

# Launch and Entry Failures

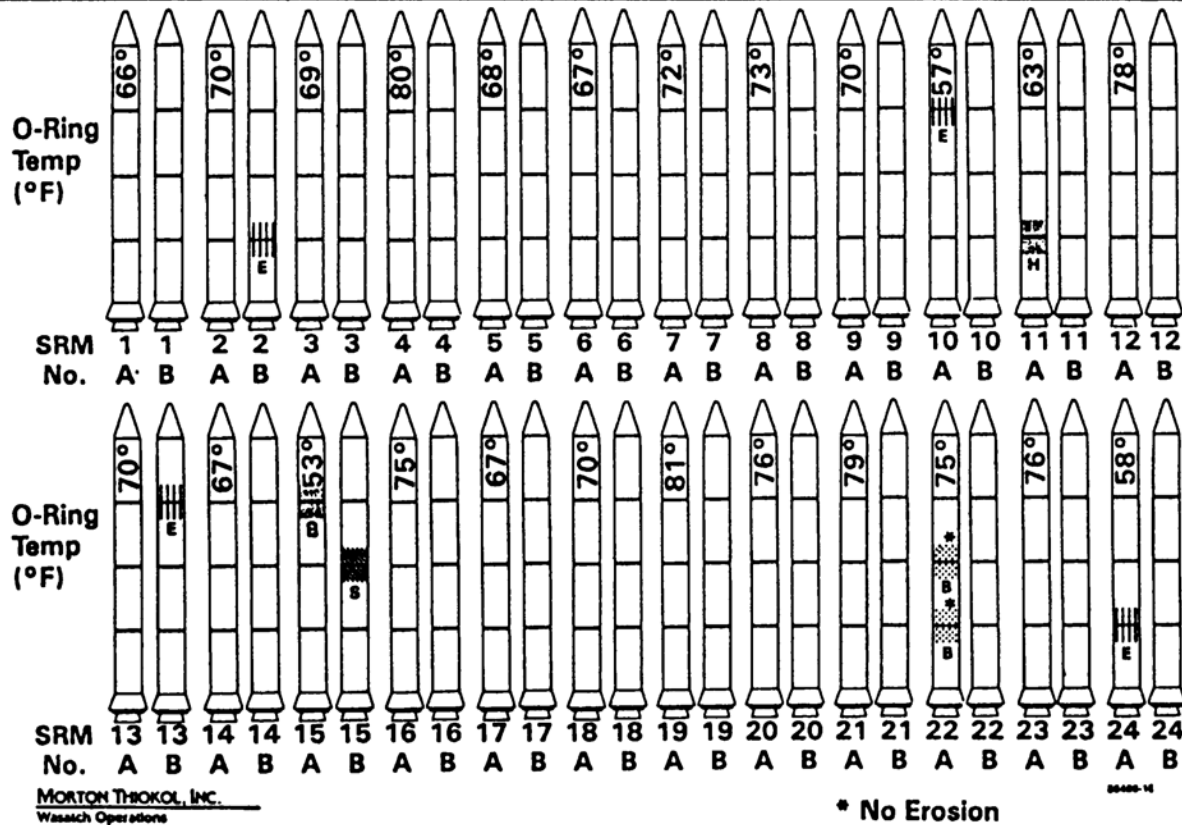
*“Failure is always an option”*

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



# 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 ORAL DISCUSSION

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



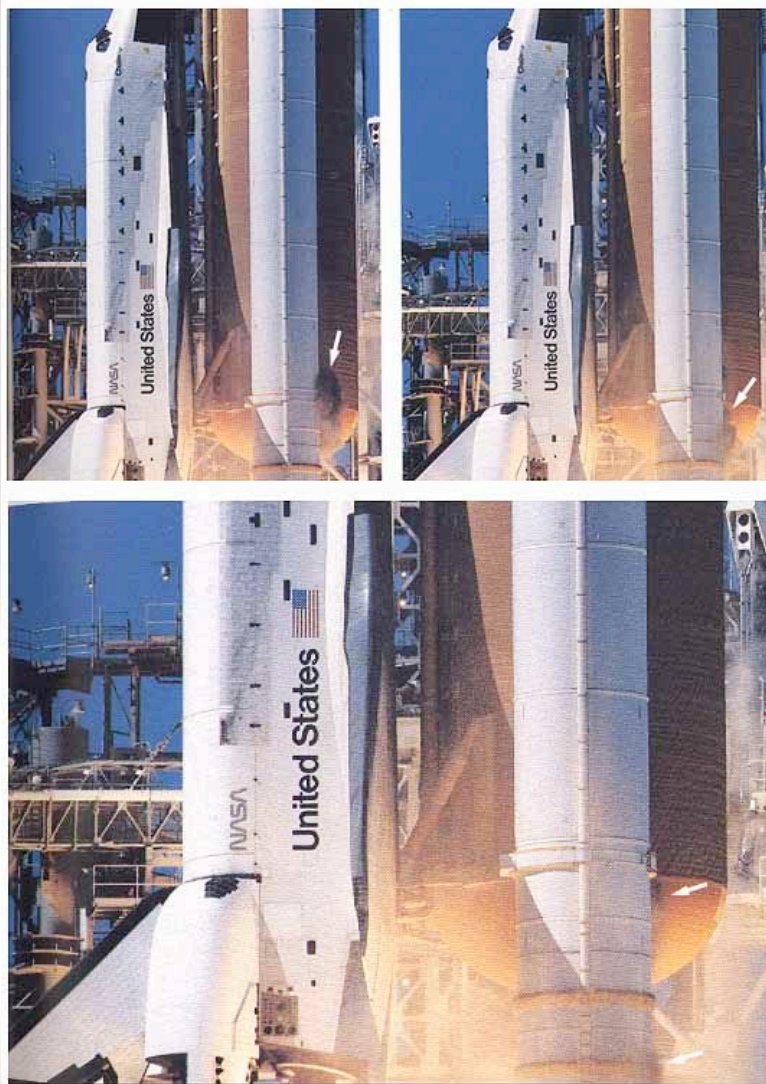
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# Black Smoke Plumes from Aft Field Joint

