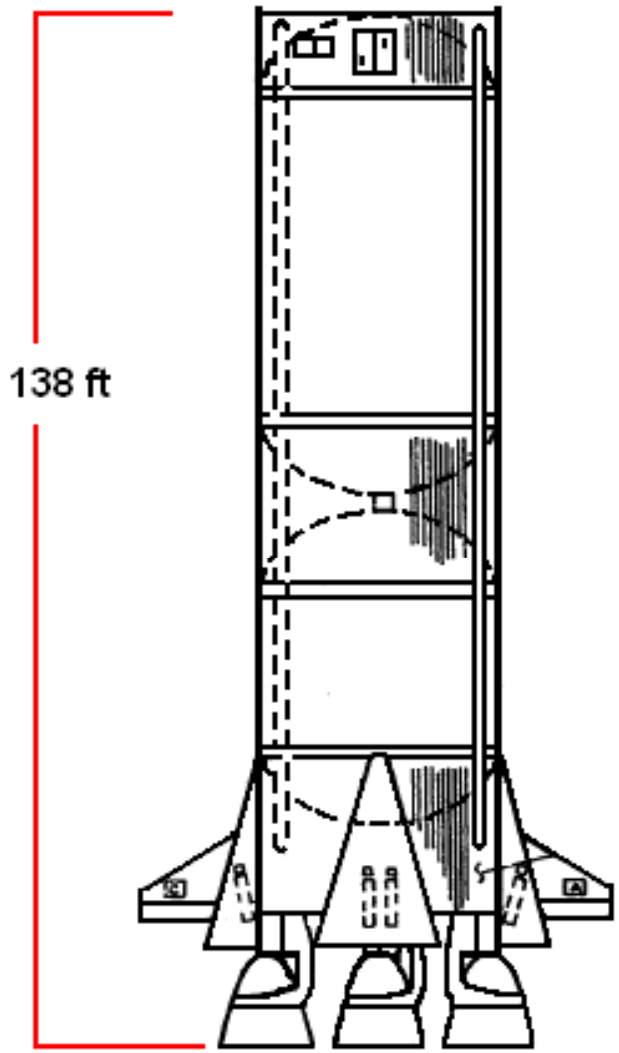
Saturn V Stage I (S-IC) Overview

Objectives

- Become familiar with the Saturn V Stage I (S-IC) major structural components:
  - Forward Skirt
  - Oxidizer Tank
  - Intertank
  - Fuel Tank
  - Thrust Structure
- Gain a general understanding of the Stage I subsystems:
  - Fuel
  - Oxidizer
  - Environmental Control
  - Electrical
  - Instrumentation
  - Flight Control
  - Control Pressure
  - Ordinance

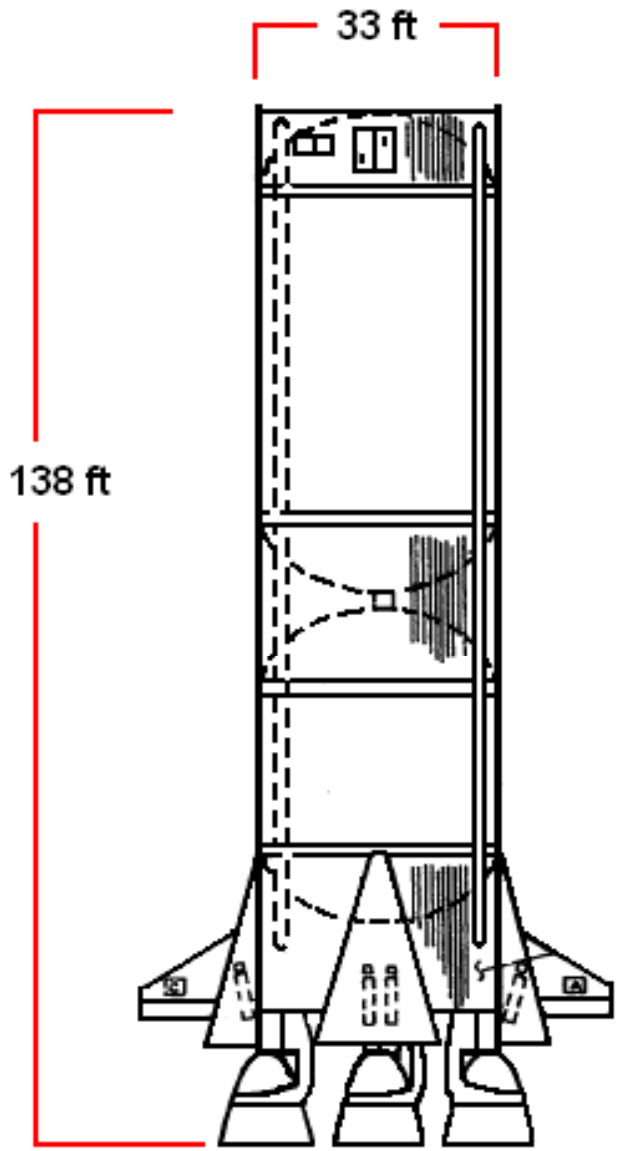
S-IC Stage Structure

- 138 feet/42 meters high



S-IC Stage Structure

- 138 ft/42 m high
- 33 ft/10 m in diameter



S-IC Stage Structure

- 138 ft/42 m high
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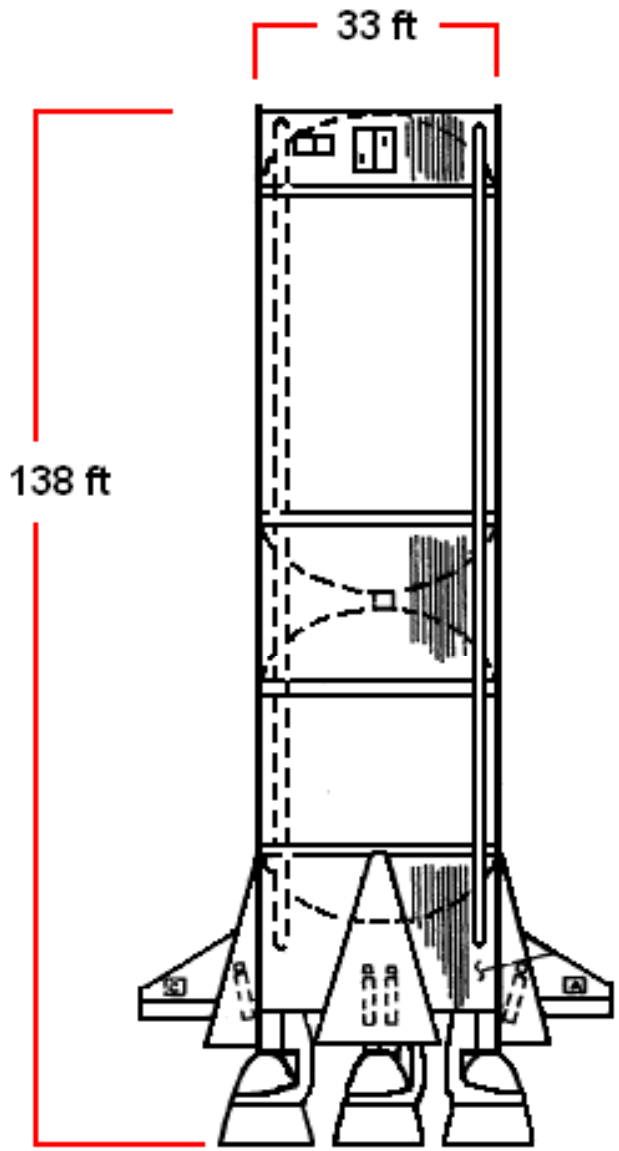
- Five F-1 engines manufactured by Rocketdyne



S-IC Stage Structure

- 138 ft/42 m high
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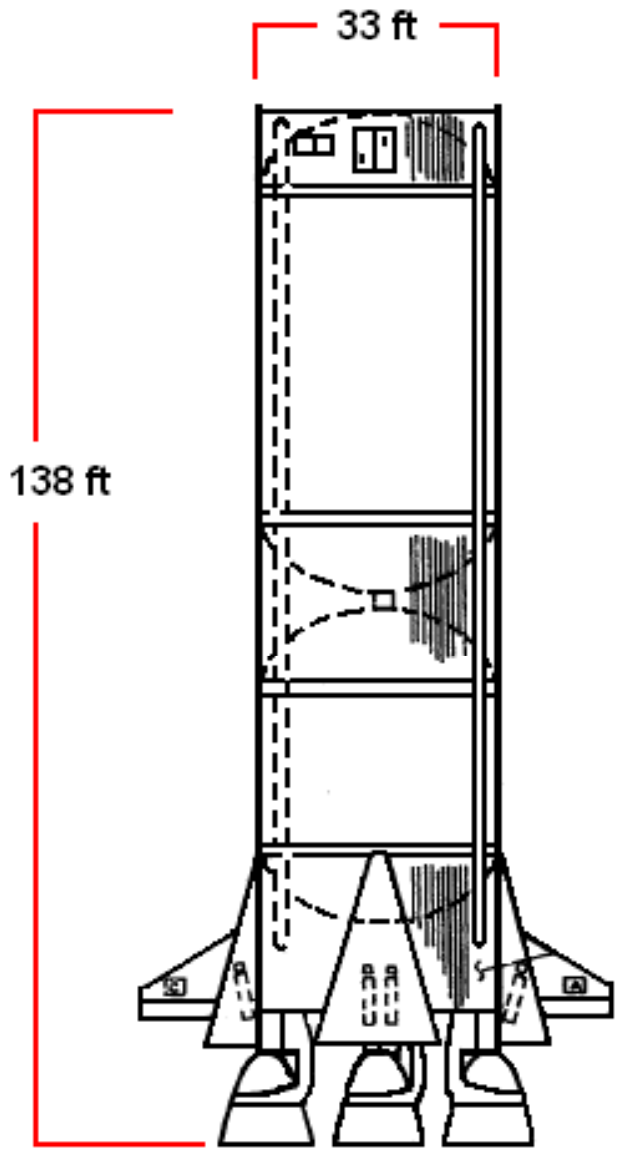
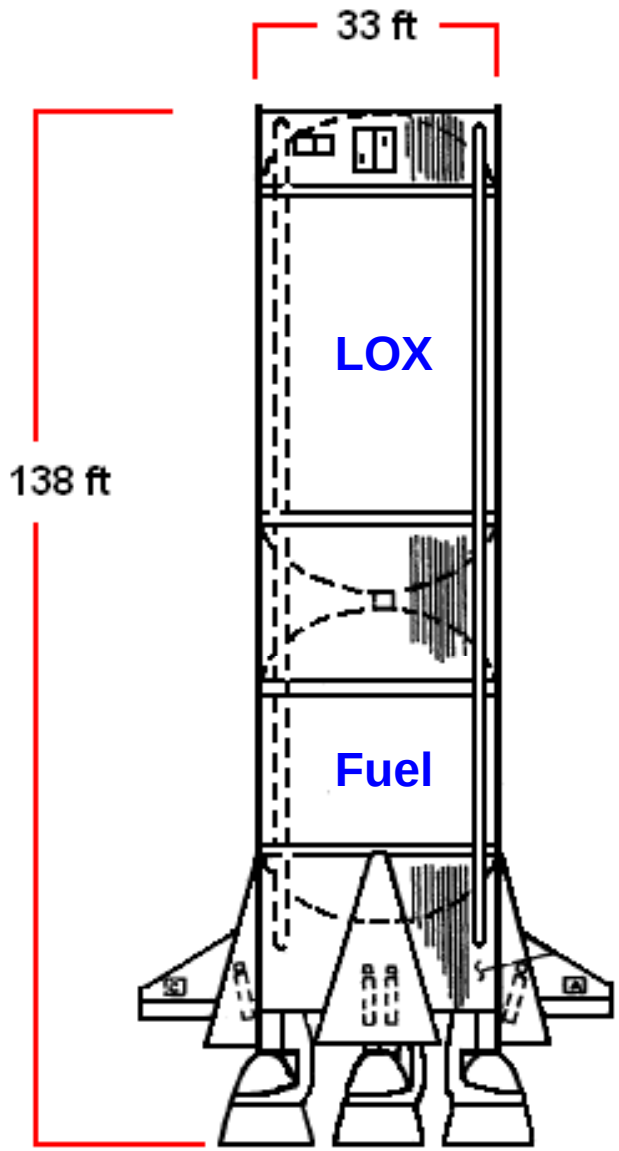
- Five F-1 engines manufactured by Rocketdyne
- Total Thrust = 7,610,000 lbs/ 3,451,838 kilograms



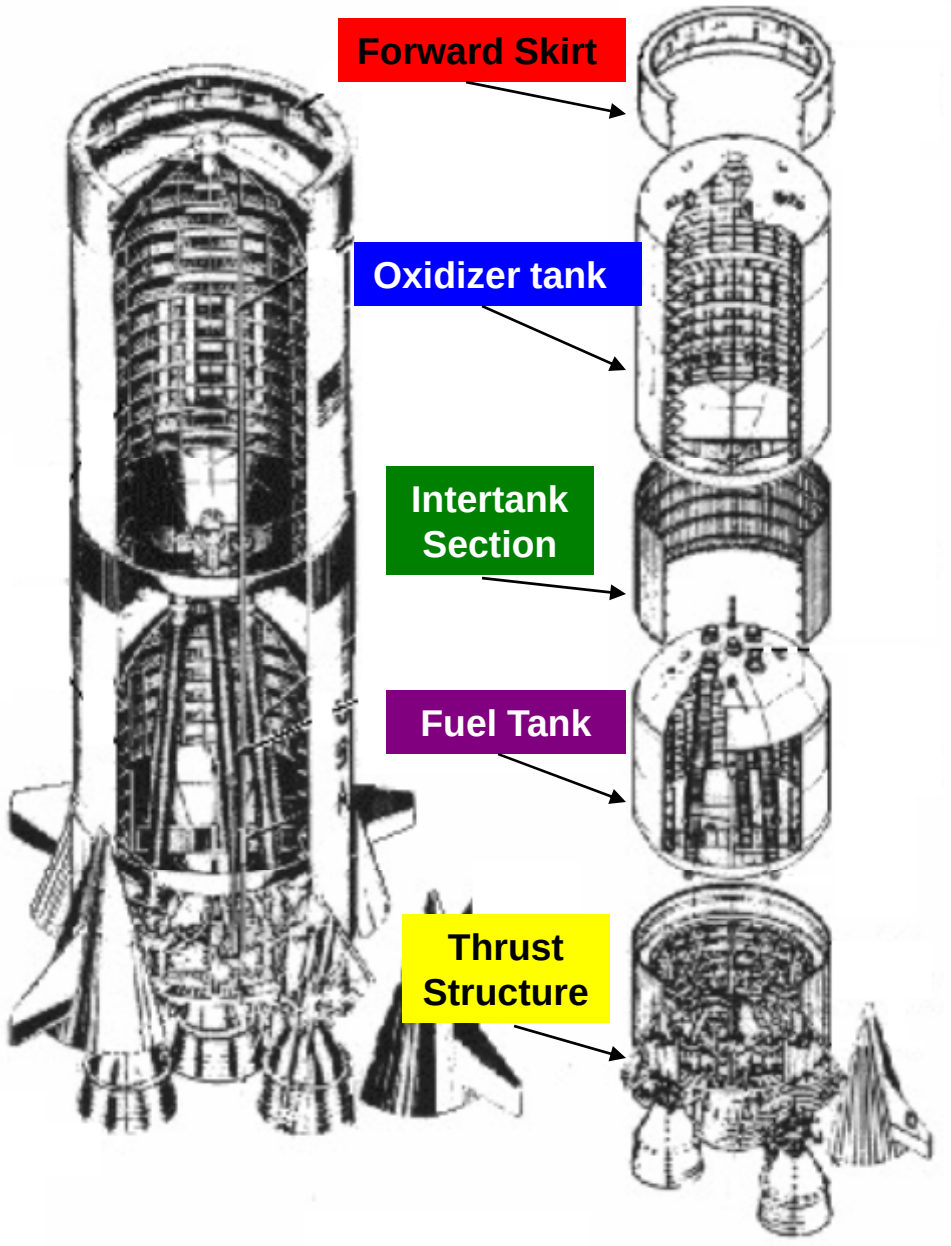
S-IC Stage Structure

- 138 ft/42 m high
- 33 ft/10 m in diameter
- Five F-1 engines manufactured by Rocketdyne
- Total Thrust = 7,610,000 lbs/ 3,451,838 kilograms
- Two propellants
  - Liquid Oxygen (LOX or RJ-1)
  - Fuel/Kerosene (RP-1)



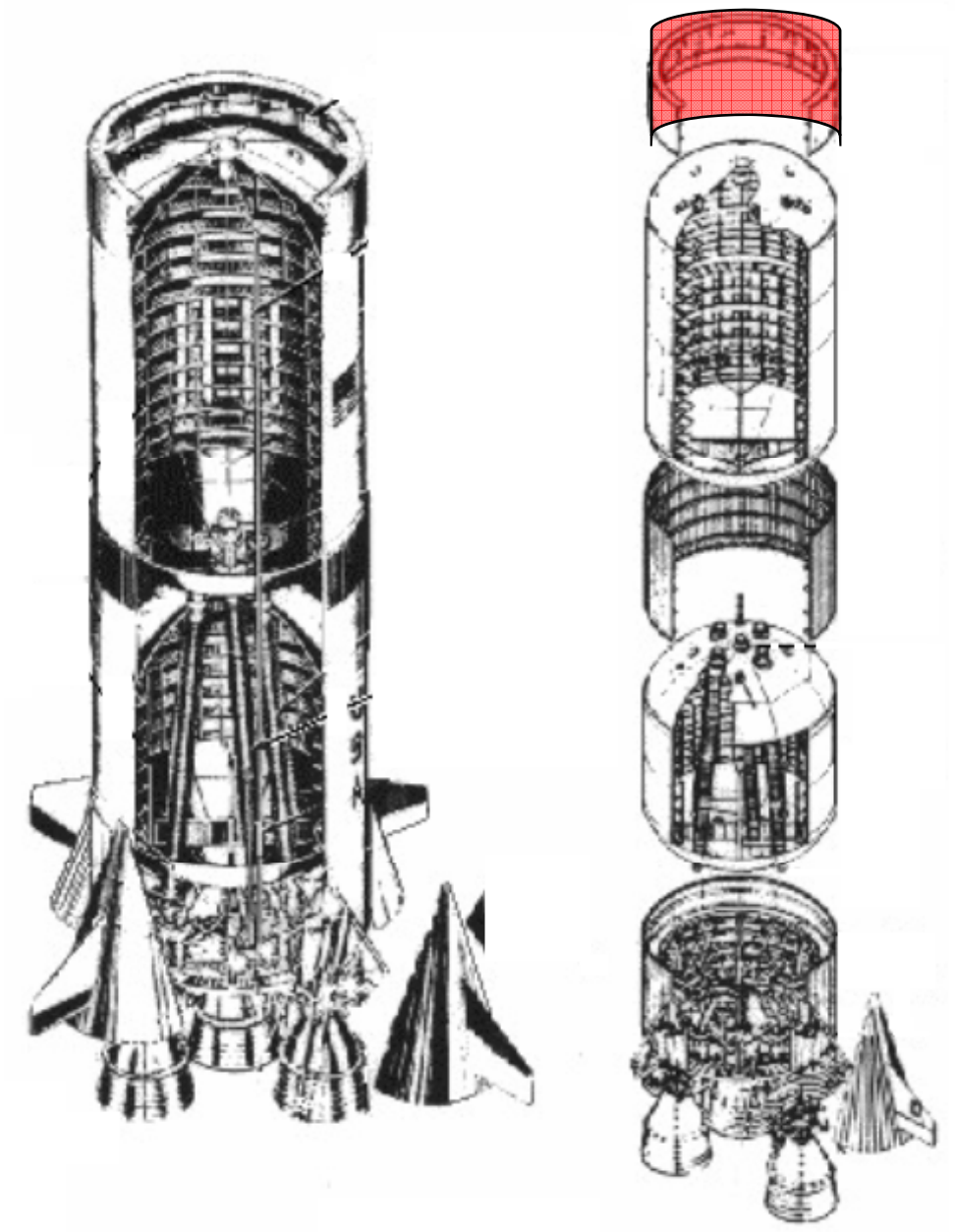
S-IC Stage Components

- Forward Skirt
- Oxidizer Tank
- Intertank Section
- Fuel Tank
- Thrust Structure



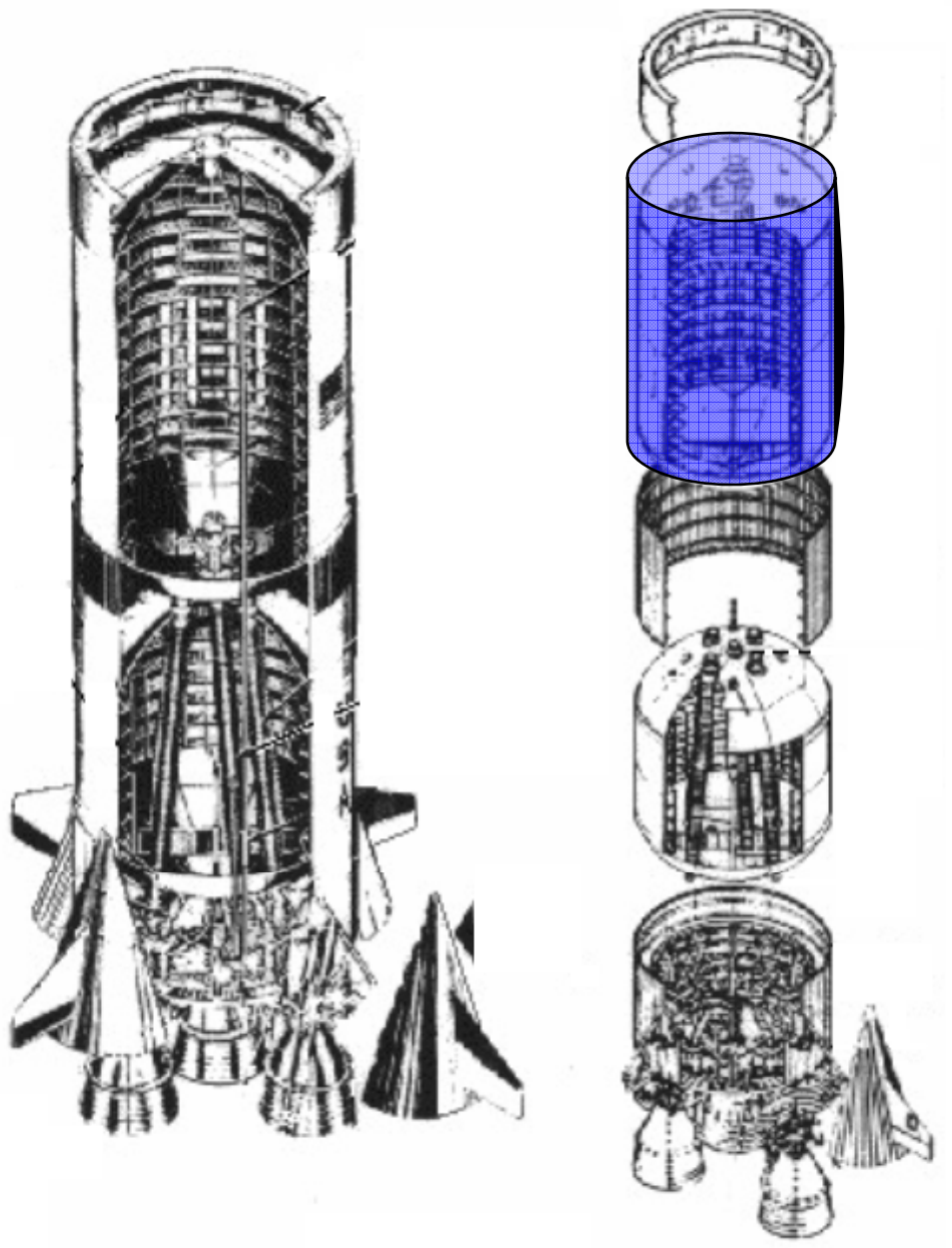
Forward Skirt

- Provides connecting link for First & Second Stage
- Accommodates:
  - Forward umbilical plate
  - Electrical canisters
  - Venting of LOX tank



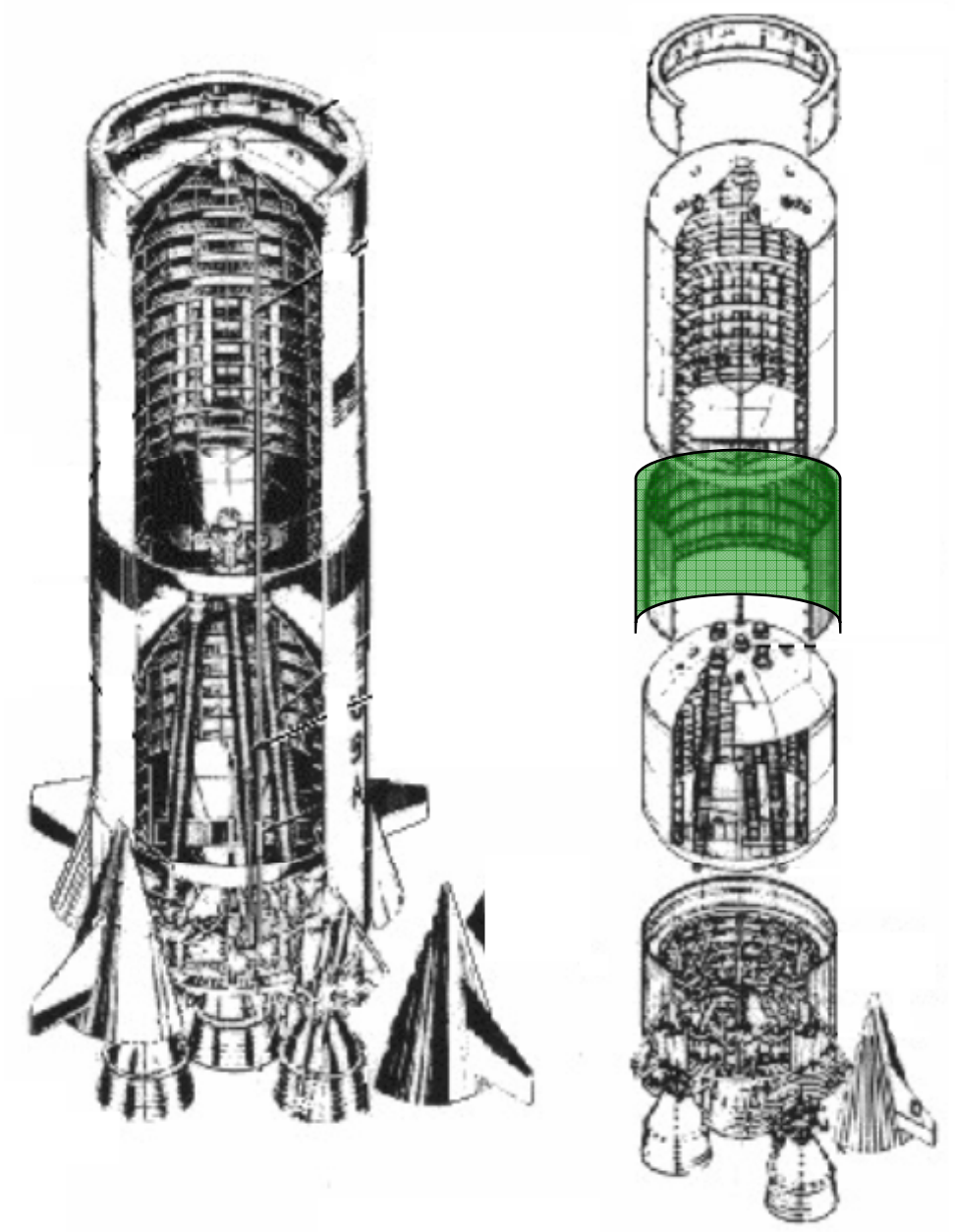
Oxidizer Tank

- Held 331,000 gallons/1,252,971 liters of liquid oxygen
- -297° F (-183° C)
- Contained ring baffles for structural stability
  - Reduced LOX sloshing
  - Supported Helium (He) bottles



