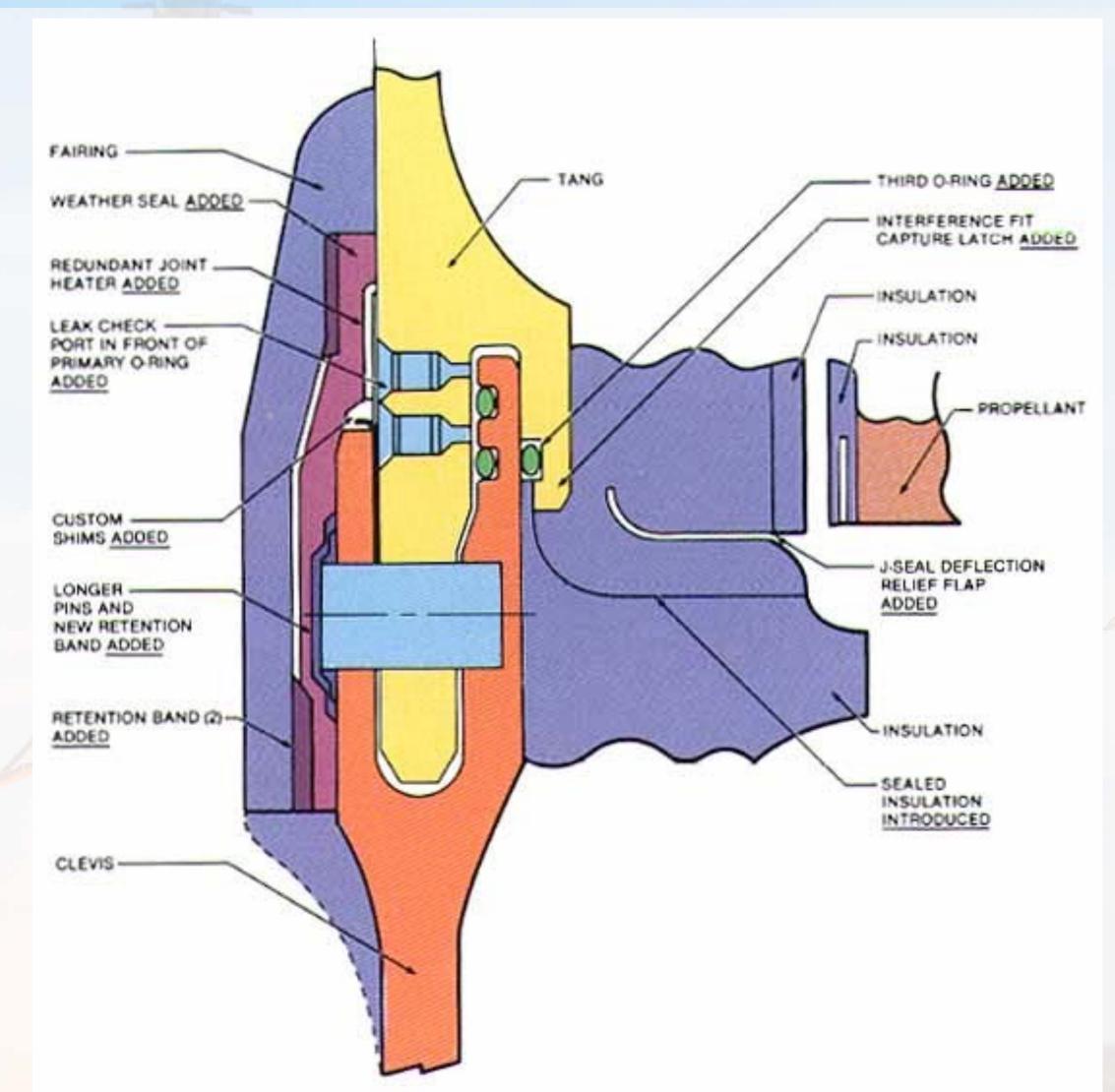
Right Hand SRM Aft Field Joint Primary And Secondary Delta Gap Opening



