
# NASA Work on Fatigue-Induced Cracking of $H_2$ Flow Control Valve Poppet

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# Agenda


- Problem Overview
- STS Hydrogen Flow Control Valve (HFCV) Layout
- Potential Issues Caused by Poppet Failure
- Discussion of Analysis & Testing Performed
- Current Work to Resolve Problem

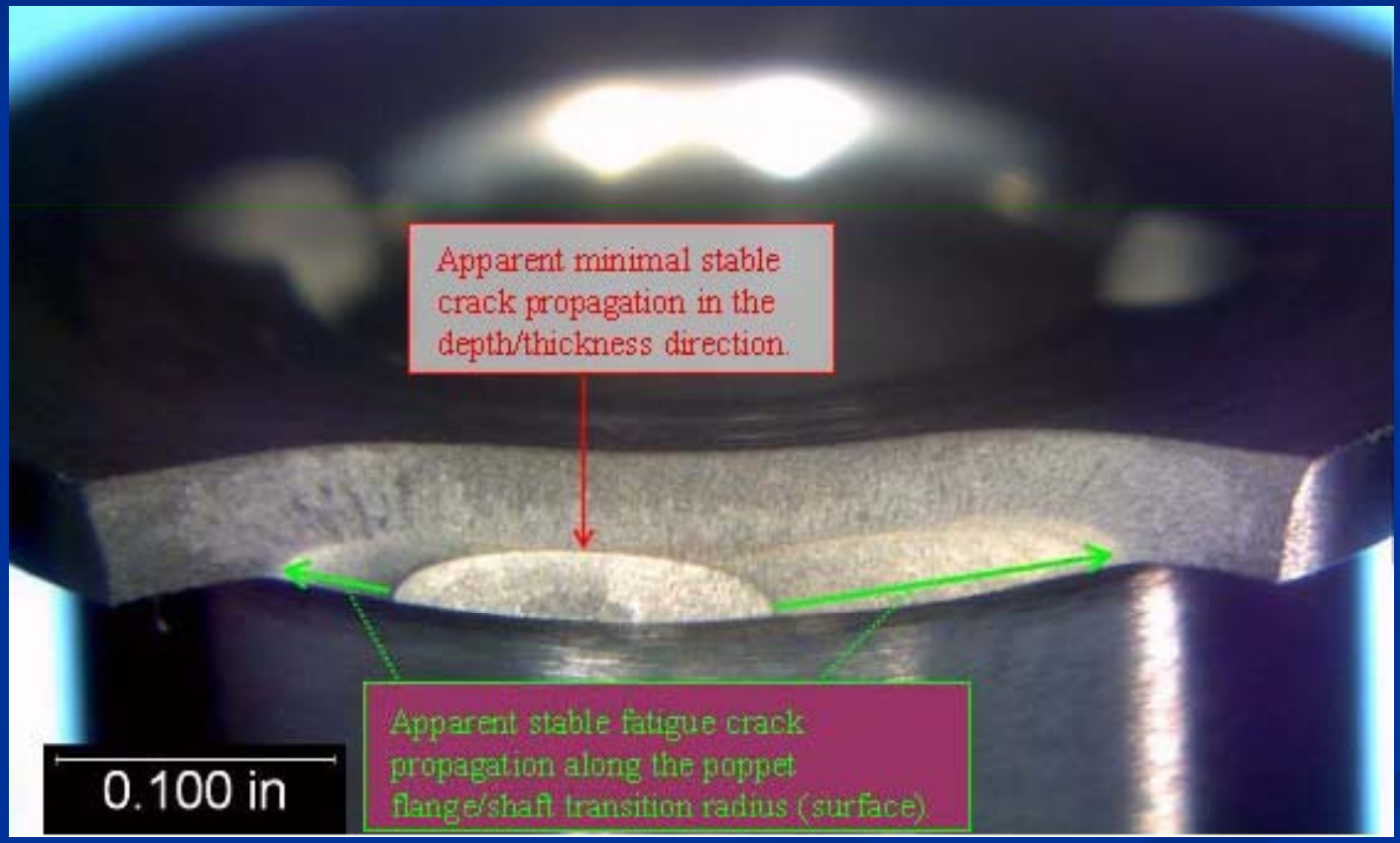
# Problem Overview

- In November 2008 (Endeavor: STS-126), $GH_2$ flow from one engine was higher than normal rate 1 min 26 s into launch (8.5 min ascent)
- The other two $GH_2$ flow control valves reduced their flow rates to compensate
- No major issue during ascent
- After returning to Earth the $GH_2$ system was inspected

