

| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                 |                                   |                                          | Form Approved<br>OMB No. 0704-0188                                  |                                                 |
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# **Liquid Rocket Engine Testing SFTE Symposium 21 October 2016**

**Jake Robertson, Capt USAF  
AFRL Rocket Lab**



# Liquid Rocket Engine Testing



- Engines and their components are extensively static-tested in development
- This requires large, complex facilities to deliver propellant at the proper pressure, temperature, and flow rates
- The enormous energies involved require great care for safety
- Operations are conducted remotely, from hardened underground bunkers



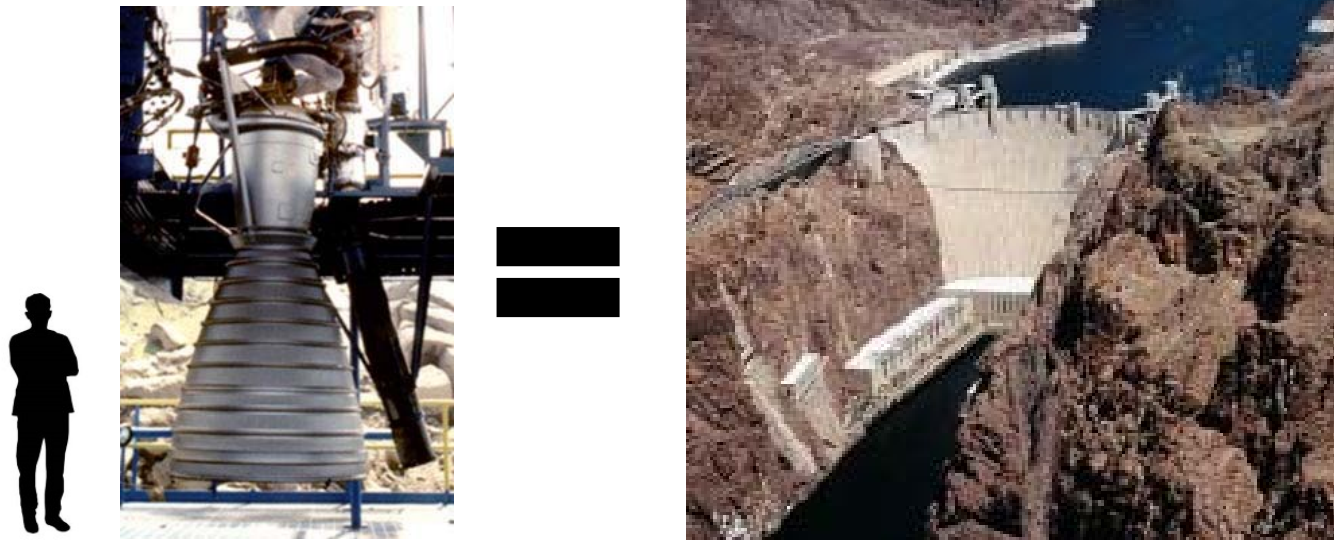


# Liquid Rocket Engine Testing



- **Power Density**

- A small booster engine releases 2 GW (2.7 million HP) of useful power (A large one can release more than 12 GW)
- The Hoover Dam is also rated at approximately 2 GW





# Liquid Rocket Engine Testing: Data



- **AFRL creates design space for the industry by demonstrating technologies and advancing TRL's**
- **Our product is data**
- **100's of sensor channels**
- **Extreme care goes into signal conditioning and processing**
- **Real time computing and control**
  - Controls are sequenced down to the millisecond to avoid catastrophic failure
- **200 KHz+ sampling in high-speed data systems**



# Liquid Rocket Engine Testing: Time



- **Single Test: 1s to 10 min**
- **Test preparation & post-test procedures can take an entire day**
  - Cryogenics
  - Facility/test article conditioning
  - Pumping up pressurant cascades
  - Data checkouts
  - Pre/Post-test inspections