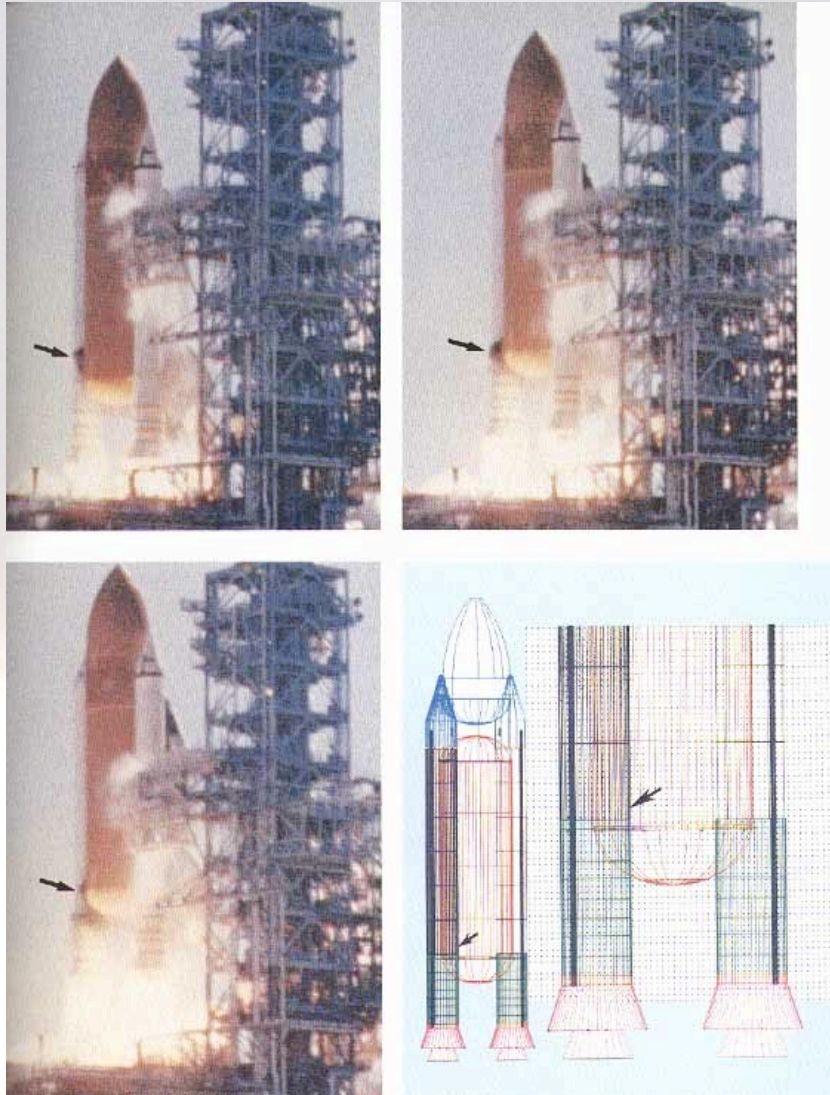


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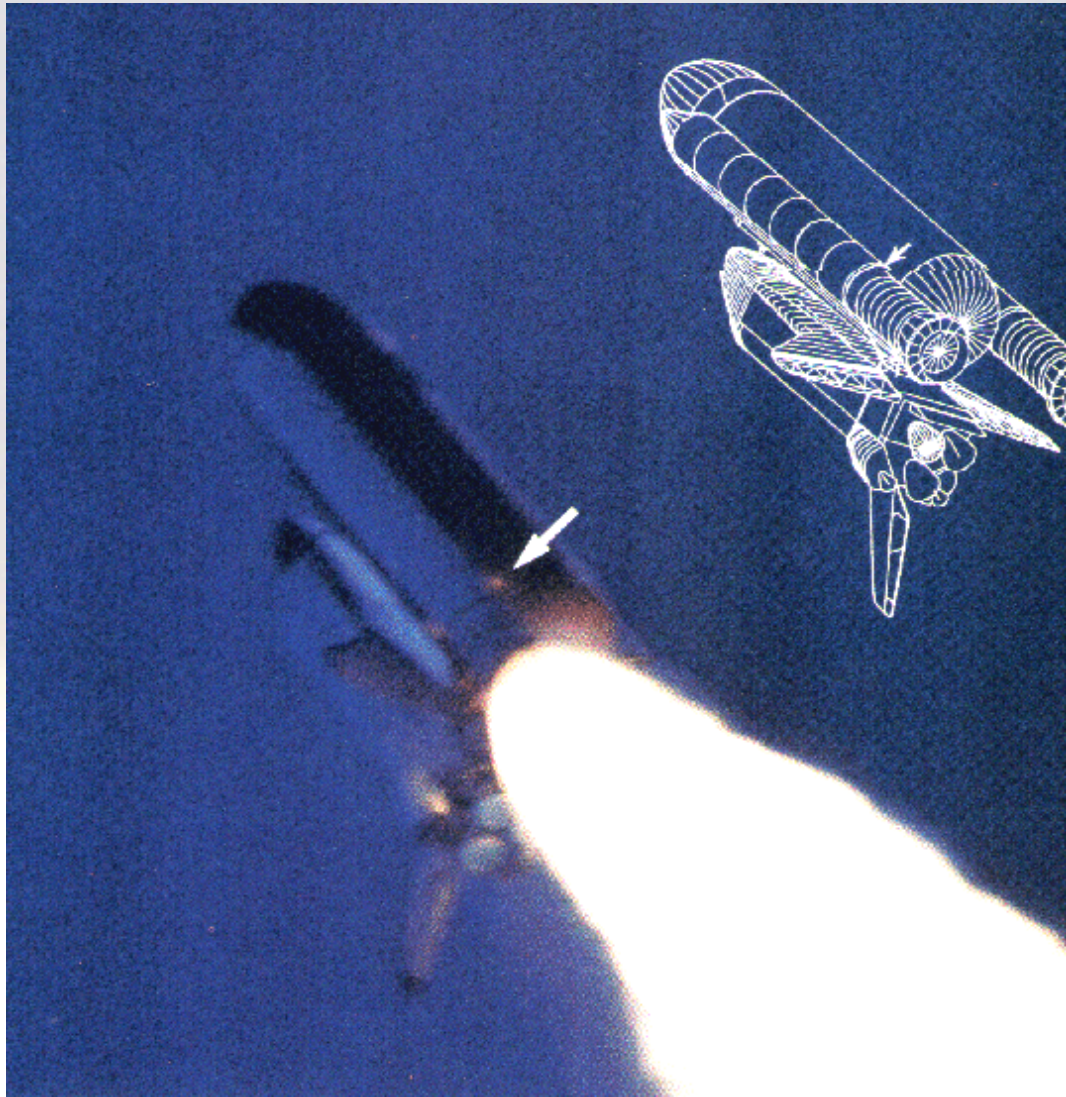


# Photographic Evidence





# T+58 sec - Appearance of External



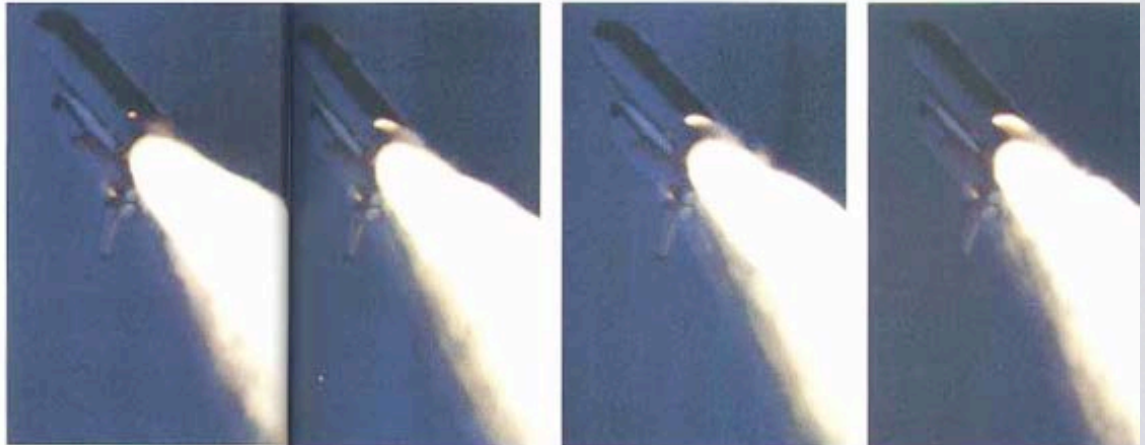
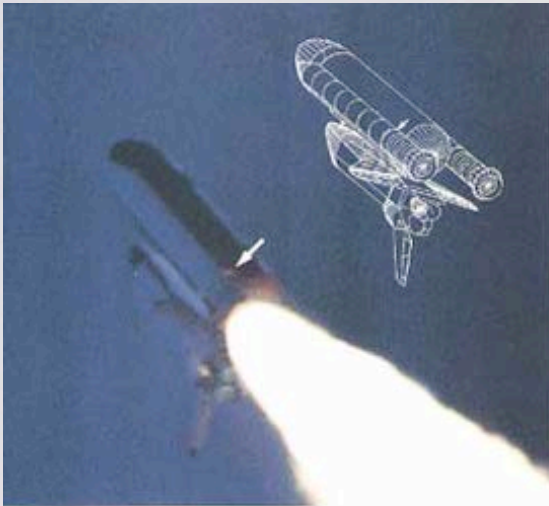


# Flame Hitting Aft Attach Fixture and ET



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# Progression of SRB Burn-through



At 58.796 seconds, the first flicker of flame appeared. Shortly visible above, it grew into a large plume and began to impinge on the External Tank at about 60 seconds. Flame is shown in the computer drawing between the right booster and the tank, as in the case of earlier smoke puffs. At far right (arrow), vapor is seen escaping from the severely breached Lateral Tank.





