Saturn V - Design Considerations & Launch Issues

Objectives

- Understand some of the design considerations that went into creating the Saturn V launch vehicle
- Gain an appreciation for some of the manufacturing issues concerning the Saturn V
- Review three major problems that affected Saturn V launches

Outline

- Lunar Voyages
- Weight Savings
- Manufacturing Issues
- Launch Issues

Lunar Voyages

- 3 Options considered:
  - Direct Ascent
  - Earth Orbit Rendezvous (EOR)
  - Lunar Orbit Rendezvous (LOR)

"NASA concluded that LOR offered the greatest assurance of successful accomplishment of the Apollo objectives at the earliest practical date."[1]

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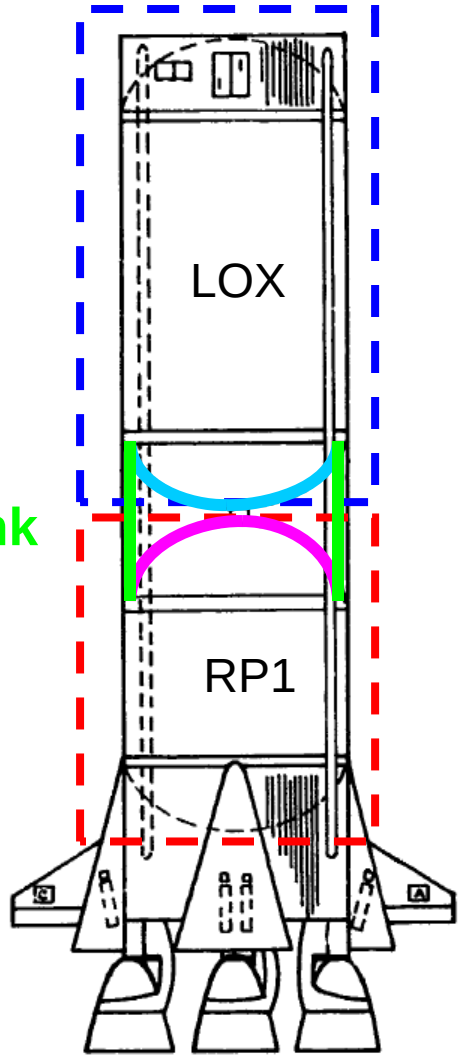
Weight Savings

- To increase the payload by 1 kg (2.2 lbs):
  - Remove 14 kg (30 lbs) from S-IC
  - Remove 4 kg (8.8 lbs) from S-II
  - Remove 1 kg (2.2 lbs) from S-IVB

- Topics
  - Common Bulkheads
  - Tank Structures
  - Propellant Utilization (PU)

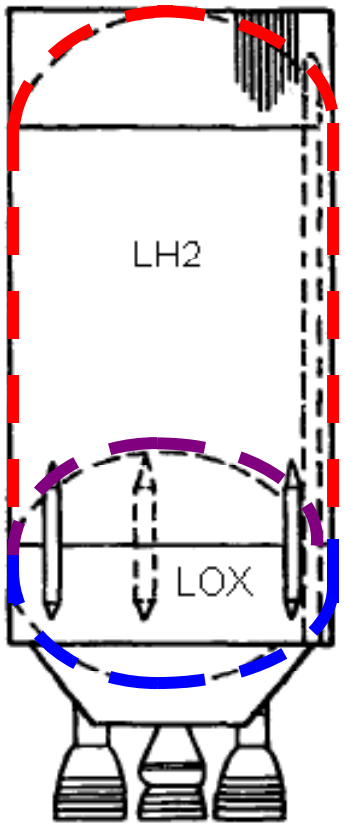
Common Bulkhead

S-IC



Intertank

S-II (S-IVB)