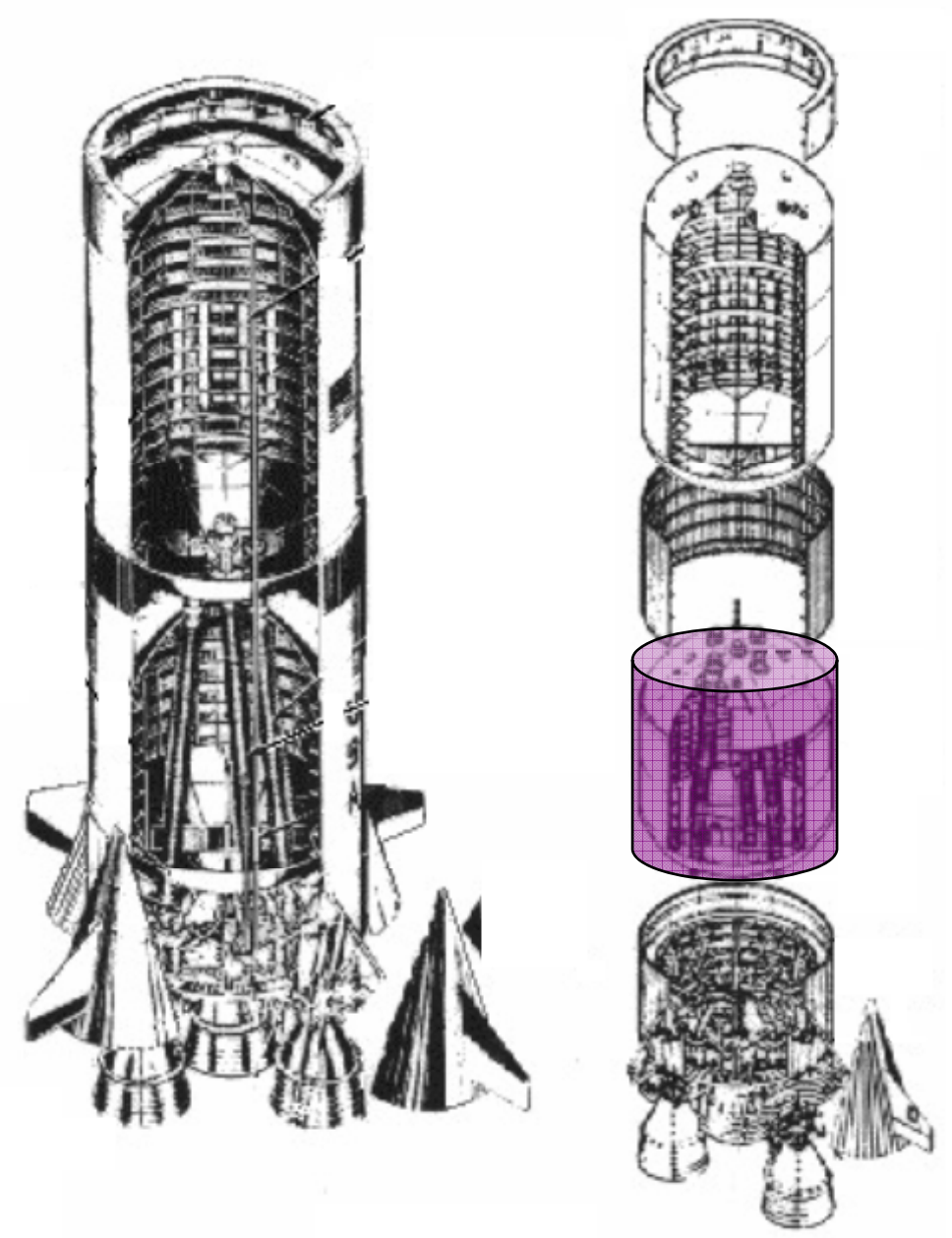
Intertank Section

- Provided structural continuity between LOX & Fuel Tank
- LOX fill & drain interface to intertank umbilical
- Vented the fuel tank



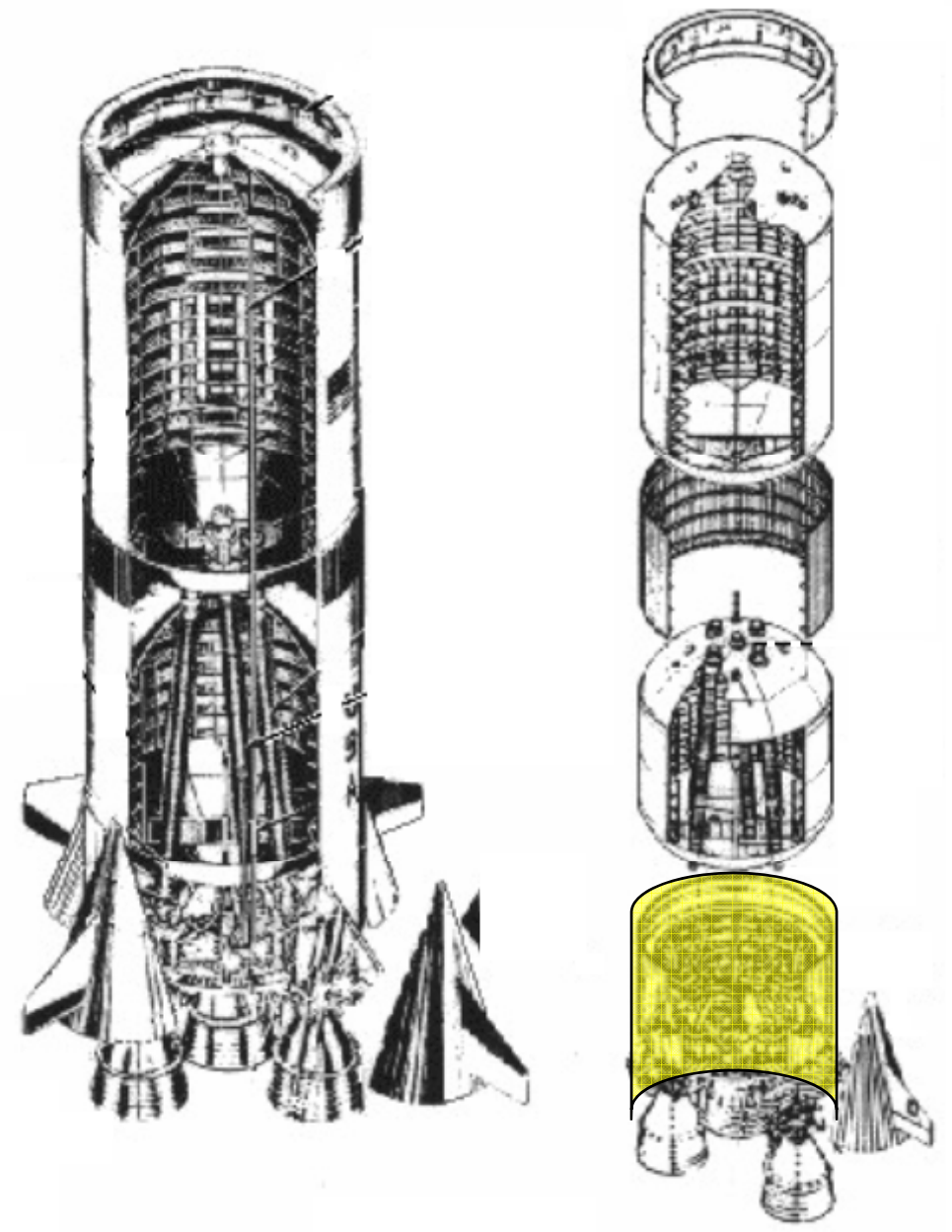
Fuel Tank

- Held 203,000 gallons/768,438 liters of RP-1
- Antislosh ring baffles on inner walls
- Antivortex ring baffles on lower bulkhead
- Five LOX ducts run from LOX tank through fuel tank



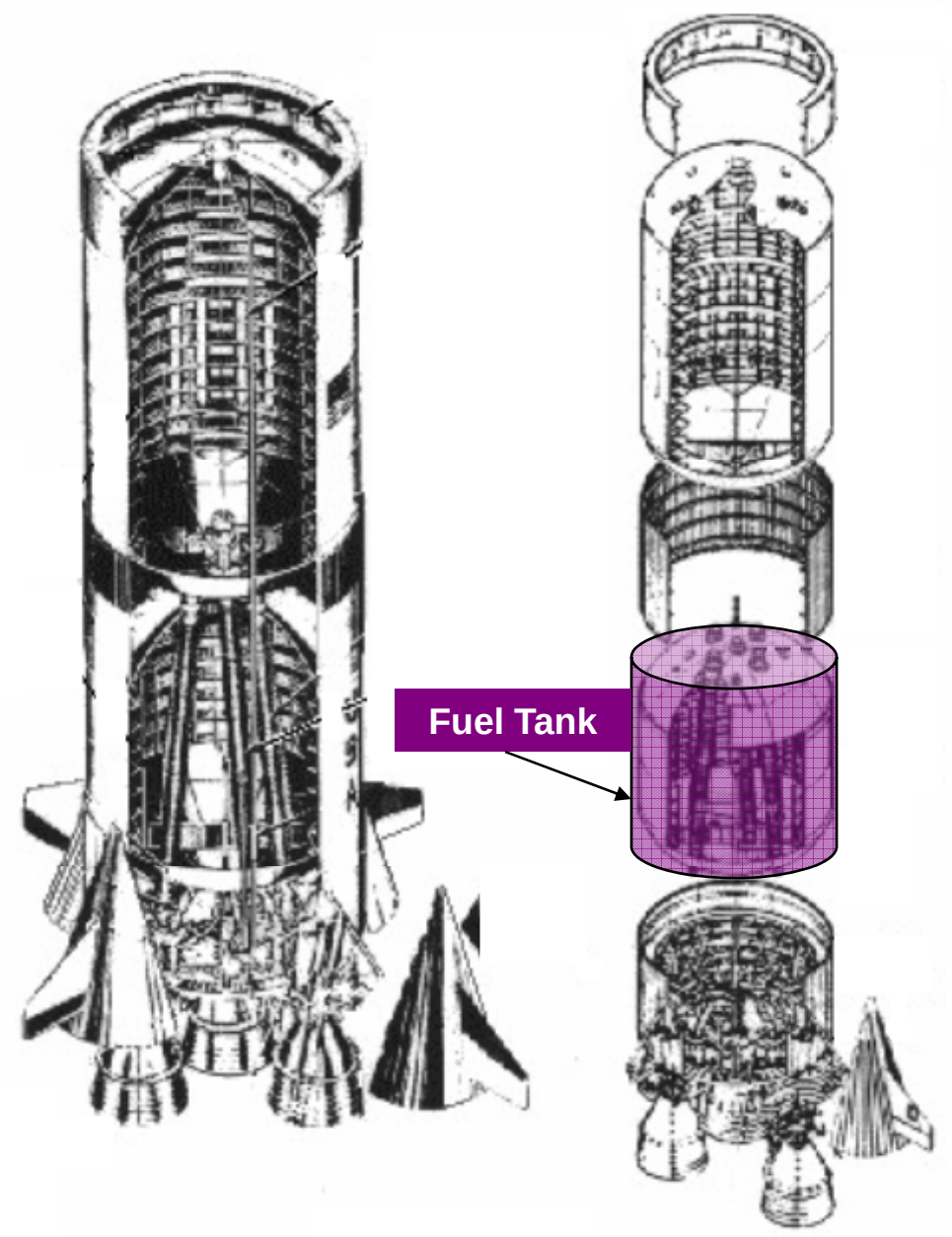
Thrust Structure

- Provided support for:
  - Base heat shield
  - Engine fairings & fins
  - Propellant lines
  - Retrorockets
  - Environmental control ducts
- Lower thrust ring had four hold-down points to restrain vehicle



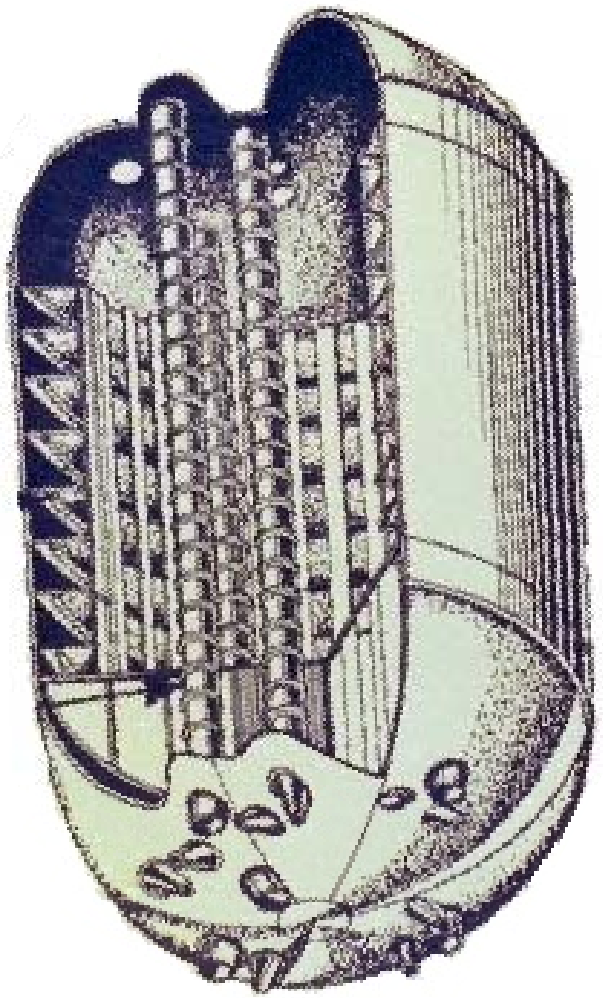
Stage I Subsystems

- **Fuel System**
- Oxidizer System
- Environmental Control System
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordinance System



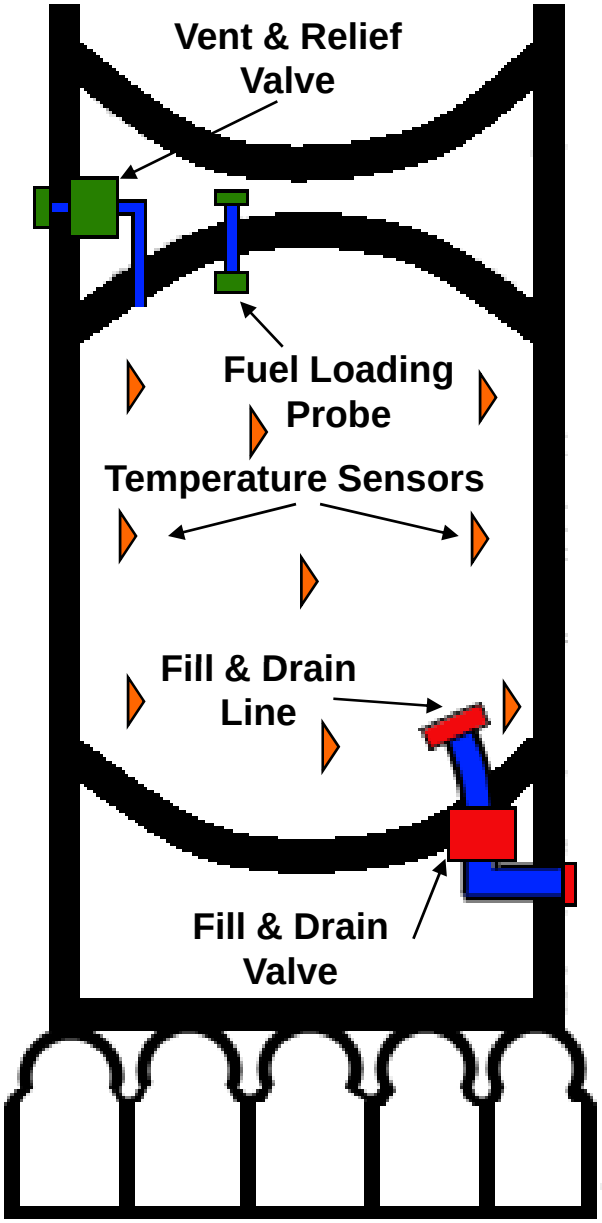
Fuel System

- Consisted of fuel tank, fuel feed lines, pressurization system, fill and drain components, & fuel conditioning system
- Held 203,000 gallons/ 768,438 liters of kerosene
- Provided 1,350 gallons/5,110 liters of fuel per second
- 10 fuel suction lines



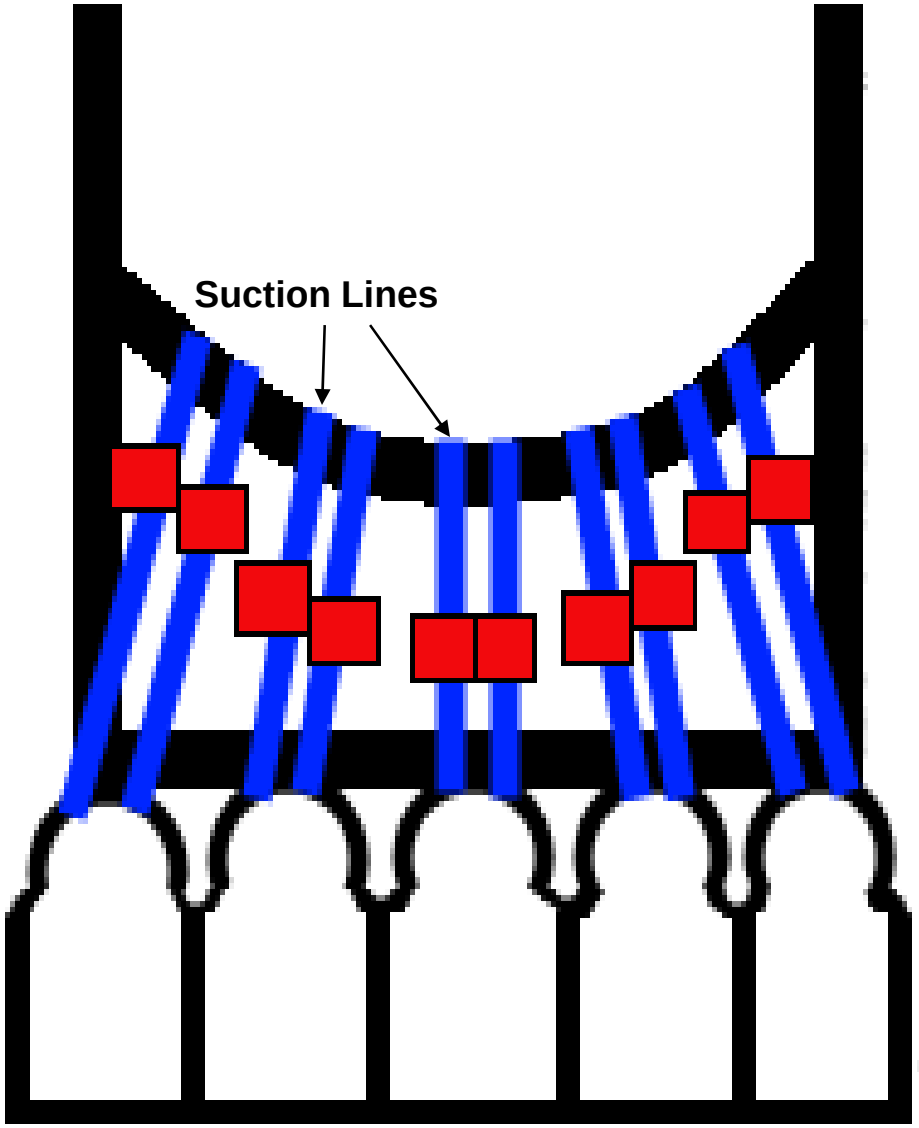
Fuel System: Fuel Fill & Drain System

- Filled through six-inch Fill & Drain Line
- Fill & Drain Valve provided fuel shutoff
- Temperature Sensors used to compute fuel density
- Tank level filled to 102%, then the Fuel Loading Probe indicated overload
- After adjustments, Fill & Drain Valve closed



Fuel System: Fuel Feed

- 10 Fuel Suction Lines
  - Two/engine
  - Supplied fuel to F-1 engine inlets



Fuel System: Fuel Feed

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  - Two/engine
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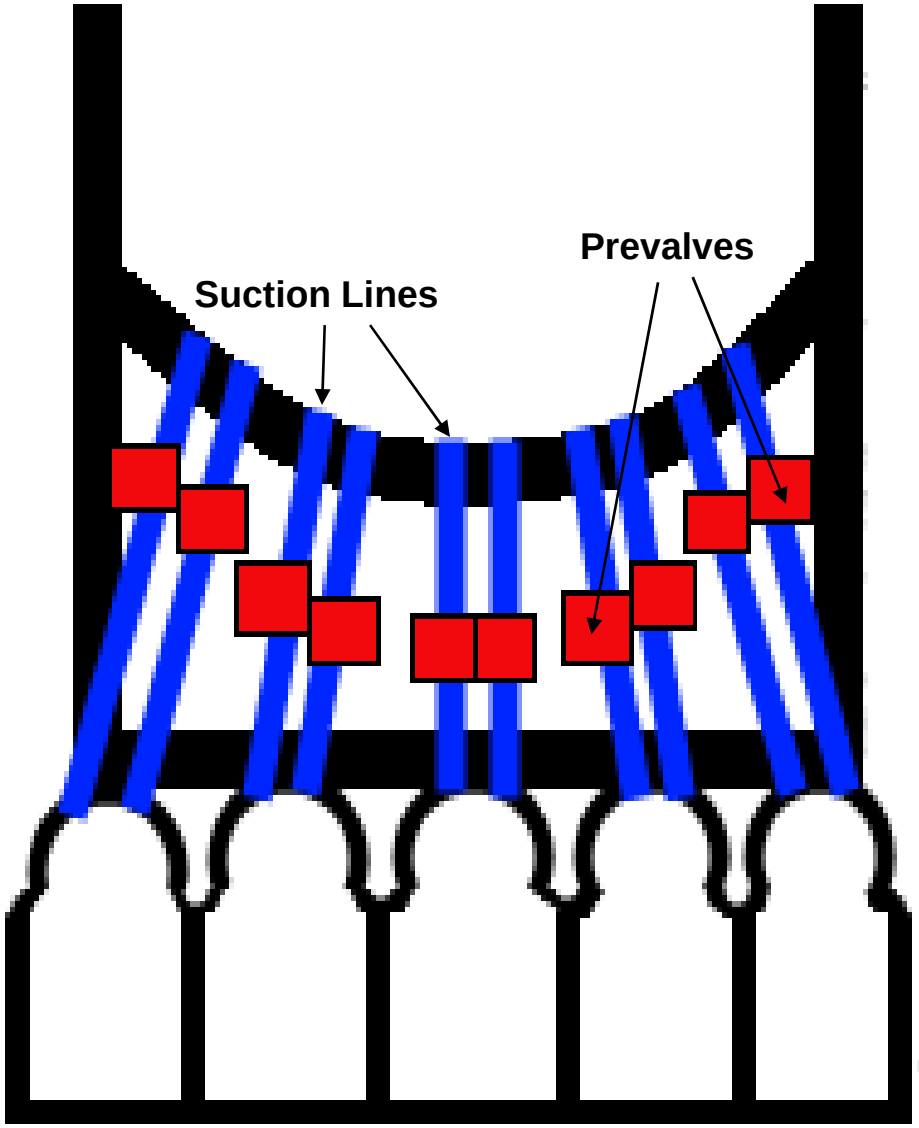
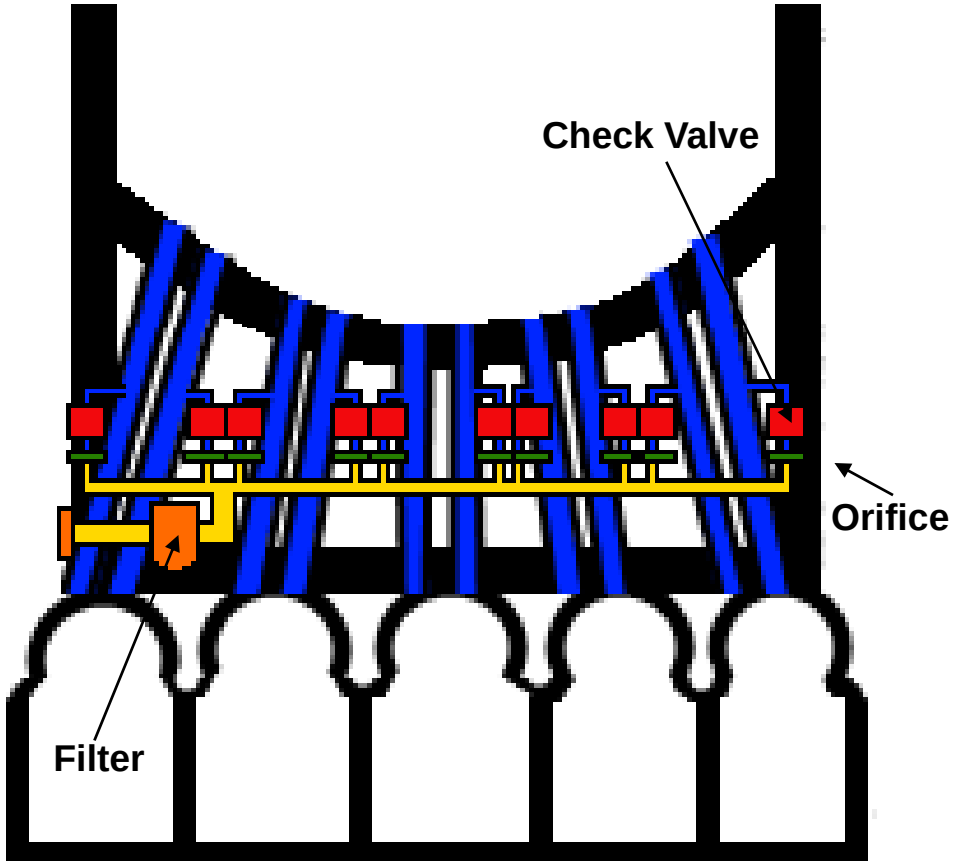
- Each line had pneumatically controlled Prevalve



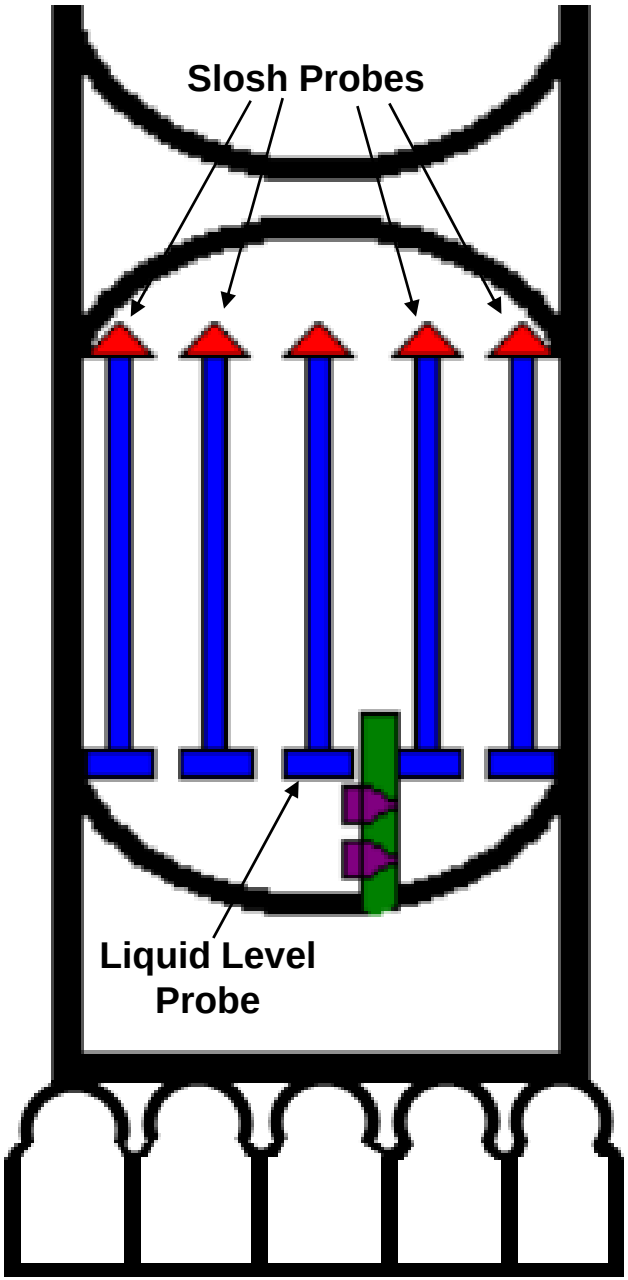
Fuel System: Fuel Conditioning

- Bubbled GN_2 through feed lines to prevent fuel temperature stratification prior to launch
- Wire mesh Filter prevented discharge of contaminants
- Check Valve prevented fuel from entering GN_2 lines
- Orifice provided proper GN_2 flow into each fuel duct