# Original SRB Field Joint Design

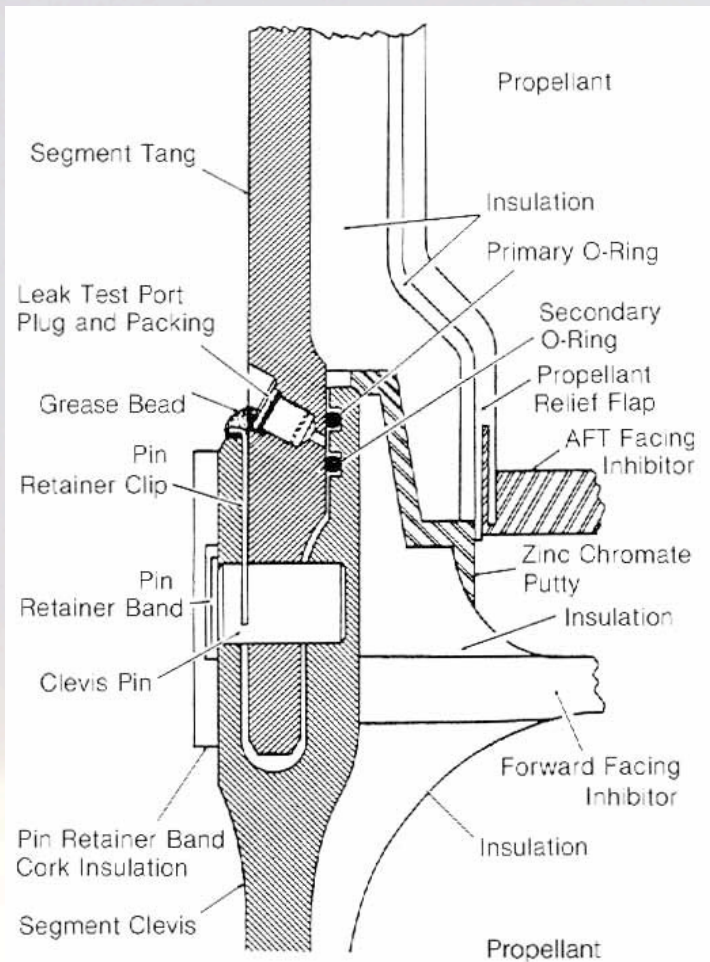
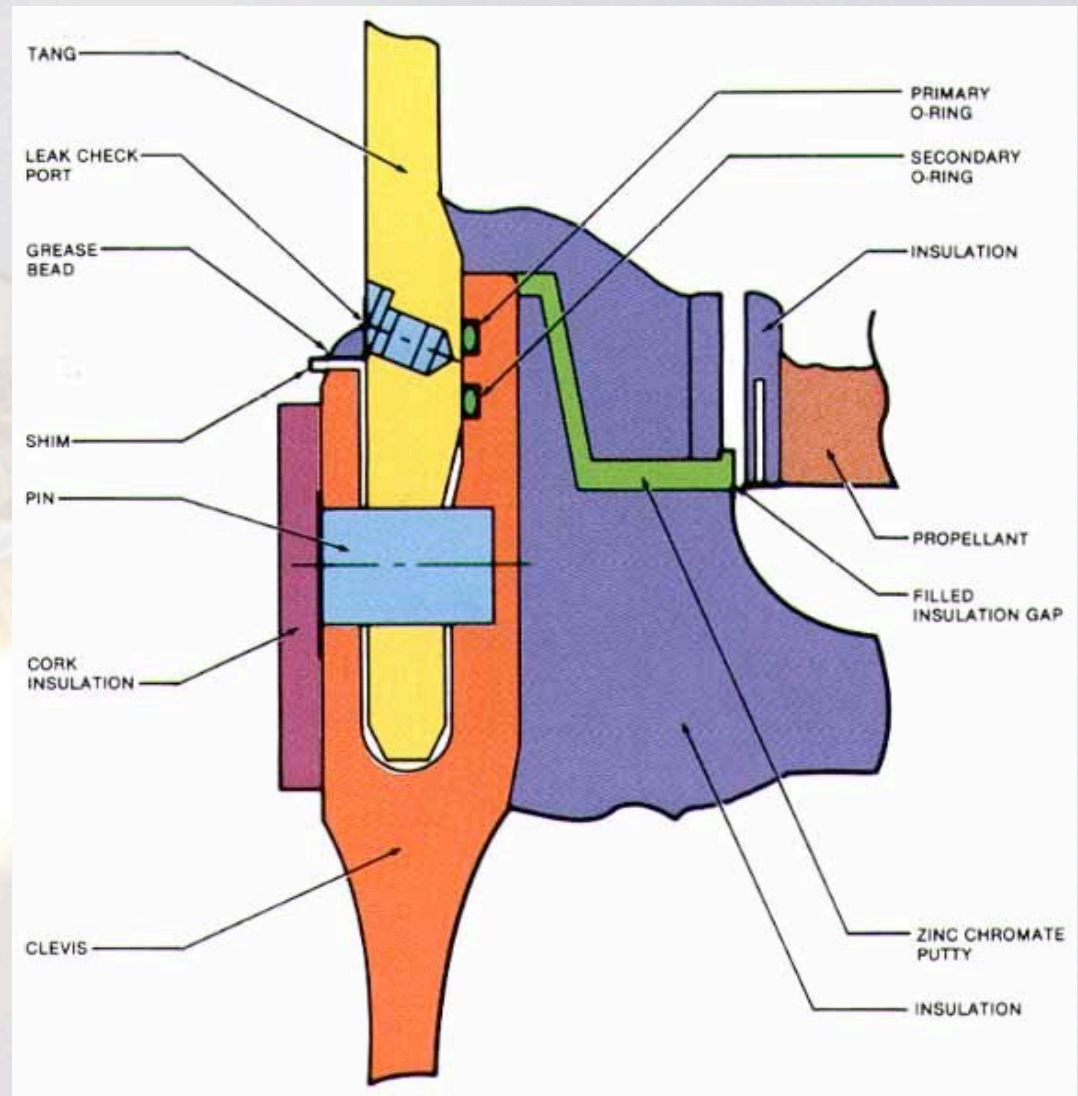
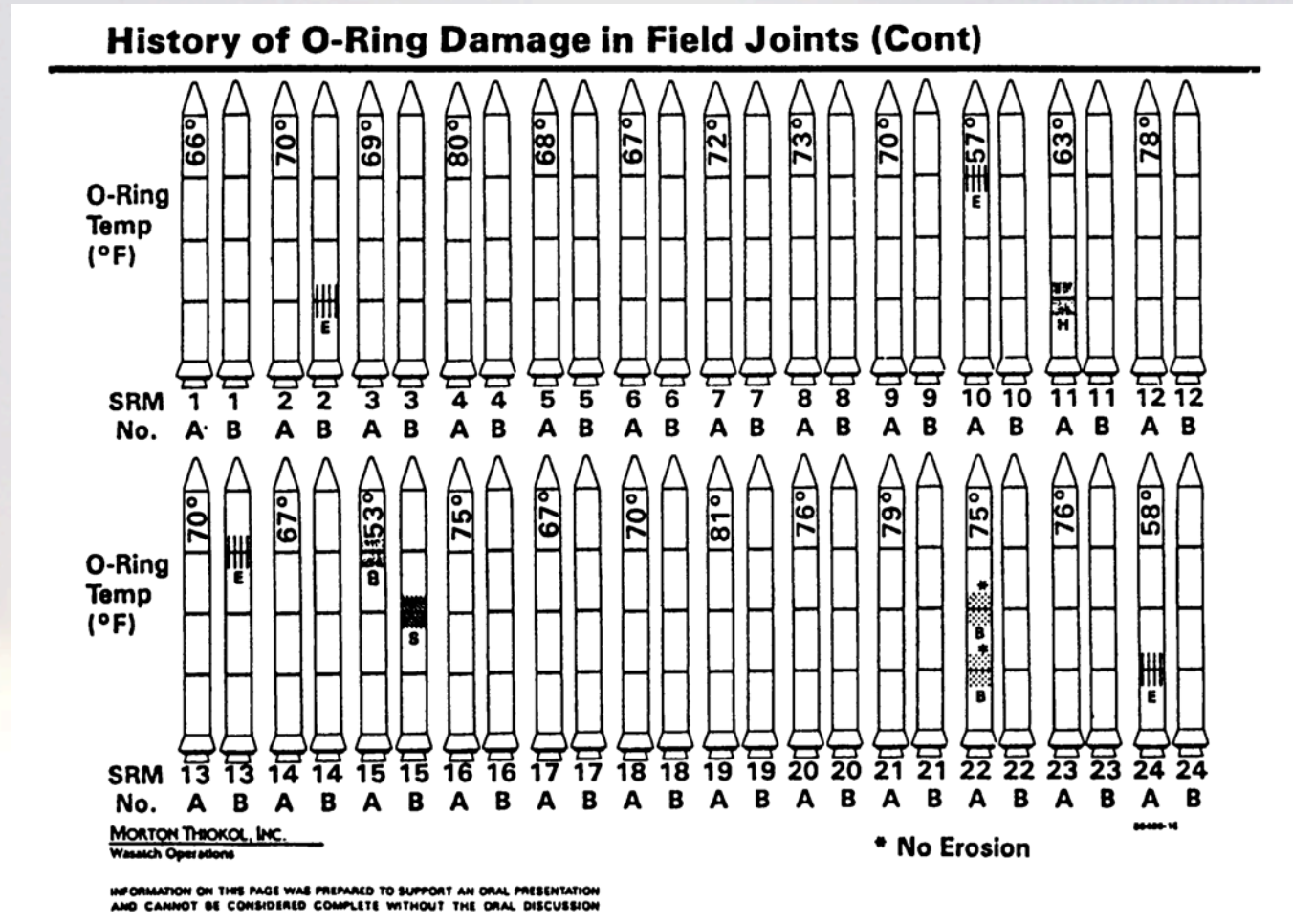