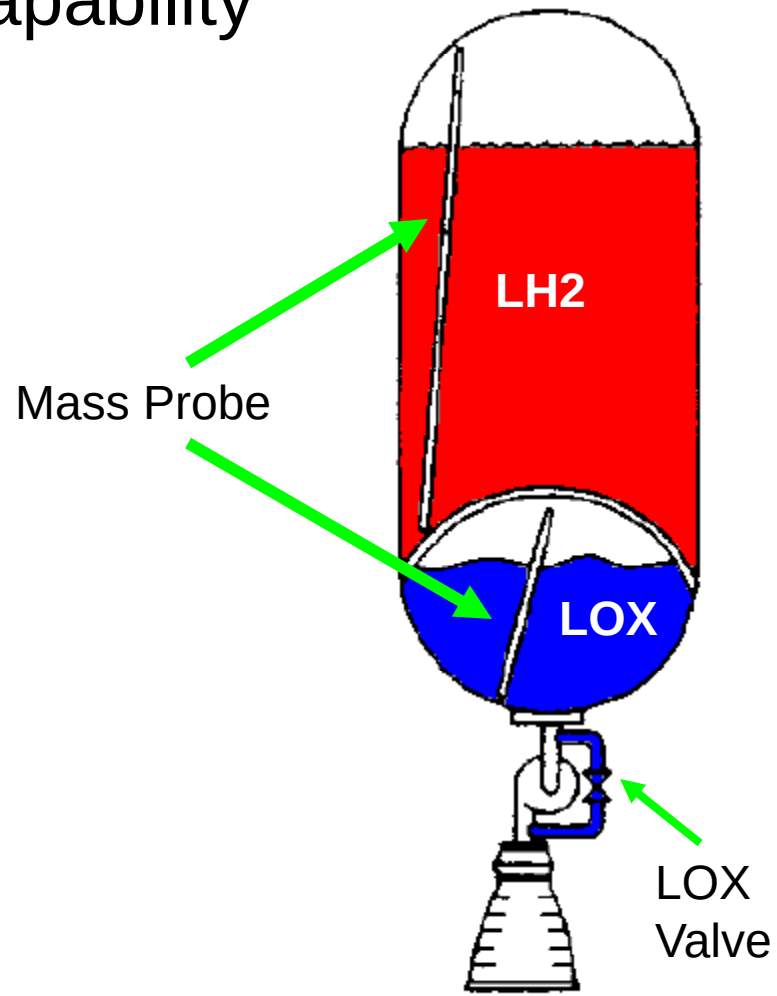


Tank Structures

- Waffle pattern was etched into the S-II and S-IVB

Propulsion Utilization (PU)

- Ensure simultaneous depletion of propellants
- Increases stage payload capability