Fuel System: Fuel Level Sensing & Engine Cutoff

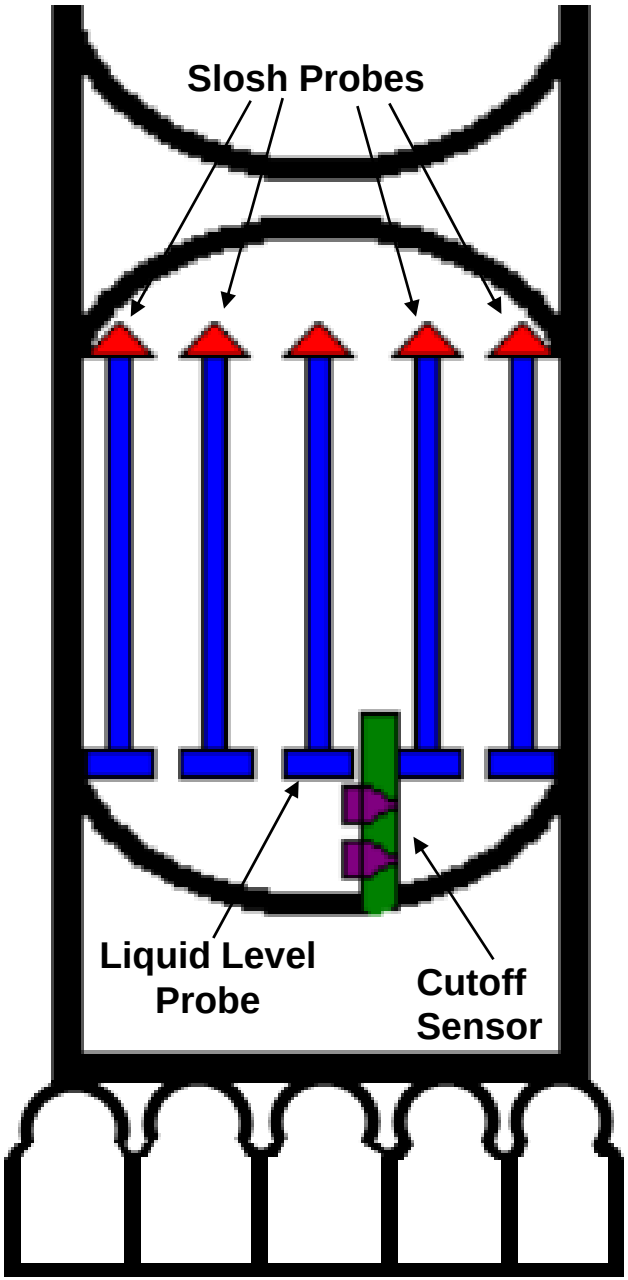
- Fuel measured by four fuel Slosh Probes & one Liquid Level Probe



Fuel System: Fuel Level Sensing & Engine Cutoff

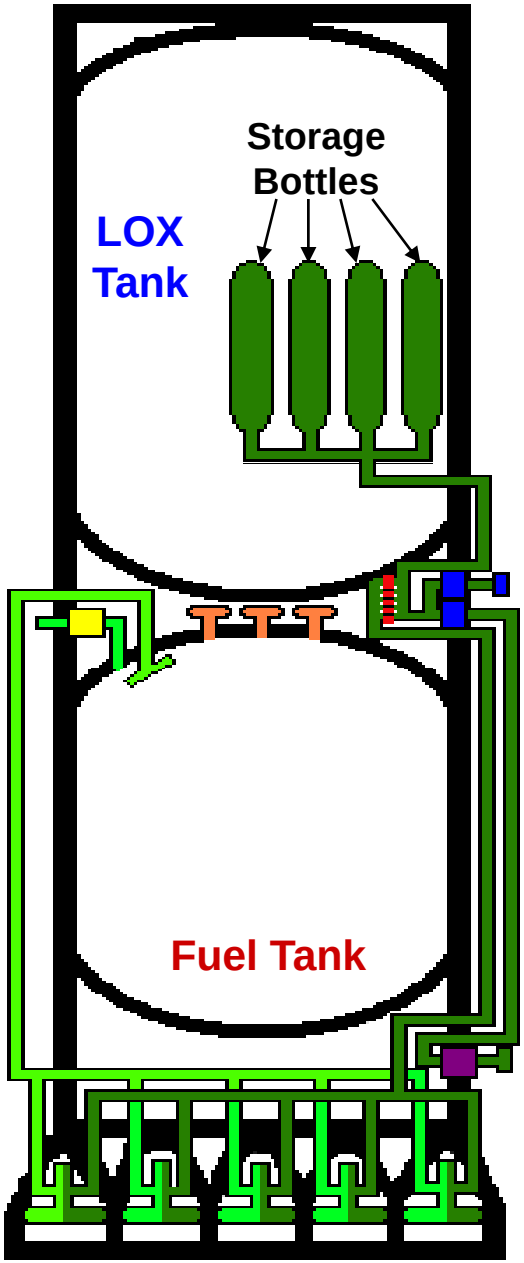
- Fuel measured by four fuel Slosh Probes & one Liquid Level Probe

- In case fuel depleted before LOX, fuel system will shut down engine
  - Cutoff Sensor provided signal voltages to shut off fuel
  - Cutoff Sensor initiated engine cutoff as fuel falls below two sensing points on probe



Fuel System: Fuel Pressurization System

- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage



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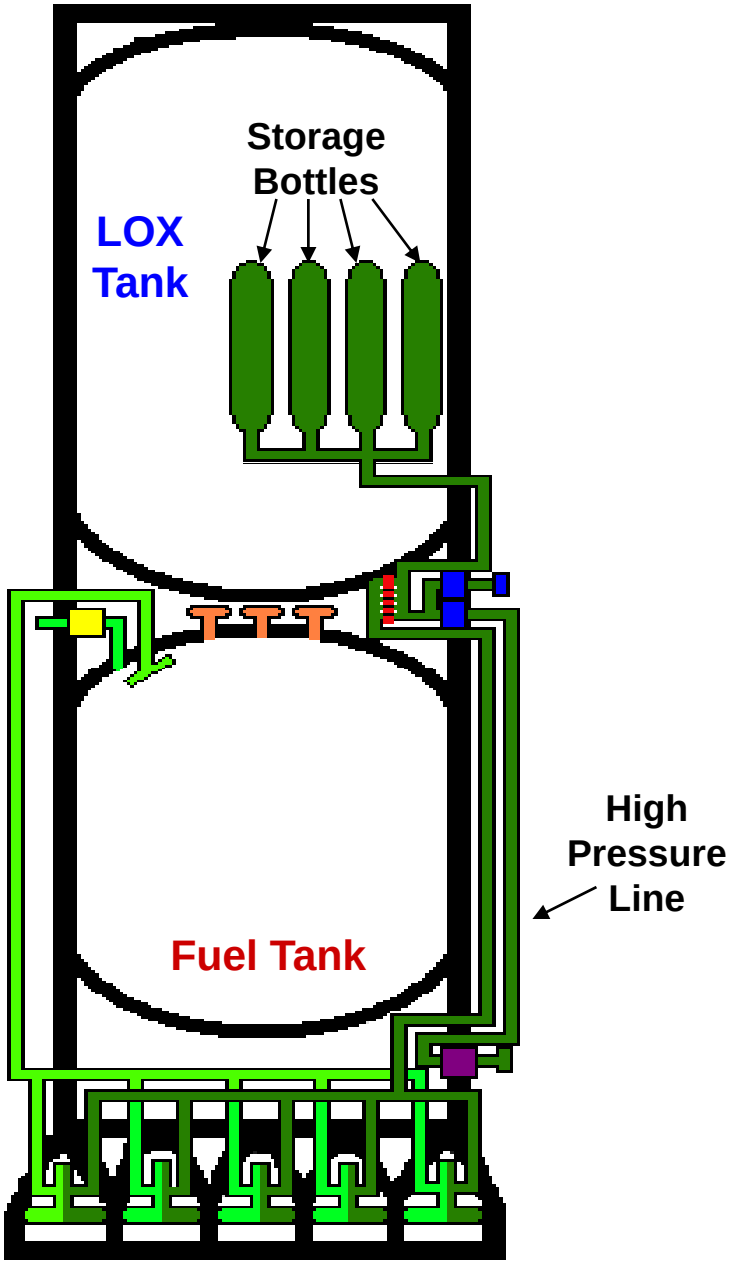
- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage
- High Pressure Line used for filling Storage Bottles



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- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage
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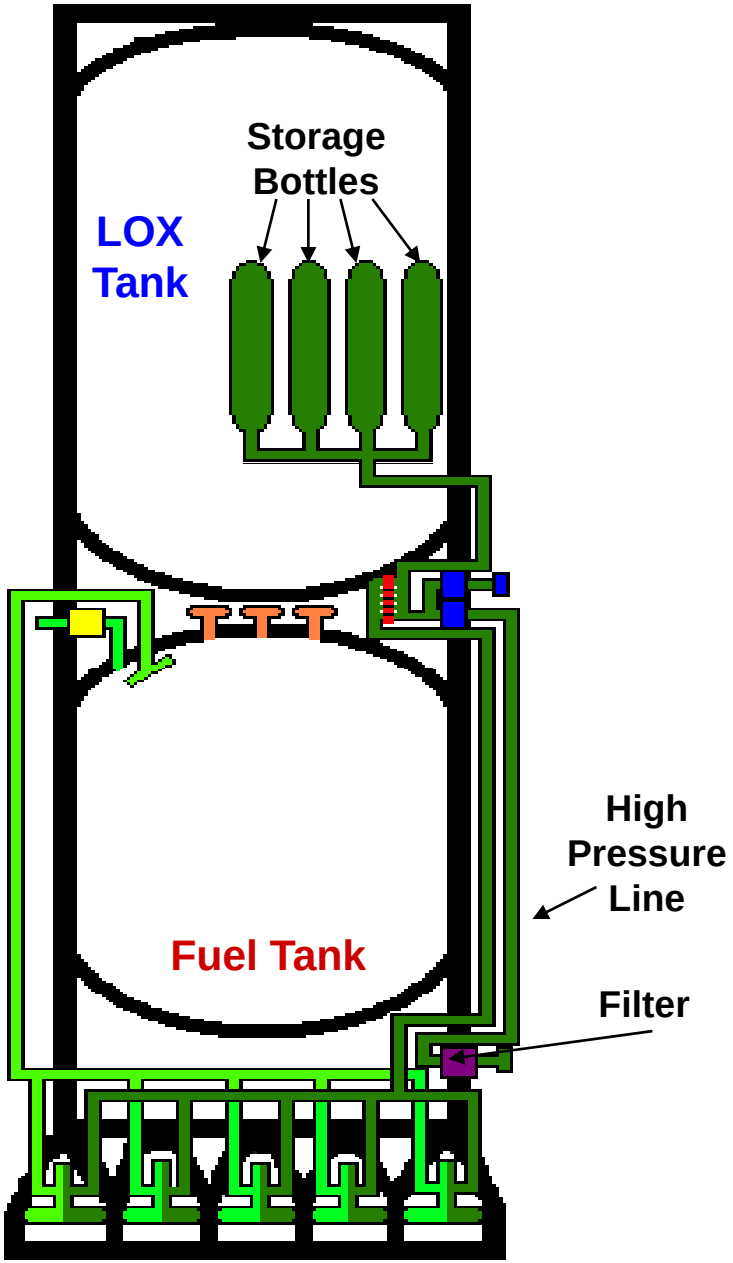
- Filter in He fill line prevented contaminants from entering Flight Pressurization System



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- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage
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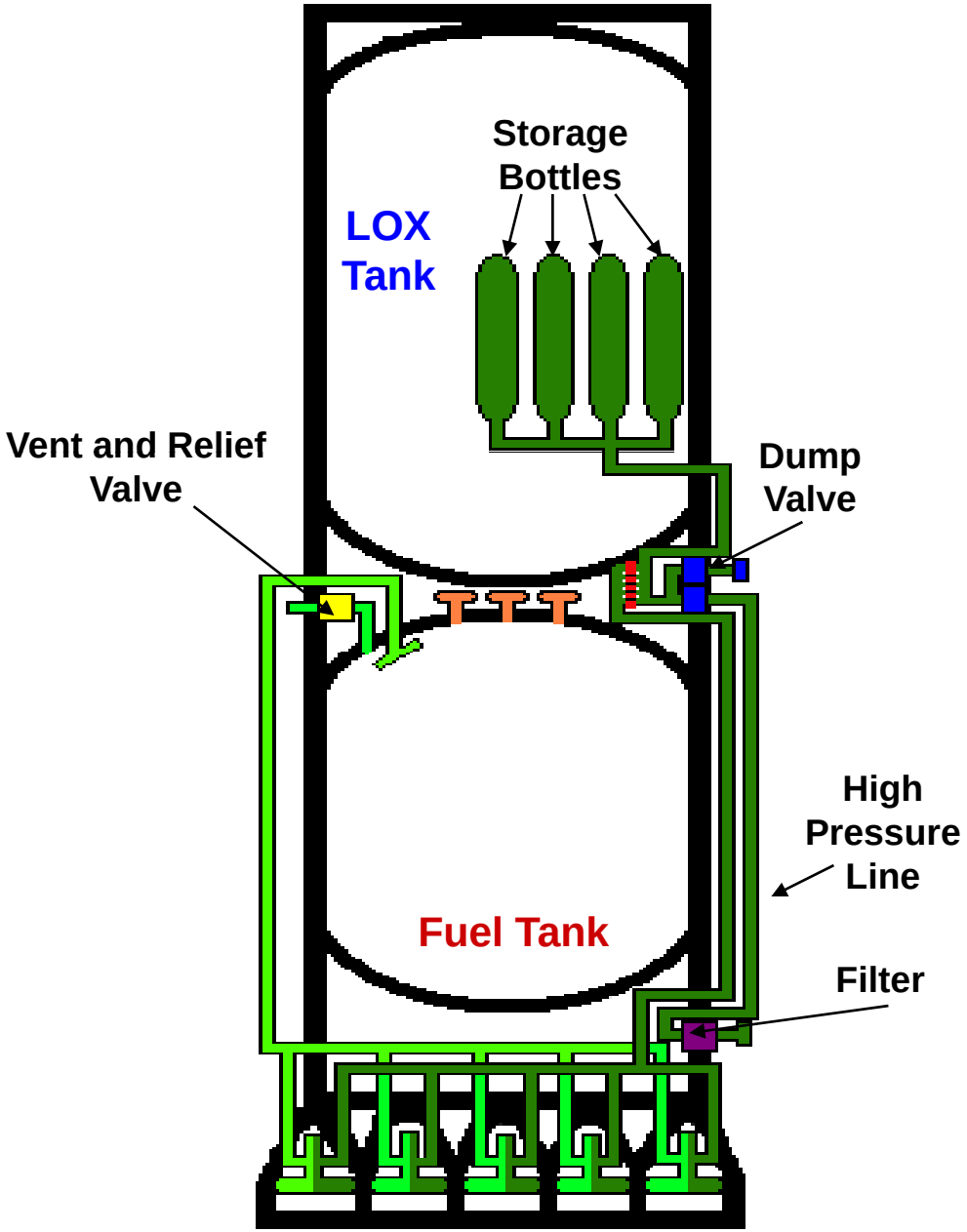
- Dump Valve for emergencies



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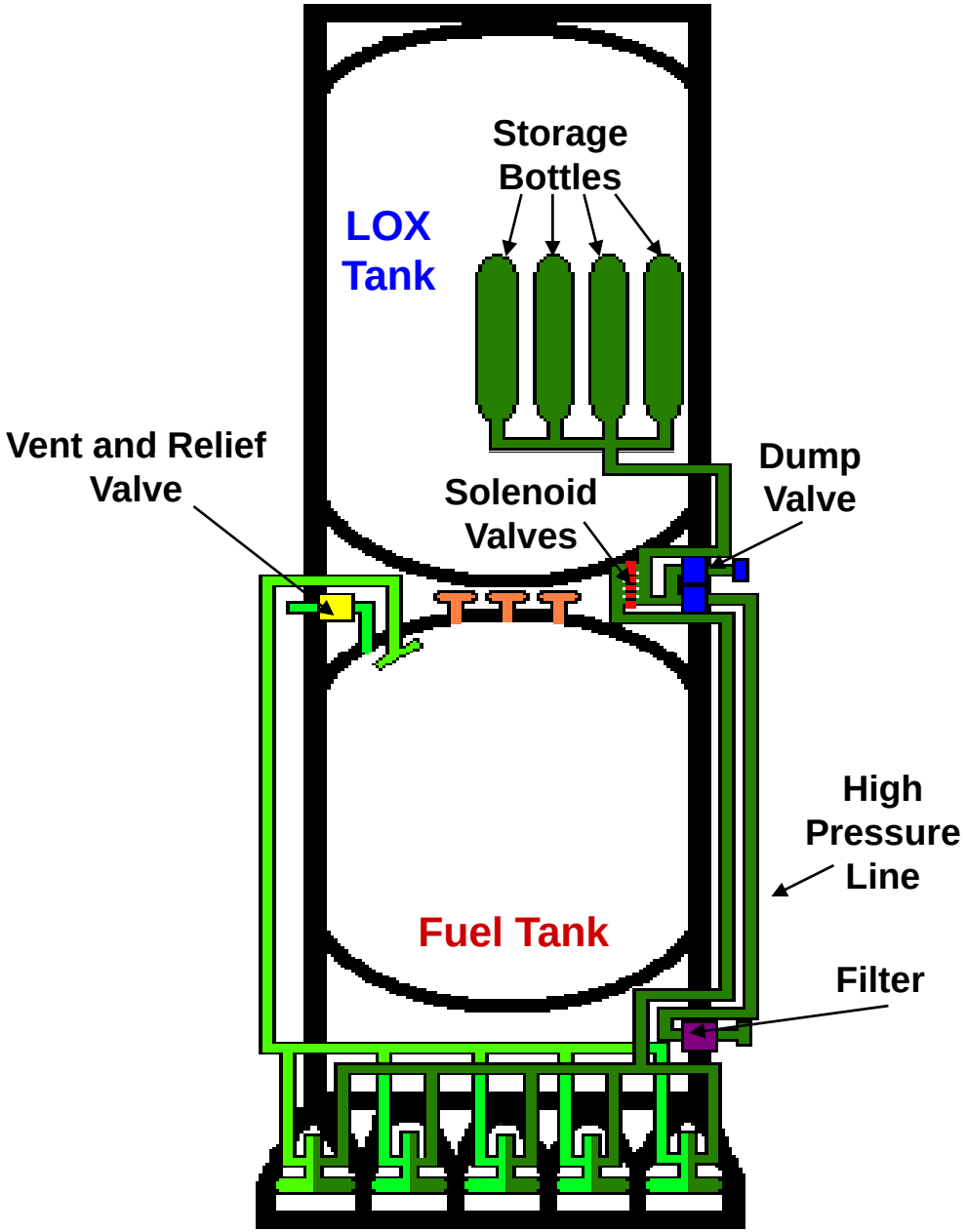
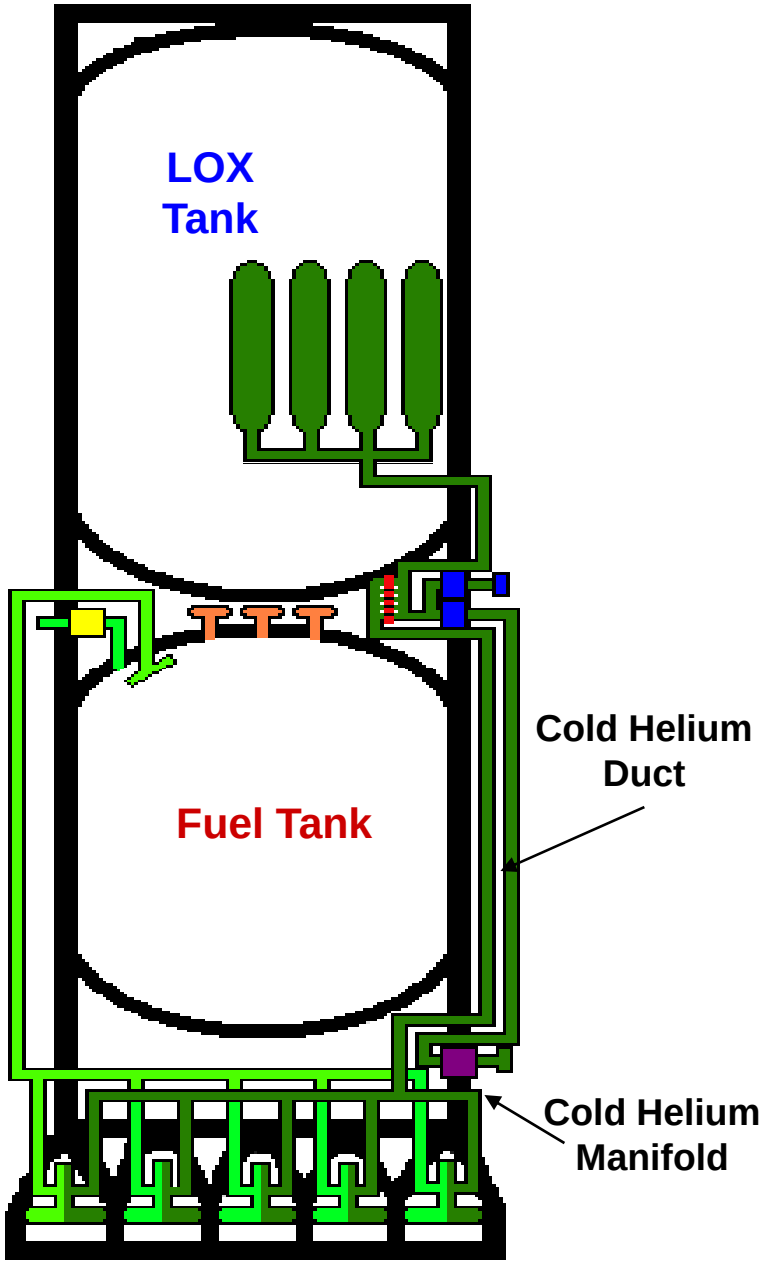
- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage
- High Pressure Line used for filling Storage Bottles
- Filter in He fill line prevented contaminants from entering Flight Pressurization System
- Dump Valve for emergencies
- Five Solenoid Valves in parallel to control He flow to Fuel Tank ullage



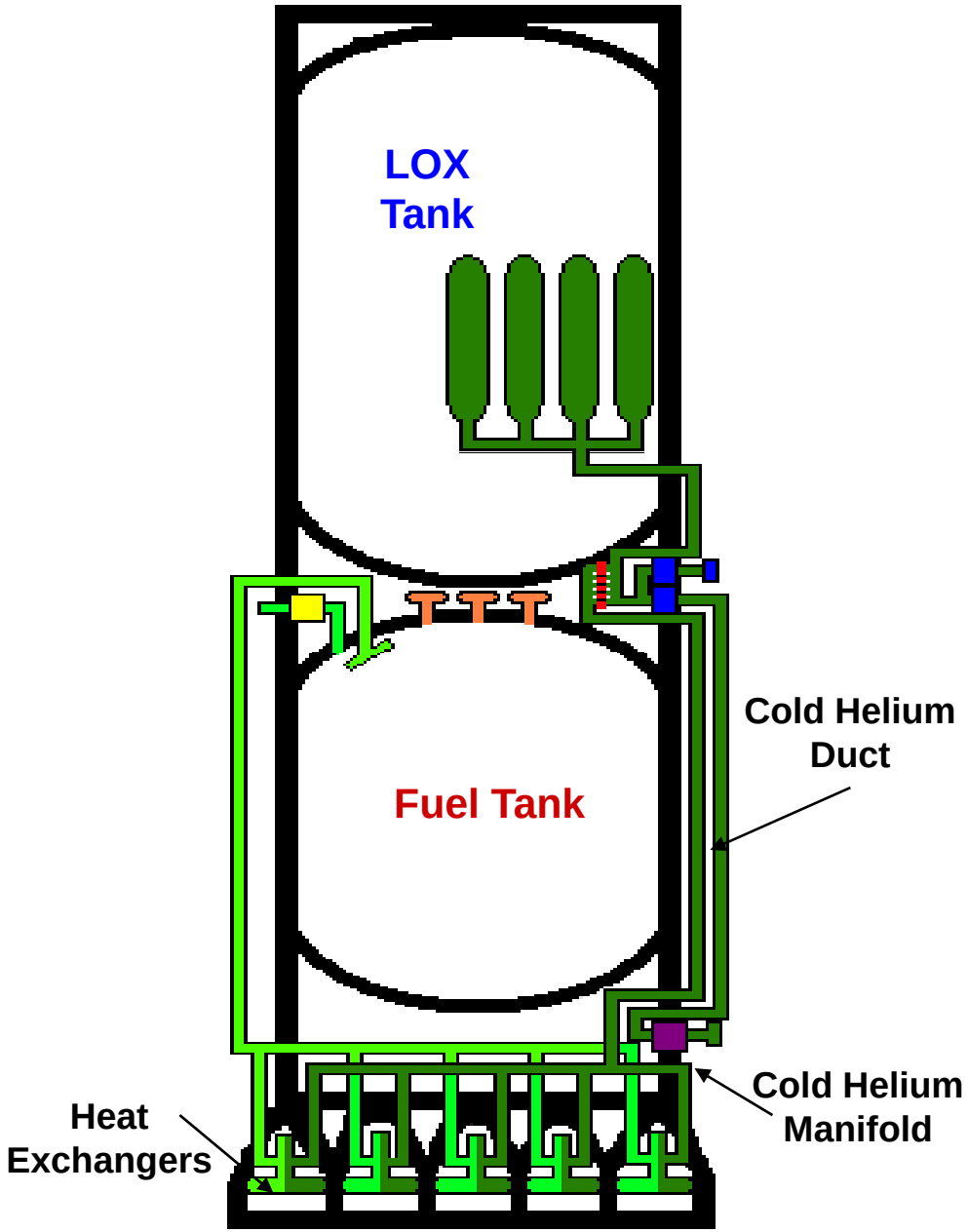
Fuel System: Fuel Pressurization System

- Cold He Duct routed He from Flow Controller to Cold He Manifold



Fuel System: Fuel Pressurization System

- Cold He Duct routed He from Flow Controller to Cold He Manifold
- He was distributed to Heat Exchangers on all five F-1 engines