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



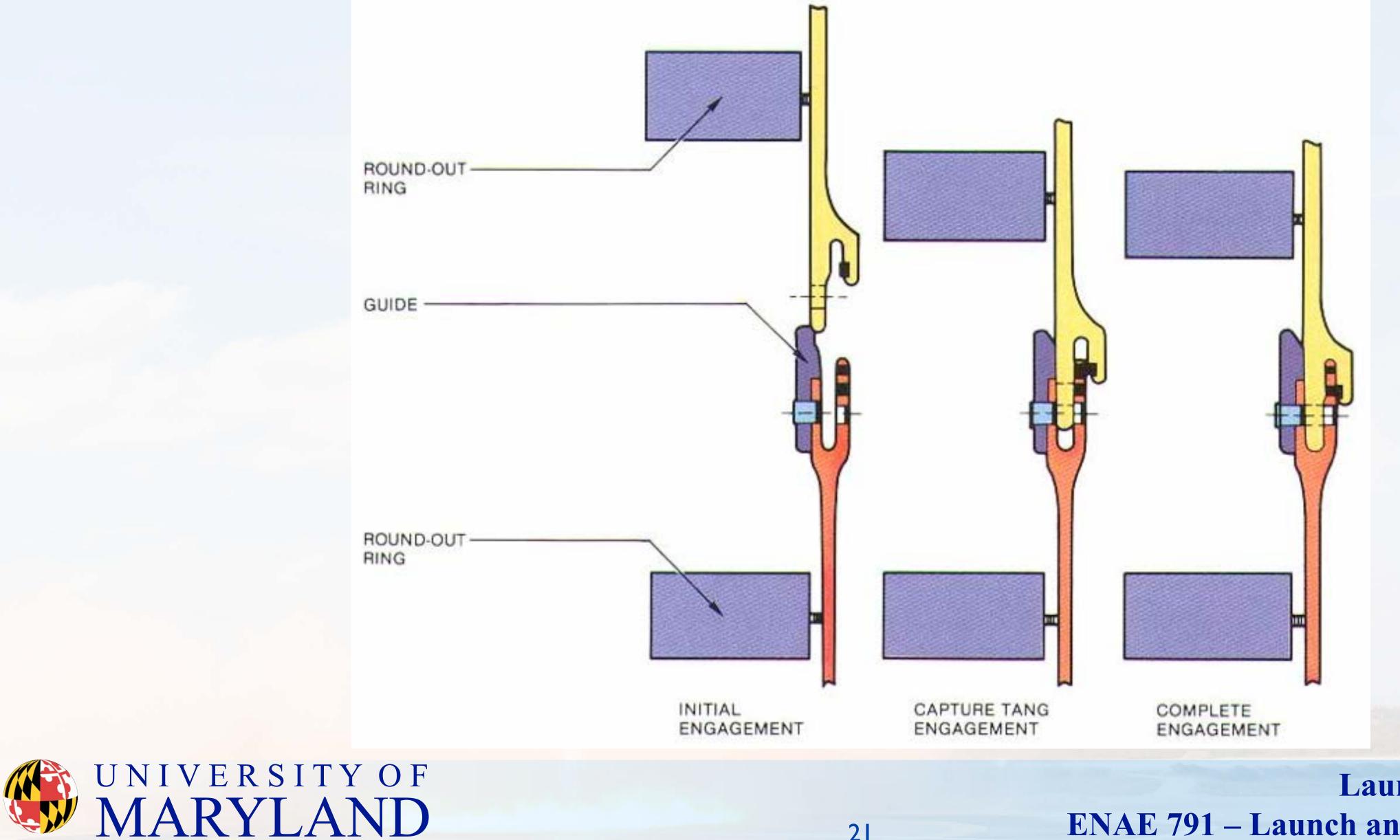
# **Redesigned SRB Field Joint**







# **Revised SRB Assembly Technique**