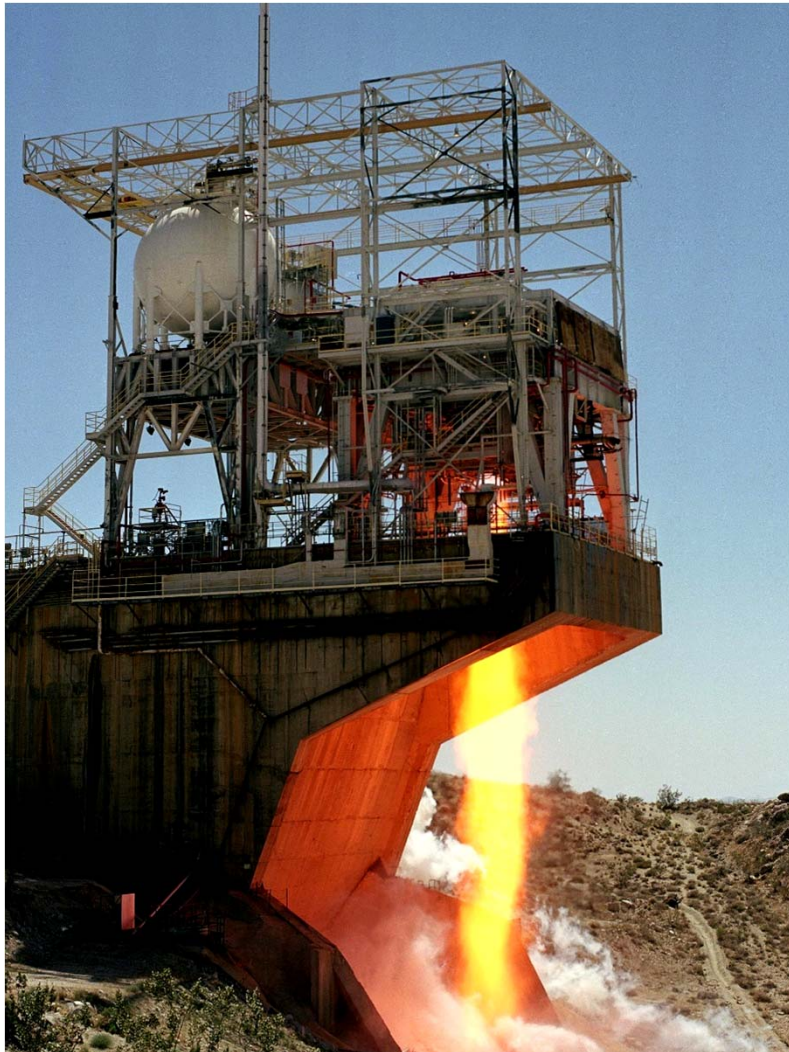


# Edwards Rocket Testing: History





# Edwards Rocket Testing: History





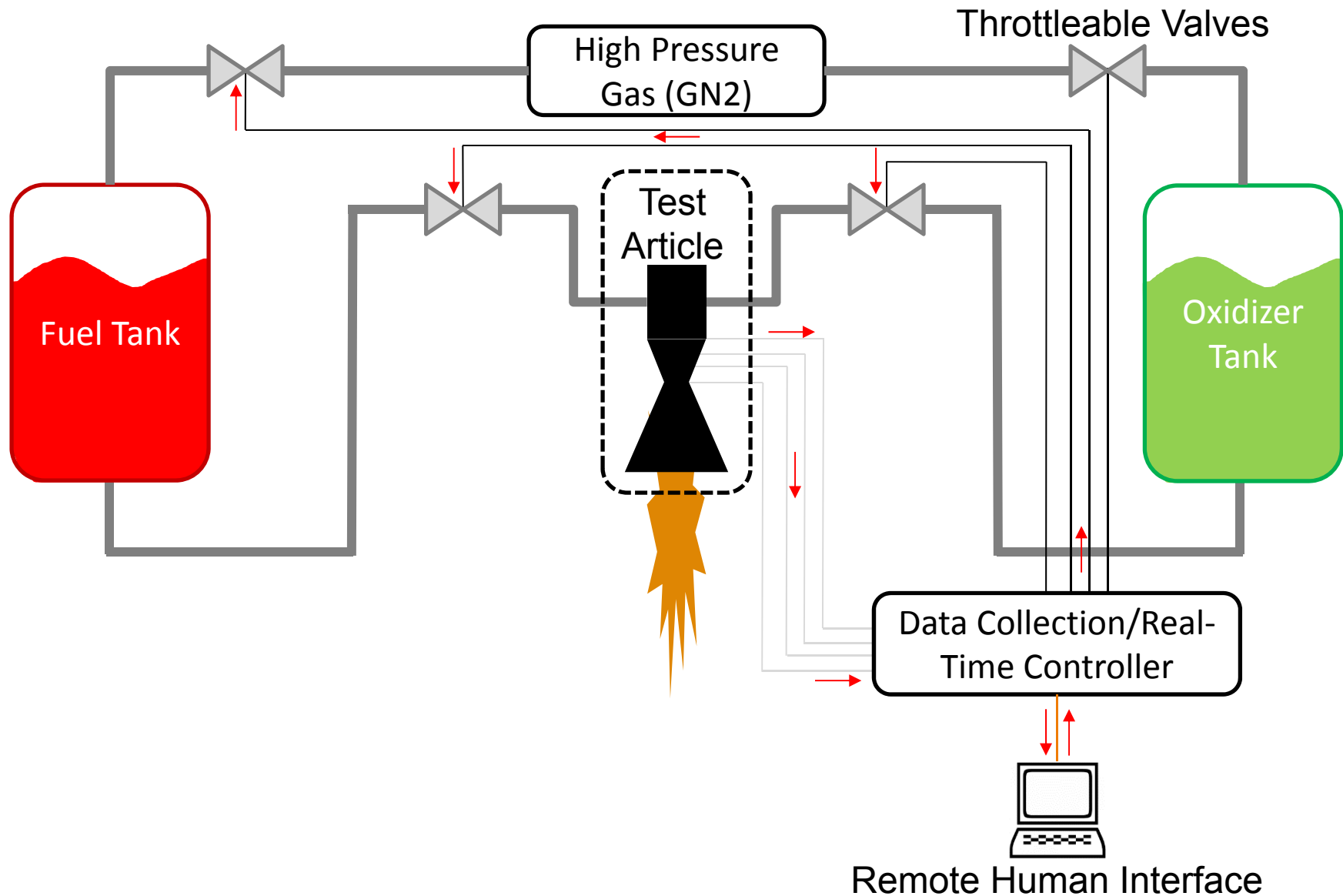
# Edwards: Test Stand 2A



- **Component test stand**
  - Can test multiple cryogenic and storable propellants
    - Liquid Oxygen (LOX)
    - RP-1 (Kerosene, very similar to JP-8)
    - Liquid Hydrogen
    - Liquid methane
- **Pressure = Performance in booster rocket engines**
- **6000-10000 psia capabilities**
  - Can use gaseous nitrogen, helium, or hydrogen to pressurize propellant tanks