# Problem Overview (cont.)

- A piece of the flow control valve poppet was missing
- The HFCV works like a pop-up sprinkler to allow more $GH_2$ to flow
- The missing piece could have caused
  - a rupture in the $GH_2$ line –loss of $H_2$, main engine (ME) shutdown
  - An over-pressurization in the external tank (ET) – overboard vent, hydrogen/oxygen mixing

# Problem Overview (cont.)



# STS HFCV Layout

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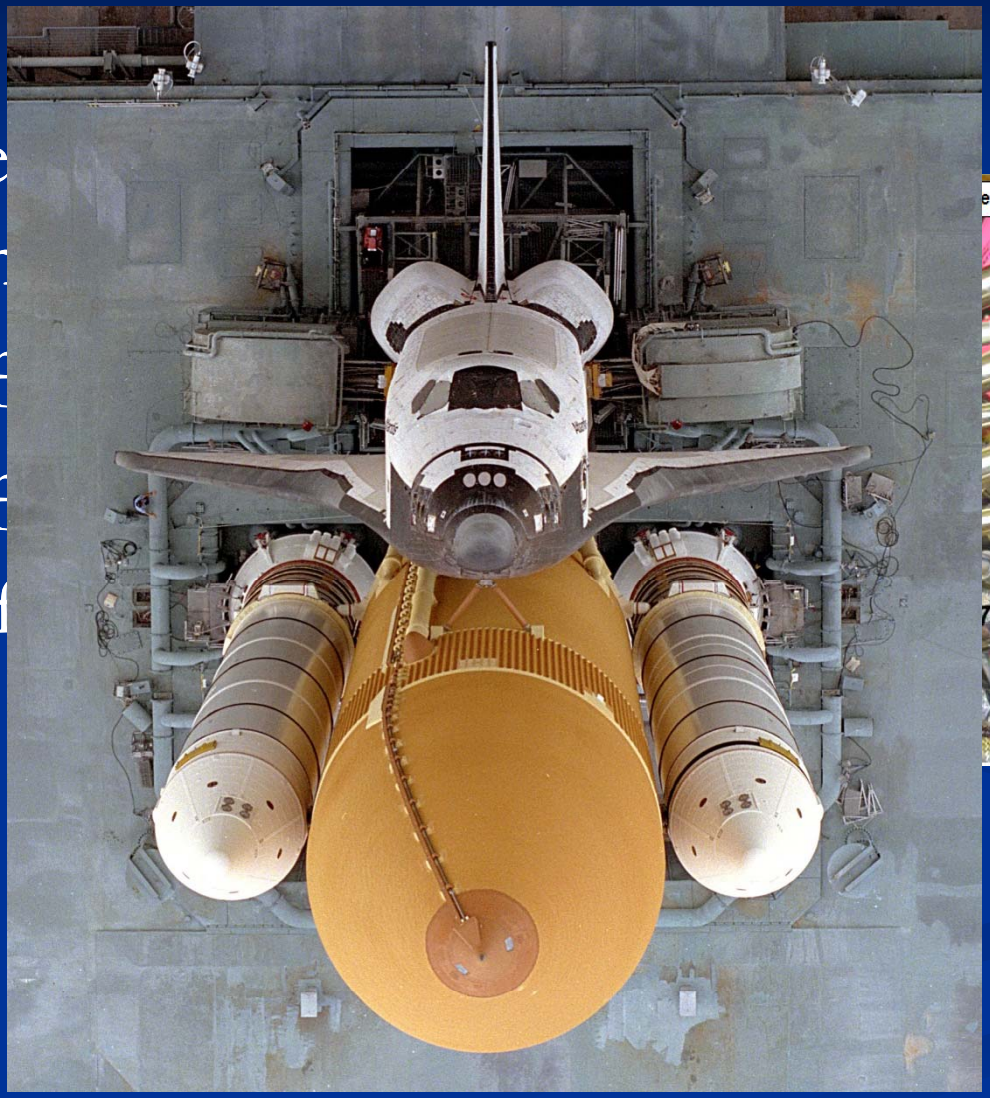
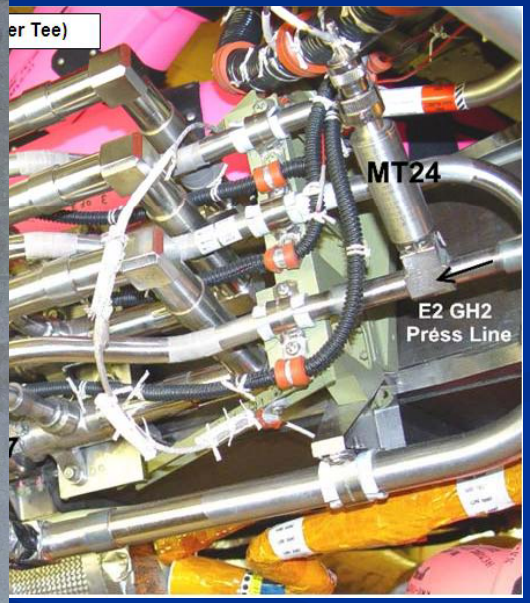
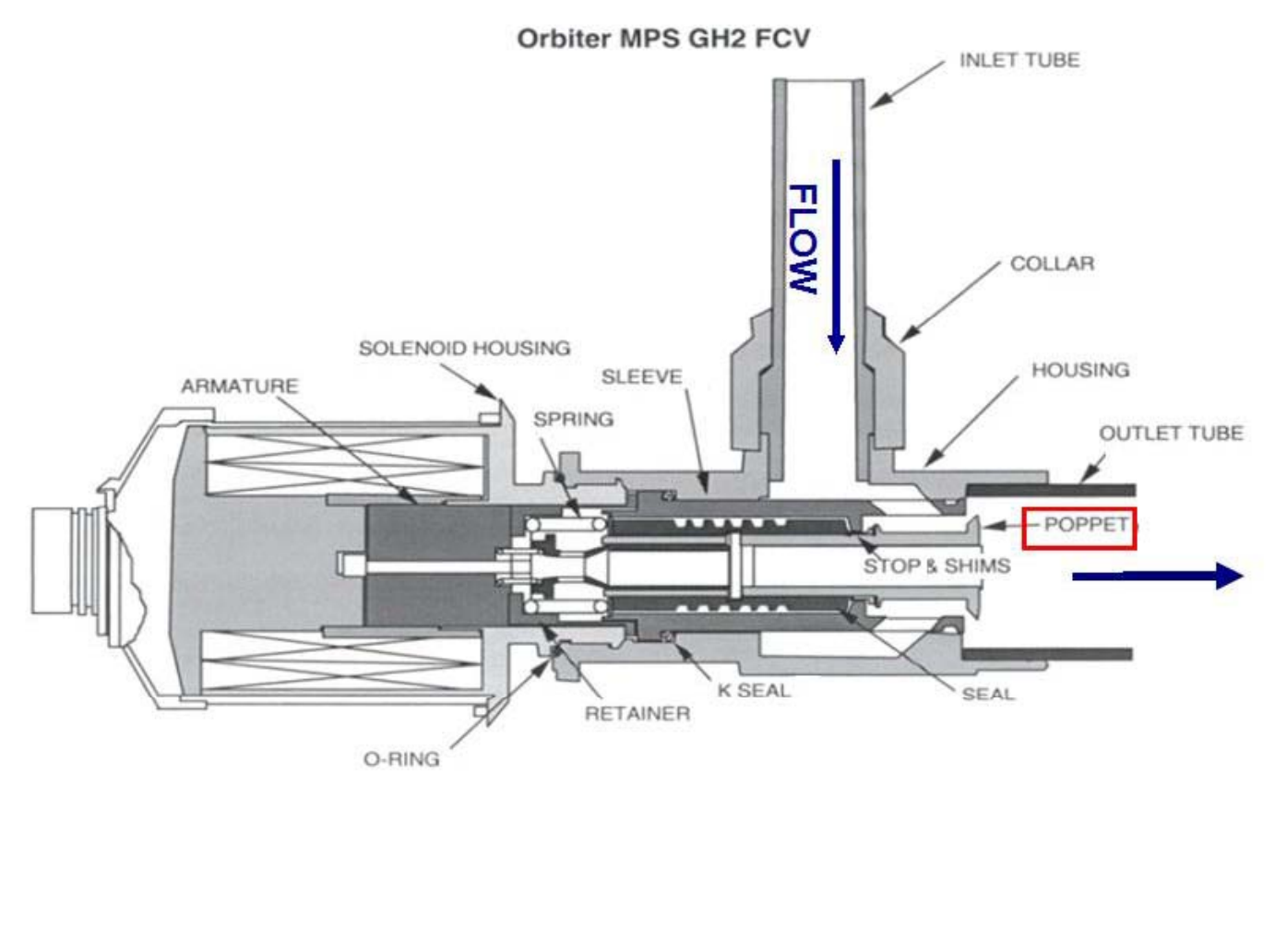