# Columbia Launch - STS-107

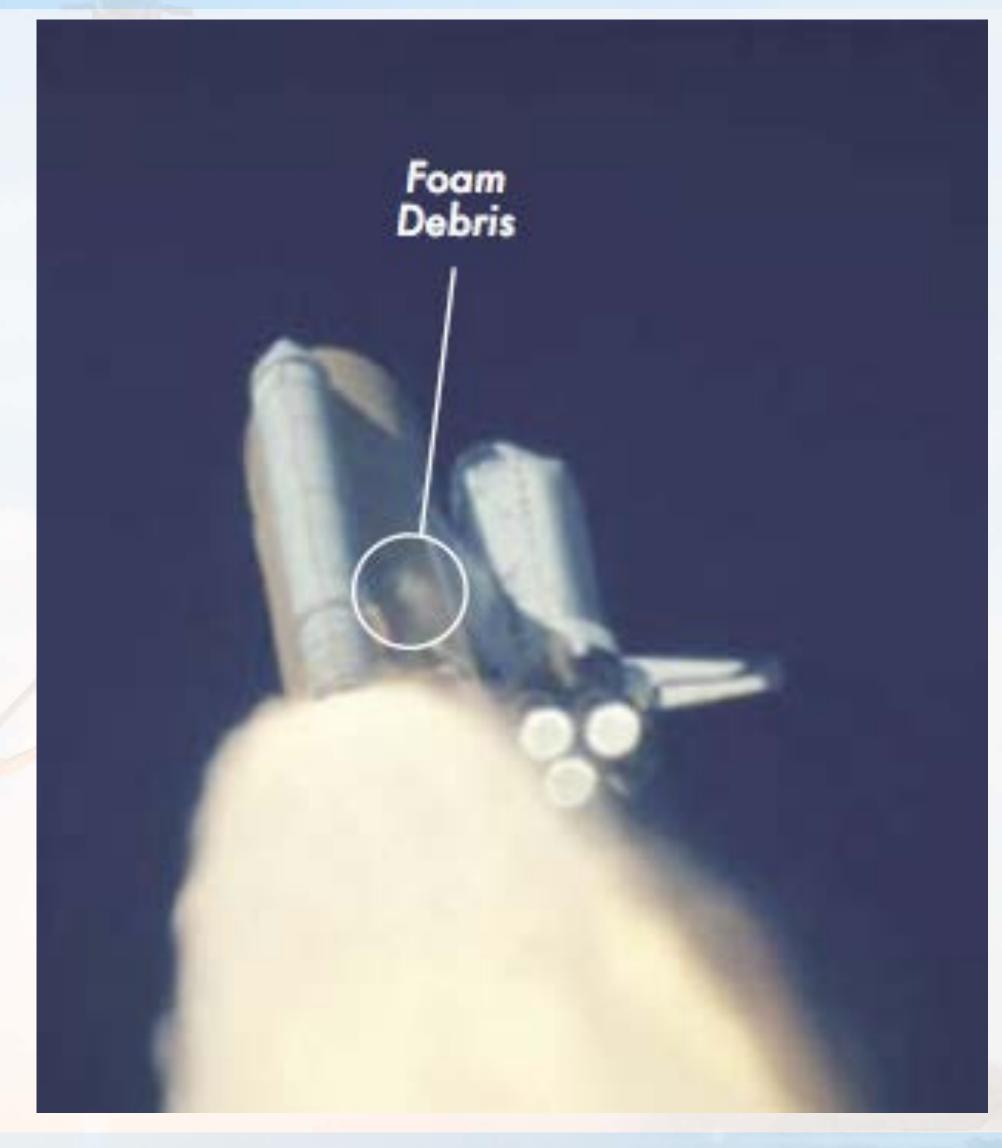






### L+81.9 sec







# Columbia Entry Break-up









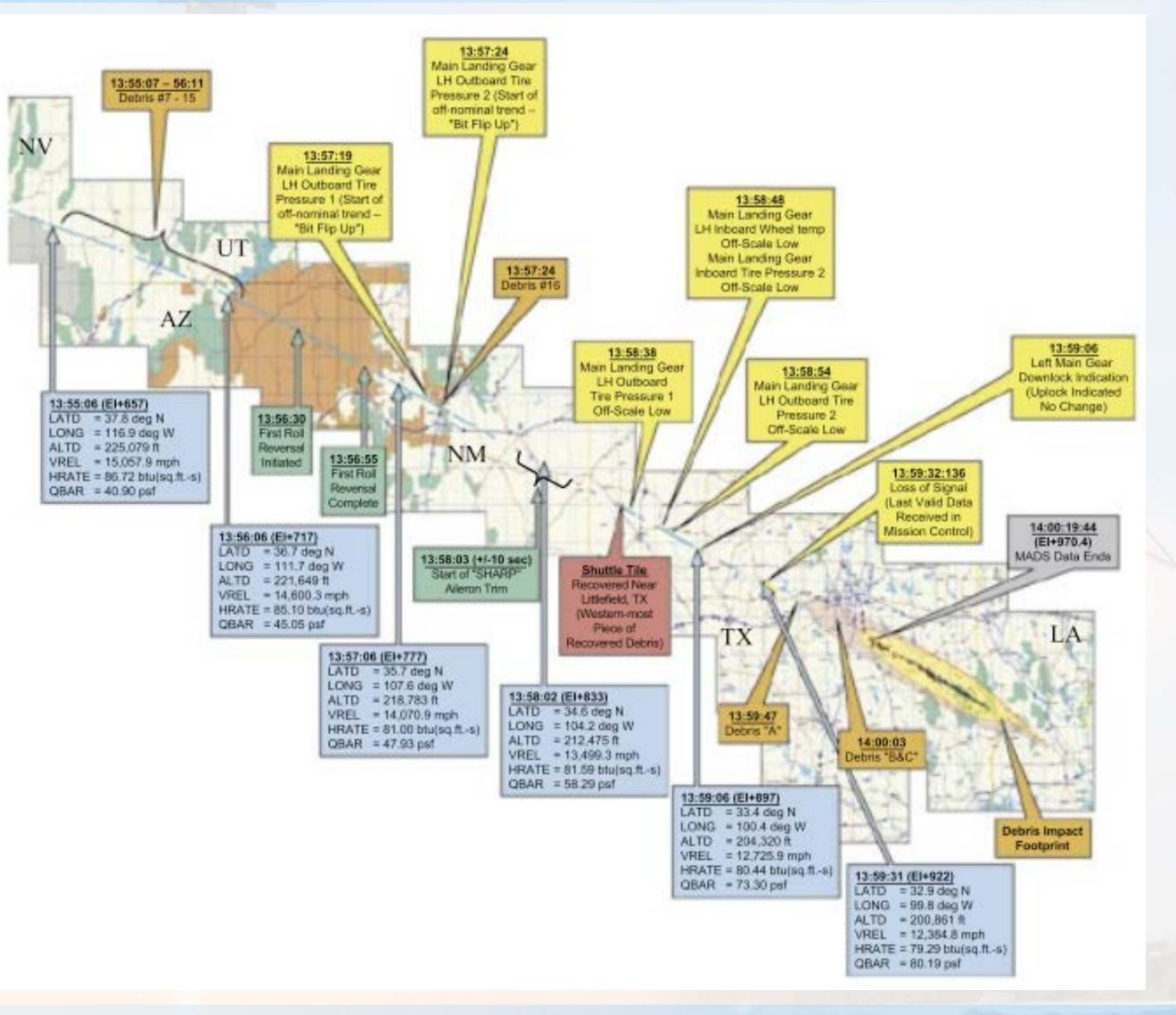