- PU on S-II and S-IVB

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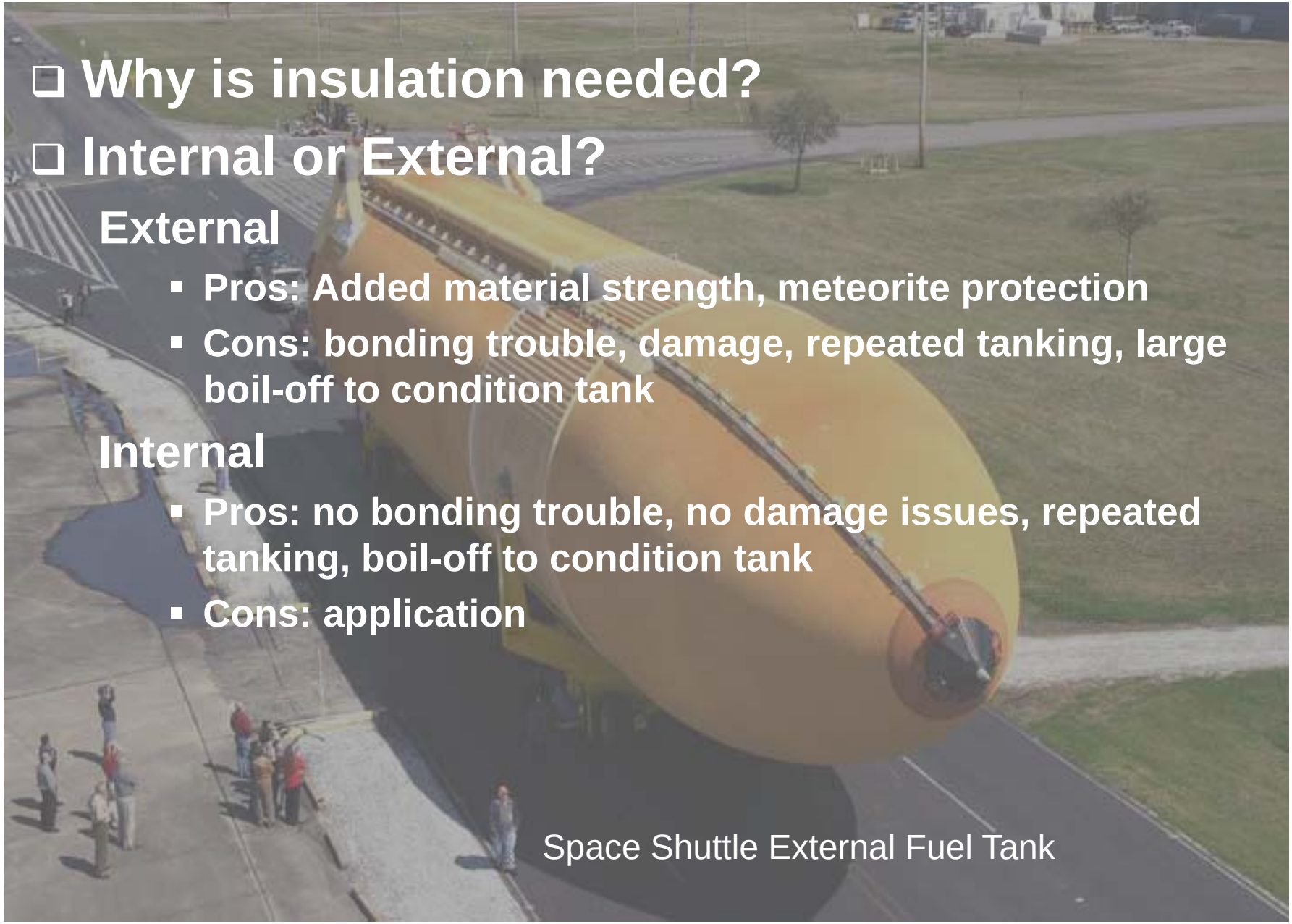
Manufacturing Issues

- Insulation
- Welding

Insulation



- Why is insulation needed?
- Internal or External?

  External
  - Pros: Added material strength, meteorite protection
  - Cons: bonding trouble, damage, repeated tanking, large boil-off to condition tank

  Internal
  - Pros: no bonding trouble, no damage issues, repeated tanking, boil-off to condition tank
  - Cons: application

Space Shuttle External Fuel Tank

Insulation

S-II (External Insulation)

- First method of application: Glue large panels of insulation
  - Trapped air posed problems
  - Tried helium purge to remove trapped air

- Sprayed insulation on, trimmed excess

Insulation

S-IVB (Internal Insulation)

- 4,300 individually shaped foam bricks glued to the interior

Welding

- Large pieces that can deform under their own weight
- Extremely long welds required with tight tolerances

Welding

- Problems
  - First couple of propellant tanks for S-IC scrapped due to poor welding
  - S-II bulkhead ruptured during testing, caused by a faulty, repaired weld
  - Cracks in welds of first S-II flight stage caused Saturn V to be de-stacked and the welds repaired (Apollo 4)
  - S-IVB flight stage exploded during an acceptance test

Welding

- Improving Weld Quality
  - Propellant tank components cleaned before welding
  - Humidity and temperature tightly controlled
  - Clean room environment
- 10 – 15 specialists per welding team
  - Every cm of weld had to be inspected
    - S-IC: 10 km/6.2 mi of welds
    - S-II: 1 km/.62 mi of welds
  - 8 hours of procedures for a single weld