# STS HFCV Layout (cont.)

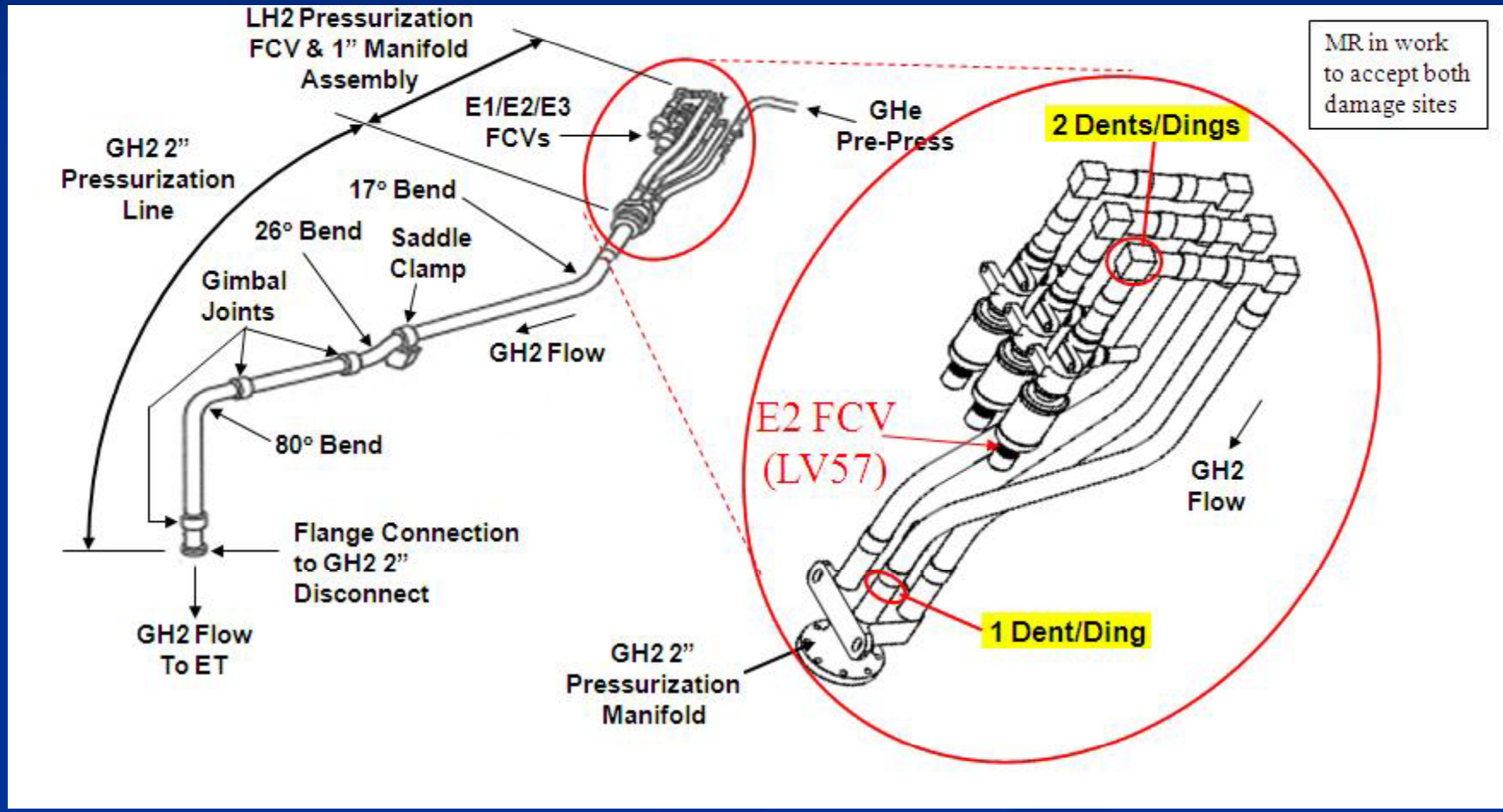


# Potential Issues Caused by Poppet Failure

- The missing piece could have caused:
  - A rupture in the $GH_2$ line –loss of $H_2$, main engine shutdown

  REASONS:
  - Poppet is a very hard material (Rc=50 min)
  - System lines are much softer, lighter material (HRB=85)
  - If a poppet particle is released, could the free particle puncture the downstream system piping?

# Potential Issues Caused by Poppet Failure



# Potential Issues Caused by Poppet Failure

- The missing piece could have caused:
  - An over-pressurization in the external tank (ET) – overboard vent, hydrogen/oxygen mixing

REASON

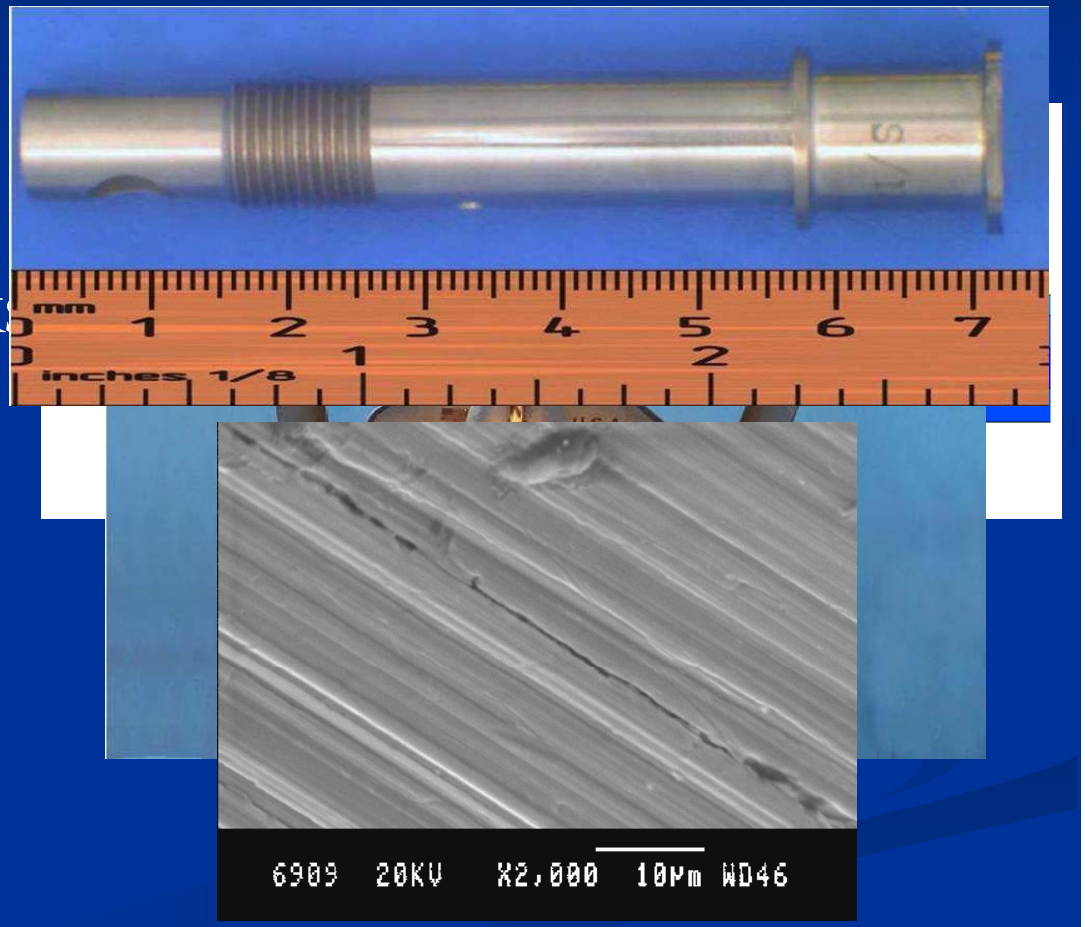
  - While a single HFCV poppet failure can be handled safely by the throttling of the other two HFCVs, multiple failures at once could over-pressurize ET
  - ET is maintained between 32 and 34 psia
  - Consider all three SSMEs could empty a large public swimming pool in 3 min (SSME=375,000 lbf is 100% throttle thrust each at liftoff )