# **In-Flight Breakup**







# **Events Along Flight Path**

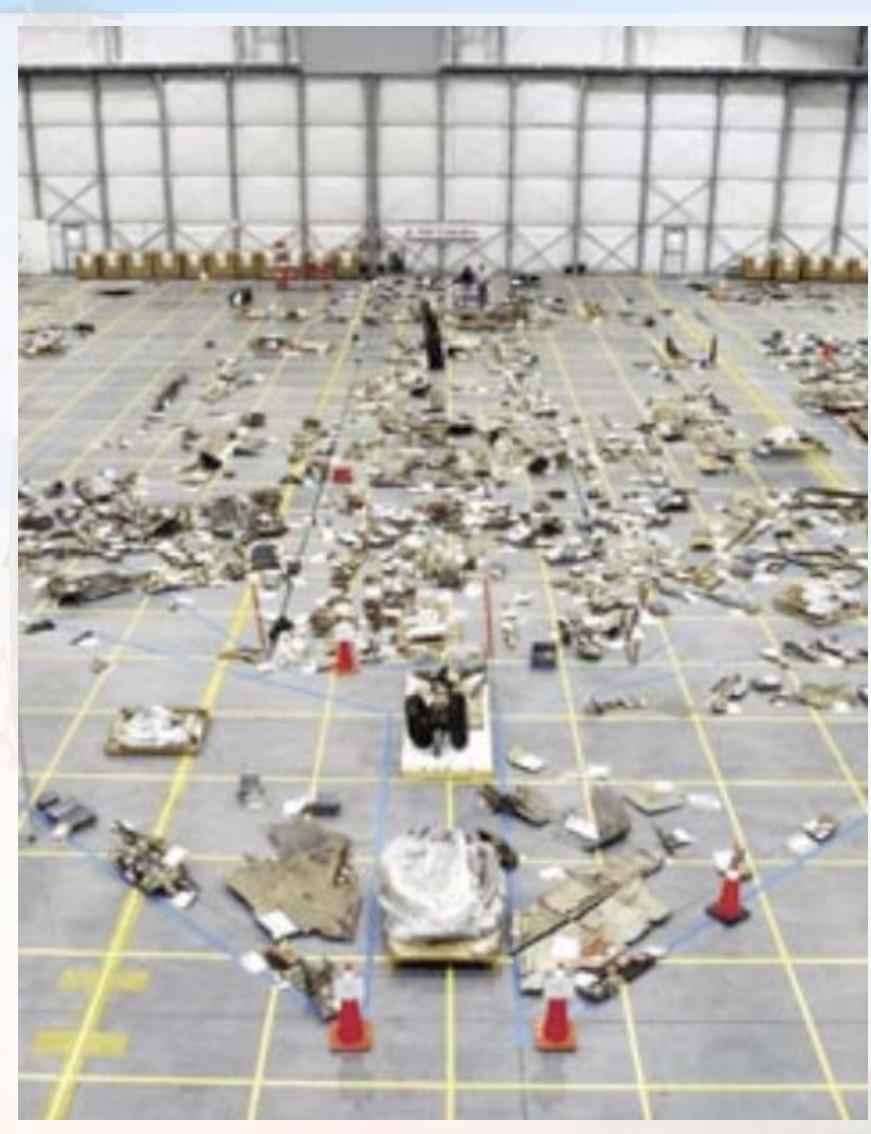






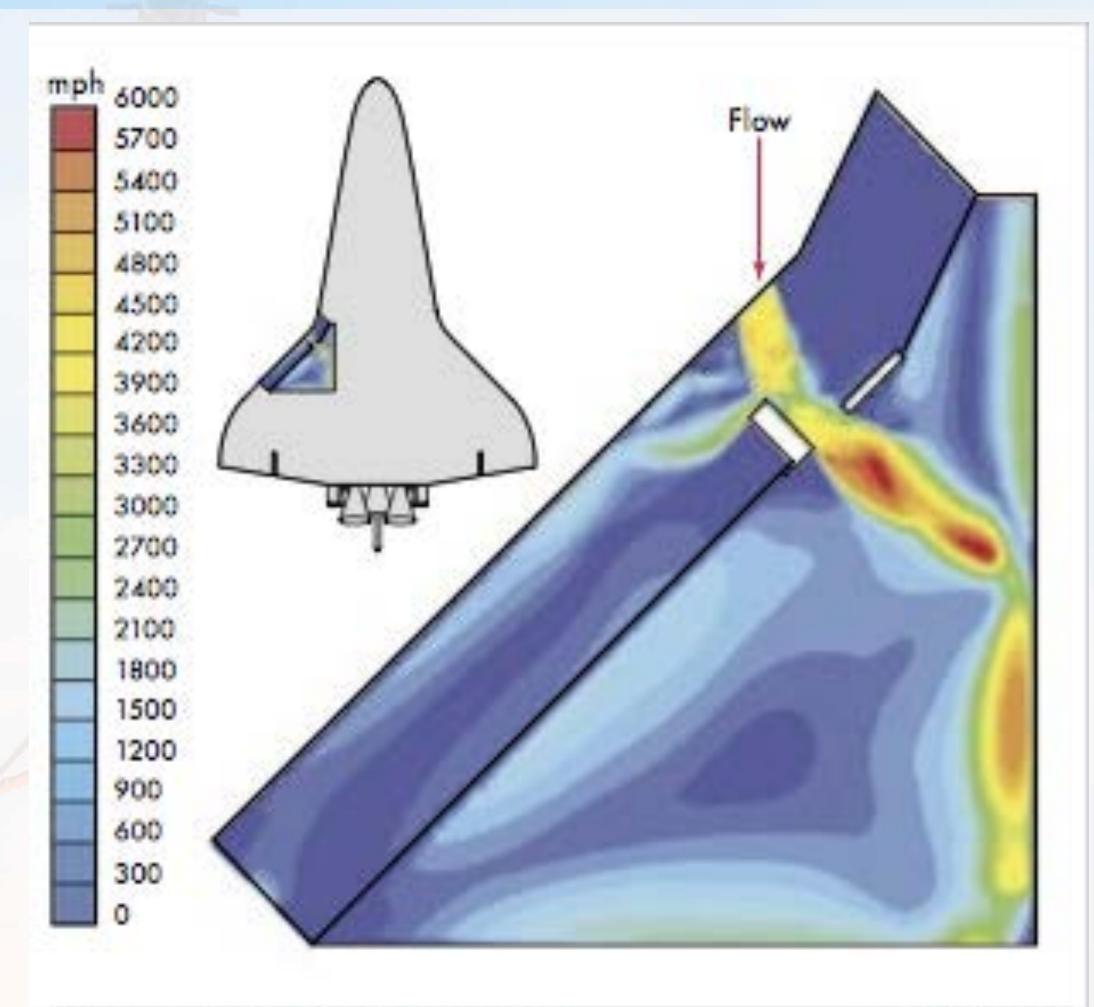