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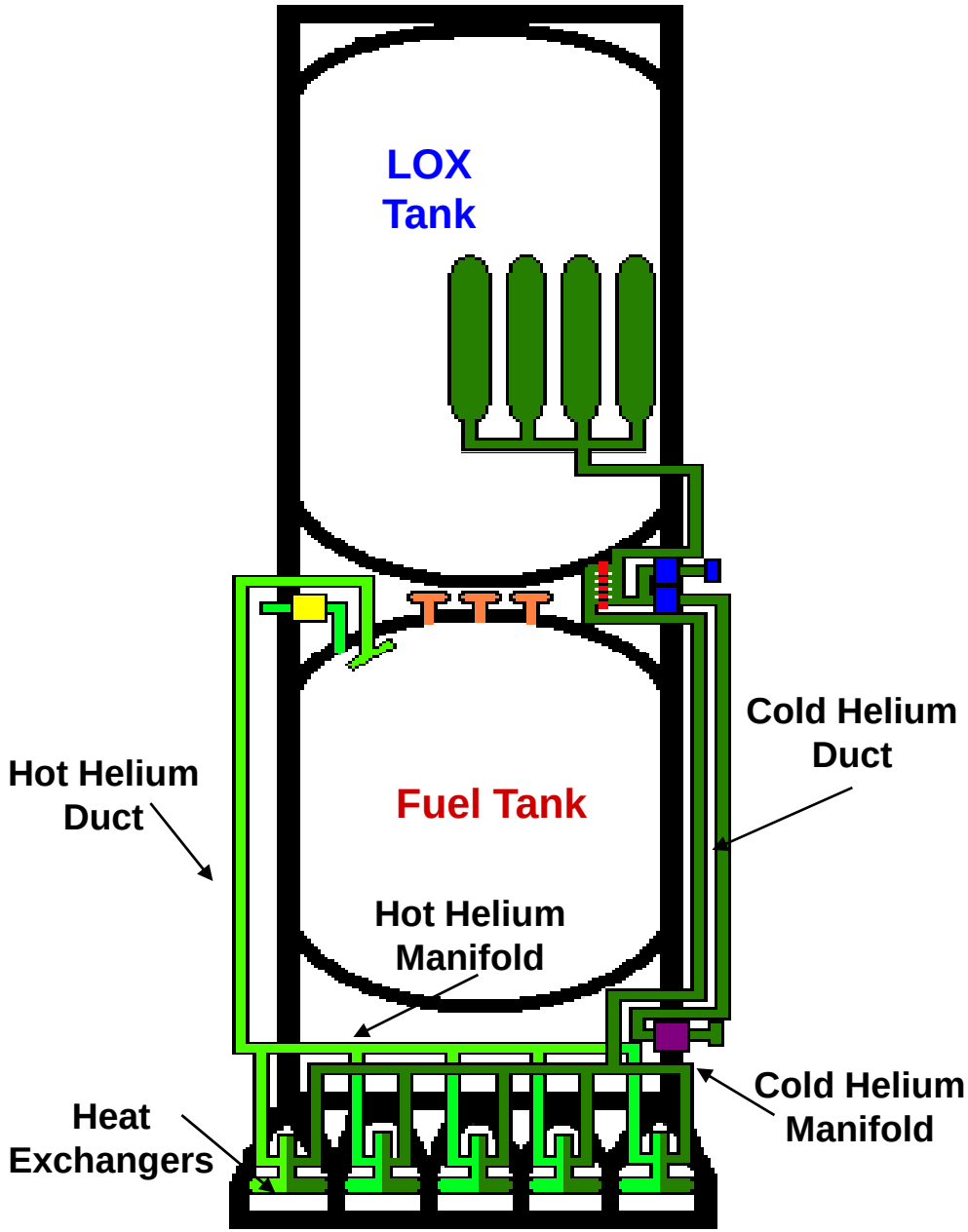

Fuel System: Fuel Pressurization System

- Cold He Duct routed He from Flow Controller to Cold He Manifold
- He was distributed to Heat Exchangers on all five F-1 engines
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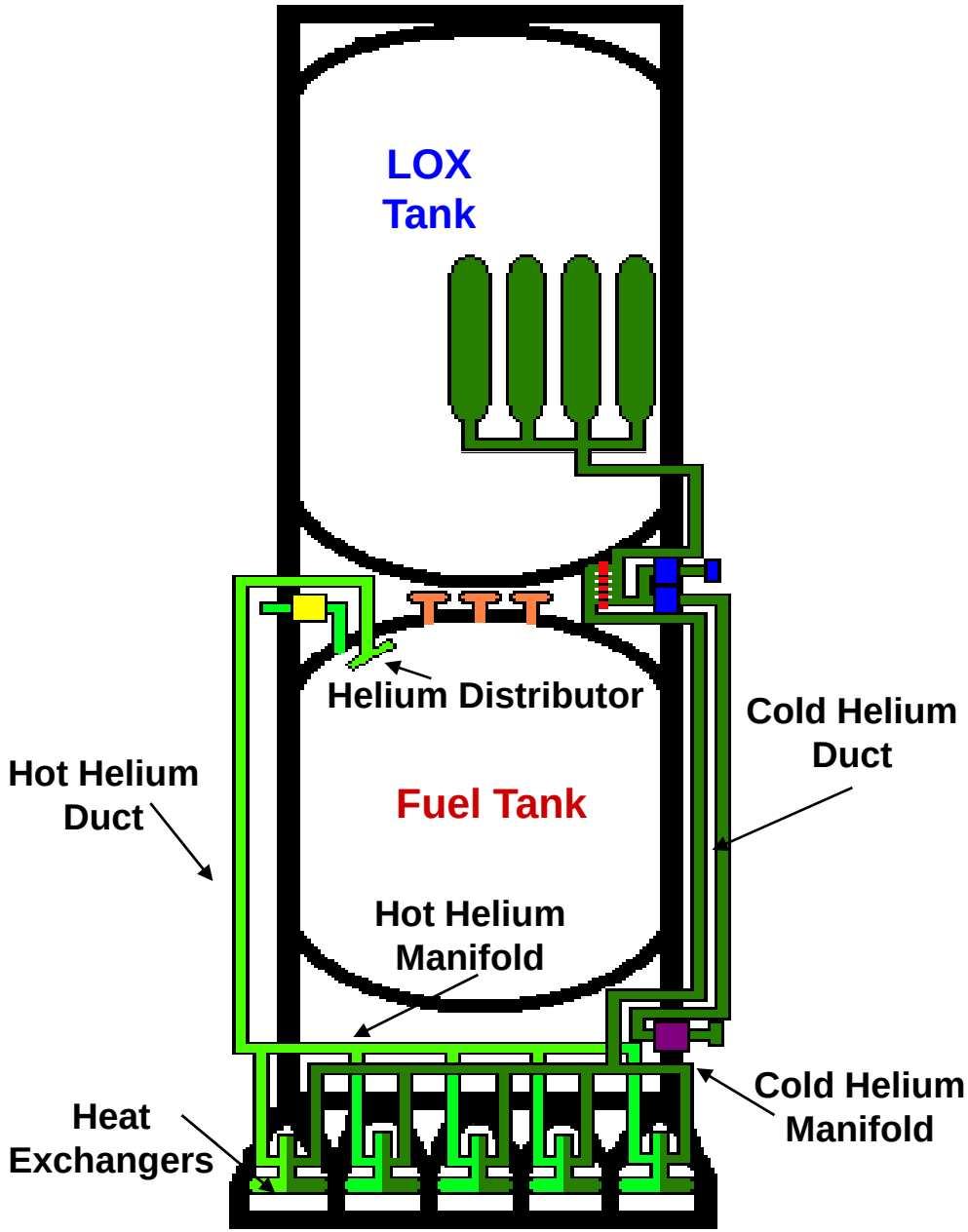
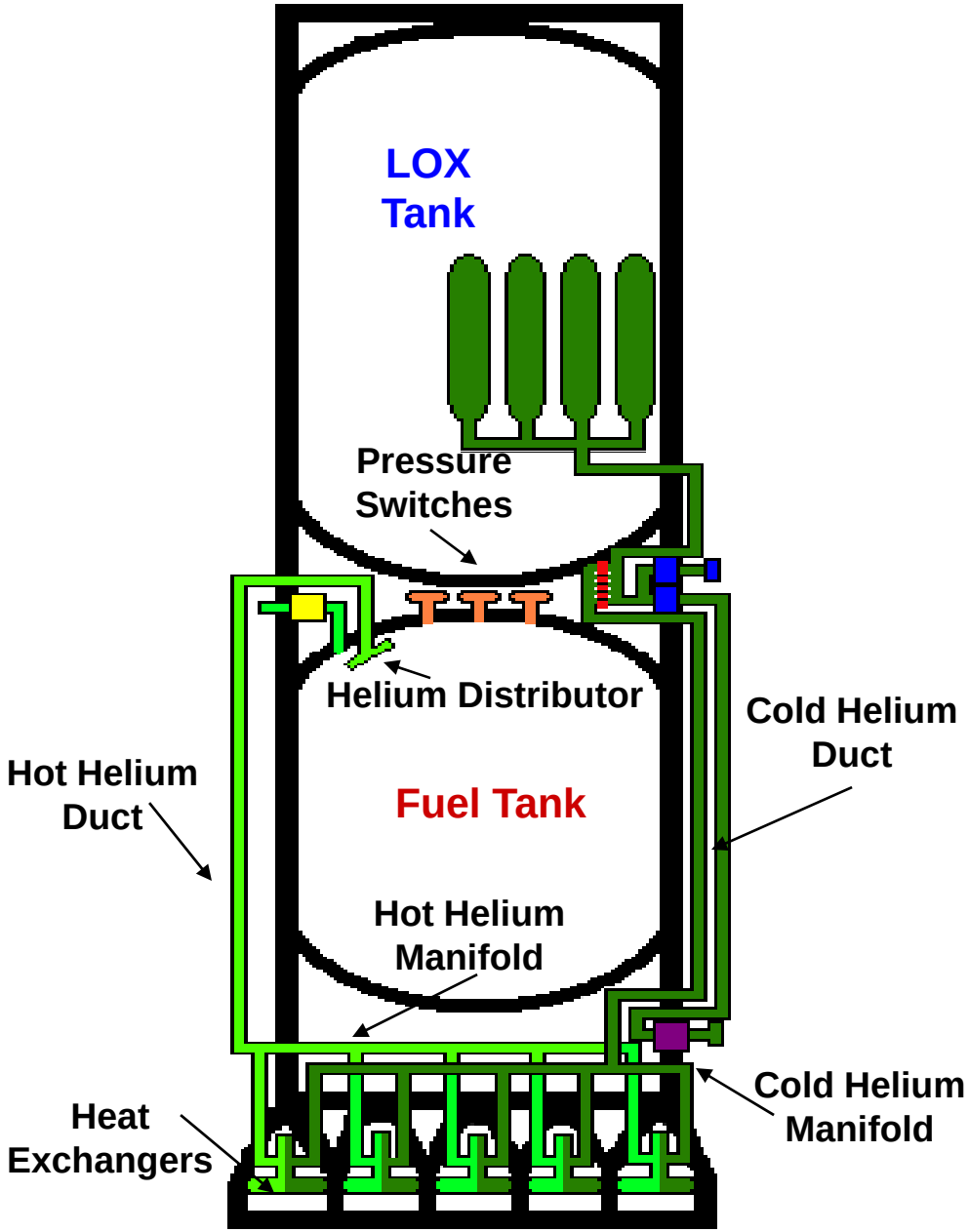
- He carried through He Distributor & into Fuel Tank



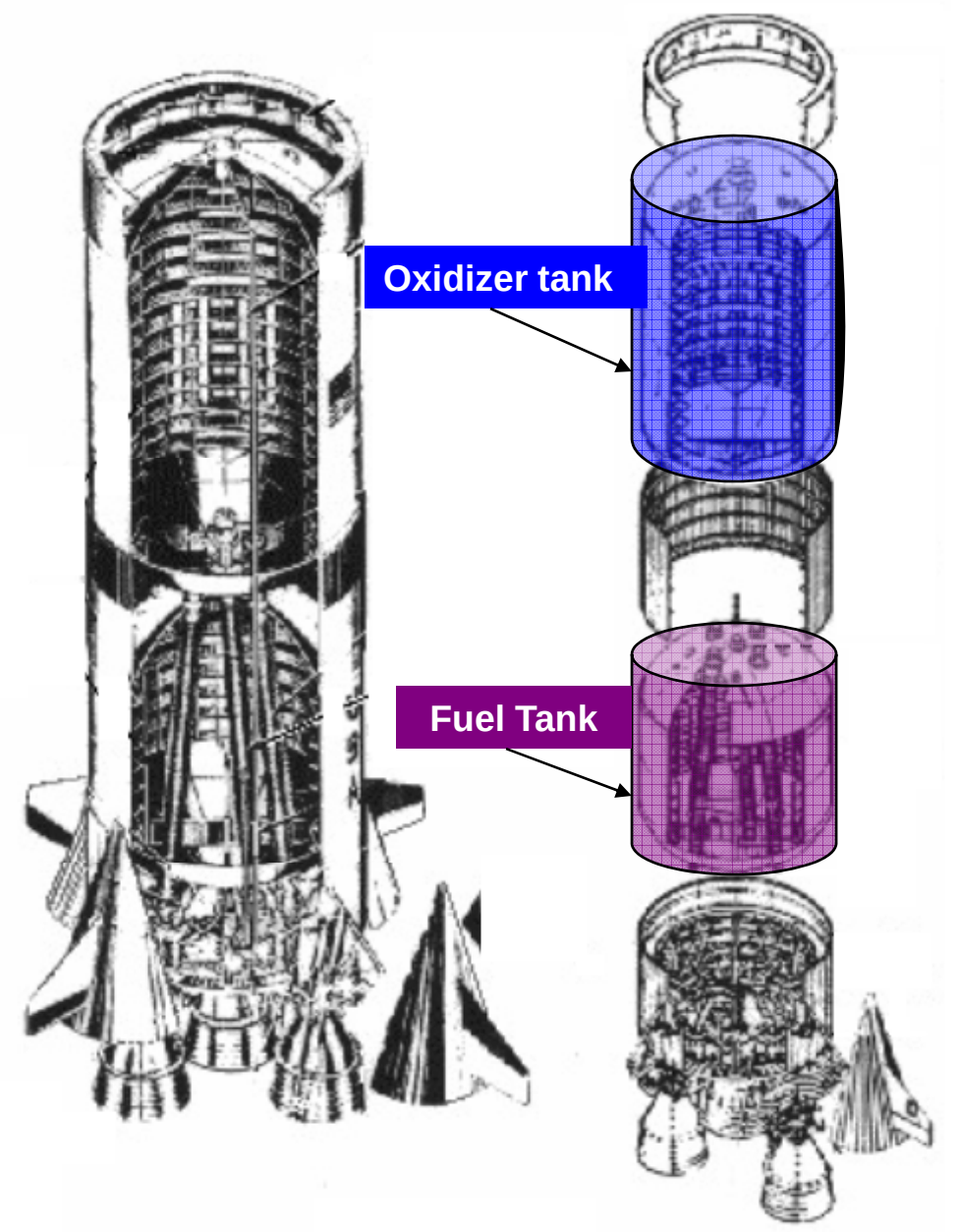
Fuel System: Fuel Pressurization System

- Cold He Duct routed He from Flow Controller to Cold He Manifold
- He was distributed to Heat Exchangers on all five F-1 engines
- Hot He Manifold received He & routed to Hot He Duct
- He carried through He Distributor & into Fuel Tank
- Three Pressure Switches monitored and controlled Fuel Tank pressurization



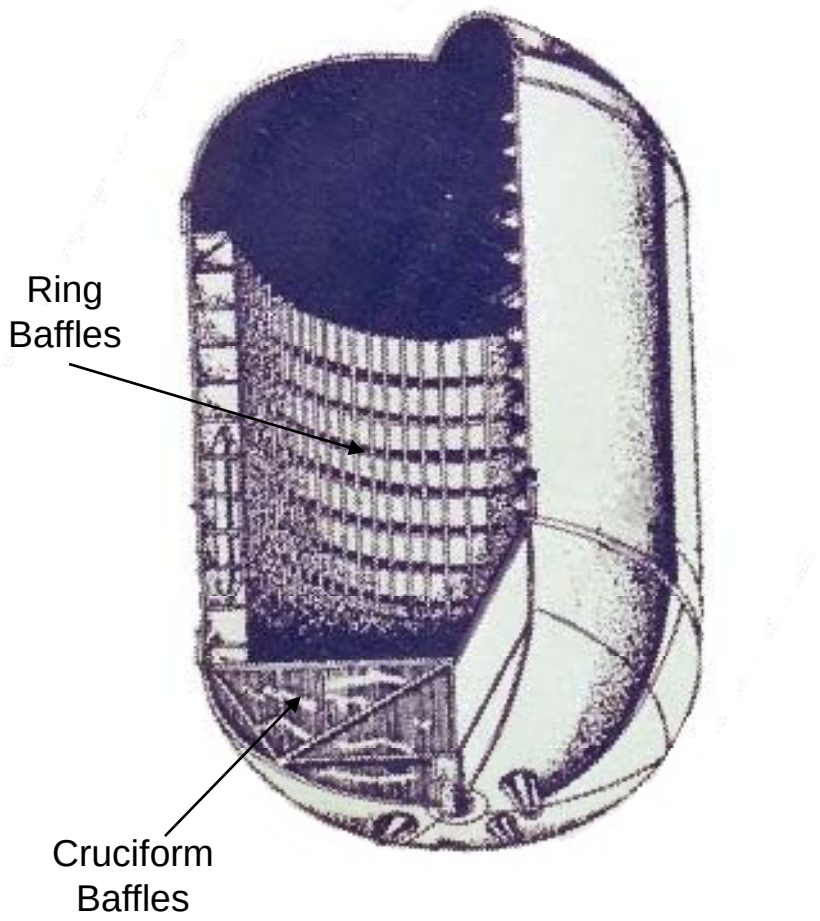
Stage I Subsystems

- Fuel System
- **Oxidizer System**
- Environmental Control System
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System



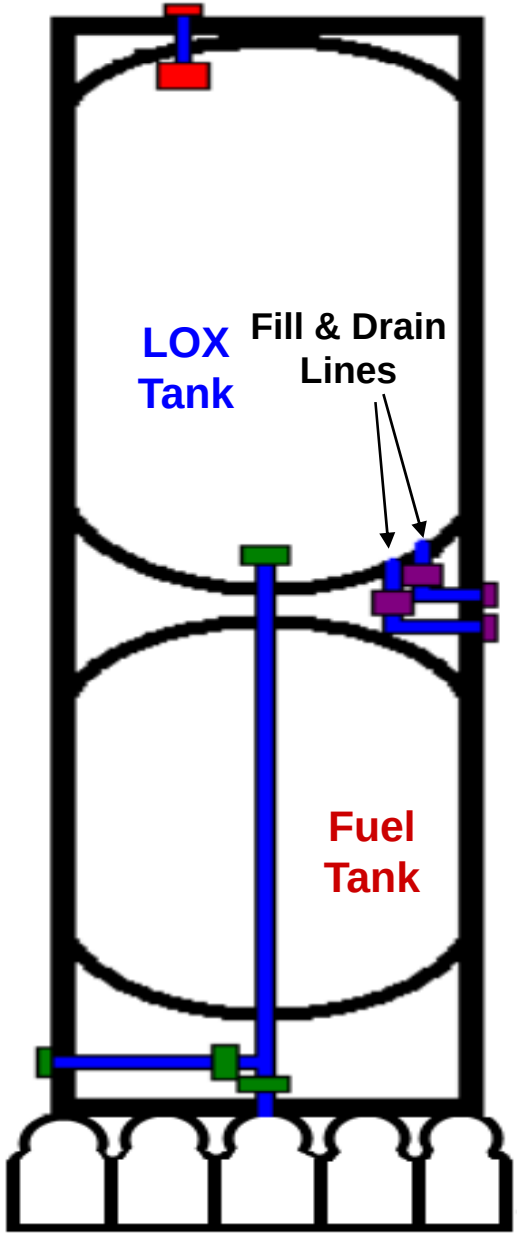
Oxidizer System

- Consisted of LOX tank, fill & drain components, LOX suction lines, pressurization subsystem
- Tank contained ring baffles to prevent sloshing
- Cruciform baffle limited swirling
- Four LOX liquid level probes monitored LOX level in tank



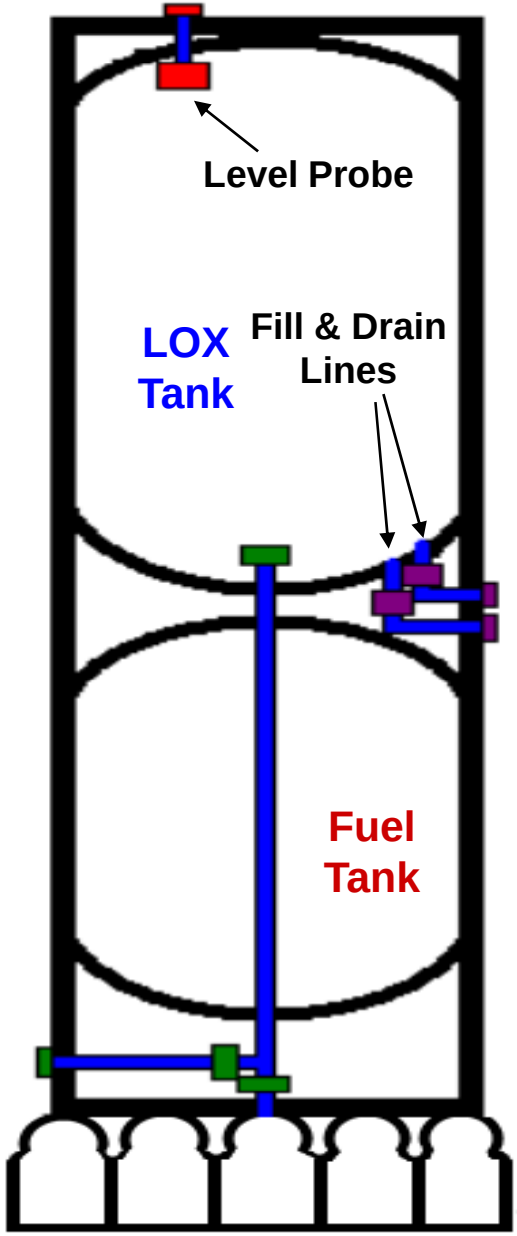
Oxidizer System: LOX Fill & Drain System

- Two six-inch Fill & Drain Lines



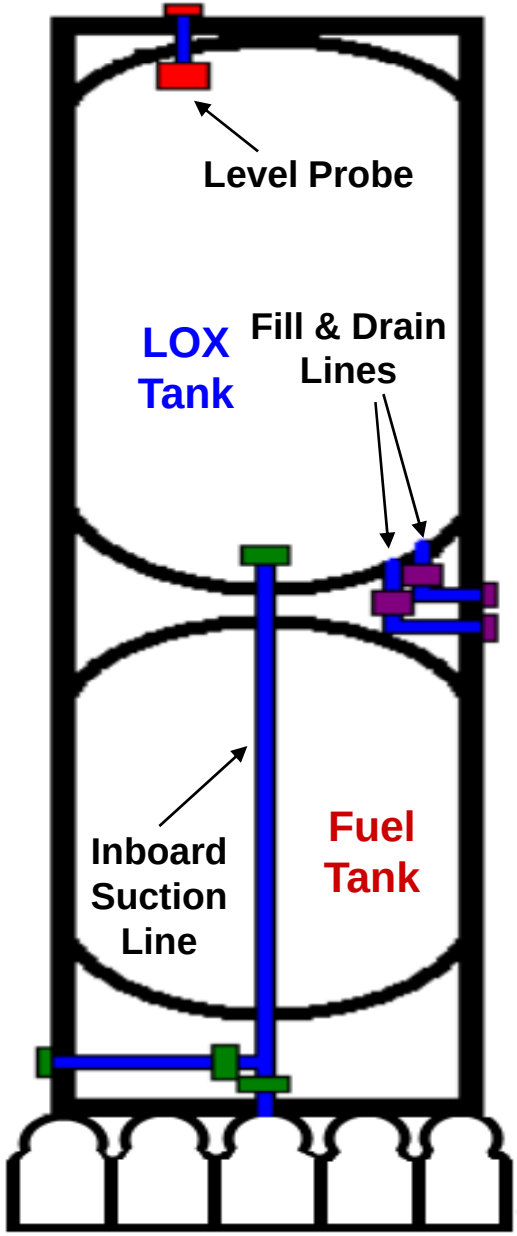
Oxidizer System: LOX Fill & Drain System

- Two six-inch Fill & Drain Lines
- Level Probe sensed full tank



Oxidizer System: LOX Fill & Drain System

- Two six-inch Fill & Drain Lines
- Level Probe sensed full tank
- Third line available to fill tank through Inboard Suction Line



Oxidizer System: LOX Fill & Drain System

- Two six-inch Fill & Drain Lines
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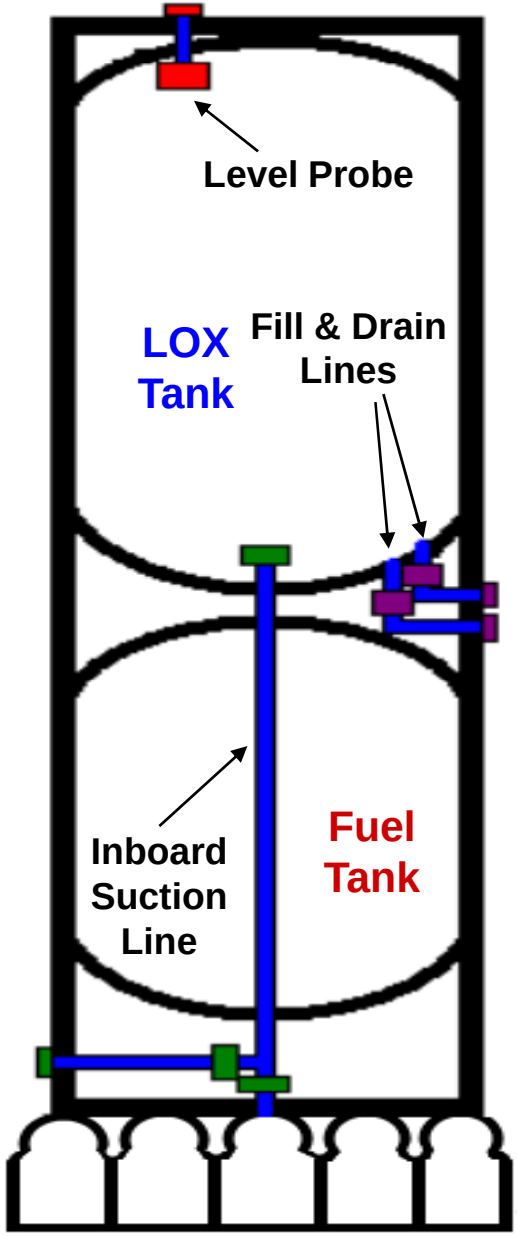
- LOX boiled to maintain temperature of -297^{o} F (-183^{o} C)



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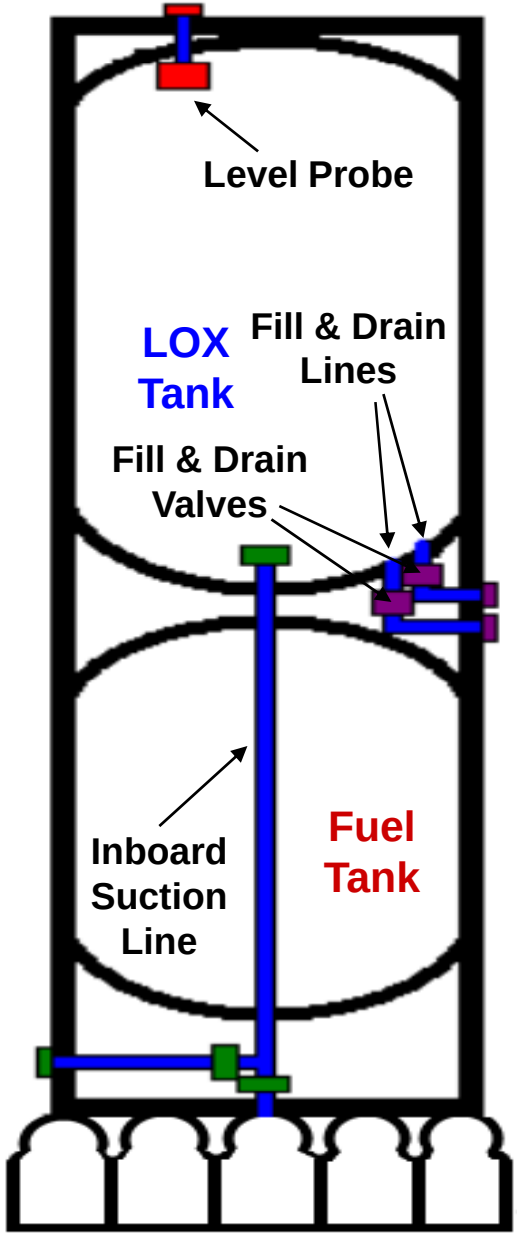
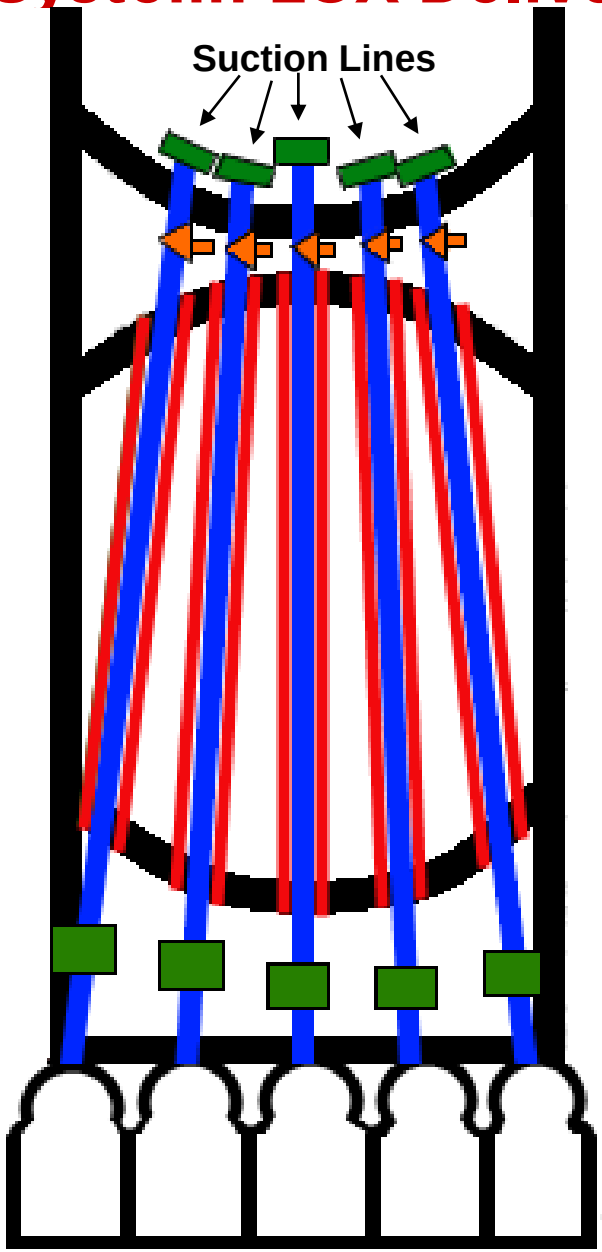
- Two six-inch Fill & Drain Lines
- Level Probe sensed full tank
- Third line available to fill tank through Inboard Suction Line
- LOX boiled to maintain temperature of -297° F (- 183° C)
- Fill & Drain Valves opened to complete drainage of LOX Tank