Figure 14  
Solid Rocket Motor cross section shows positions of tang, clevis and O-rings. Putty lines the joint on the side toward the propellant.



# The Slide That Was Presented



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



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**ENAE 791 - Launch and Entry Vehicle Design**

# Clearance Effects on O-Ring Seating

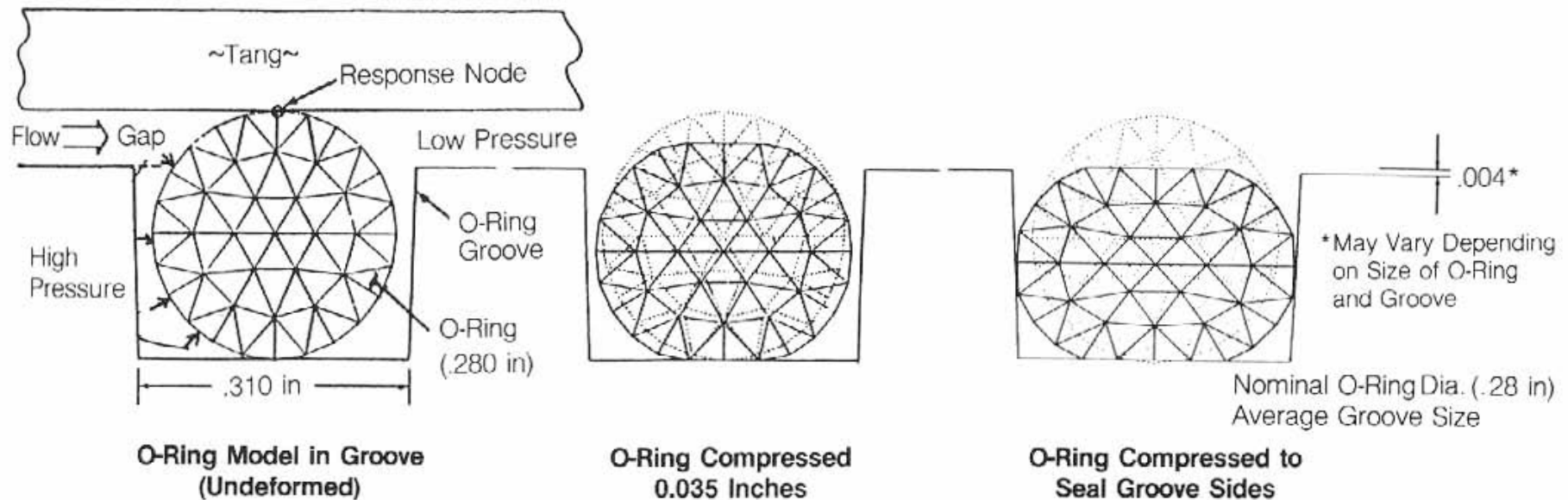


Figure 18  
Drawings show how progressive reduction of gap between tang and clevis can inhibit and eventually block motor cavity's high-pressure flow from getting behind O-ring.