# **Columbia Debris Reconstruction**







# **CFD Analysis of Internal Airflow**



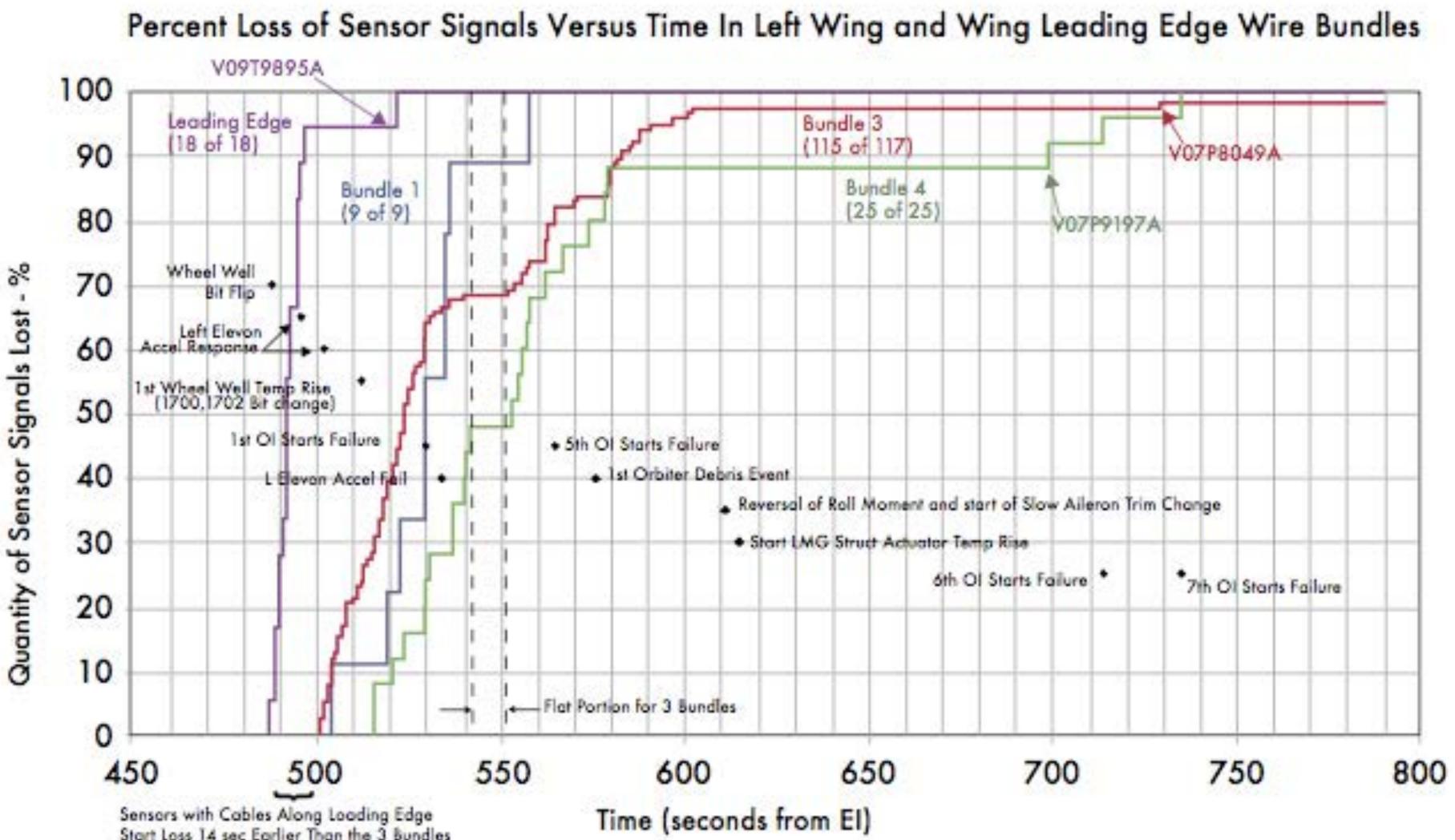
Contours of Velocity Magnitude (fps)