Welding

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Launch Issues – Apollo 6

- Apollo 6 (Saturn 502)
  - S-IC Pogo (duration ~35 seconds)
  - S-II Engines 2 & 3 shut down early
  - S-IVB J-2 failed to restart in orbit

Launch Issues – Apollo 12

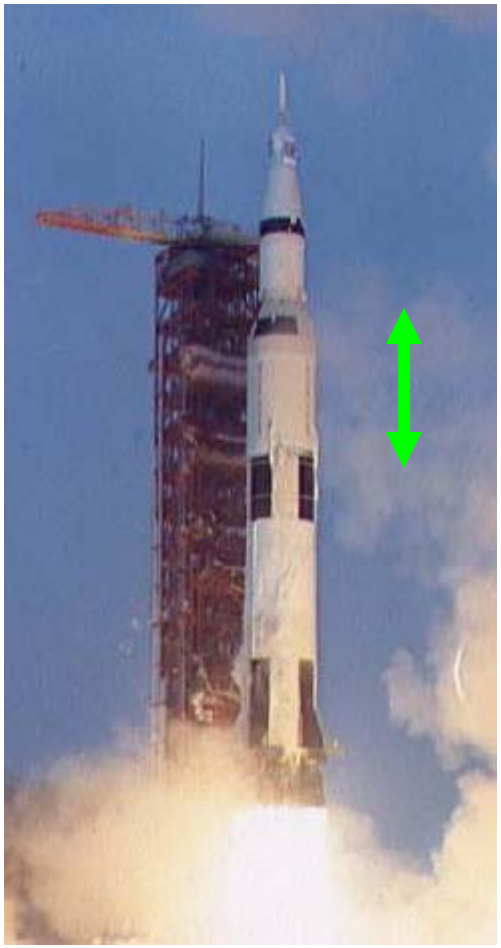
- Apollo 12 (Saturn 507)
  - Struck twice by lightning
  - Command Module lost guidance platform
  - No issues to the launch vehicle

Launch Issues – Apollo 13

- Apollo 13 (Saturn 508)
  - Pogo on Stage 2 caused S-II Center Engine to shut down early