# Simplified Test Stand Layout





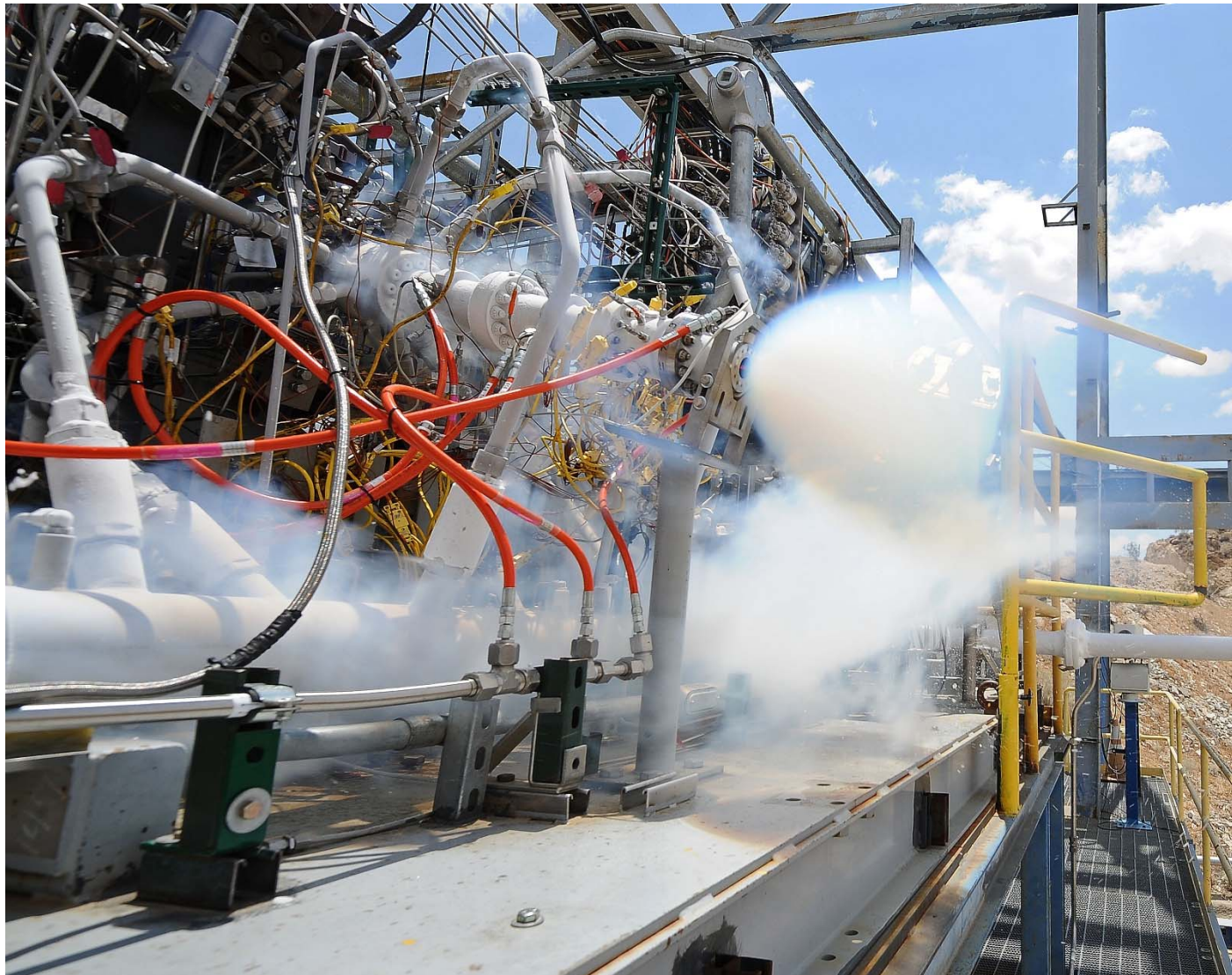
# Hydrocarbon Boost Program



- **Hydrocarbon Boost (HCB) is a long-running AFRL program to develop a brass-board demonstrator of a Kerosene-LOX, 250,000 lbf, 3000 psi oxygen-rich staged combustion engine (ORSC)**
- **AFRL's Test Stand 2A recently completed a two-year test campaign on HCB's sub-scale oxygen-rich preburner (SSORPB)**
  - Deep throttle capable (3:1) preburner
  - Very uniform exhaust characteristics
  - Overall mixture ratio exceeding 100:1 ( $\Phi \approx 0.03$ ) at low power



# Sub-Scale Preburner Test



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# Test Anomalies



- Several anomalies occurred during the course of testing
- Almost pure oxygen at high pressure and temperature regards everything as a fuel, even metal!