# Dynamic Motion of O-Ring Seals

Pressurized Joint Deflection

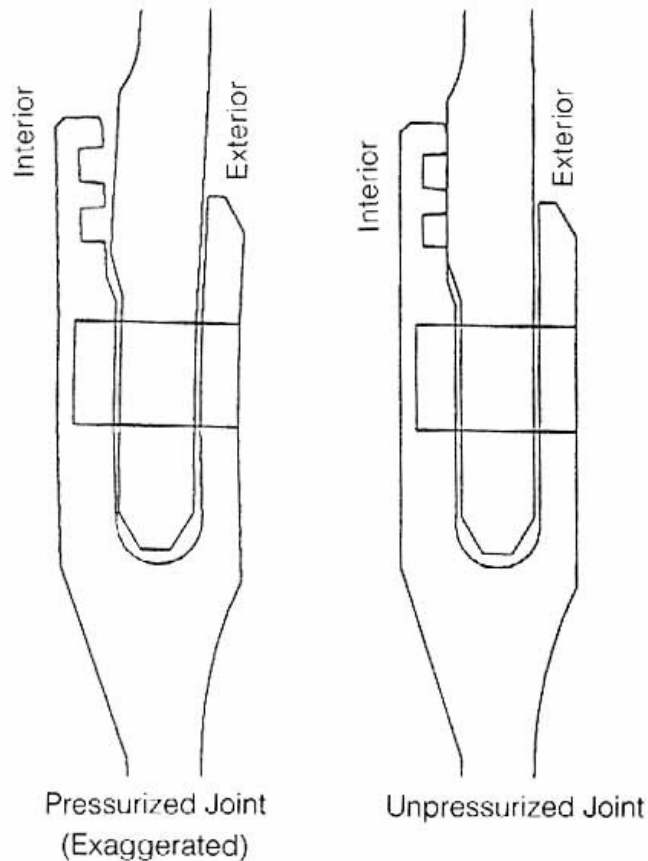


Figure 16

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

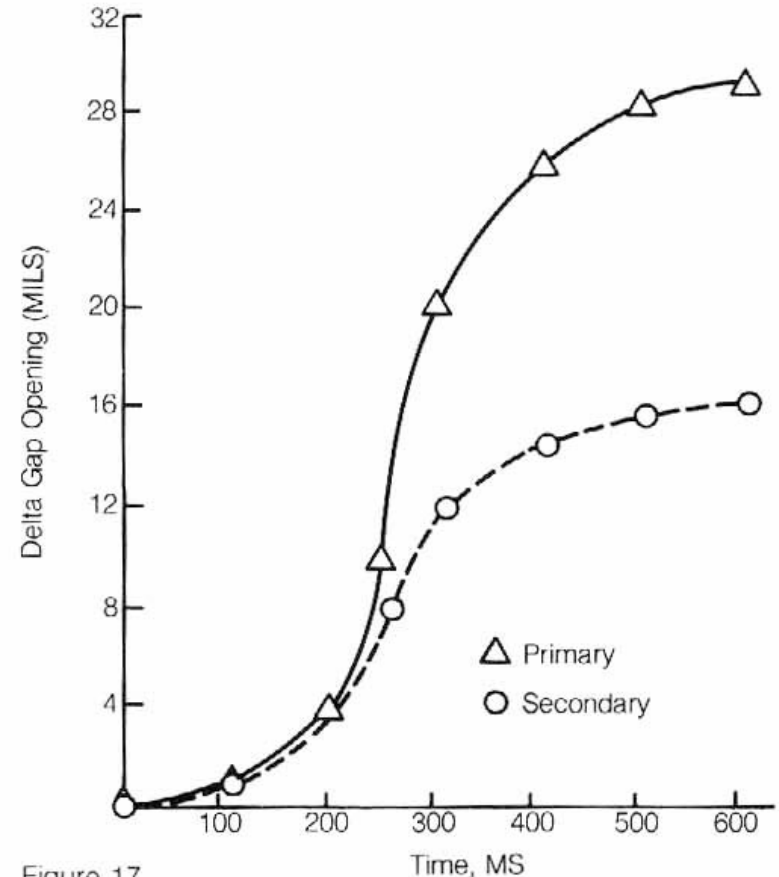
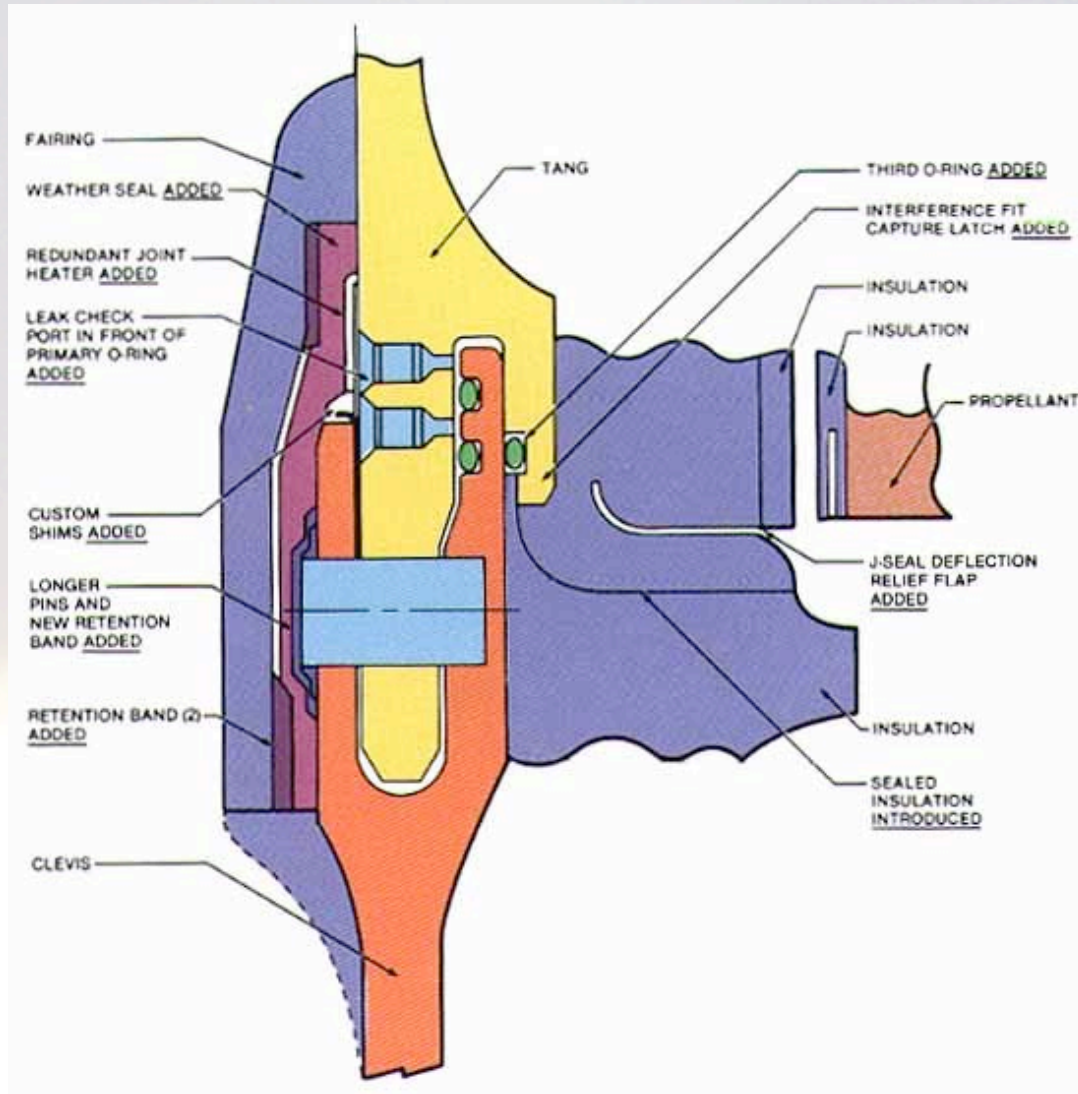