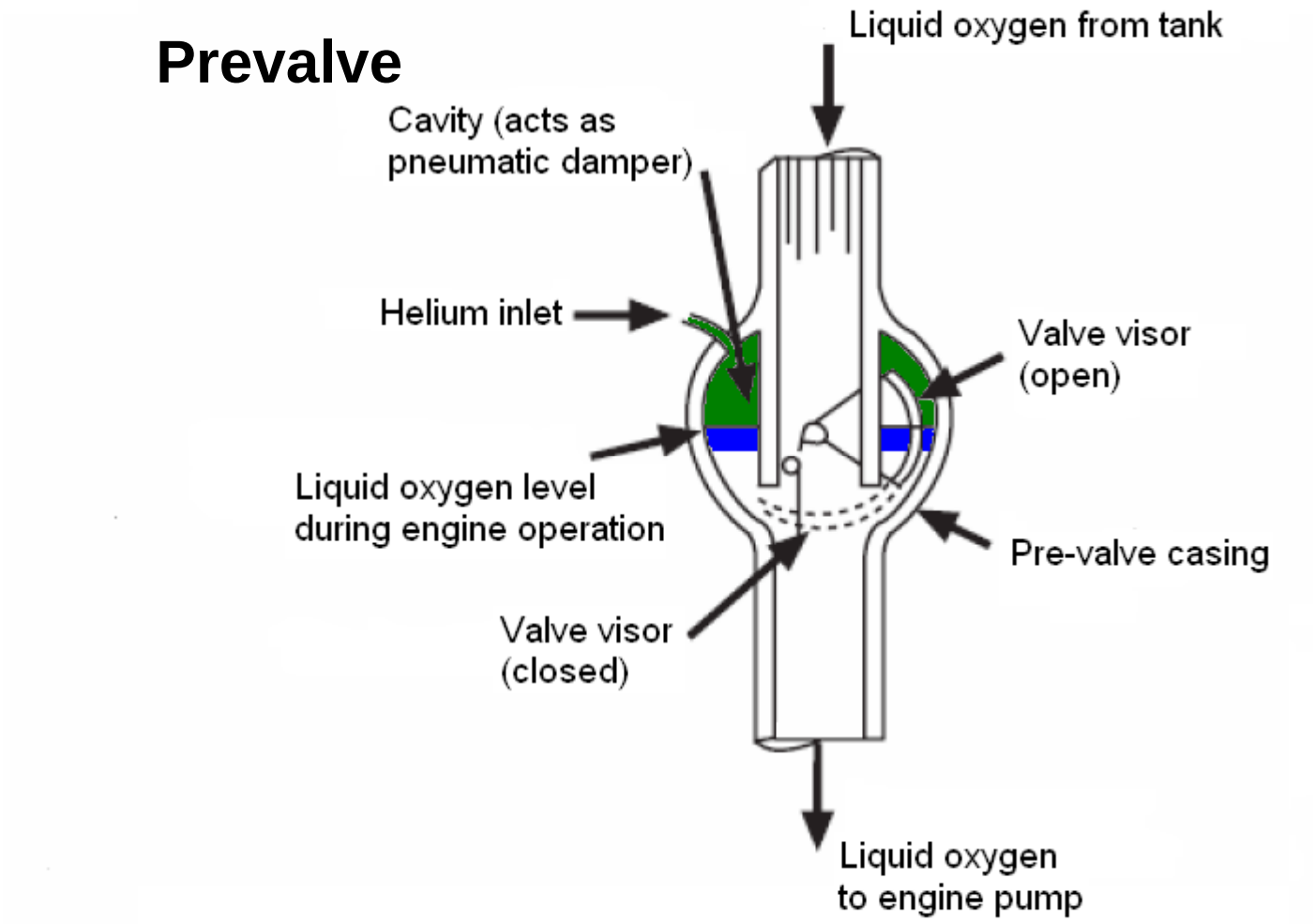
Pogo

- "Pogo" is a rocket scientist's slang for a longitudinal vibration or oscillation that sometimes occurs in rockets
- Caused by an interaction between the vehicle structure, propellant feed system, and engine system
  - Forced harmonic oscillations
- Can lead to structural failures or exceed human limitations
  - Tacoma Narrows Bridge collapse