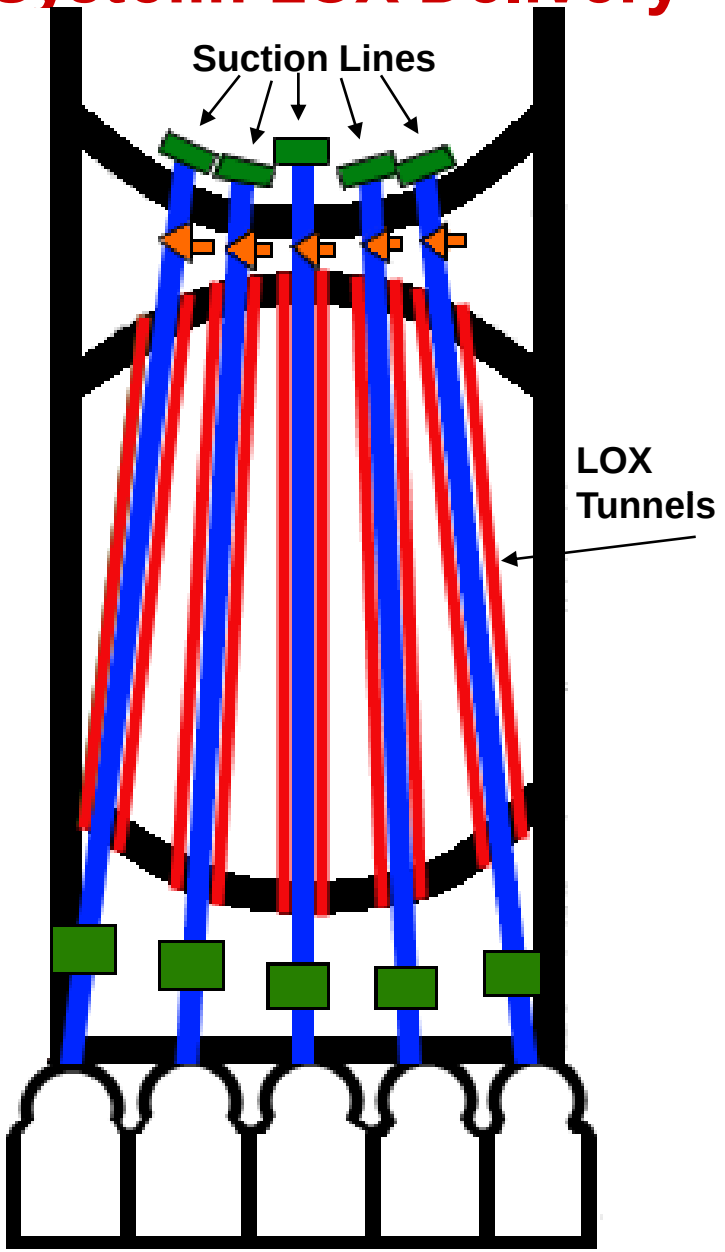
Oxidizer System: LOX Delivery

- Five 17-inch Suction Lines



Oxidizer System: LOX Delivery

- Five 17-inch Suction Lines
- Suction lines passed through Fuel Tank in five LOX Tunnels



Oxidizer System: LOX Delivery

- Five 17-inch Suction Lines
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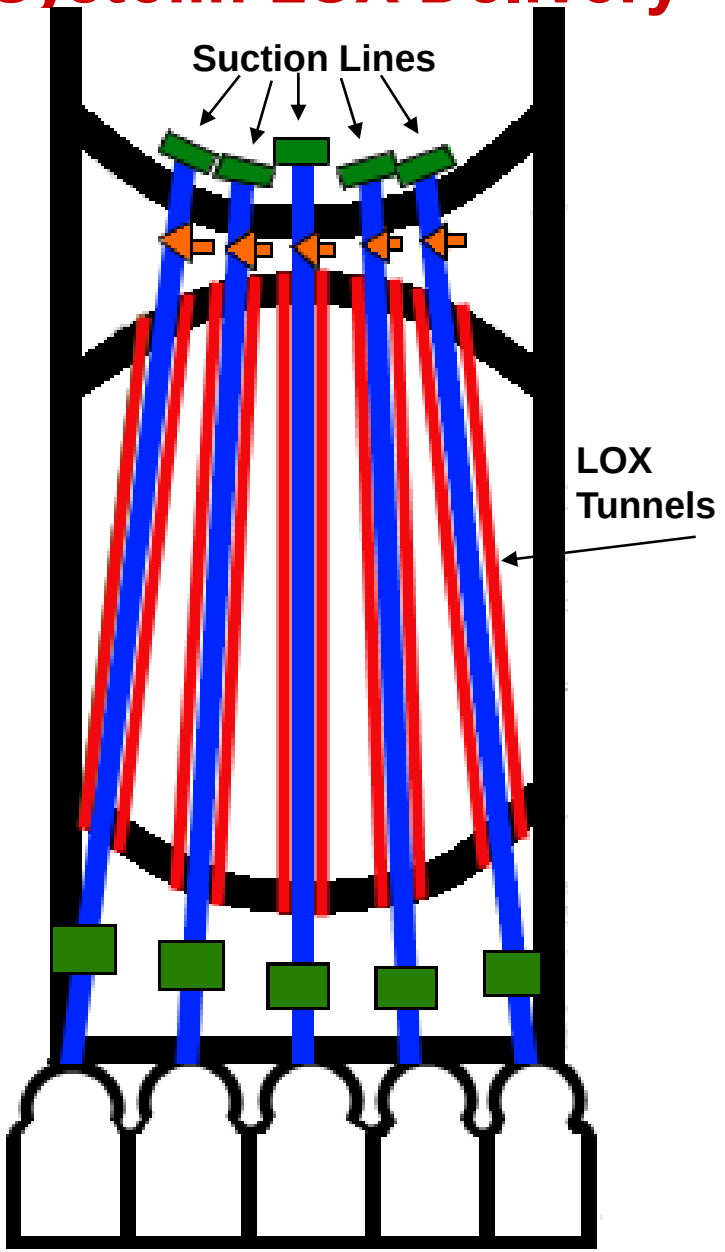
- Inside LOX Tunnels, air acted as insulation between LOX lines & fuel lines



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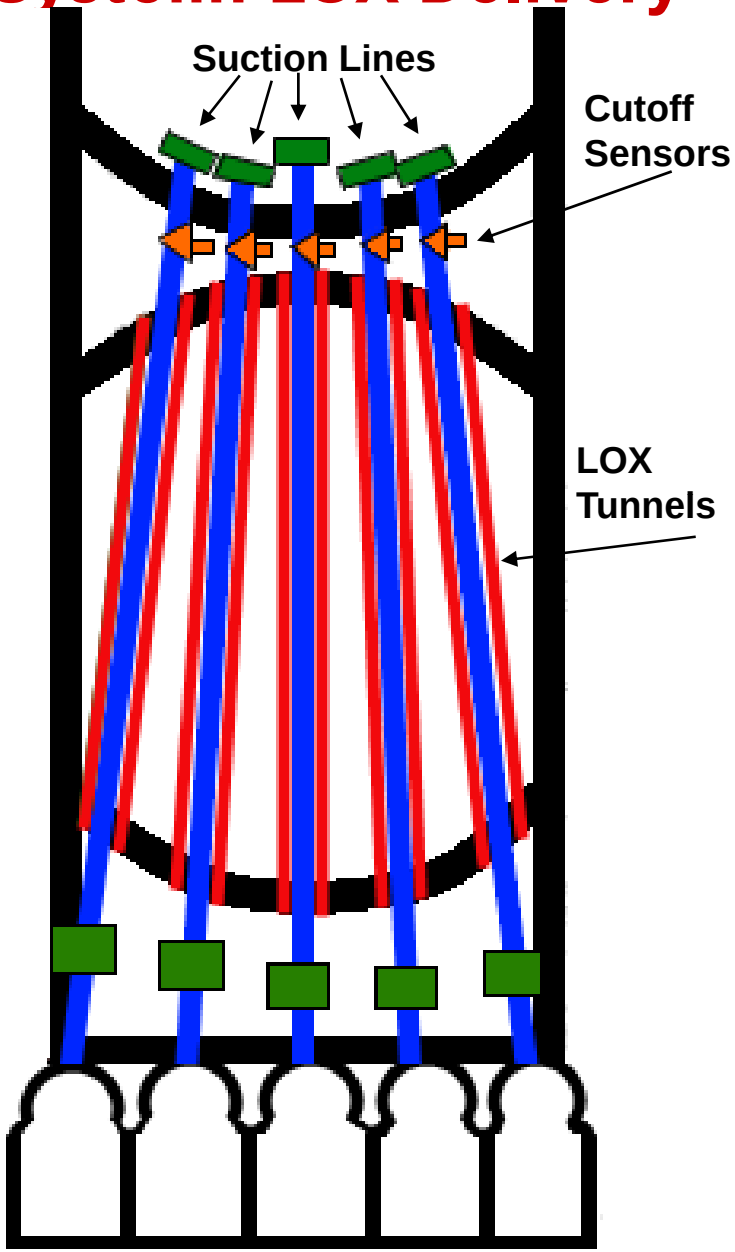
- Cutoff Sensors assured safe engine shutdown



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- Five 17-inch Suction Lines
- Suction lines passed through Fuel Tank in five LOX Tunnels
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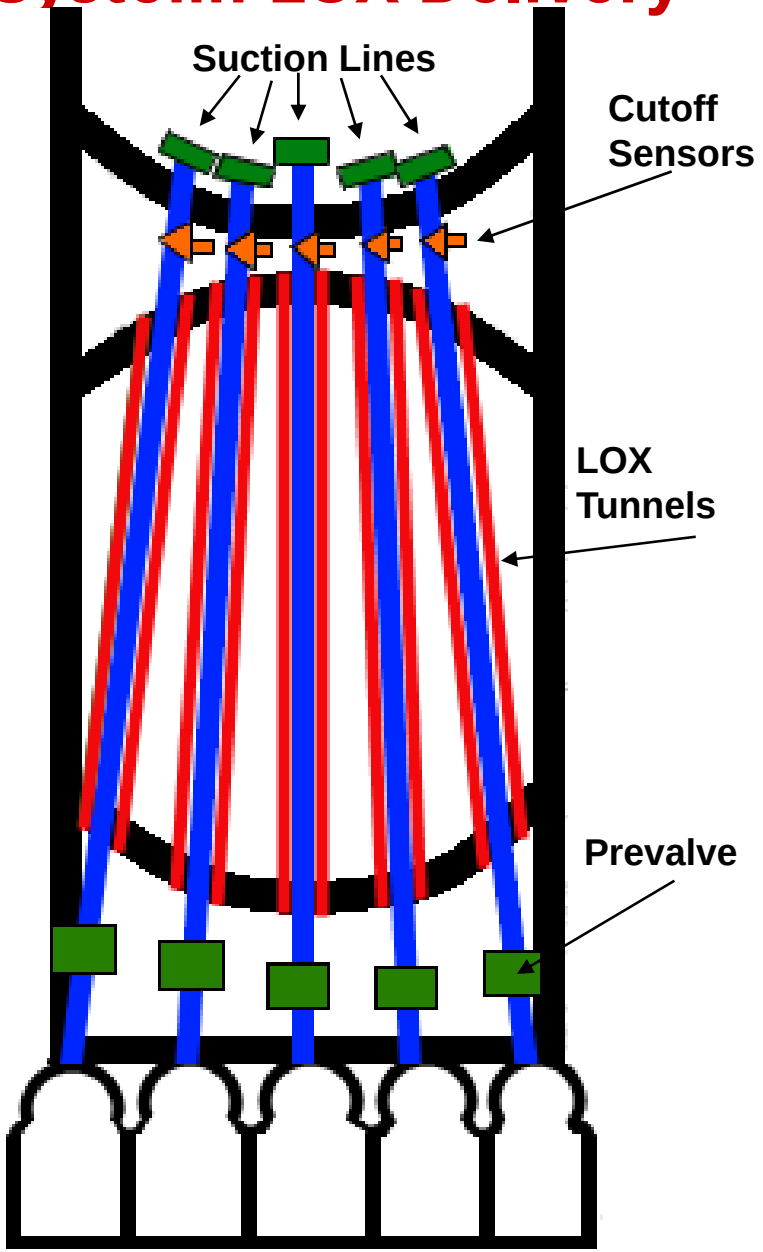
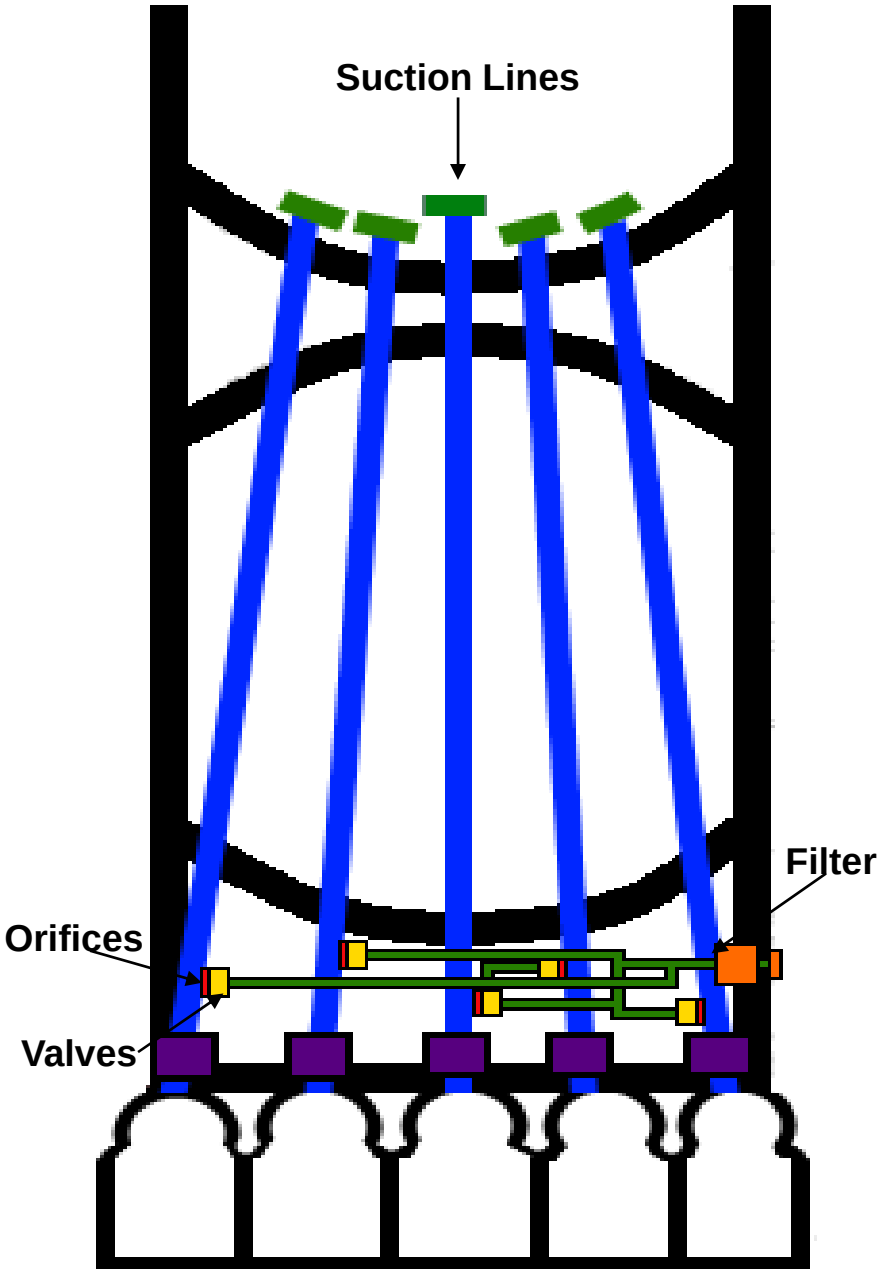
- Cutoff Sensors assured safe engine shutdown
- Prevalves can stop flow of LOX to engine in emergency



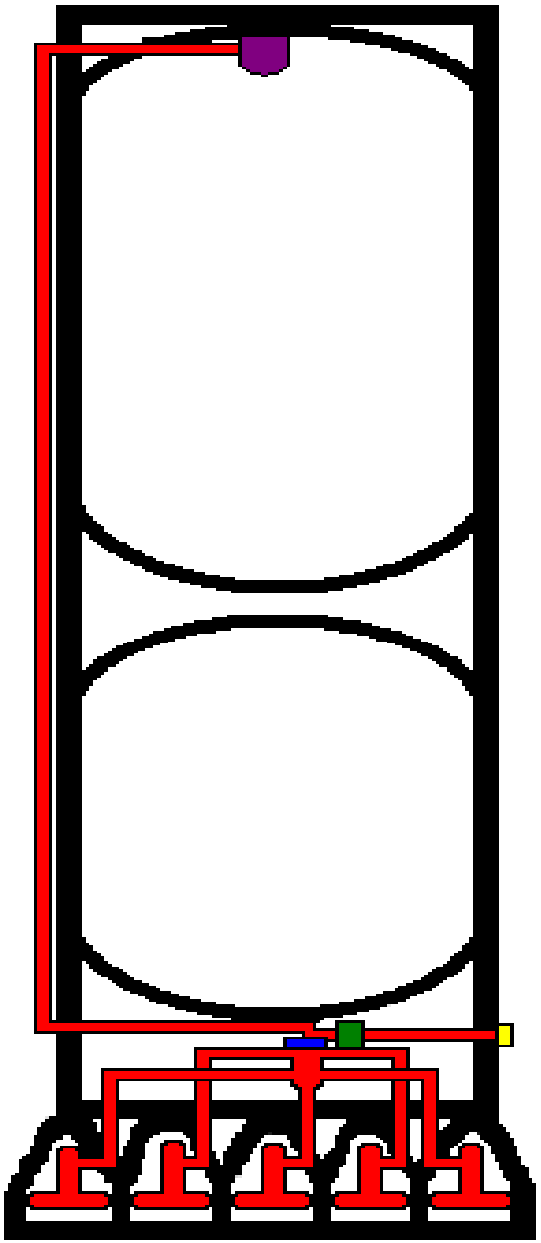
Oxidizer System: LOX Conditioning

- LOX cannot exceed -297^{o} F (-183^{o} C) or it will result in gaseous oxygen (GOX)
- Emergency bubbling corrected GOX situation
  - Bubbling technique sent He into five Suction Lines to cool LOX
- Filter Valves & Orifices controlled flow of He into Suction Lines



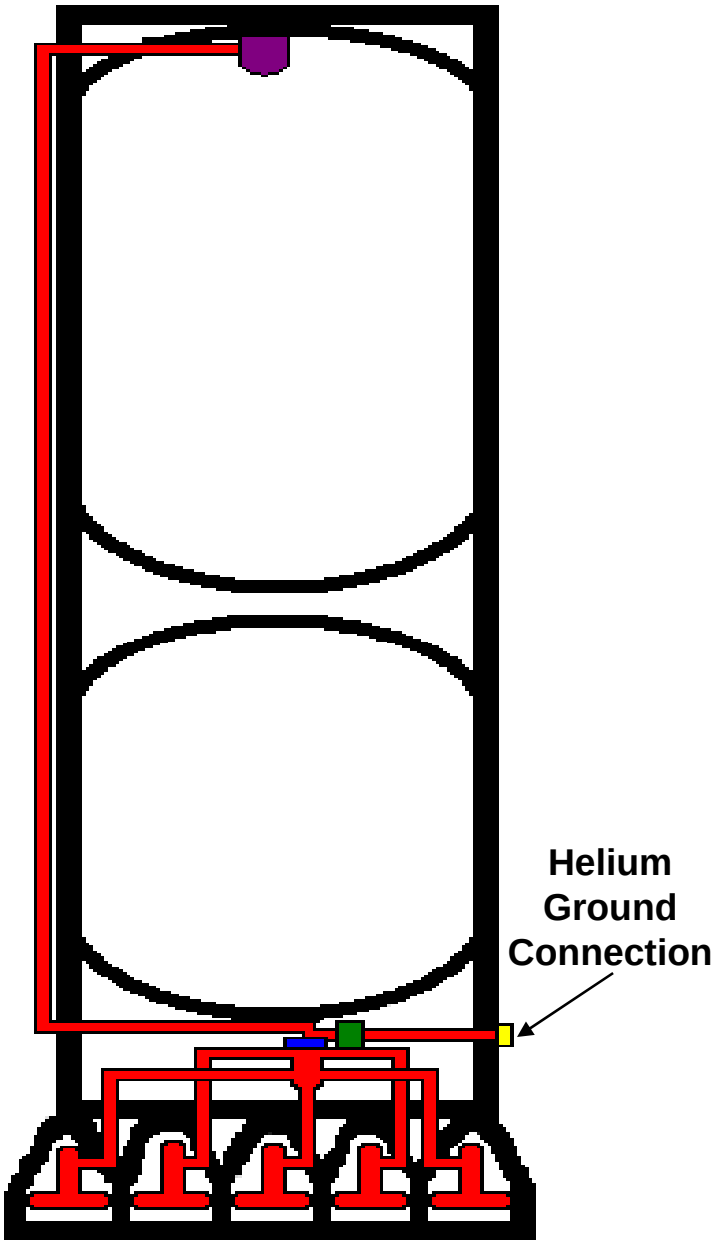
Oxidizer System: LOX Pressurization

- Pressurization occurred at T-45 seconds



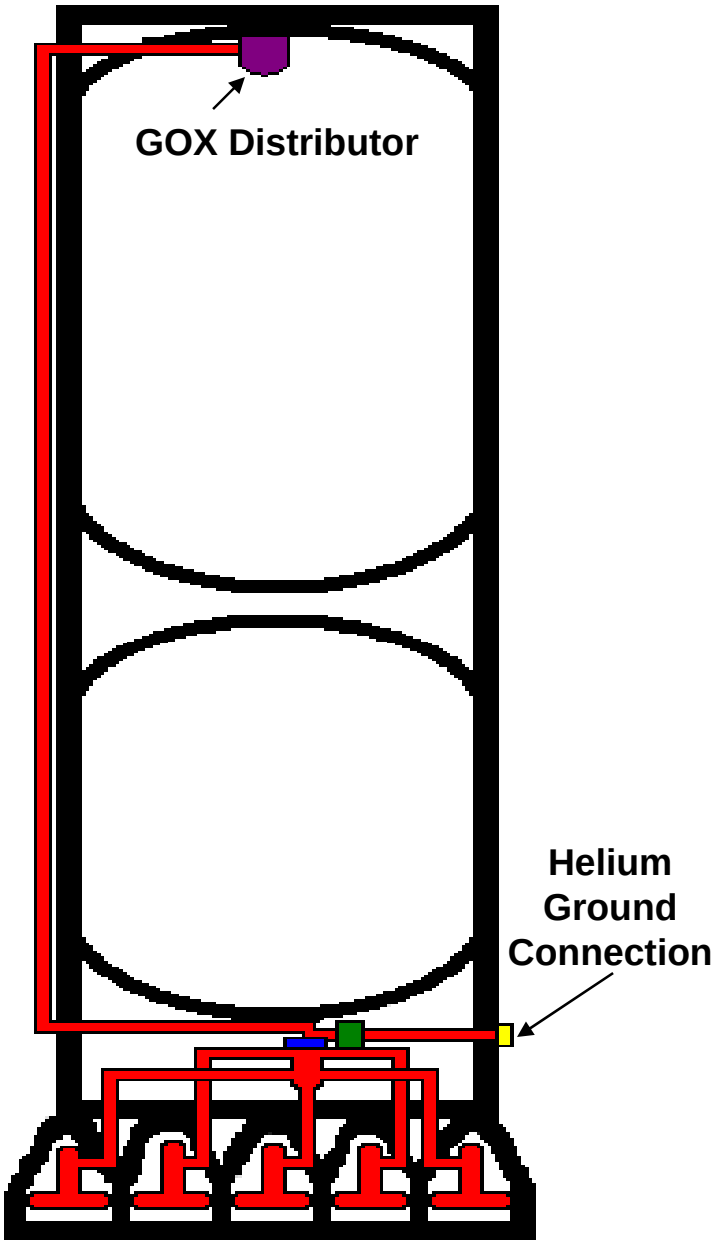
Oxidizer System: LOX Pressurization

- Pressurization occurred at T-45 seconds
- He was supplied by GSE through He Ground Connection



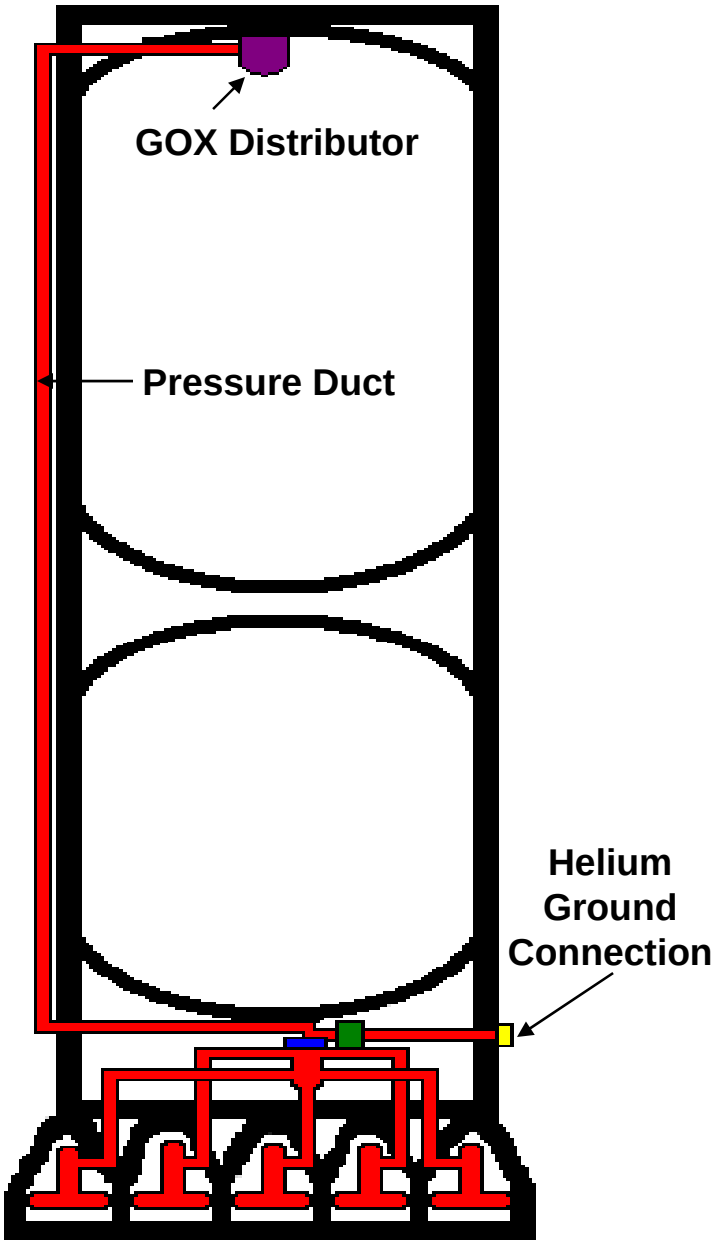
Oxidizer System: LOX Pressurization

- Pressurization occurred at T-45 seconds
- He was supplied by GSE through He Ground Connection
- He proceeded up GOX line into LOX tank through GOX Distributor