# Discussion of Analysis & Testing Performed


- Analysis
  - Computational fluid dynamics (CFD) modeling for vibrational modes
  - Hydrogen/oxygen mixing at supersonic velocities
  - Lots of material analysis, nondestructive evaluation (NDE), and NDE technique development
- Testing:
  - Particle velocity testing
  - Particle release testing
  - Resonance/flutter testing
  - Acceptance testing

# Discussion of Analysis & Testing Performed (cont.)

- [illegible]
- WSTF consultation
- Empirical Data from WSTF



# Discussion of Analysis & Testing Performed (cont.)

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- Testing:
  - Particle Release Testing


After all preparations were made, testing at SSC was cancelled, this apparatus not used

# Current Work to Resolve the Problem

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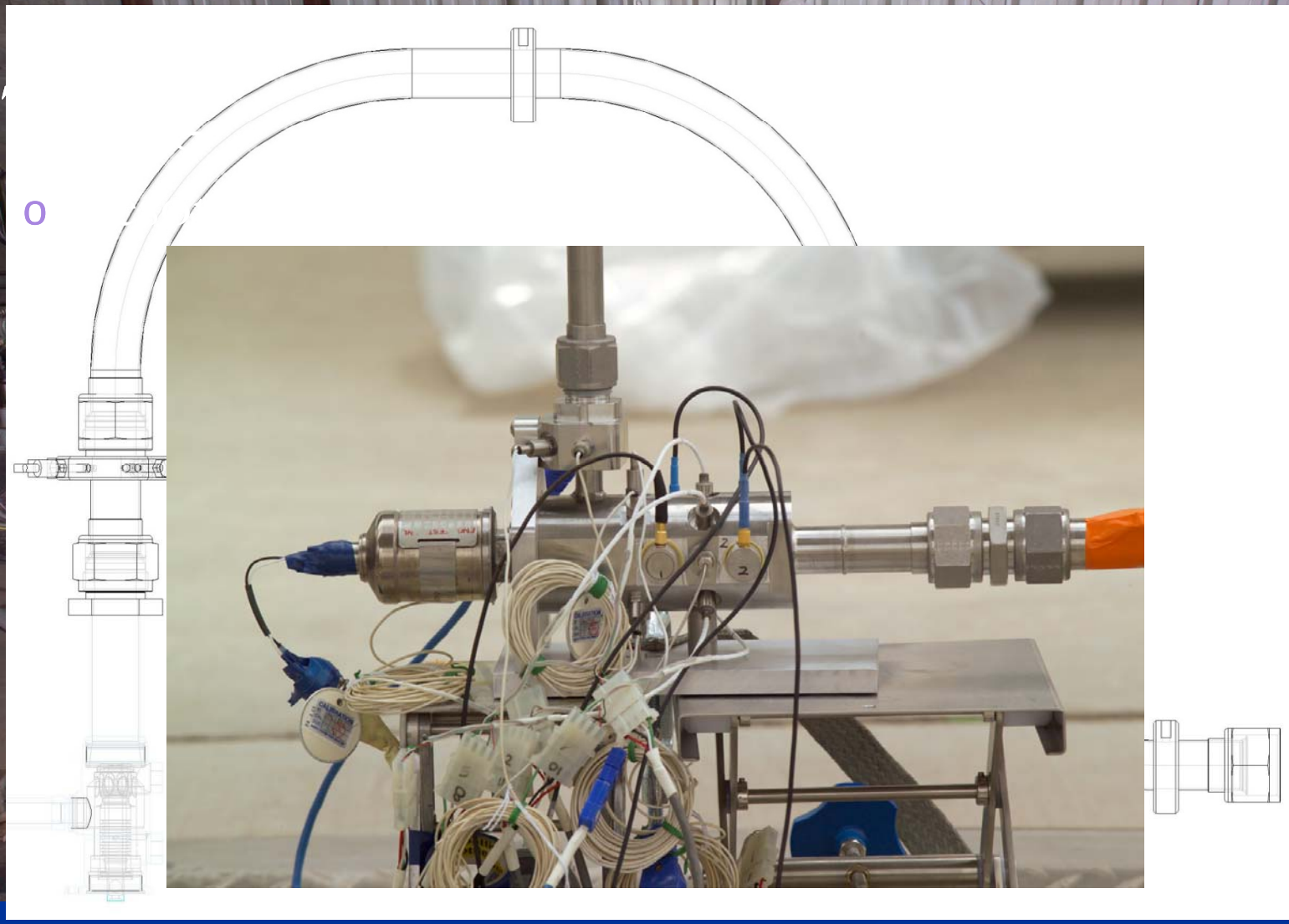
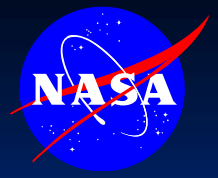


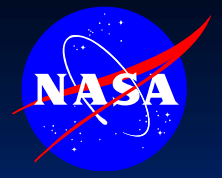
# Current Work to Resolve the Problem


- Testing:
  - Acceptance Testing
    - NDE (eddy current) new poppets ⟵ New process
    - $GN_2$ poppet balance (at vendor)
    - EC post test ⟵ New process
    - $GN_2$ flow calibration (at vendor)
    - EC post test ⟵ New process
    - $GH_2$ flow calibration (at WSTF)
    - $GH_2$ mission duty cycle for acceptance (at WSTF)
    - EC post test ⟵ New process

# Current Work to Resolve the Problem




- New poppet materials under review
  - Considerations
    - Need a material that has resistance to cycle fatigue
    - But still has good hydrogen compatibility
    - And can maintain dimensional stability through a wide range of operating temperatures (- 40 to 90 °F)
    - Shuttle program is slated to retire in 2010
      - Difficult to get funding for a whole new qual program with 1 year remaining




# Questions?

# References


- Flow Control Valve Fact sheet (publicly available) Feb. 3, 2009 http://www.nasa.gov/pdf/313985main_Flow_Valve_Fact.pdf
- NSTS 1988 News Reference Manual (publicly available) http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/stsref-toc.html
- Main Propulsion System Propellant Management Subsystem http://spaceflight.nasa.gov/shuttle/reference/shutref/orbiter/prop/propellant.html