(fps) Jun 10, 2003 FLUENT 6.1 (2d, coupled imp, ske)



# **Failure Rates of Sensor Wiring Bundles**



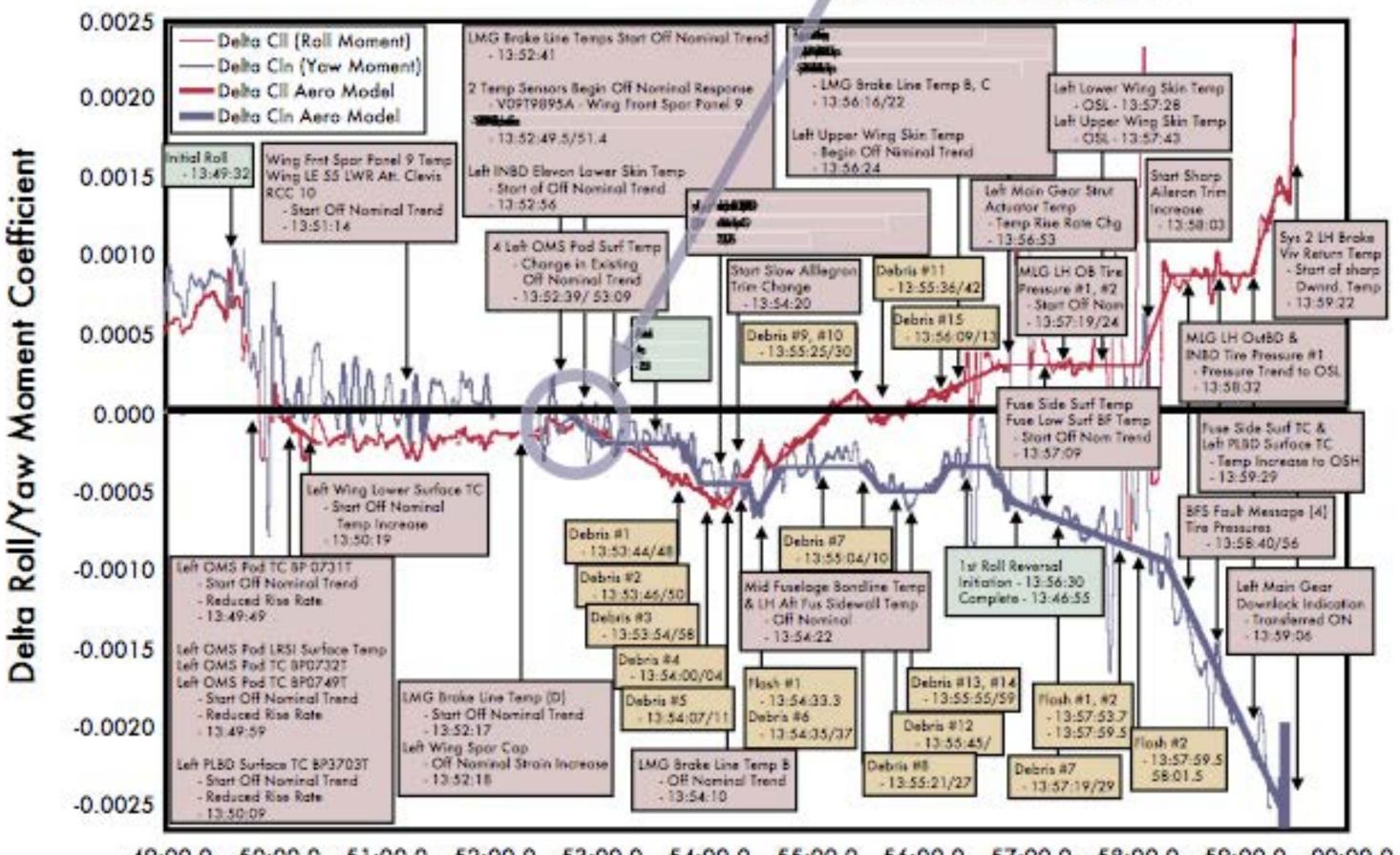
Start Loss 14 sec Earlier Than the 3 Bundles