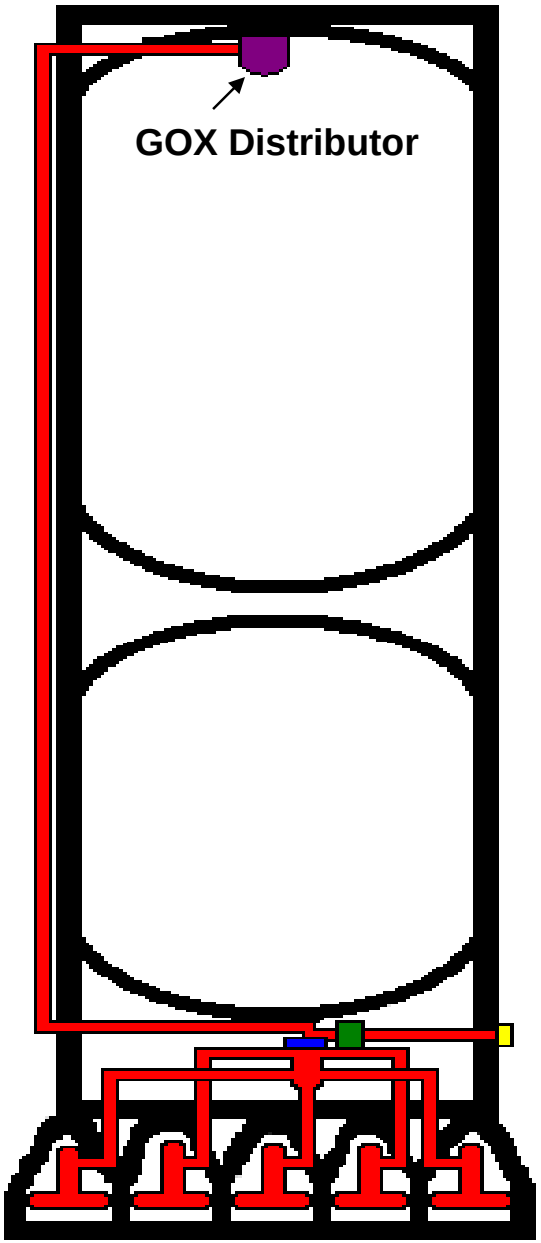
Oxidizer System: LOX Pressurization

- Pressurization occurred at T-45 seconds
- He was supplied by GSE through He Ground Connection
- He proceeded up GOX line into LOX tank through GOX Distributor
- Pressure Duct monitored flow of He



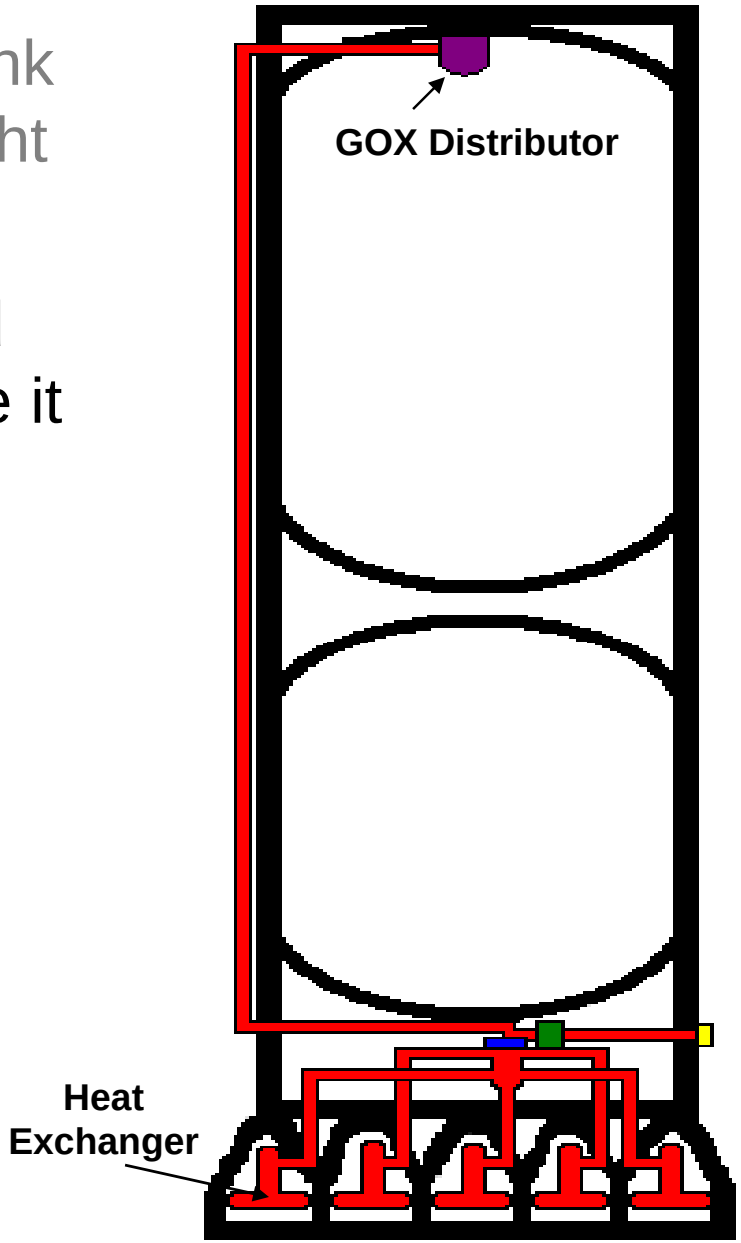
Oxidizer System: LOX Pressurization

- GOX was added to LOX Tank for pressurization during flight



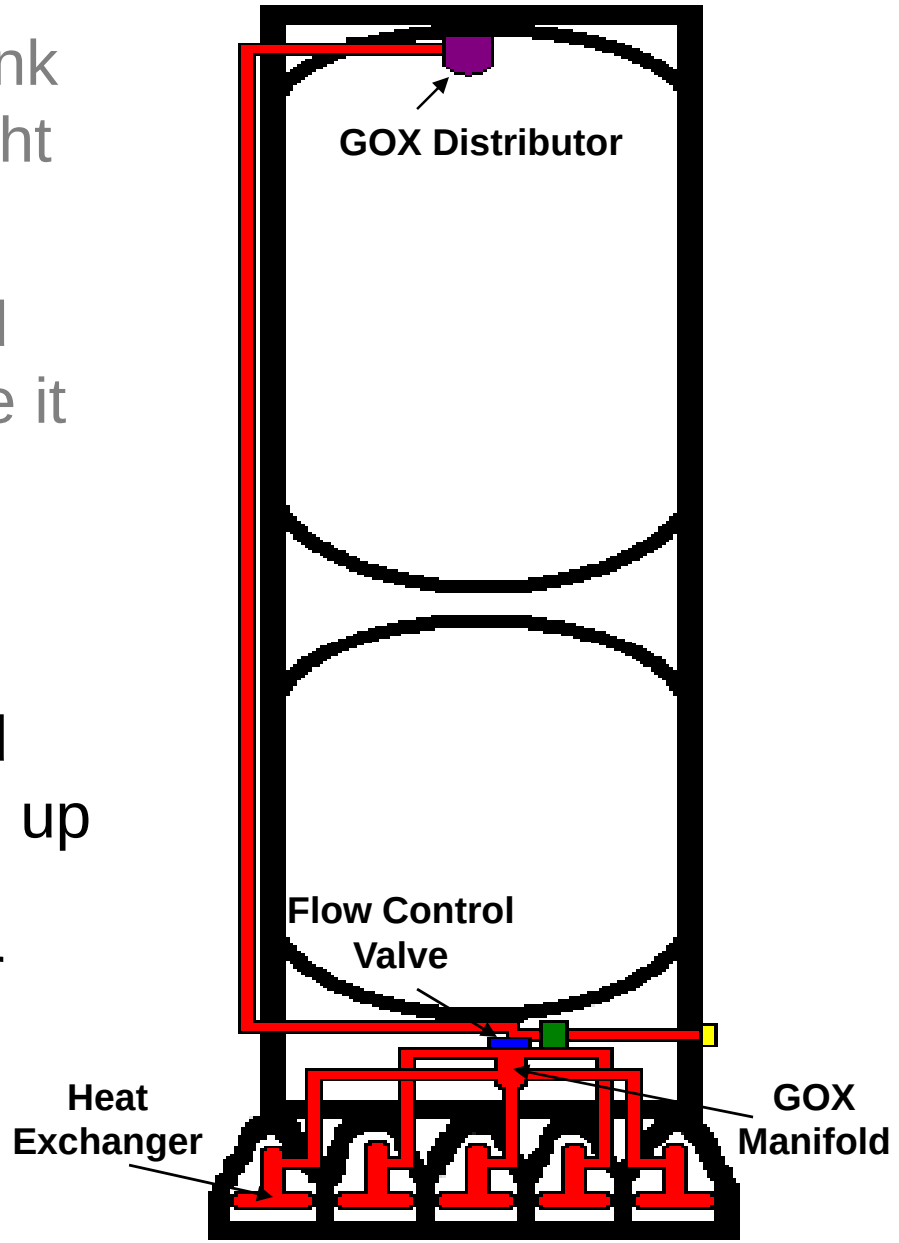
Oxidizer System: LOX Pressurization

- GOX was added to LOX Tank for pressurization during flight
- Portion of LOX was diverted into Heat Exchangers where it was transformed into GOX



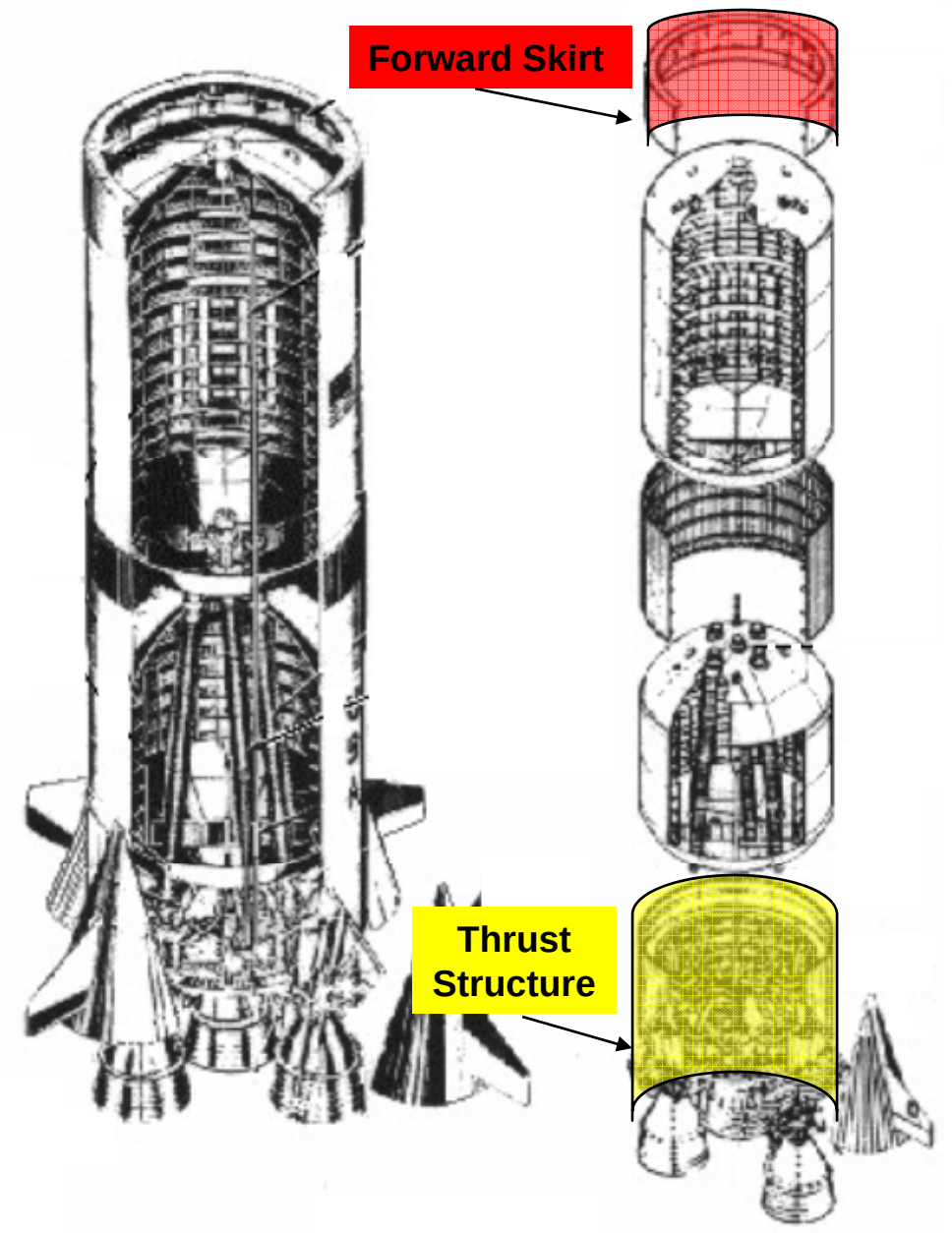
Oxidizer System: LOX Pressurization

- GOX was added to LOX Tank for pressurization during flight
- Portion of LOX was diverted into Heat Exchangers where it was transformed into GOX
- GOX flowed from Heat Exchanger to GOX Manifold through Flow Control Valve, up GOX Line, & into LOX Tank through the GOX Distributor



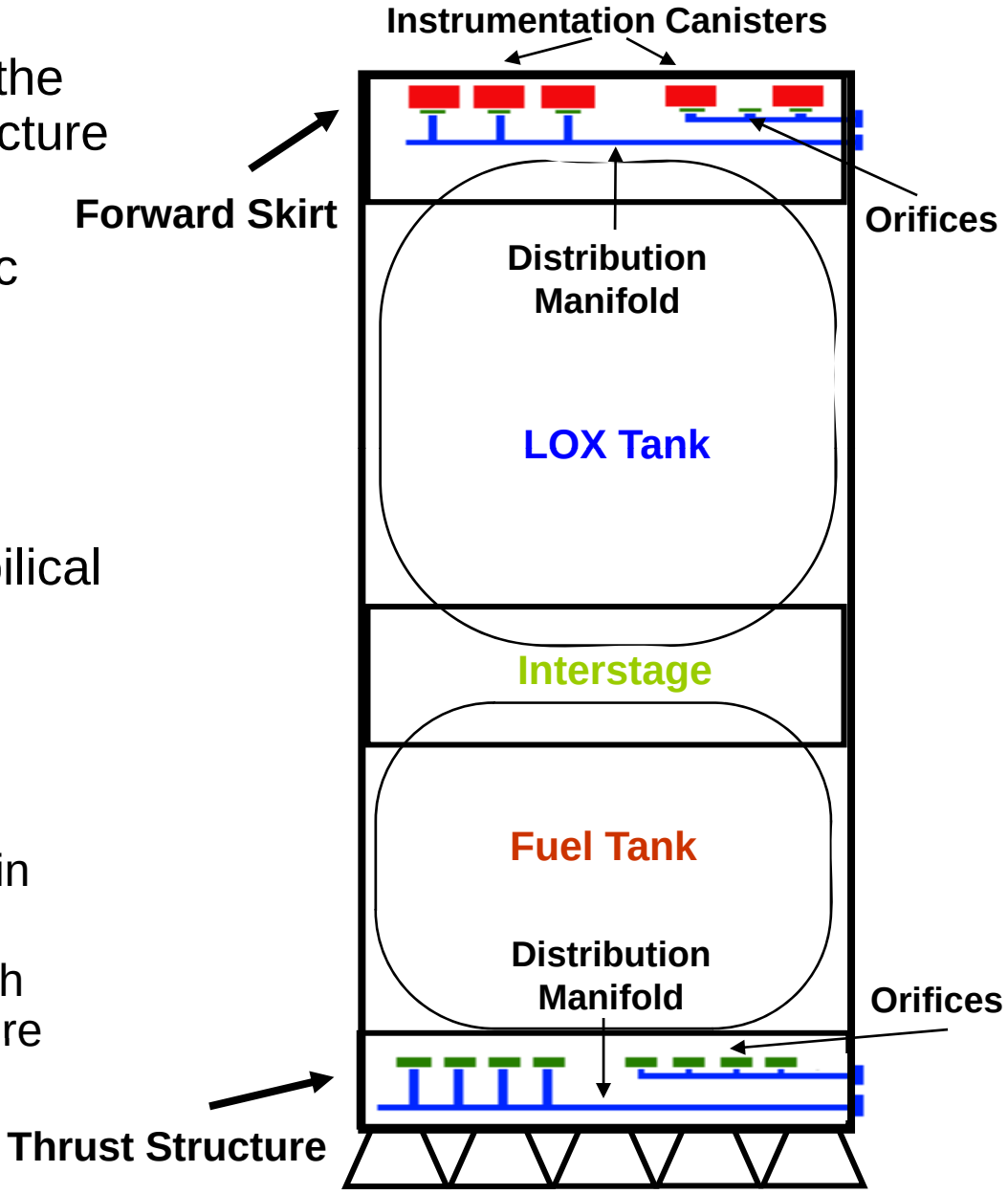
Stage I Subsystems

- Fuel System
- Oxidizer System
- **Environmental Control System**
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System



Environmental Control System (ECS)

- Forced conditioned air into the Forward Skirt & Thrust Structure
- 20 minutes before cryogenic loading, flow switched from conditioned air to gaseous nitrogen (GN_2)
- GN_2 flow terminated at umbilical disconnect (liftoff)
- Distribution Manifolds
  - Distributed air & GN_2 to Instrumentation Canisters in Forward Skirt
  - Vented air and GN_2 through Orifices into Thrust Structure



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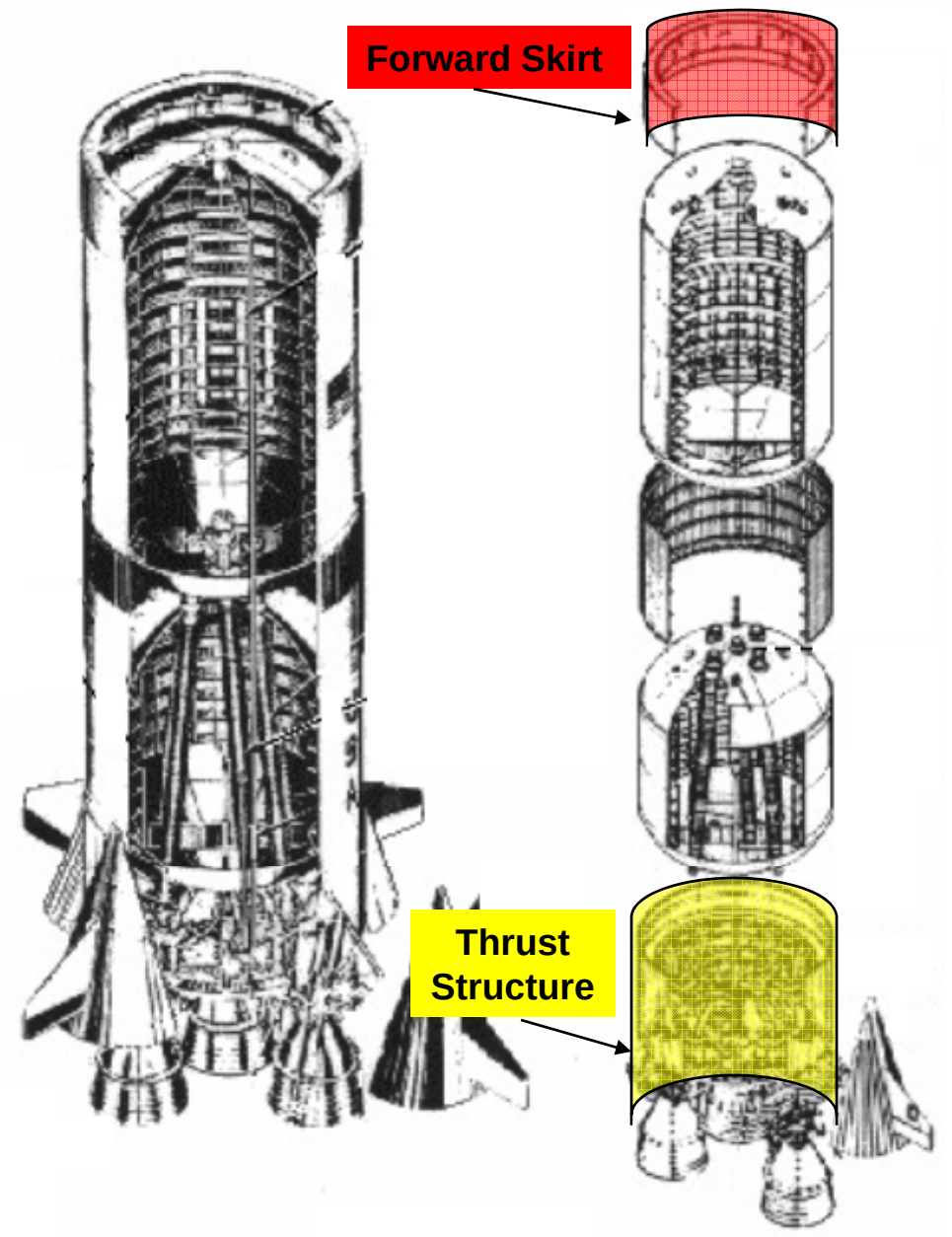
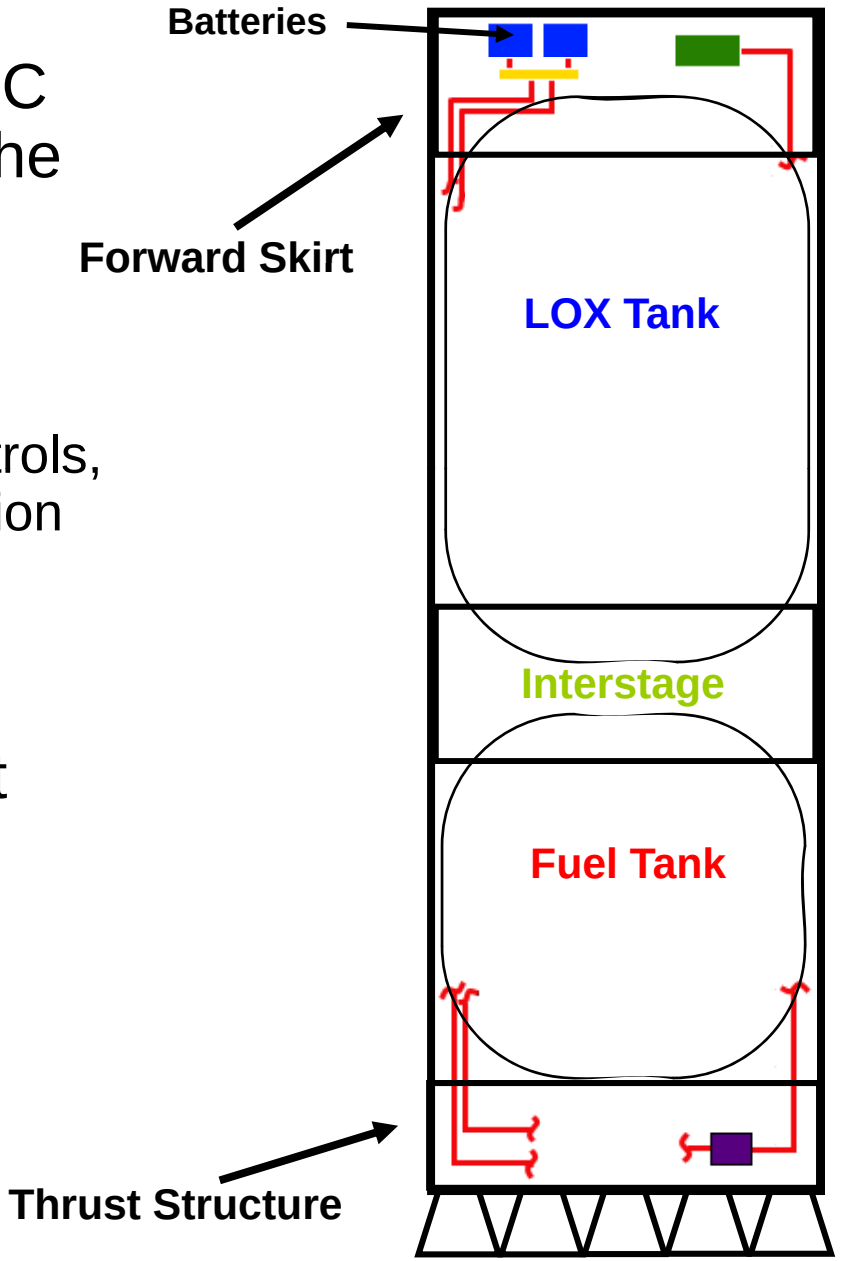


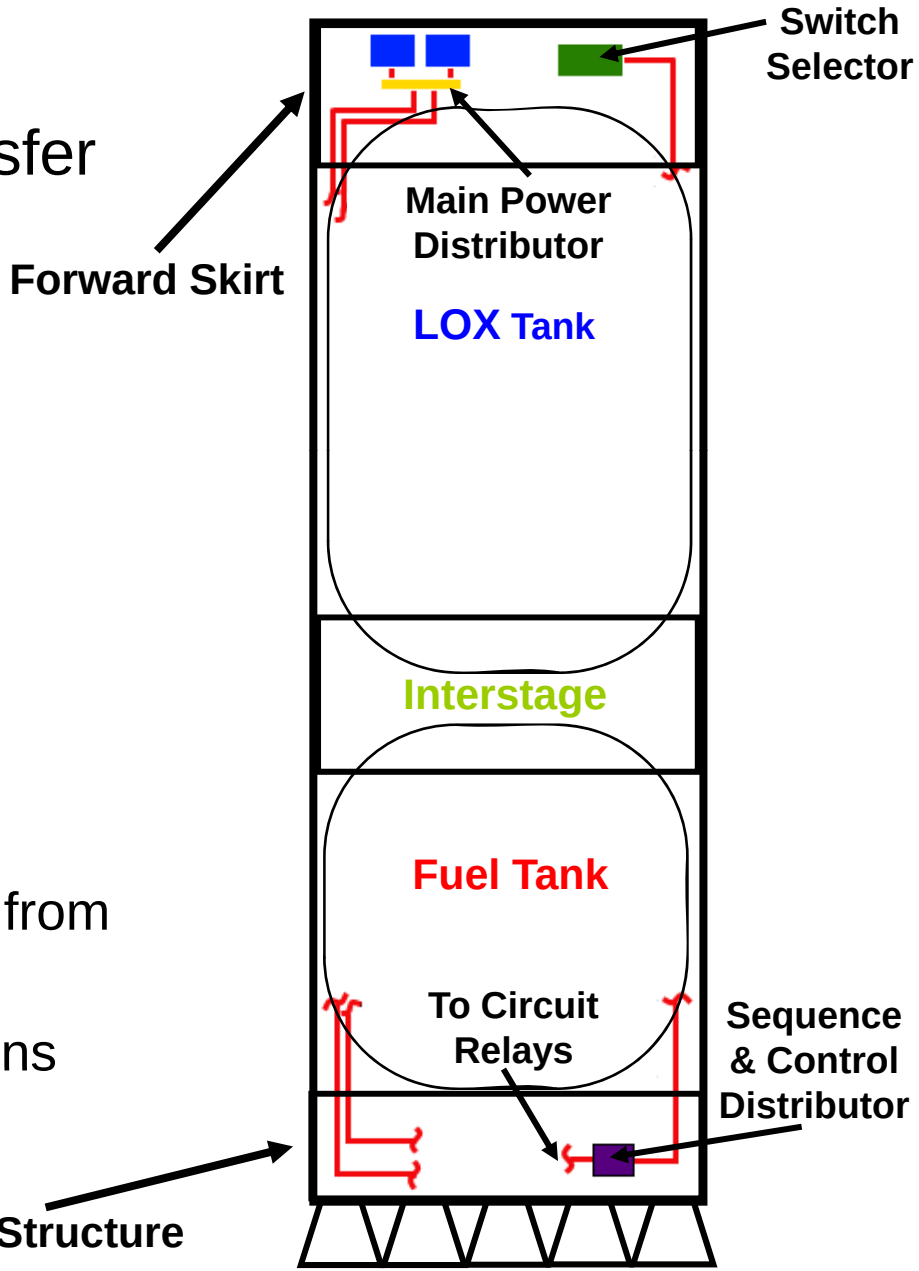
Electrical System

- Two independent 28-volt DC power systems located in the Forward Skirt
- Battery # 1 – Operational power system battery
  - Supplied power to valve controls, venting systems, pressurization systems, sequencing & flight control
  - Controlled solenoids
- Battery # 2 – Measurement power system battery
  - Supplied power to telemetry systems, transducers, multiplexers, & transmitters