Figure 17

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

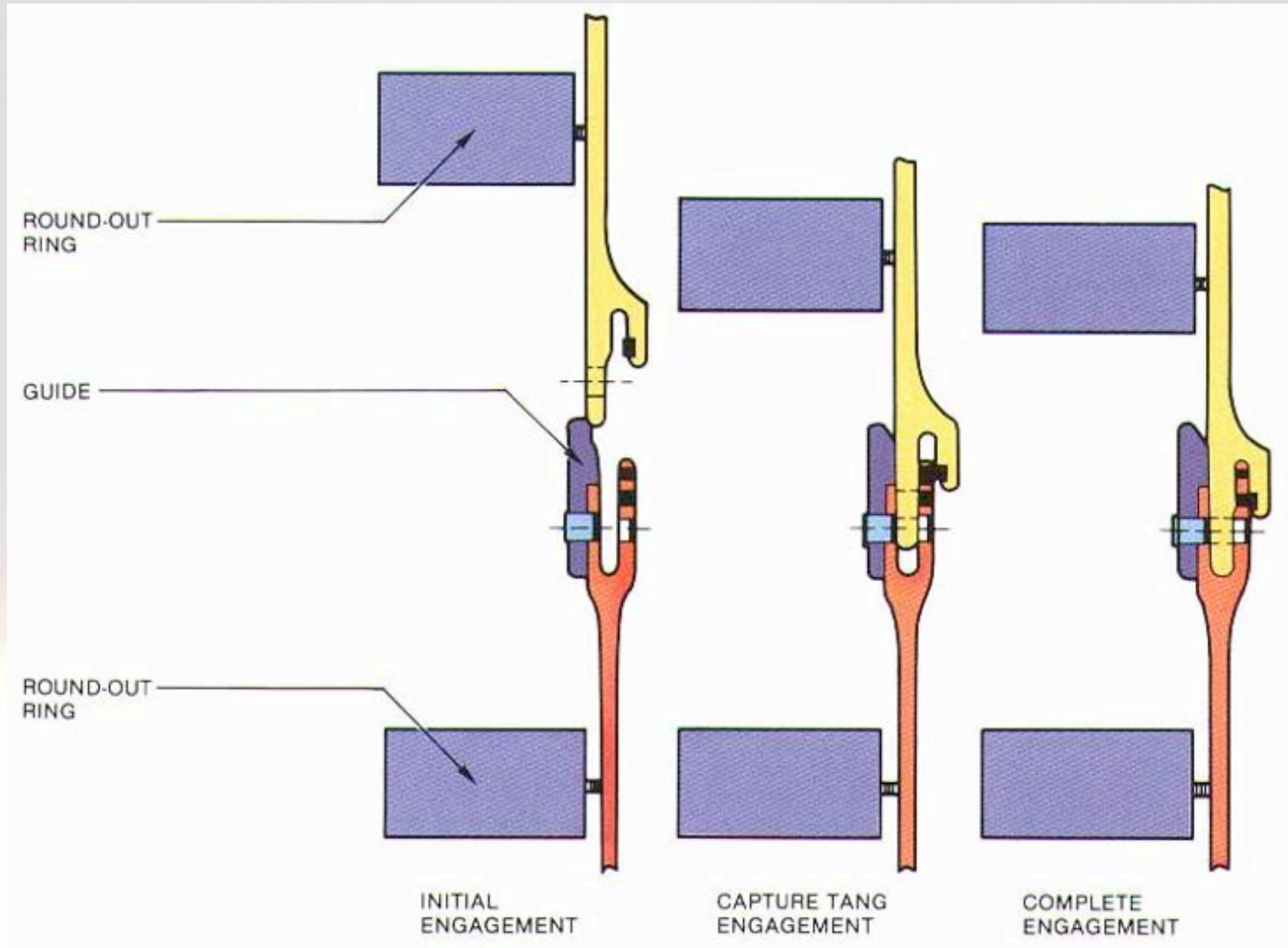


# Redesigned SRB Field Joint





# Revised SRB Assembly Technique



# Columbia Launch - STS-107



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**L+81.9 sec**



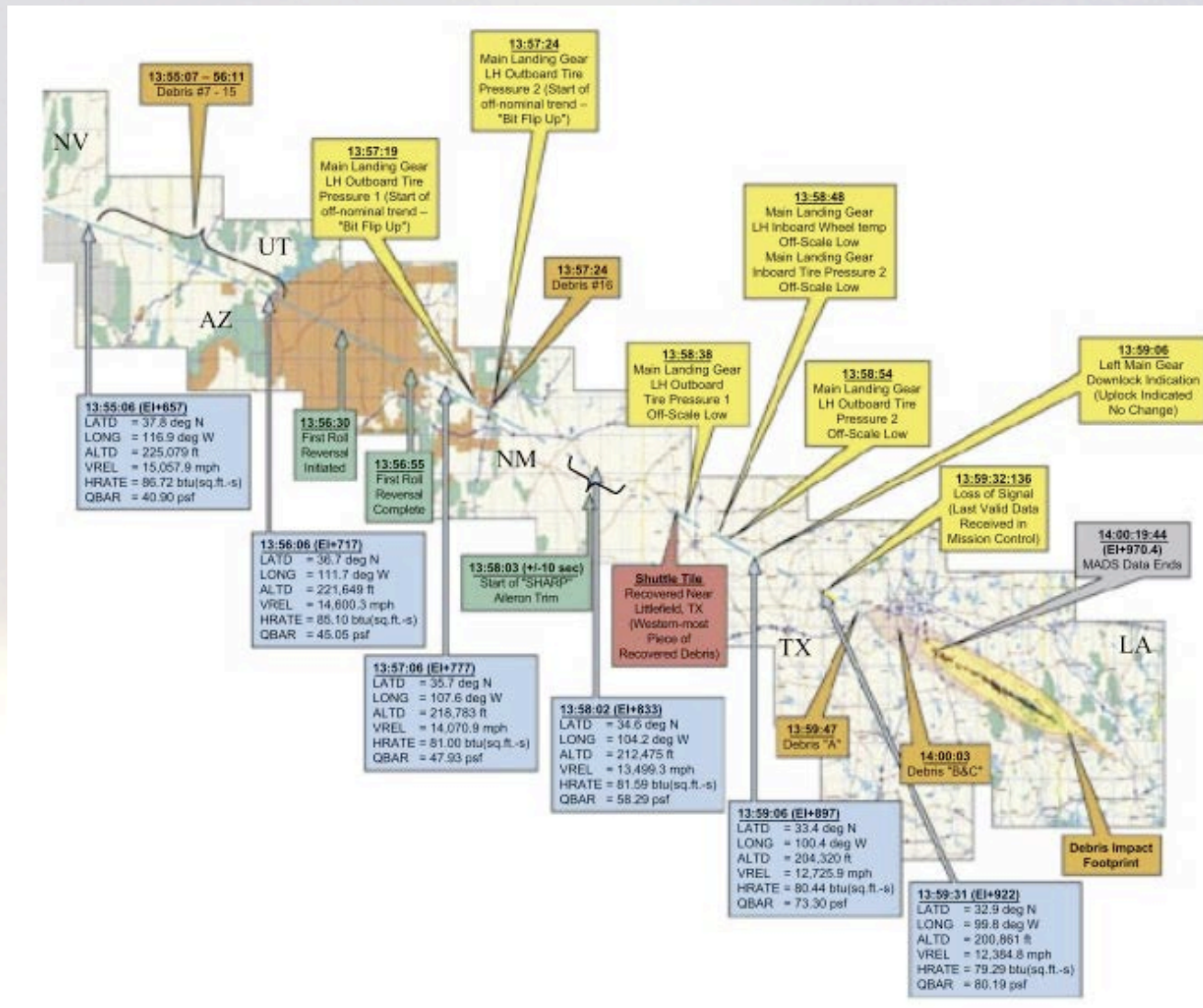
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# In-Flight Breakup