# **Divergence of Roll/Yaw Angles**

#### STS 107 Delta Rolling/Yawing Moment Coefficients Off-Nominal Roll & Yaw

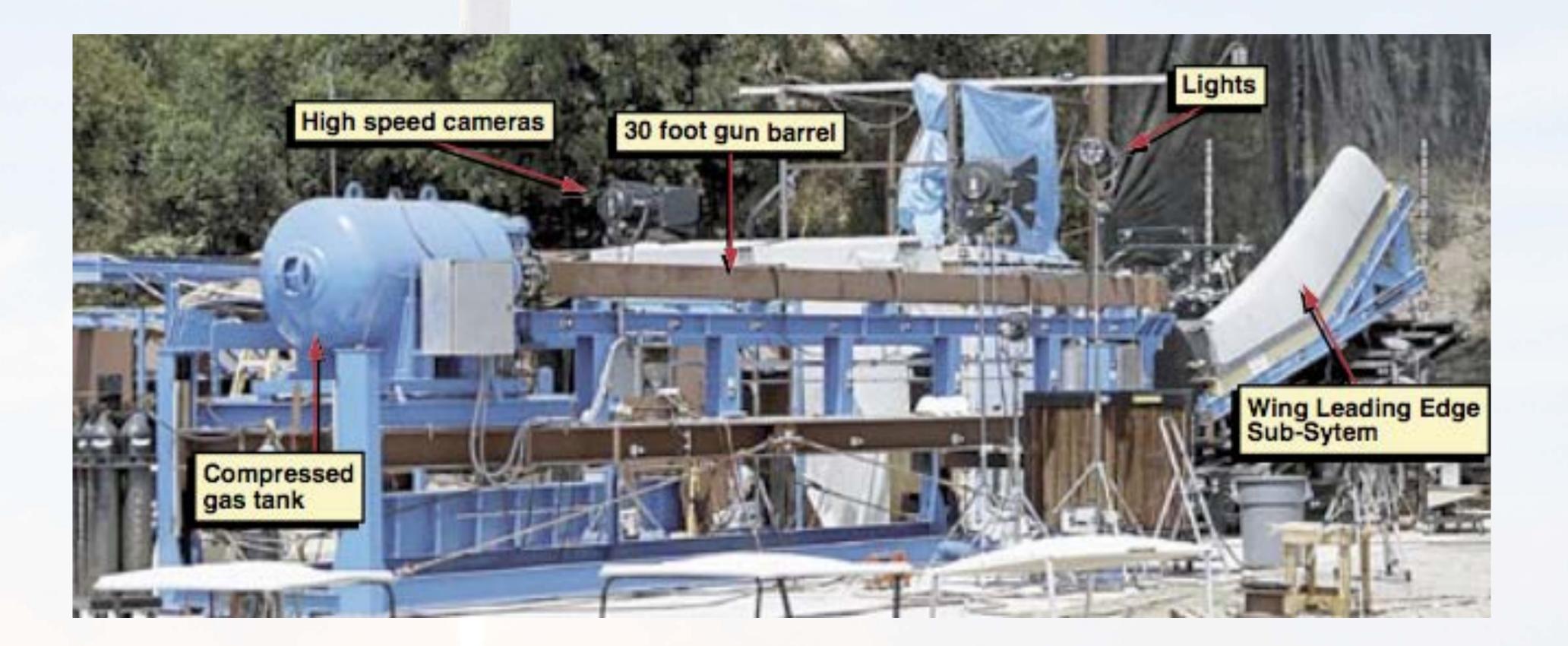




49:00.0 50:00.0 51:00.0 52:00.0 53:00.0 54:00.0 55:00.0 56:00.0 57:00.0 58:00.0 59:00.0 00:00.0 Time (min:sec)