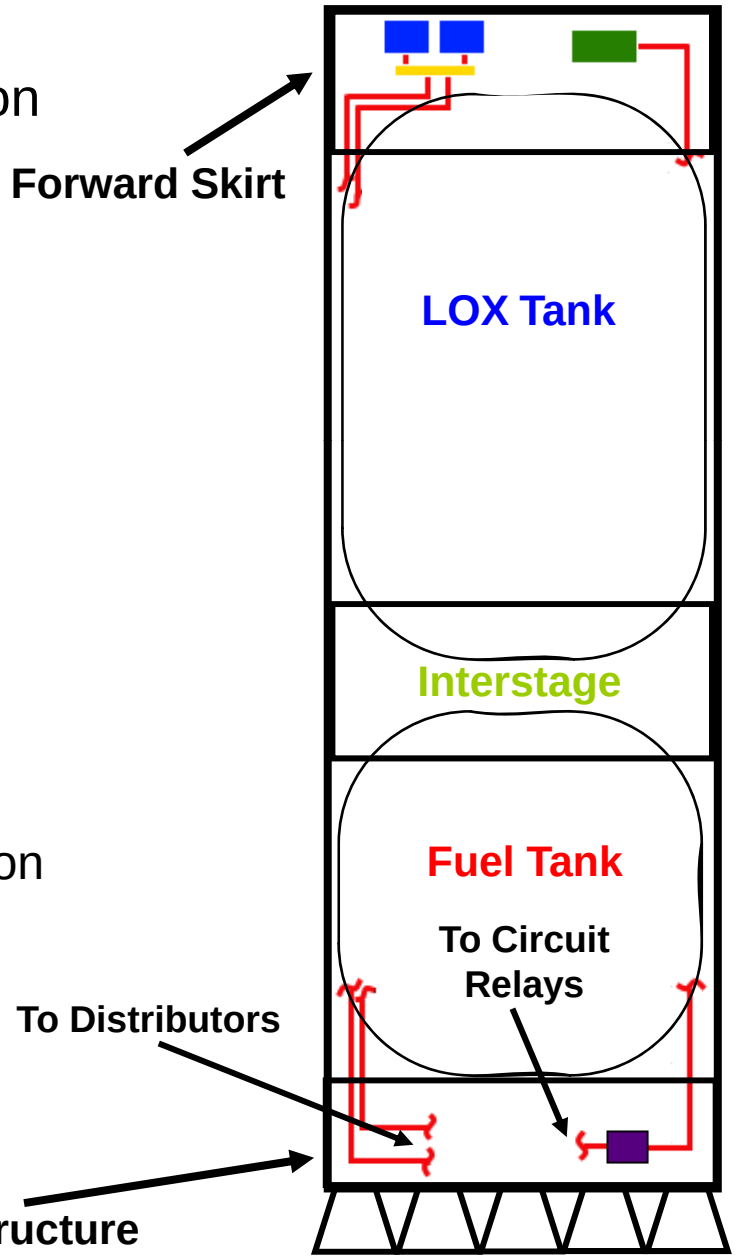
Electrical System

- Main Power Distributor housed relays, power transfer switch, & other electrical equipment
- Relays controlled time-programmed circuits
- Sequence & Control Distributor
  - Accepted command signals from Switch Selector
  - Commanded staging functions



Electrical System

- Propulsion Distributor contained monitor & control circuits for propulsion system
- Thrust OK Distributor contained circuits that shut down engines when thrust was inadequate
- Timer Distributor contained circuits to delay operation of relay valves
- Measuring Power Distributor
  - Contained electrical buses
  - Routed data from measuring racks
  - Served as measurement signal junction box
  - Switched data between hardwire & telemetry



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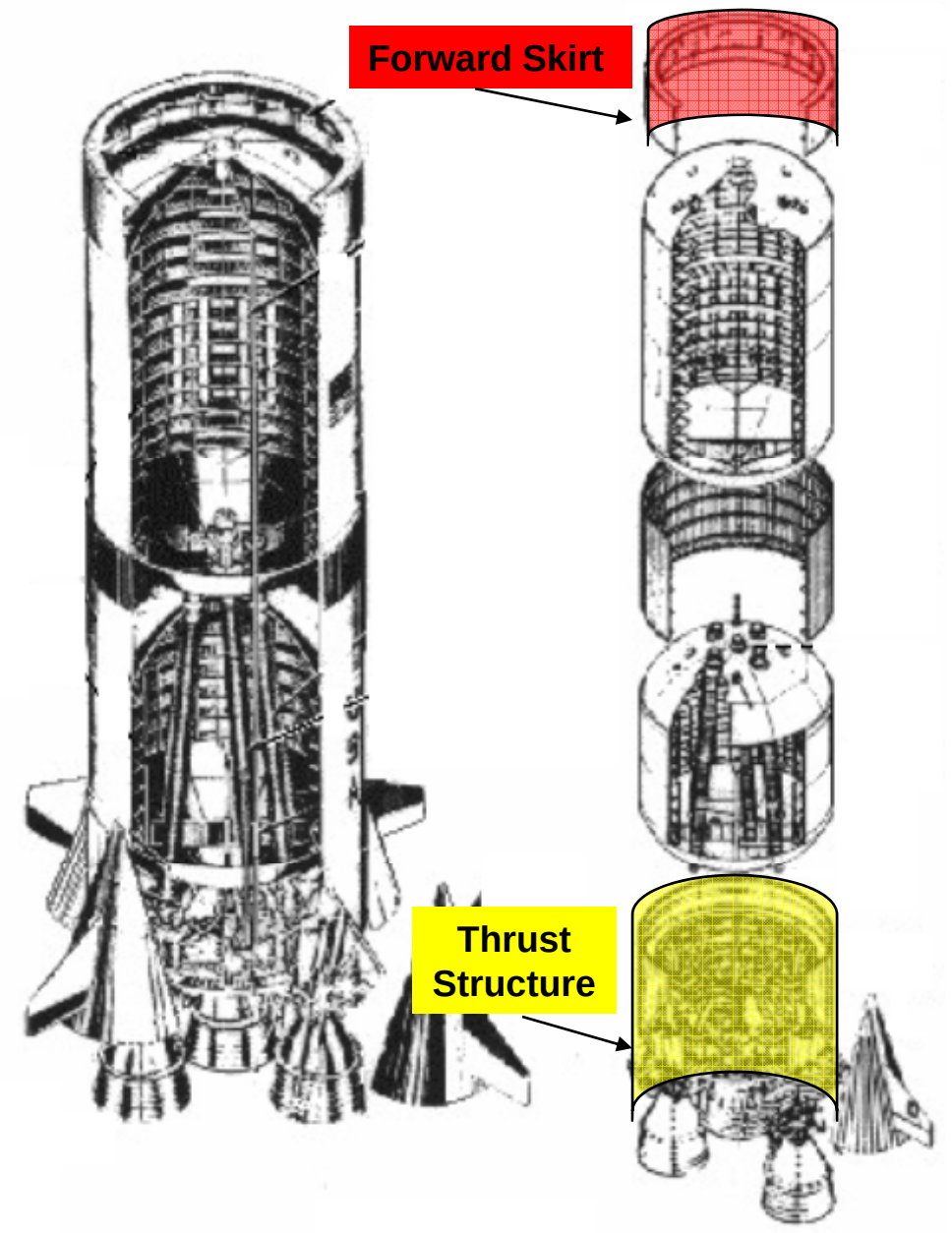


Instrumentation System

- Reported information on stage systems & components
- Provided data on internal & external environments
- Monitored approximately 900 Stage I (SI-C) measurements
- Measurements were telemetered by
  - Coaxial cable to GSE preflight
  - Radio Frequency (RF) transmission to ground stations during flight

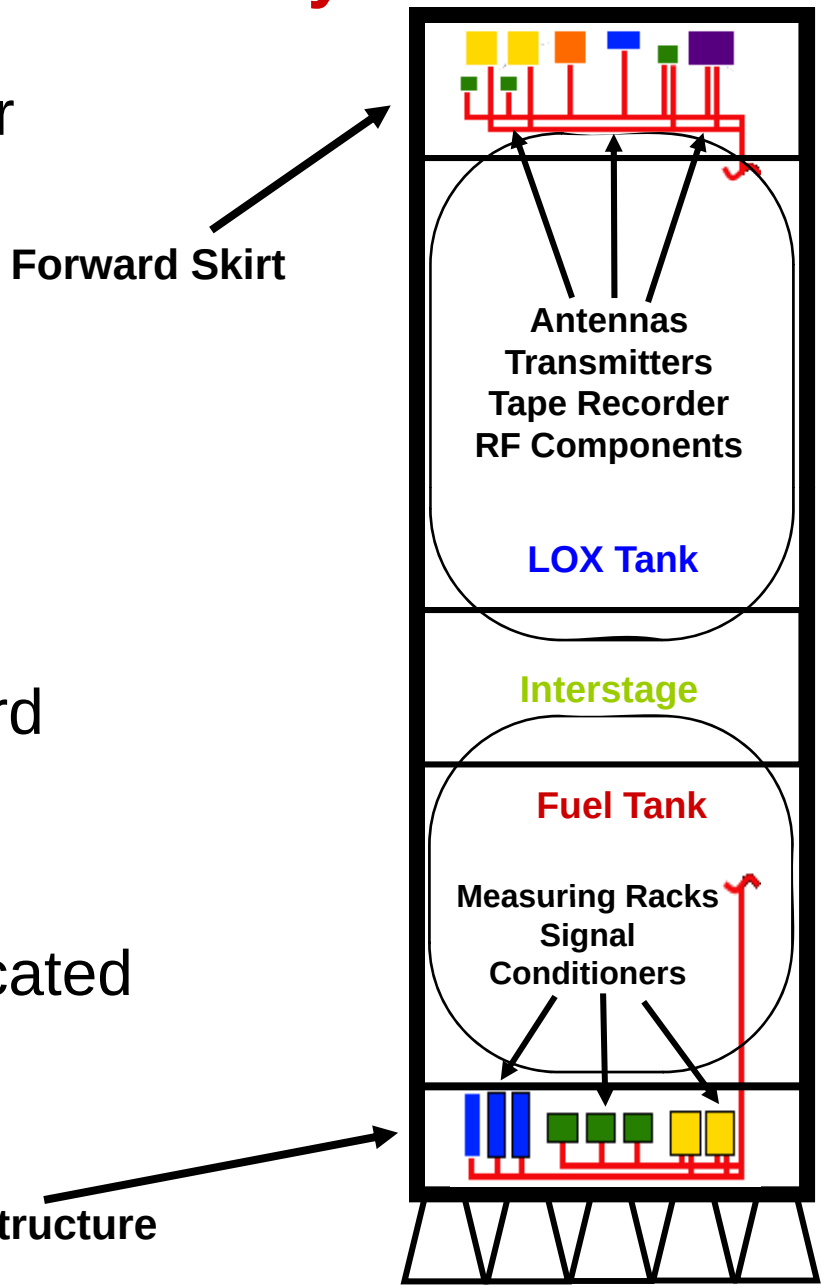
Instrumentation System: Measurement

- Used transducers, signal conditioners, measuring rack assemblies, measuring distributors, & the onboard portion of the remote automatic calibration system

- Measured acceleration, acoustics, current, flow, flight angles, valve position, pressure, RPM's, stress, temperature, vibration, & separation

Instrumentation System: Telemetry

- Method to remotely monitor flight data through RF links
- Six RF links
  - F1, F2, F3, S1, S2, & P1
- RF Assemblies & Tape Recorder located in Forward Skirt
- Remaining components located in Thrust Structure

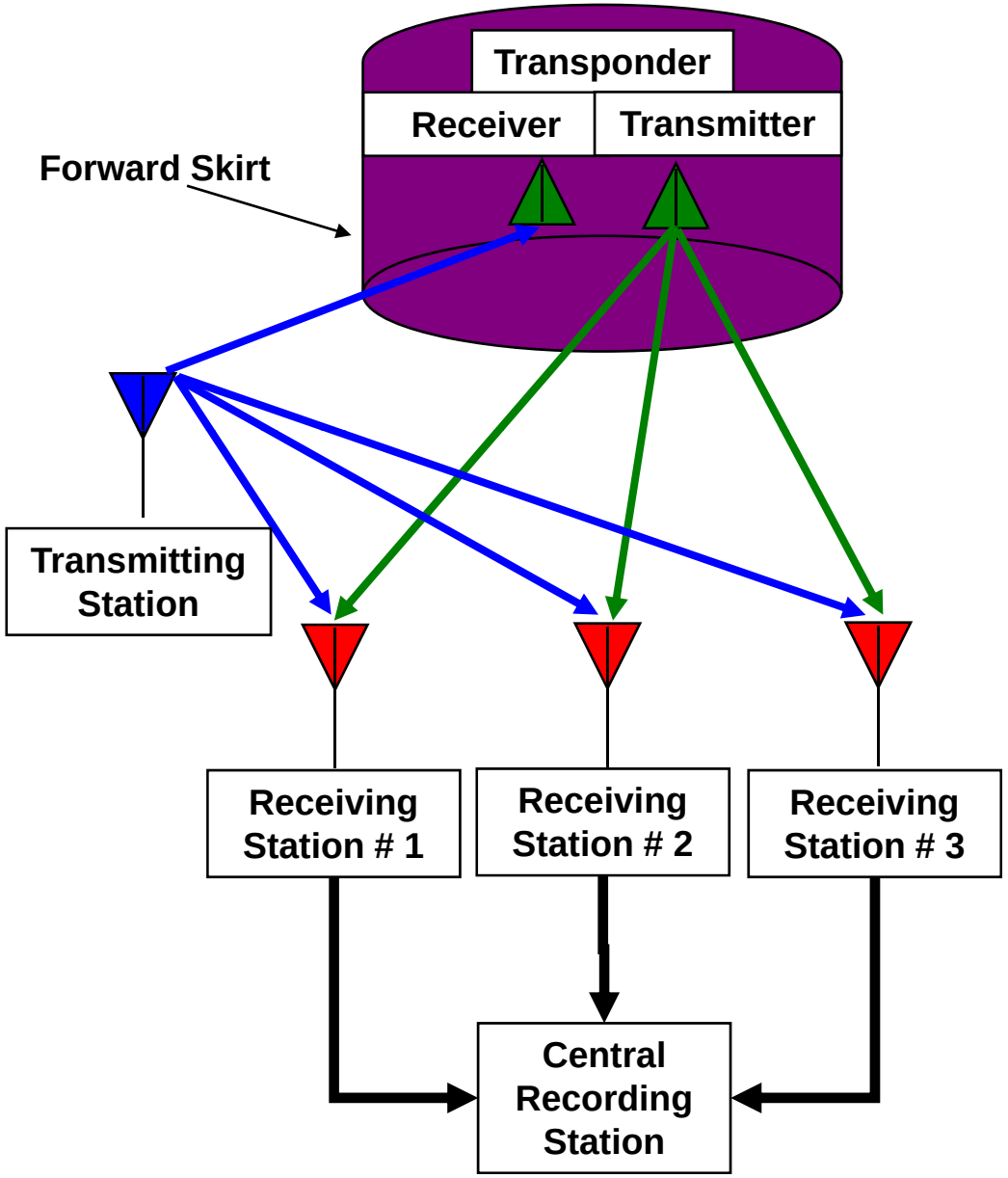


Instrumentation System: Telemetry

- Links F1, F2, & F3
  - Transmitted narrow-band, frequency-type data such as strain gages, temperature gages, & pressure gages
  - Could handle 234 measurements on time-sharing basis & 14 measurements transmitted continuously
- Links S1 & S2
  - Transmitted wide-band, frequency-type data generated by vibration sensors
  - Each provided 15 continuous channels or max of 75 multiplexed channels
- Telemeter P1
  - Transmitted either pulse code-modulated or digital type data

Offset Doppler Tracking (ODOP) System

- Measured rate of motion the vehicle was moving away from/toward a Tracking/Receiving Station
- Signal was received by transponder, modified, and retransmitted back to ground
- Retransmitted signals were received by three Receiving Stations
- Separate antennas on stage were used for receiving and retransmitting the signals



Instrumentation System: Separation System

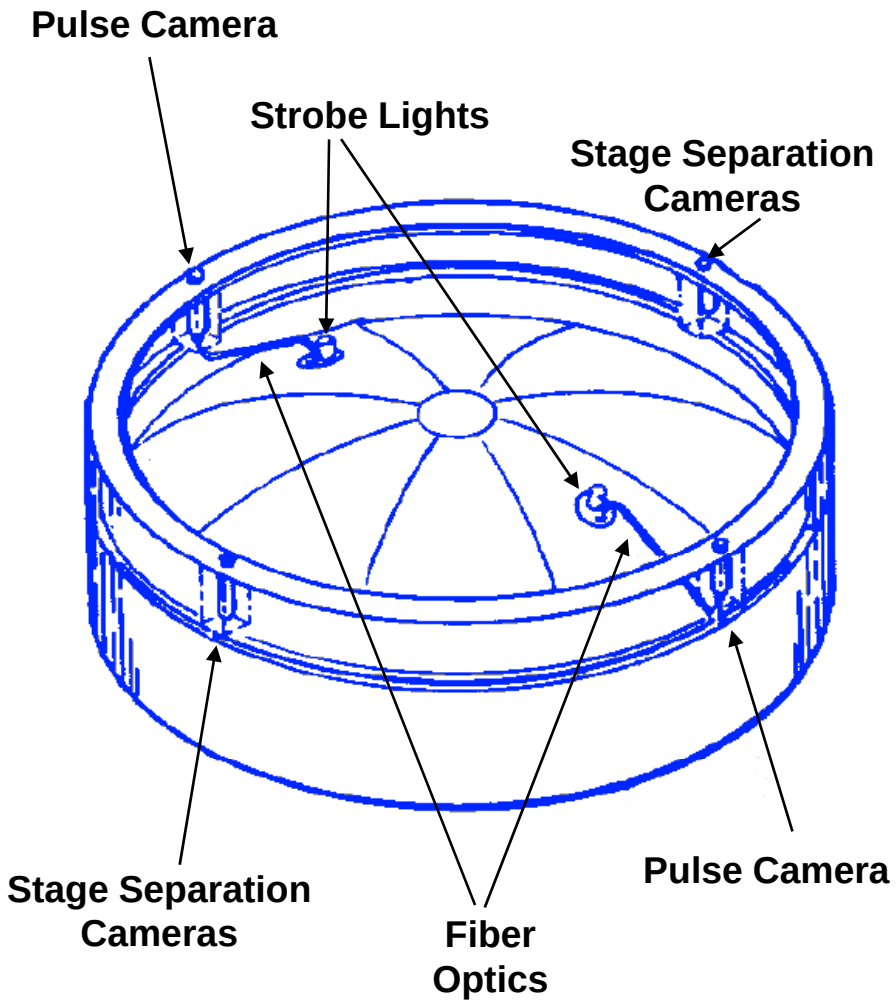
- Redundant ignition system activated separation of First Stage from Second Stage

- Command signal for arming & firing initiation systems were generated by Instrumentation Unit (IU) computer
  - The IU is located above the Third Stage (S-IVB) and below the Apollo Spacecraft (CSM/LM)

- After LOX depletion, the IU signaled the Switch Selector and Sequence & Control Distributor to activate the exploding bridgewire firing units (explosive devices) to initiate the staging sequence

Visual Instrumentation: Film Cameras

- Four film cameras, each in a recoverable capsule
- Two LOX tank-viewing Pulse Cameras, provided motion pictures to show:
  - Behavior of LOX
  - Possible wave or slosh motions
  - Cascading or waterfall effects of liquid from internal tank structure
- Two Strobe Lights illuminated interior of LOX tank for Pulse Cameras
- Two direct-viewing Stage Separation Cameras
- The nine ft (3 m) Fiber Optics, the coupling lens, and the objective lens connected the remotely located camera capsules and flash head



Visual Instrumentation: Television System

- Airborne Television System provided in-flight, real-time visual performance information on all five First Stage F1 engines
- Also stored televised pictures from fueling through First Stage separation
- System utilized two split fiber optic viewing systems & two cameras
- Fiber optic bundles transmitted images to the cameras located in Thrust Structure

Stage I Subsystems

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- Oxidizer System
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- Electrical System
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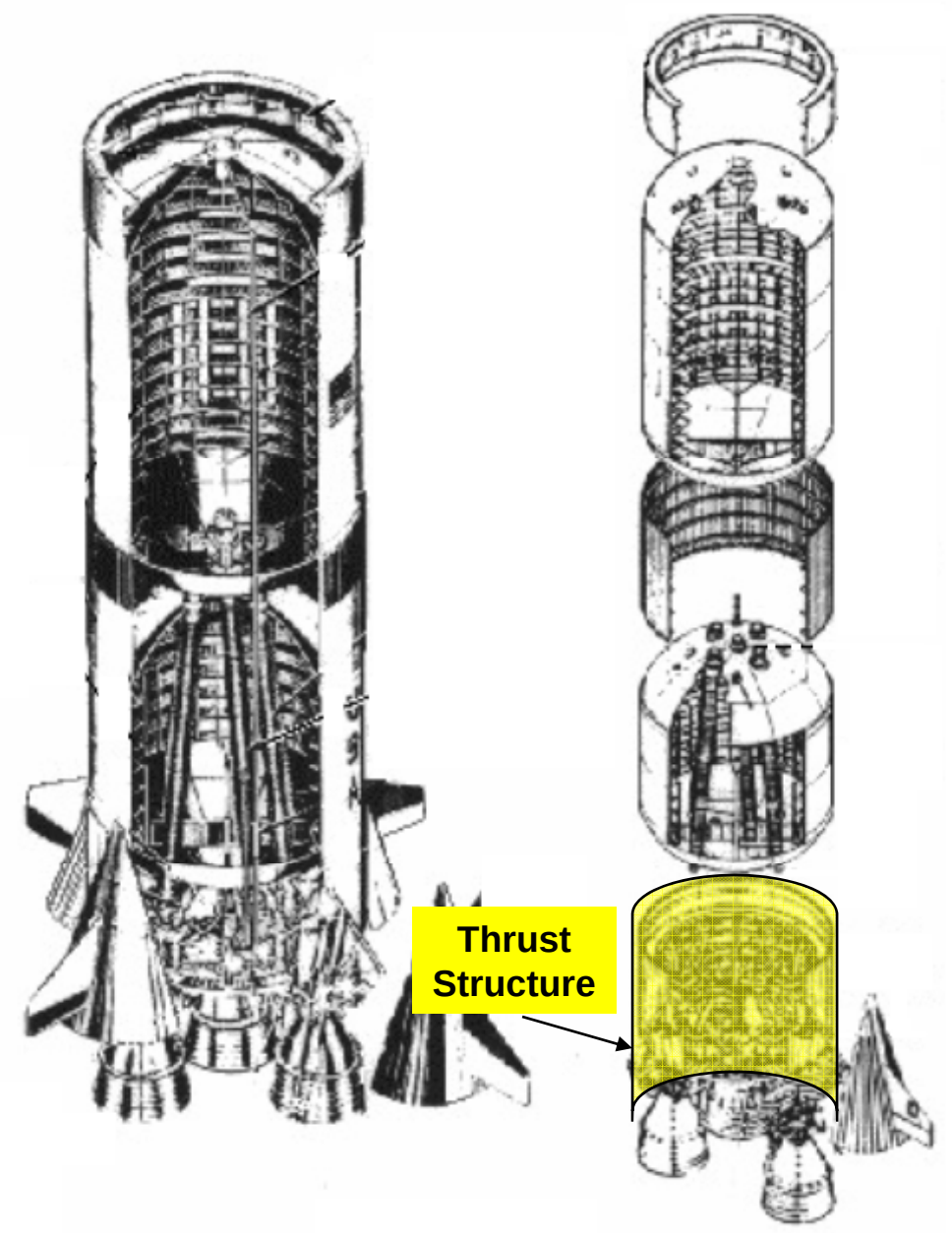
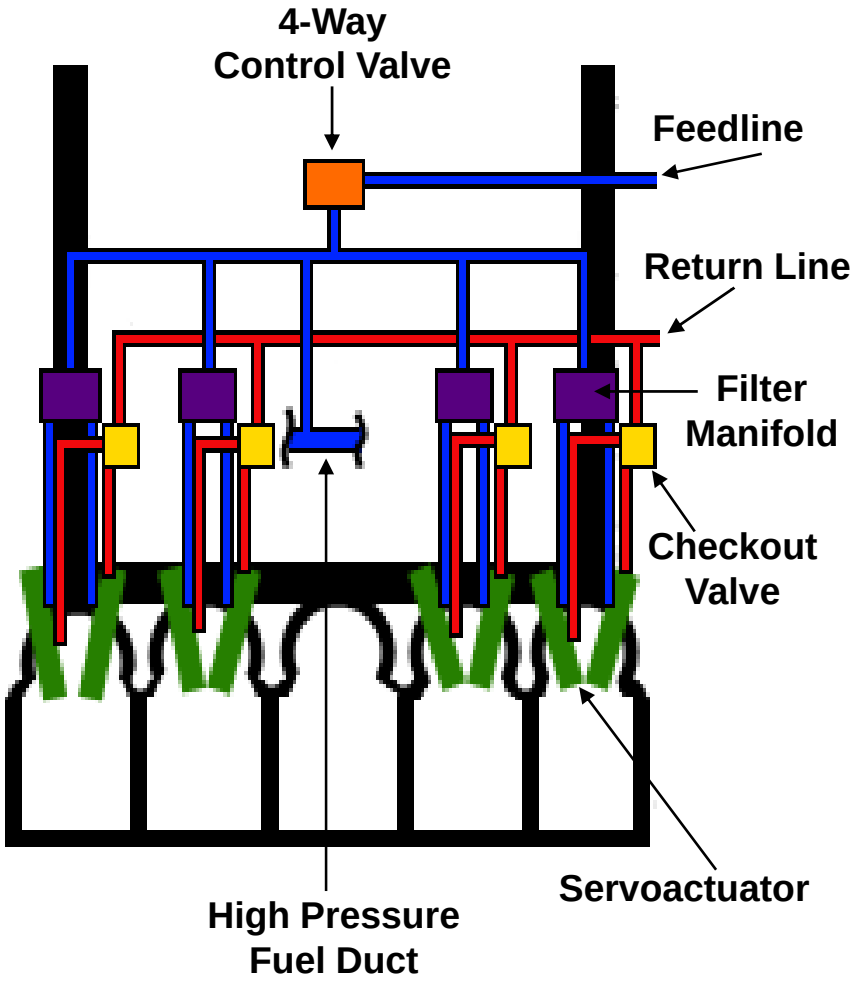
- **Flight Control System**
- Control Pressure System
- Ordnance System