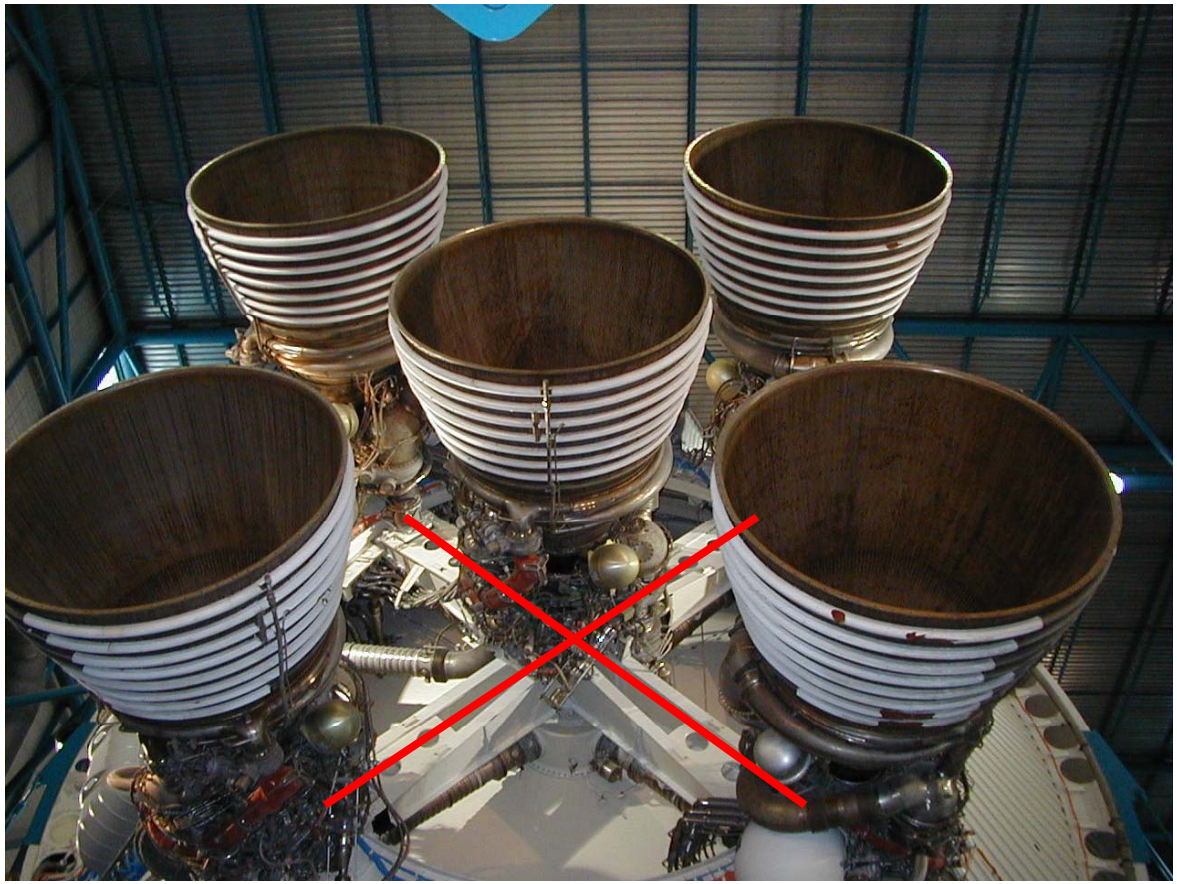
Pogo – Stage 1

- Gaseous helium was pumped into propellant line cavities (Prevalve) to dampen out the pressure changes



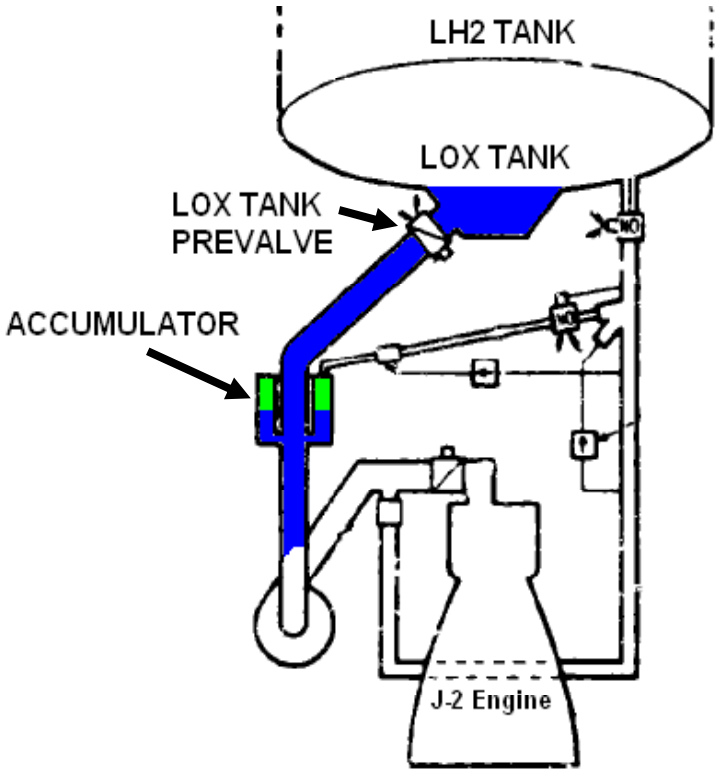
Pogo – Stage 2

- Center Engine (#5) on S-II supported only via cross beams
  - Allowed engine to move, which contributed to the Pogo effect