# Events Along Flight Path

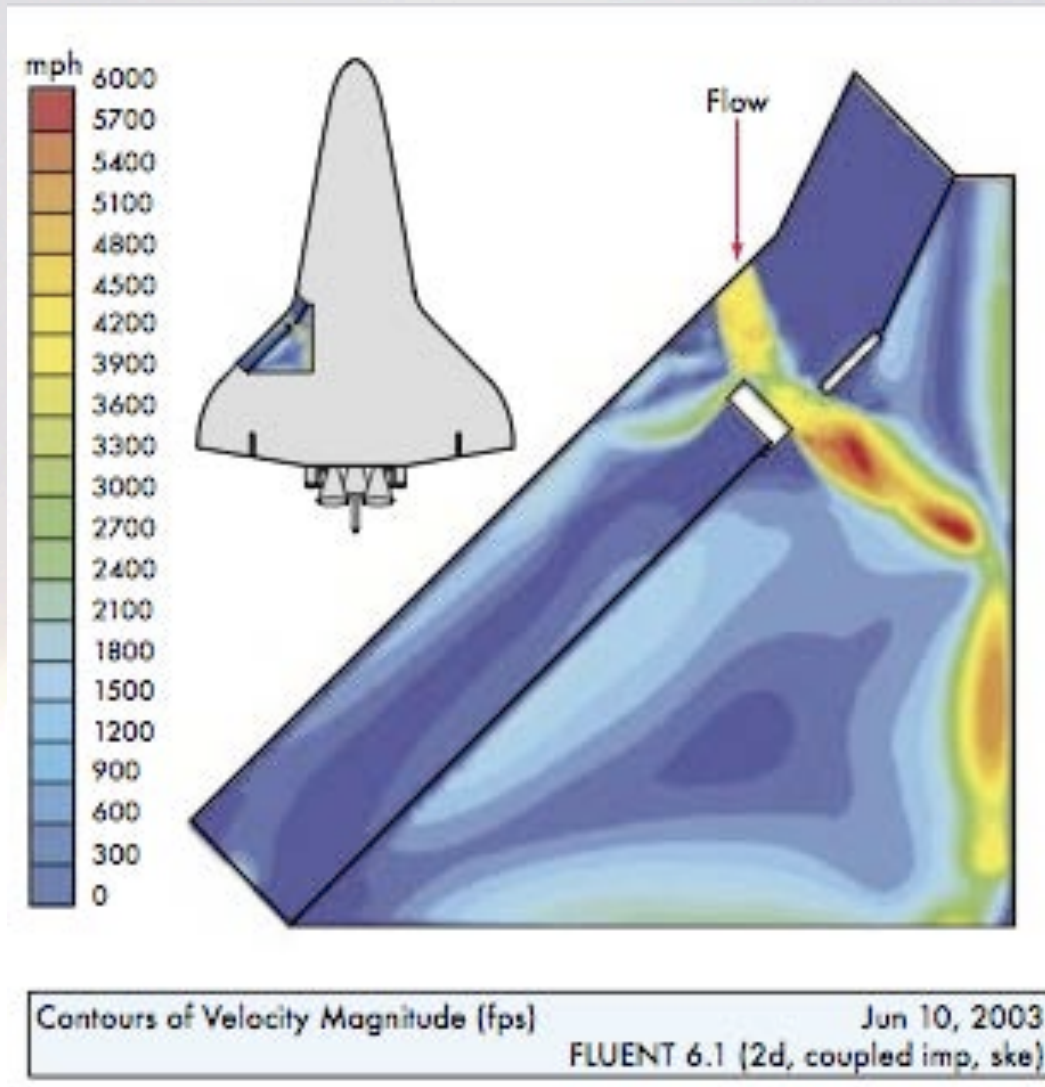


# Columbia Debris Reconstruction

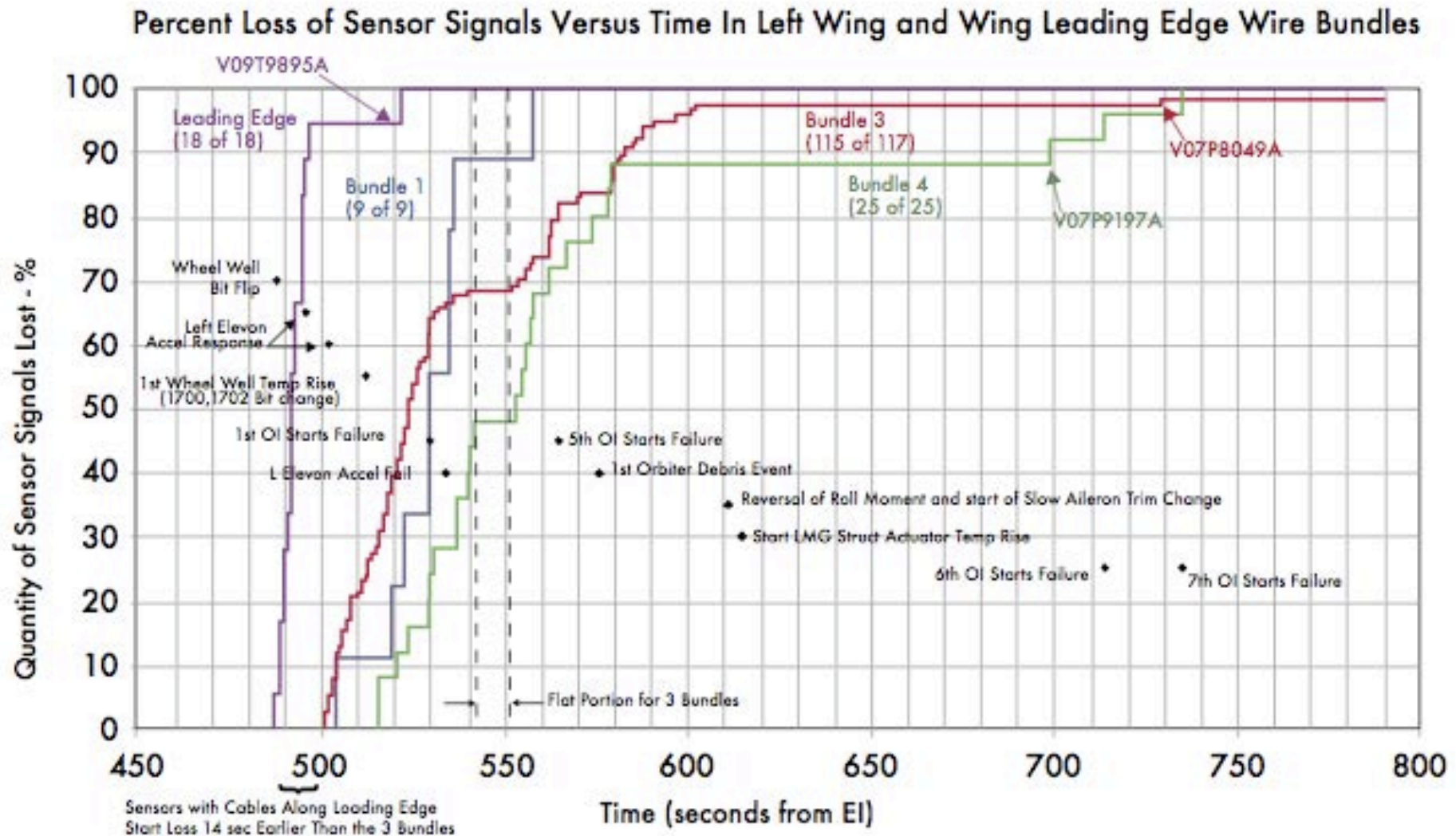




# CFD Analysis of Internal Airflow

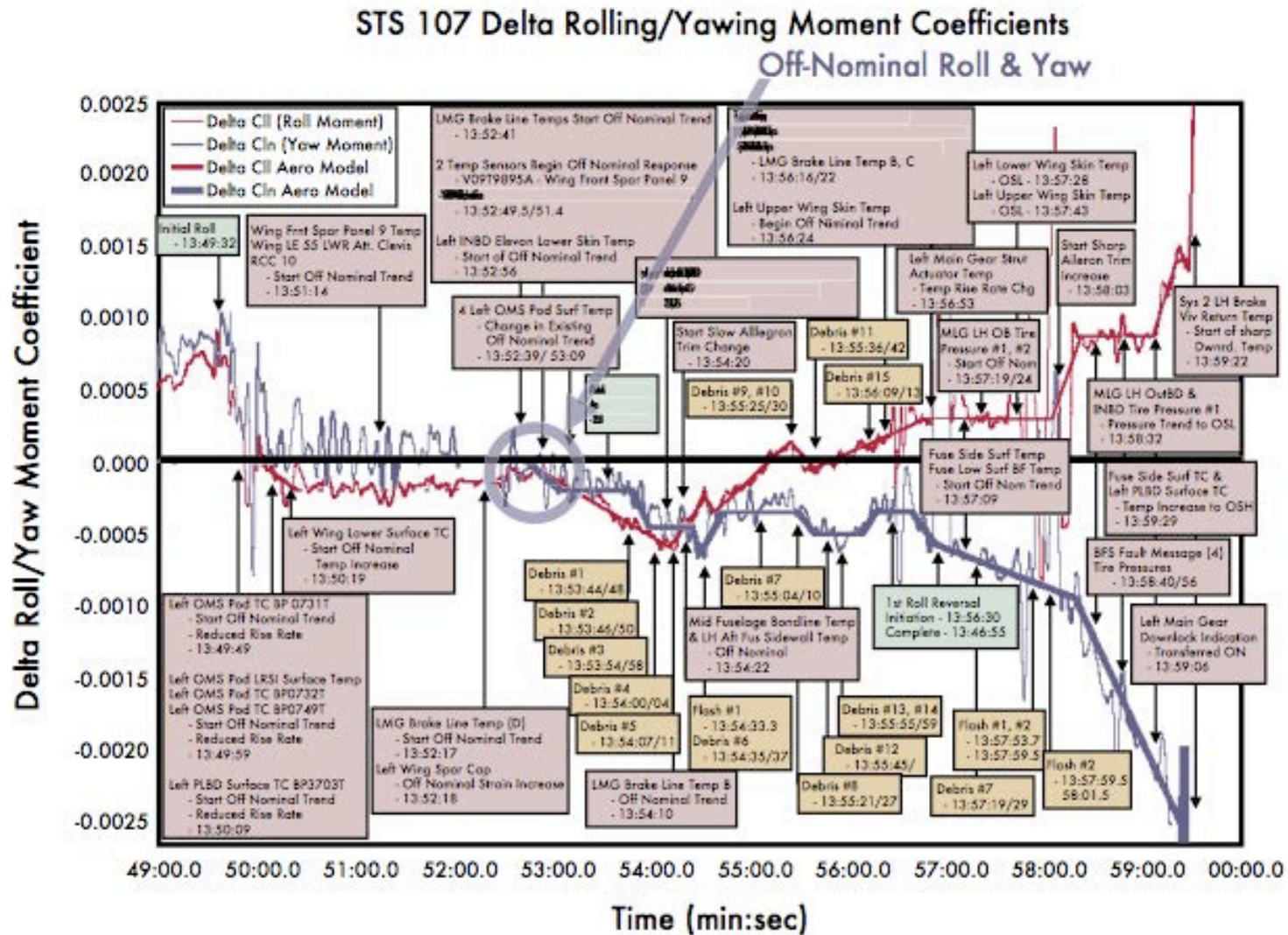


# Failure Rates of Sensor Wiring Bundles





# Divergence of Roll/Yaw Angles



# High-Velocity Impact Testing of RCC



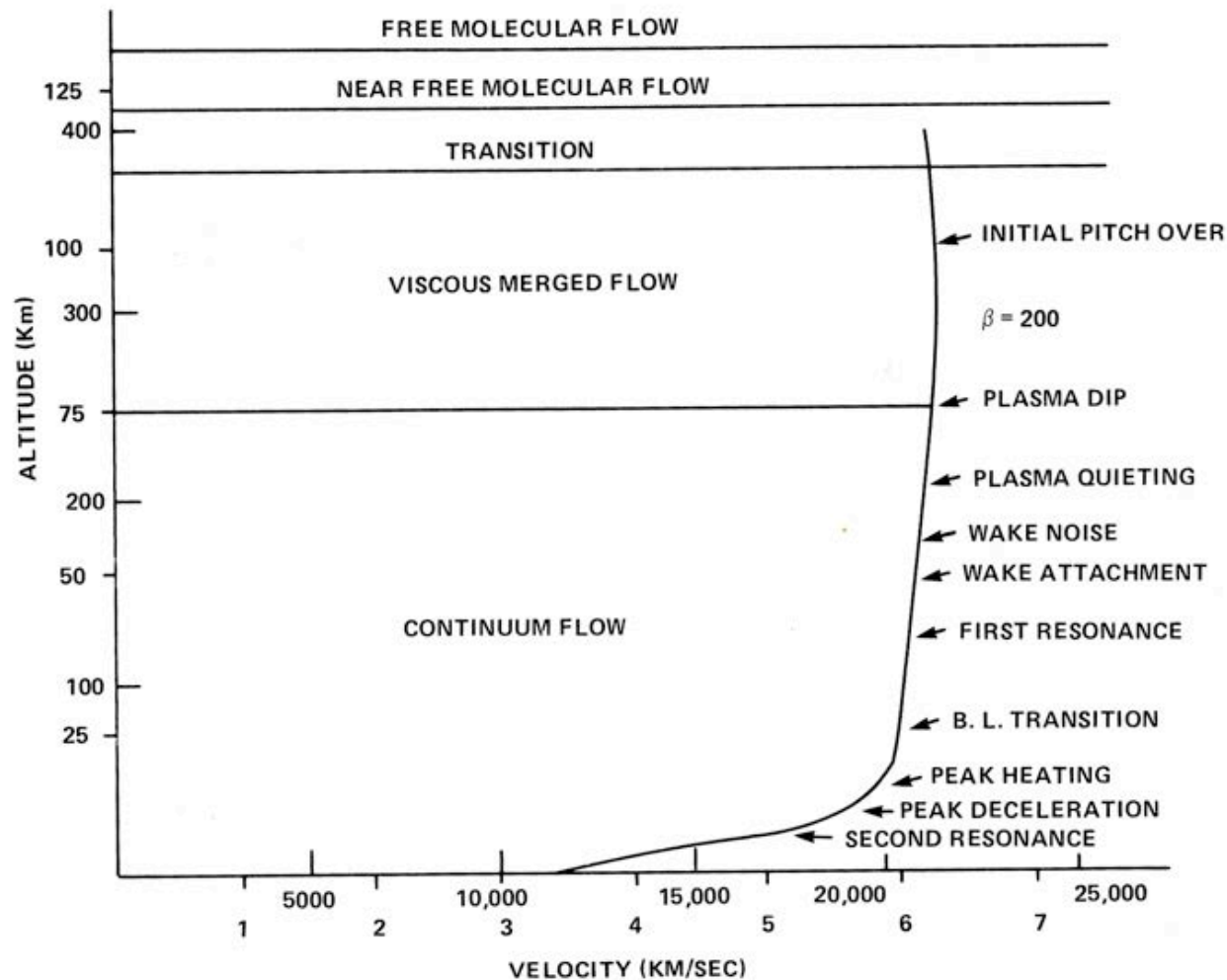


# Results of Impact Tests on RCC





# Entry Flow Regimes



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



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# October 5, 1989 - T+2 sec



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# October 6, 1989 - Aftermath



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