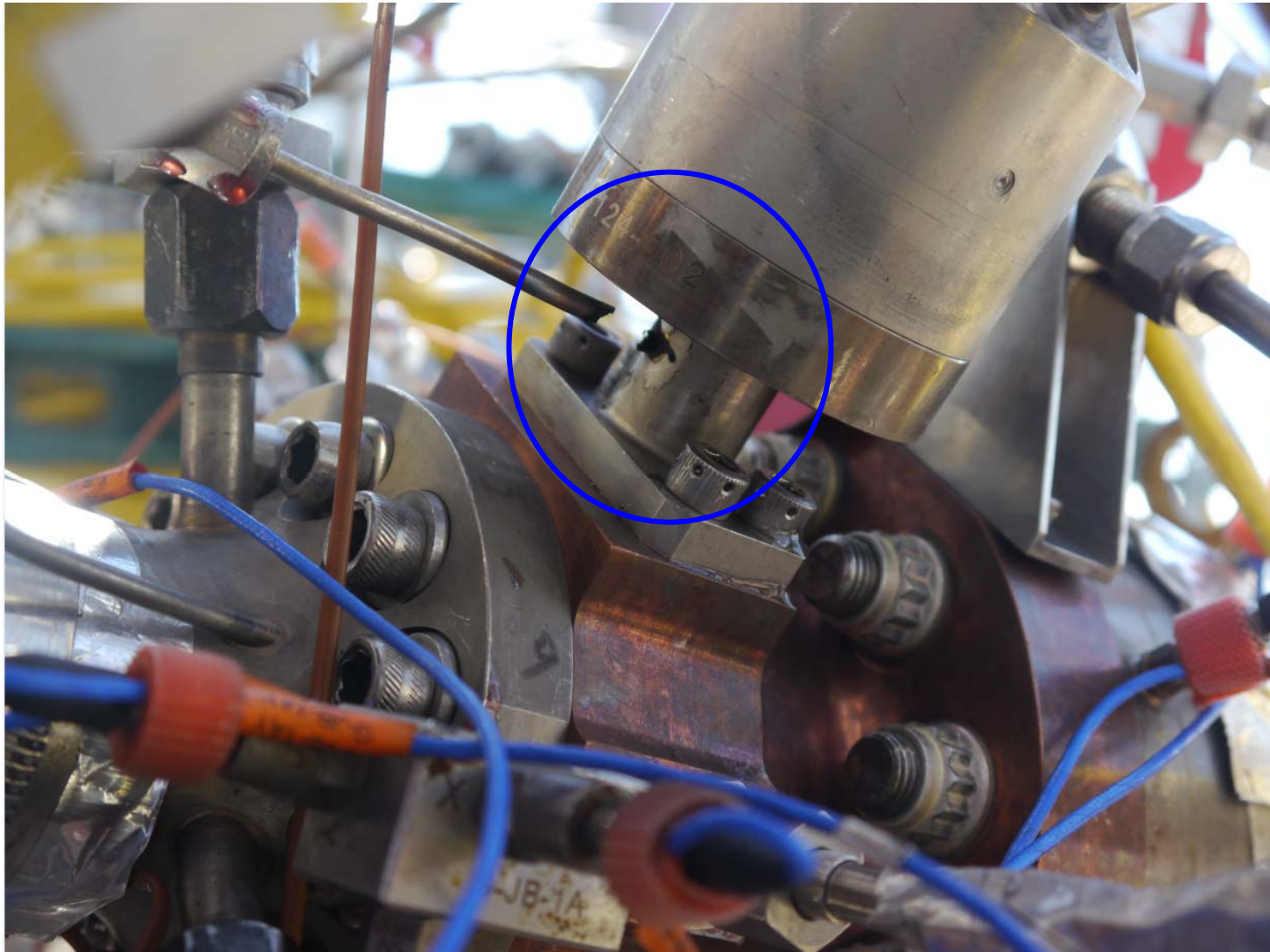


# Test Anomaly Example





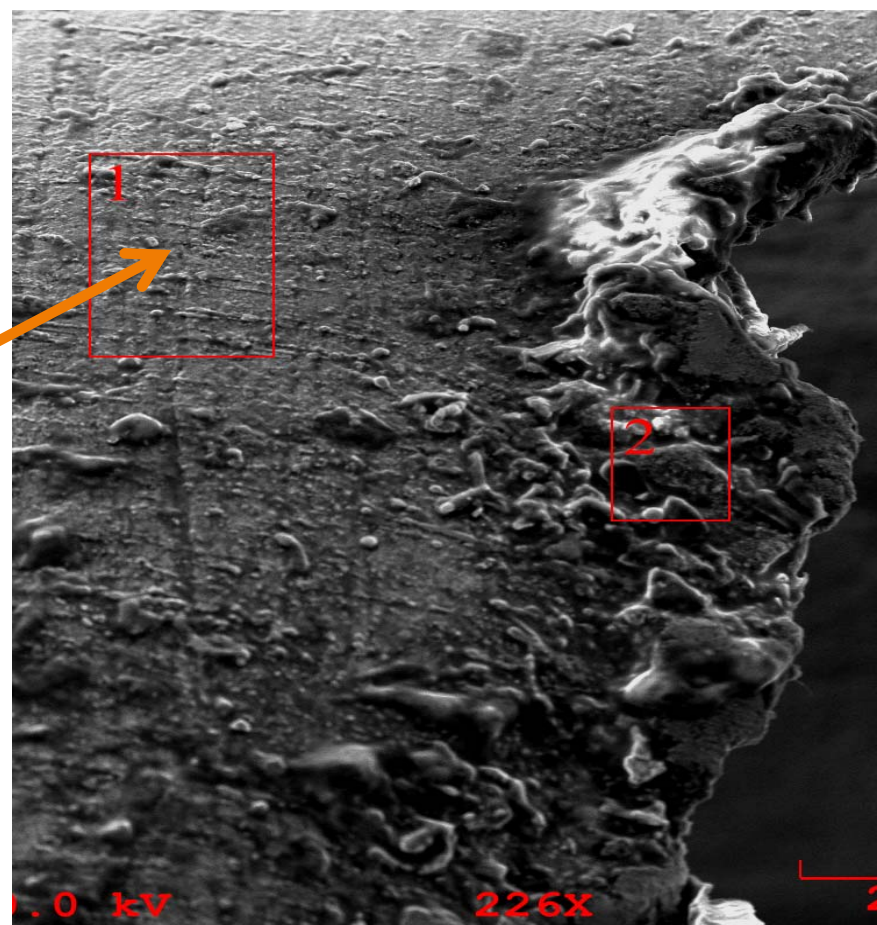
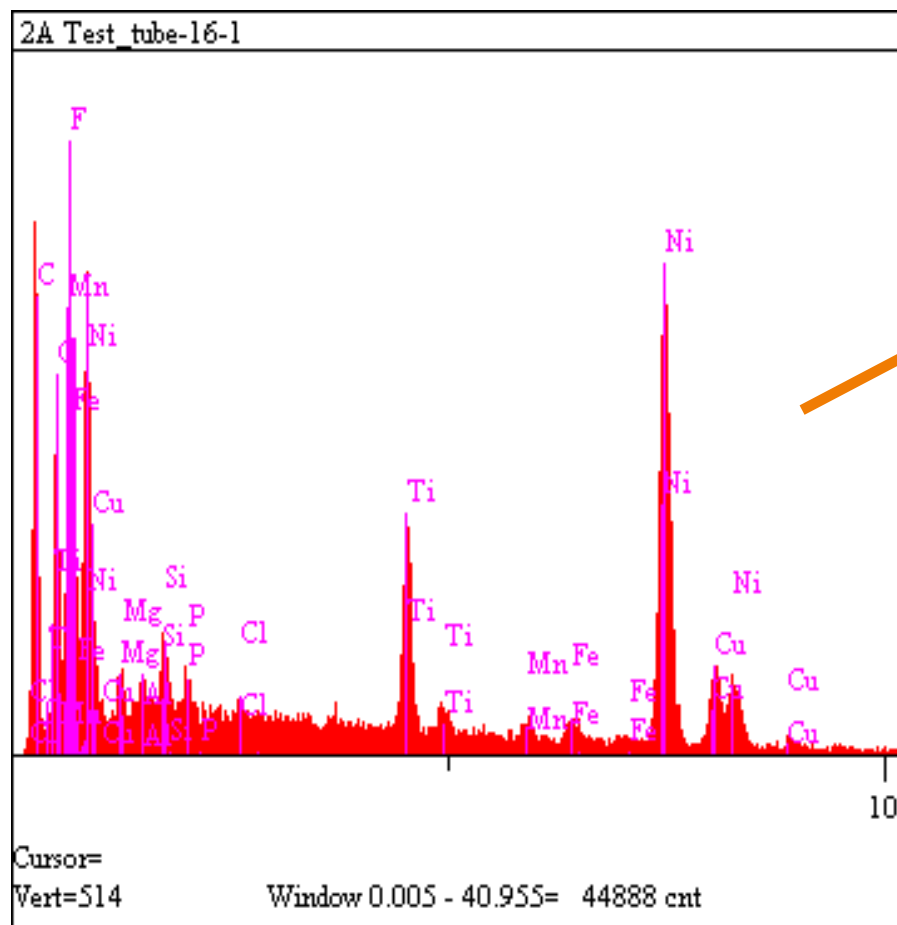
# Typical Oxygen Fire Aftermath



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# SEM/Spectroscopy: Failed tubing





# Conclusion



- **Liquid rocket engine testing is a demanding field that requires extreme care, years of preparation, and gives seconds of payout**
- **Multidisciplinary teams are vital to success**
- **Mission ultimately enables untold capabilities in space, spanning ISR, communication, and navigation**