Pogo – Stage 2

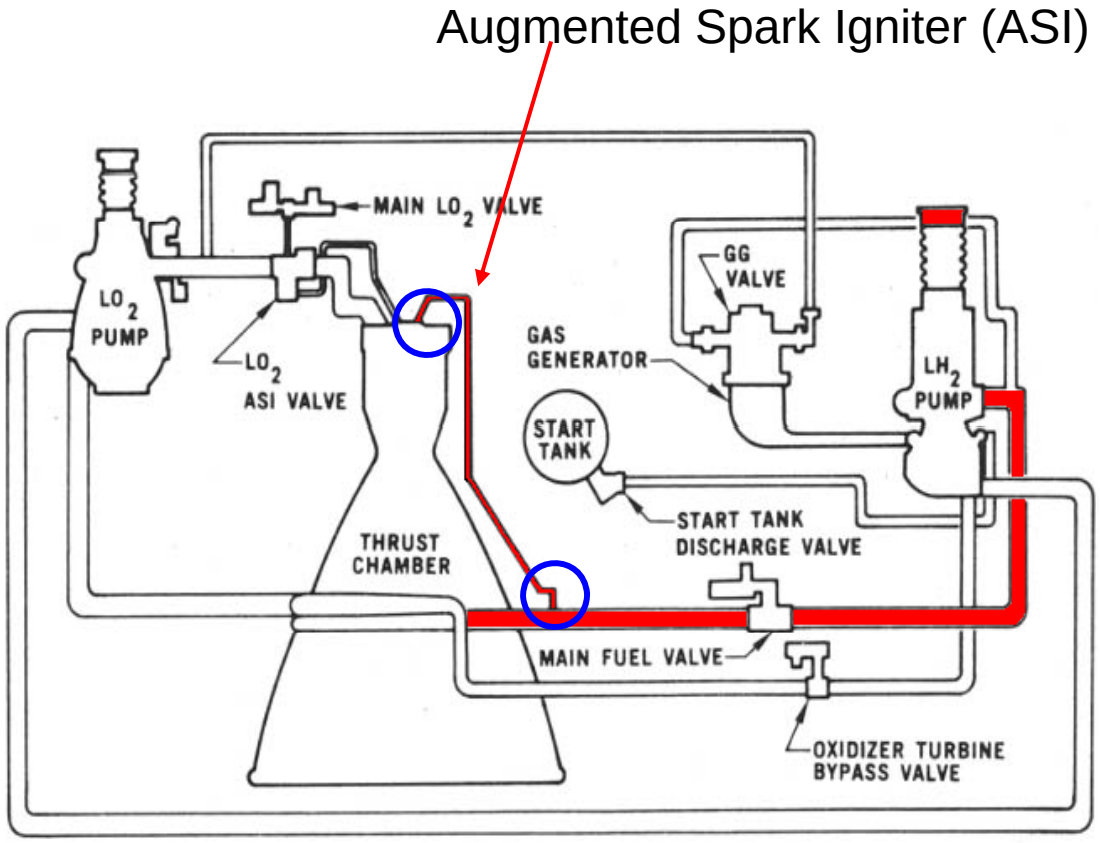
- Solution was to install a Pogo suppressor on the Center Engine
  - Accumulator filled with LOX pre-start, Helium post-ignition