# **High-Velocity Impact Testing of RCC**







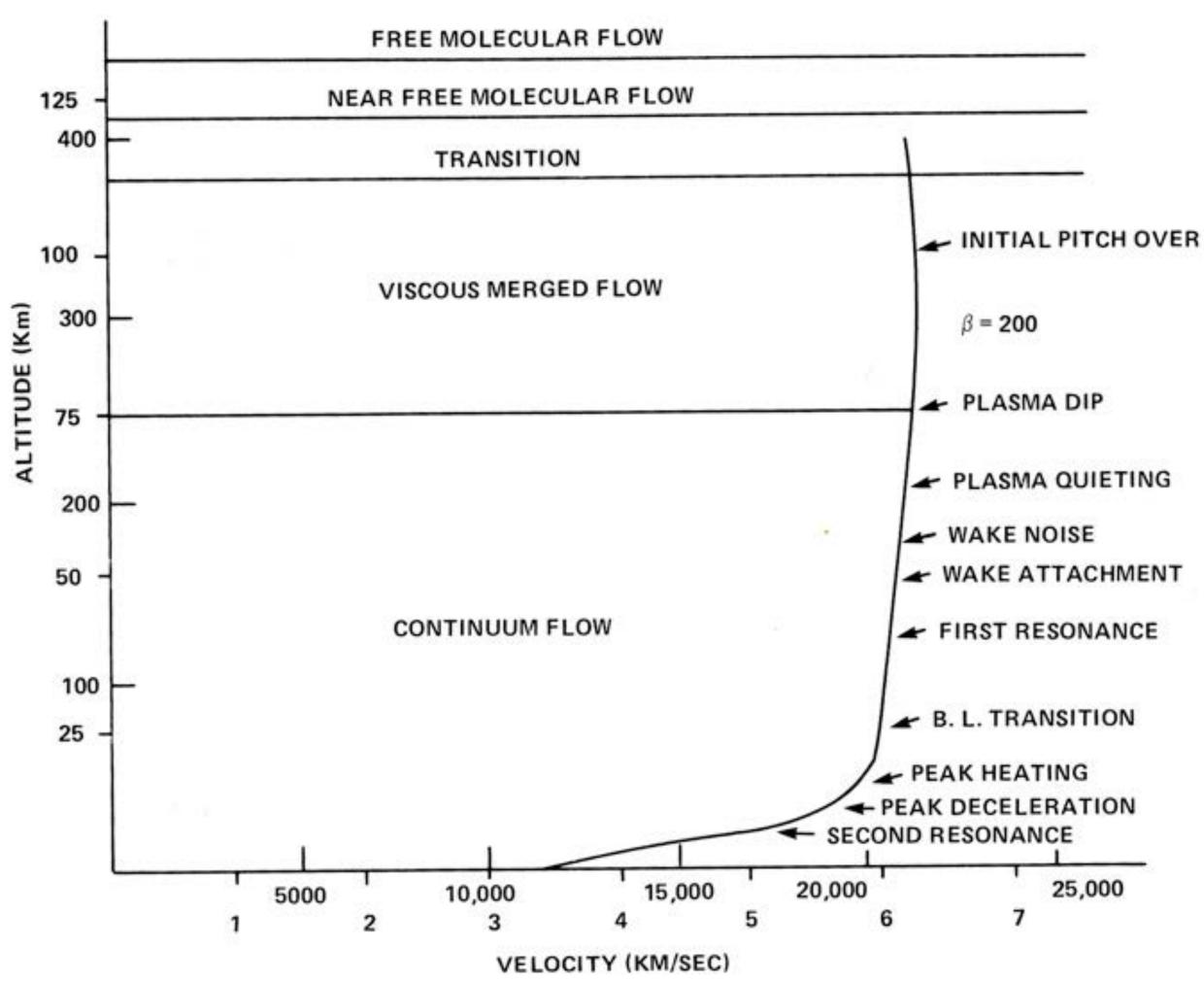
## **Results of Impact Tests on RCC**







# **Entry Flow Regimes**



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





# **AMROC SET-1 Launch Attempt**







## October 5, 1989 - T+2 sec









## October 6, 1989 - Aftermath