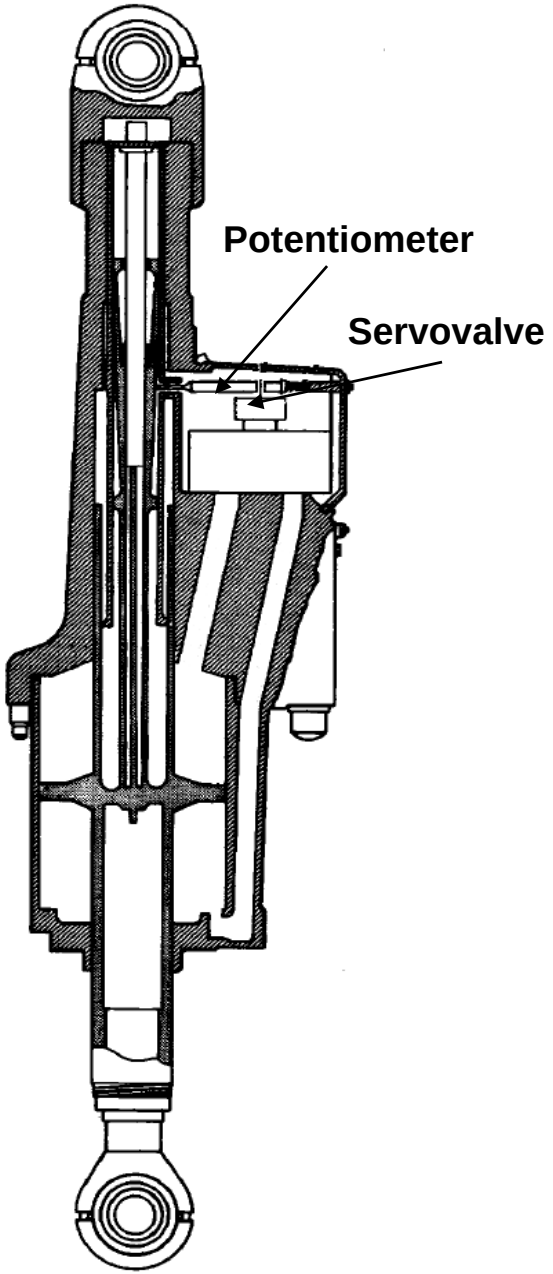
Flight Control System: Fluid Power System

- Used RP-1 and RJ-1 as hydraulic fluid
  - Same type of fuel used for stage fuel system
- Ground supply of RJ-1 routed to all five F1 engines
- After ignition, RP-1 routed from High Pressure Fuel Duct to Servoactuators
- Center Engine directed hydraulic fluid through Feedline & 4-way Hydraulic Control Valve to supply pressure to closing ports of Gas Generator, Main Fuel Valves, & Main LOX Valves
- The four outboard engines directed RJ-1 through Servoactuators to ground Checkout Valve where it was returned through coupling to ground supply



Flight Control System: Hydraulic Servoactuator

- Power control unit for converting electrical command signals & hydraulic power into mechanical outputs to gimbal engines
- The engine gimbaling was a closed loop system
  - IU received inputs from its guidance system and sent signals to Servoactuators to gimbal the engines
  - Potentiometer sensed Servoactuator position and transmitted that feedback (engine piston position) to the IU
  - IU modified effect of control signal to continue to gimbal the engines in the required direction



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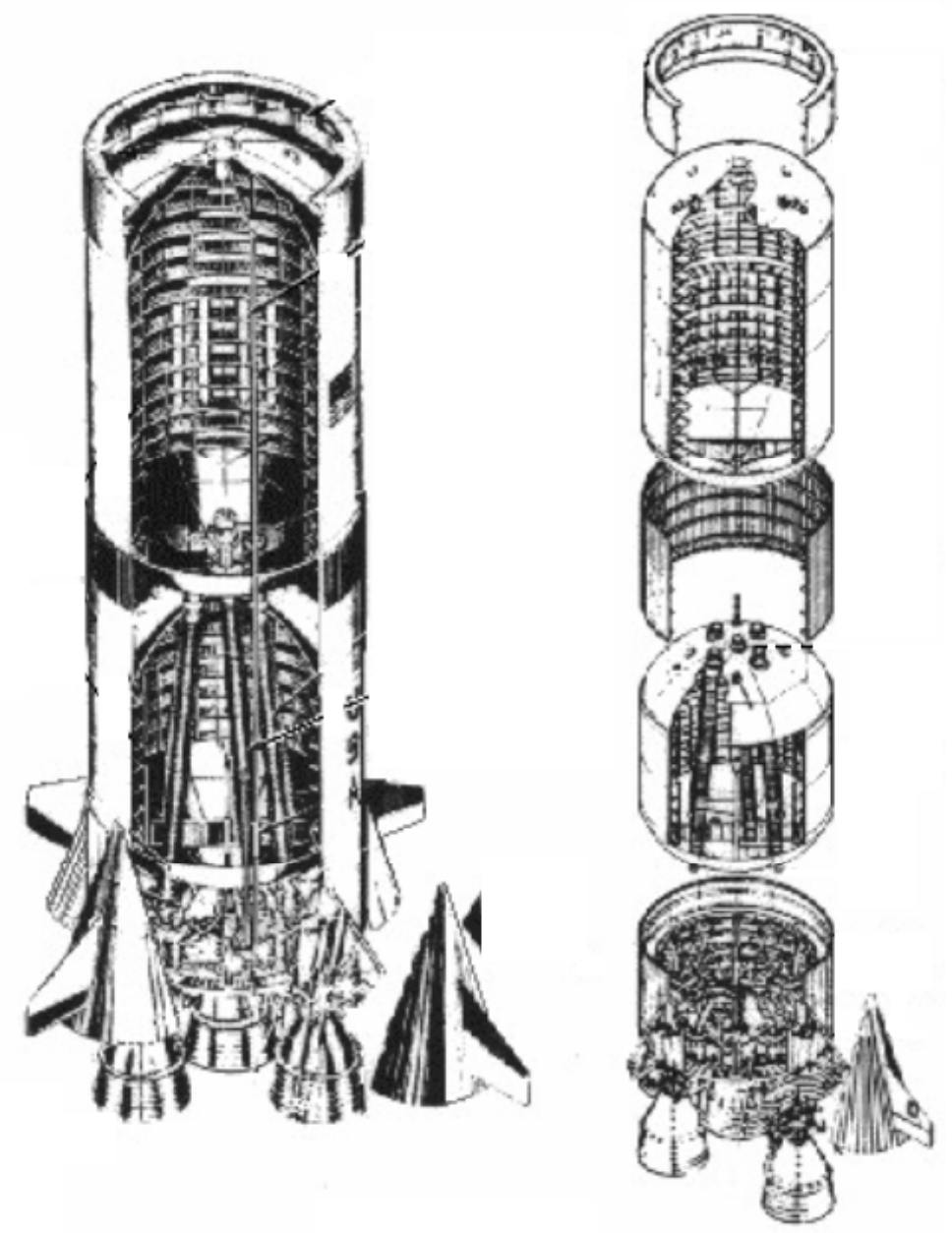
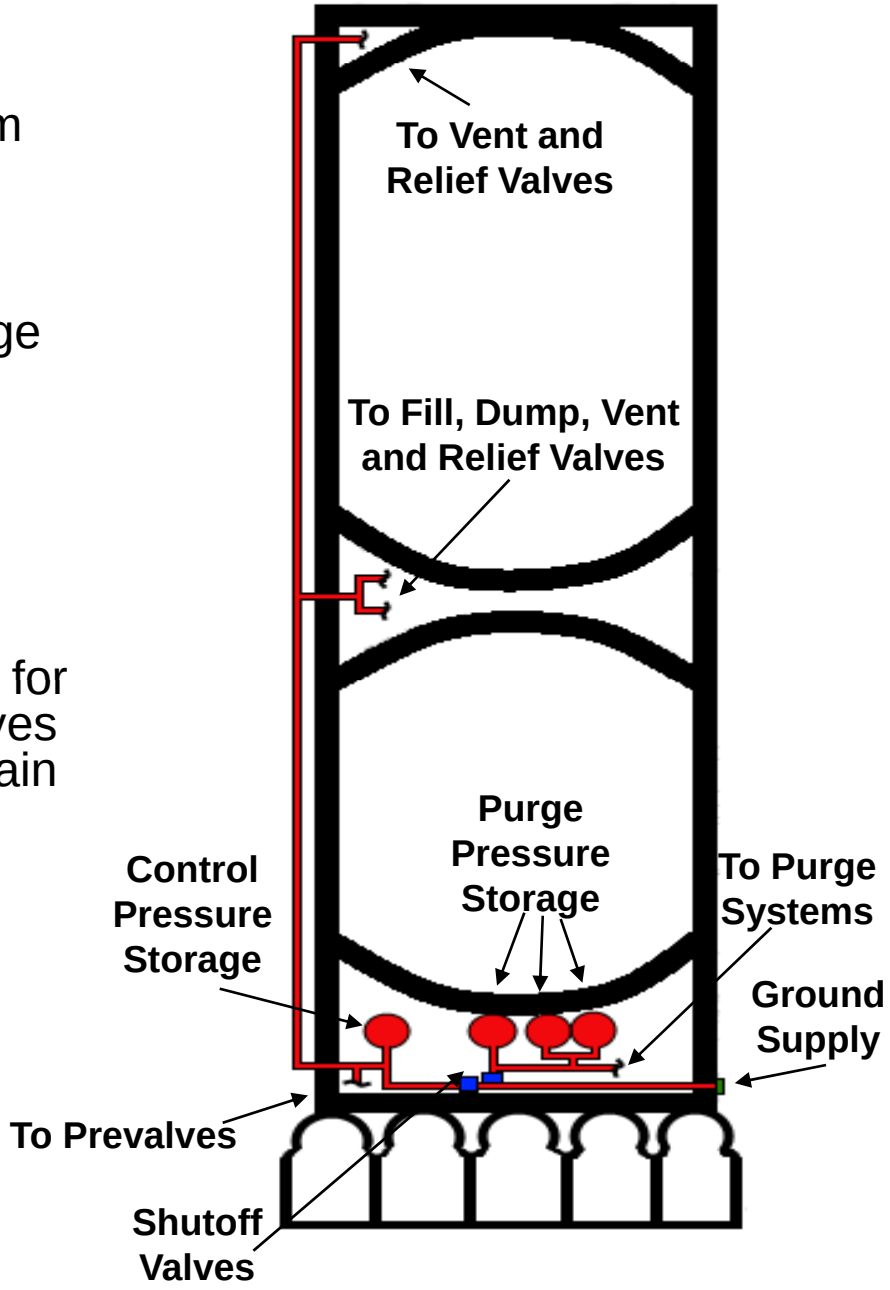


Control Pressure System

- Supplied pressurized GN_2 to pneumatically actuate propellant system valves & purge the F-1 engines
- **Onboard Control Pressure System –** contained high pressure nitrogen storage bottle, an umbilical coupling & tubing assembly for filling bottle, manifold assembly, & control valves at terminal ends of nitrogen distribution lines
- **Ground Control Pressure System** – provided direct ground pressure supply for First Stage pneumatically-actuated valves that were involved with propellant fill/drain & emergency engine shutdown system operations
- **Onboard Purge Pressure System** – expelled propellant leakage



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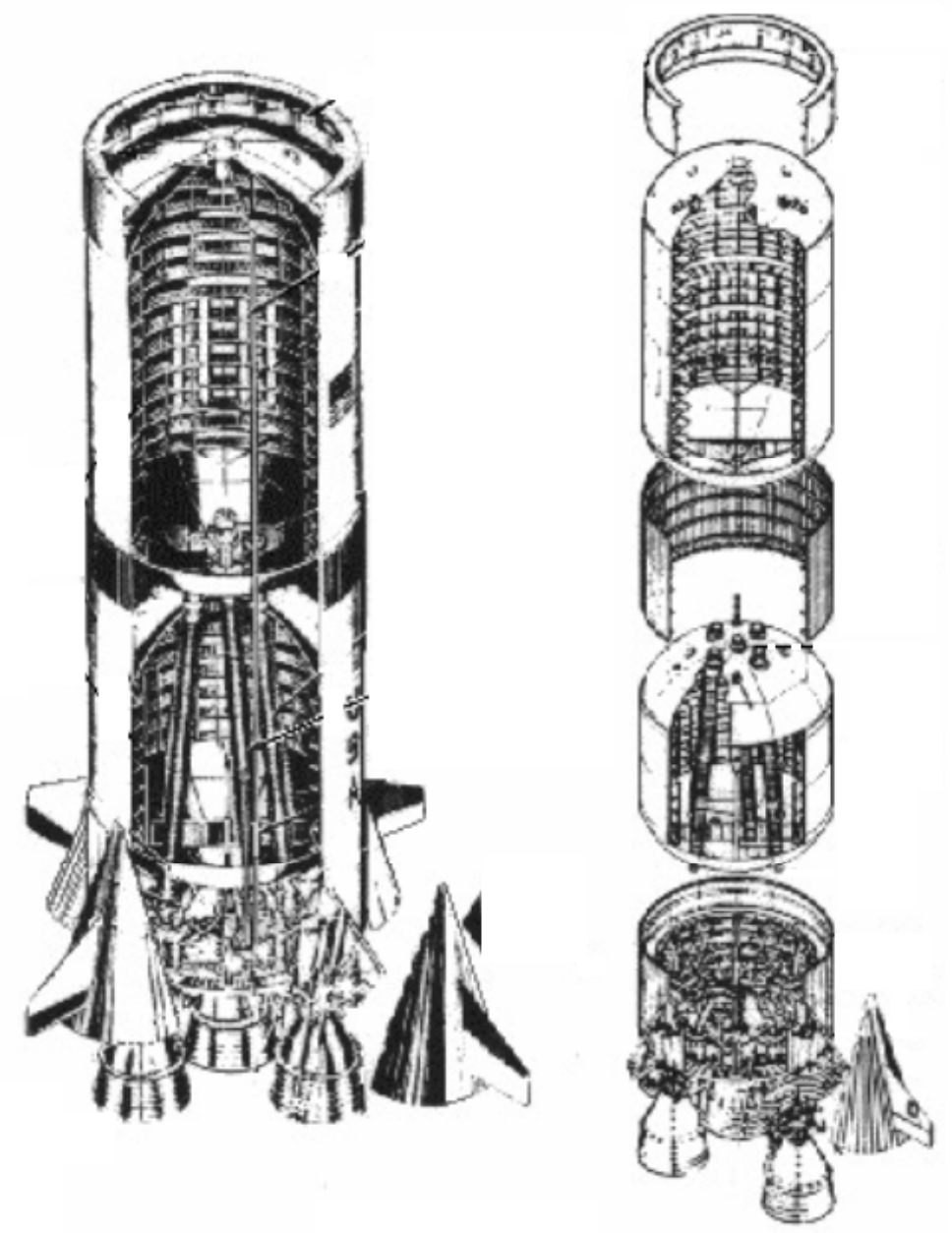
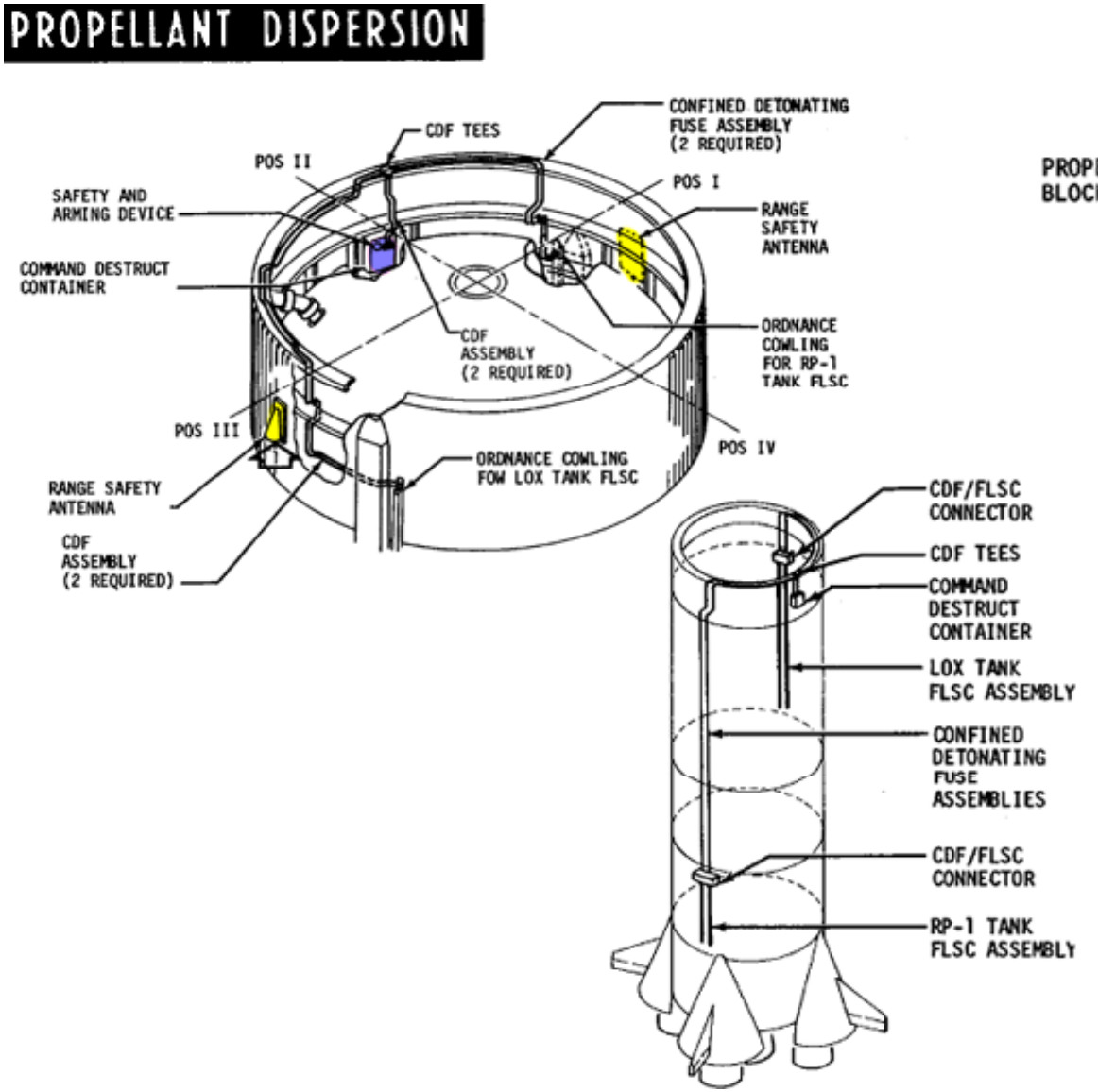


Ordnance System: Propellant Dispersion System (PDS)

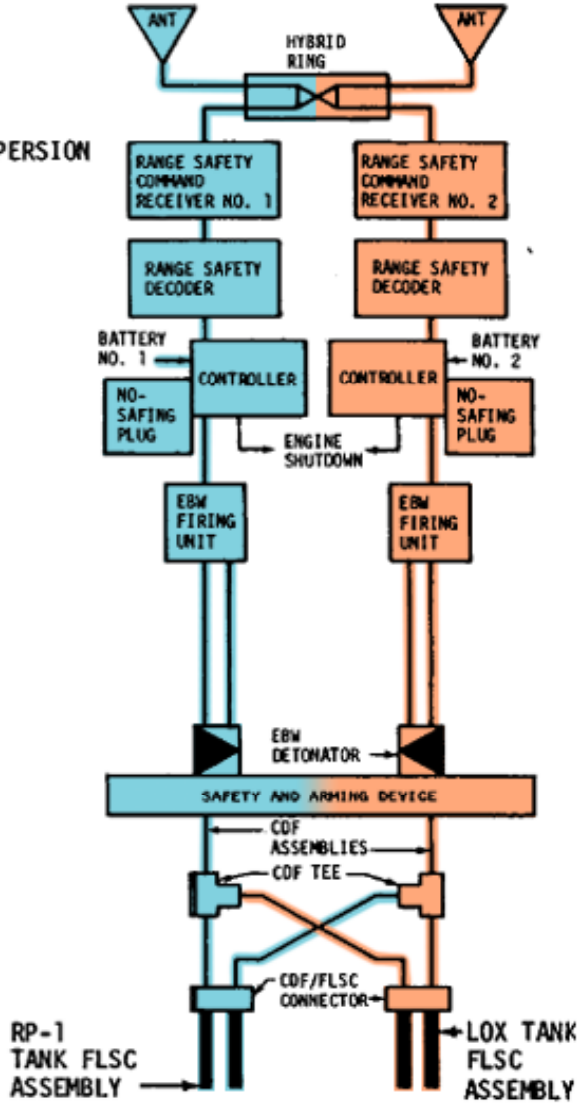
- Terminated flight of Saturn V if it strayed from flight path or if it became a safety hazard

- PDS was a dual channel, parallel redundant system composed of two segments
  - Radio frequency segment received, decoded, & controlled propellant dispersion commands
  - Ordnance train segment consisted of two exploding bridgewire (EBW) firing units, two EBW detonators, one safety & arming (S&A) device, six confined detonating fuse (CDF) assemblies, two CDF tees, two CDF/flexible linear shaped charge (FLSC) connectors, & two FLSC assemblies

Ordnance System: PDS



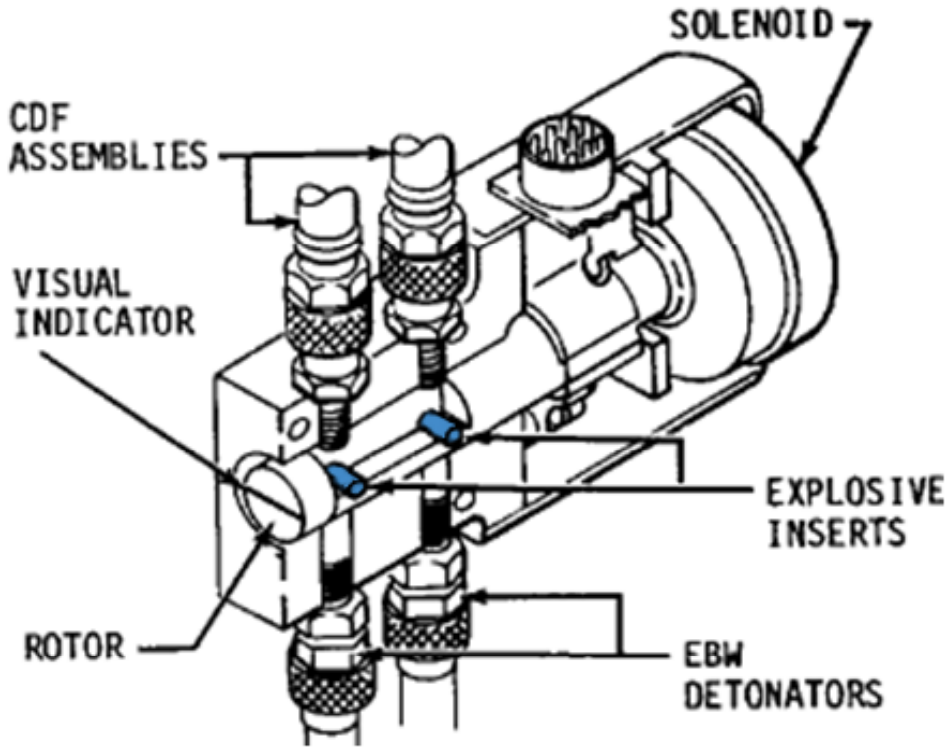
PROPELLANT DISPERSION BLOCK DIAGRAM



For detailed view, select presentation under References below

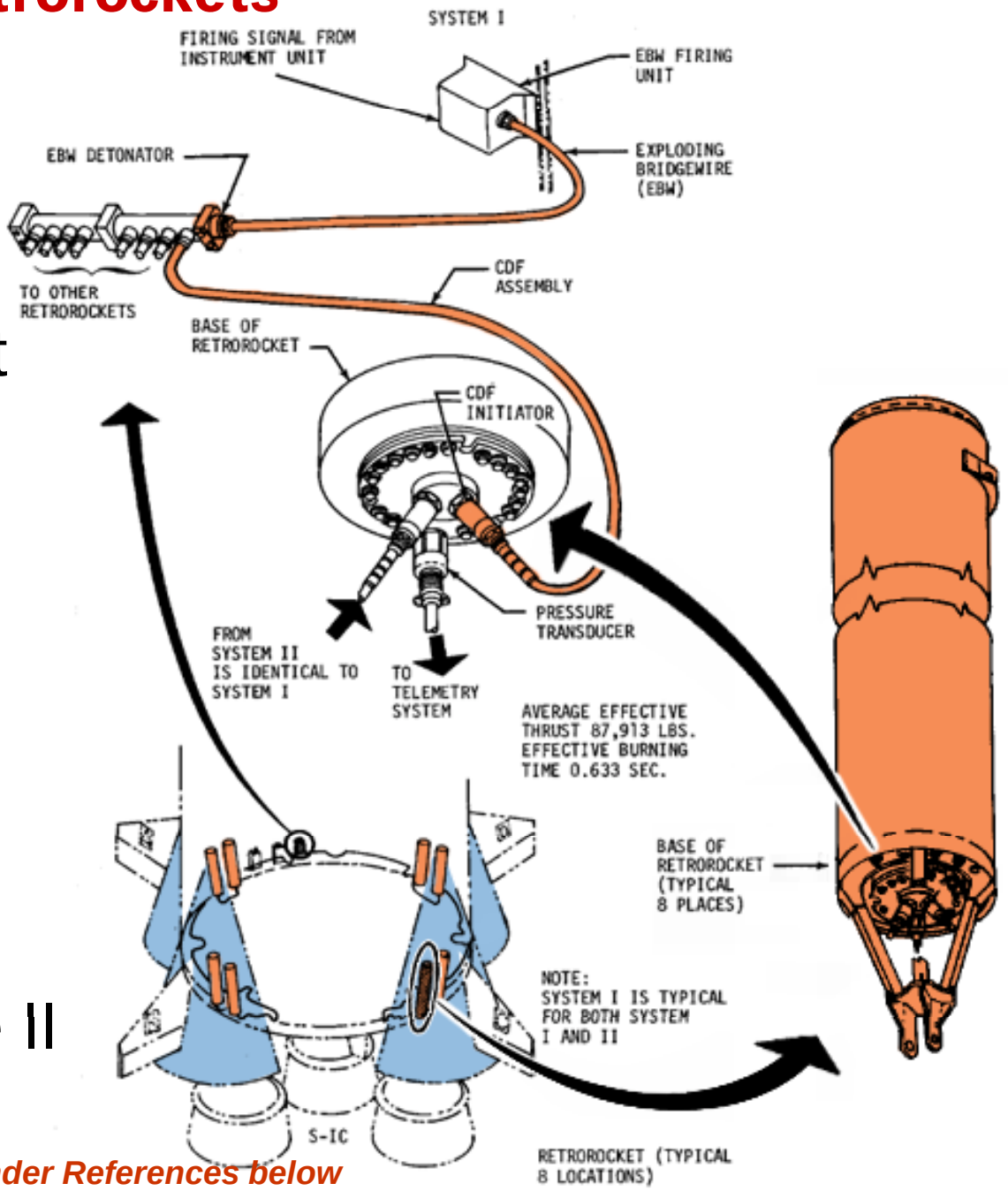
Ordnance System: Safety and Arming Device (S&A)

- Remotely controlled electro-mechanical ordnance device
- Used to make safe & to arm S-IC, S-II, and S-IVB stage PDS's
- Completed & interrupted explosive train by remote control
- Provided position indications to remote monitoring equipment



Ordnance System: Retrorockets

- The eight retrorockets provided separation thrust after Stage S-IC burnout
- Propelled Stage S-IC away from the rest of the launch stack as it progressed through to Stage II



For detailed view, select presentation under References below

Saturn V Stage I Summary

- Become familiar with the Saturn V Stage I (S-IC) major structural components:
  - Forward Skirt
  - Oxidizer Tank
  - Intertank
  - Fuel Tank
  - Thrust Structure
- Gain a general understanding of the Stage I subsystems:
  - Fuel
  - Oxidizer
  - Environmental Control
  - Electrical
  - Instrumentation
  - Flight Control
  - Control Pressure
  - Ordinance

For More Information

- Apollo Mission Familiarization for Constellation Personnel
  - Apollo-Saturn Wiki

- References
  - Saturn V News Reference, August 1967
  - Saturn V Flight Manual, SA 503, 1 November 1968
  - Technical Information Summary Apollo-10 (AS-505), 1 May 1969