Post-Flight Analysis of Apollo 6

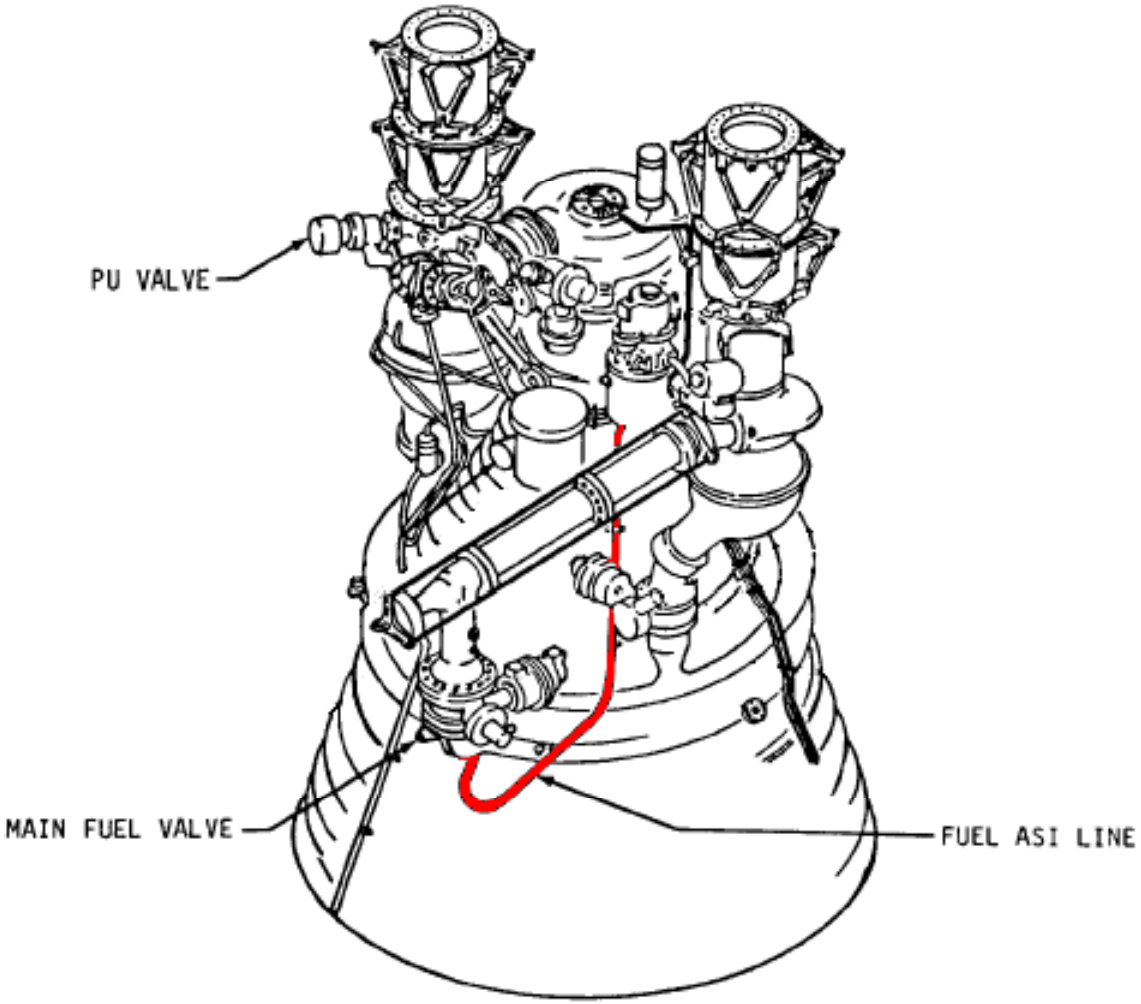
- S-II
  - Engine 2 shut down due to a fuel leak
  - Engine 3's LOX valve was incorrectly commanded to close
- S-IVB
  - Same fuel leak that occurred in S-II occurred in S-IVB

J-2 Engine Failure



- ASI ignited propellants
- ASI fuel line broke at attach points in vacuum conditions

J-2 Engine Failure



Vehicle Failures

- 13 Launches
- 0 Catastrophic failures

Summary

- Discussed a couple of weight saving measures
- Discussed a couple of manufacturing issues for the Saturn V
- Discussed Saturn V launch issues

References

- [1] “Saturn V News Reference”, August 1967
- “Stages to Saturn”, Roger Bilstein, University Press of Florida, 1993
- “NASA Experience with Pogo in Human Spaceflight Vehicles”, Dr. Curtis E. Larsen, JSC,
- “Saturn V Flight Manual (SA 503)”, November 1, 1968,
- “Saturn V Launch Vehicle Flight Evaluation Report-AS-502 Apollo 6 Mission”, June 25 1968

For More information, please visit the Apollo-Saturn Wiki