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Rocket Turbomachinery Shaft Seals

- **Introduction**

- **Operating Environments**
 - **Fluids and fluid conditions**
 - **Various stages of turbopump operation**

- **Design Issues**
 - **Inter-Propellant-Seal (IPS) Systems**
 - **'Lift-off' Seal Systems**

- **Technology Development Needs**

Design Issues

- **Function**
- **Safety**
- **Performance**
 - **Propellant loss**
 - **Turbopump efficiency**
 - **System weight**
- **Environment -- Physical and Chemical**
- **Packaging**
 - **Influence on turbopump configuration**
 - **External systems**
- **Life, 'ilities,* Health Monitoring Systems**
- **Cost and Schedule**

*Jargon for Operability, Maintainability, Reliability, and other similar terms.

Operating Environment

- **Fluids**
 - **Cryogenic: Liquid Oxygen (LOX), Liquid Hydrogen**
 - **Storable**
 - **Oxidizers: Nitrogen Tetroxide (NTO), Hydrogen Peroxide**
 - **Fuels: Kerosene (RP-1), Monomethylhydrazine (MMH)**
 - **Hot Gas**
 - **Generally fuel rich**
 - **Oxygen rich for LOX-RP-1 staged combustion**

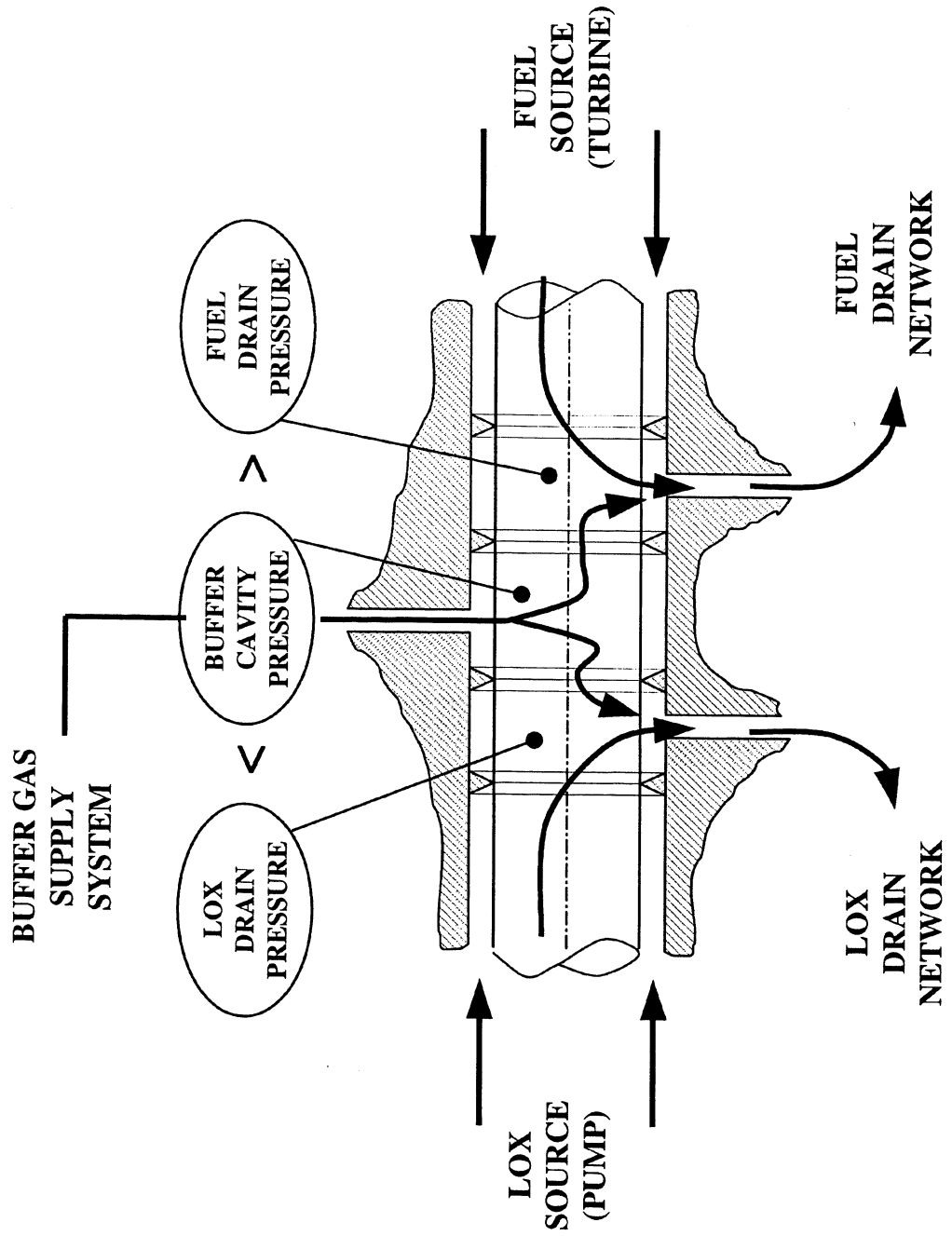
Operating Environment

- **Stages of Operation**
 - **Chilldown**
 - **Start**
 - **Operating**
 - **Shutdown**
 - **Coast**
 - **Restart**
 - **Purge and Secure**

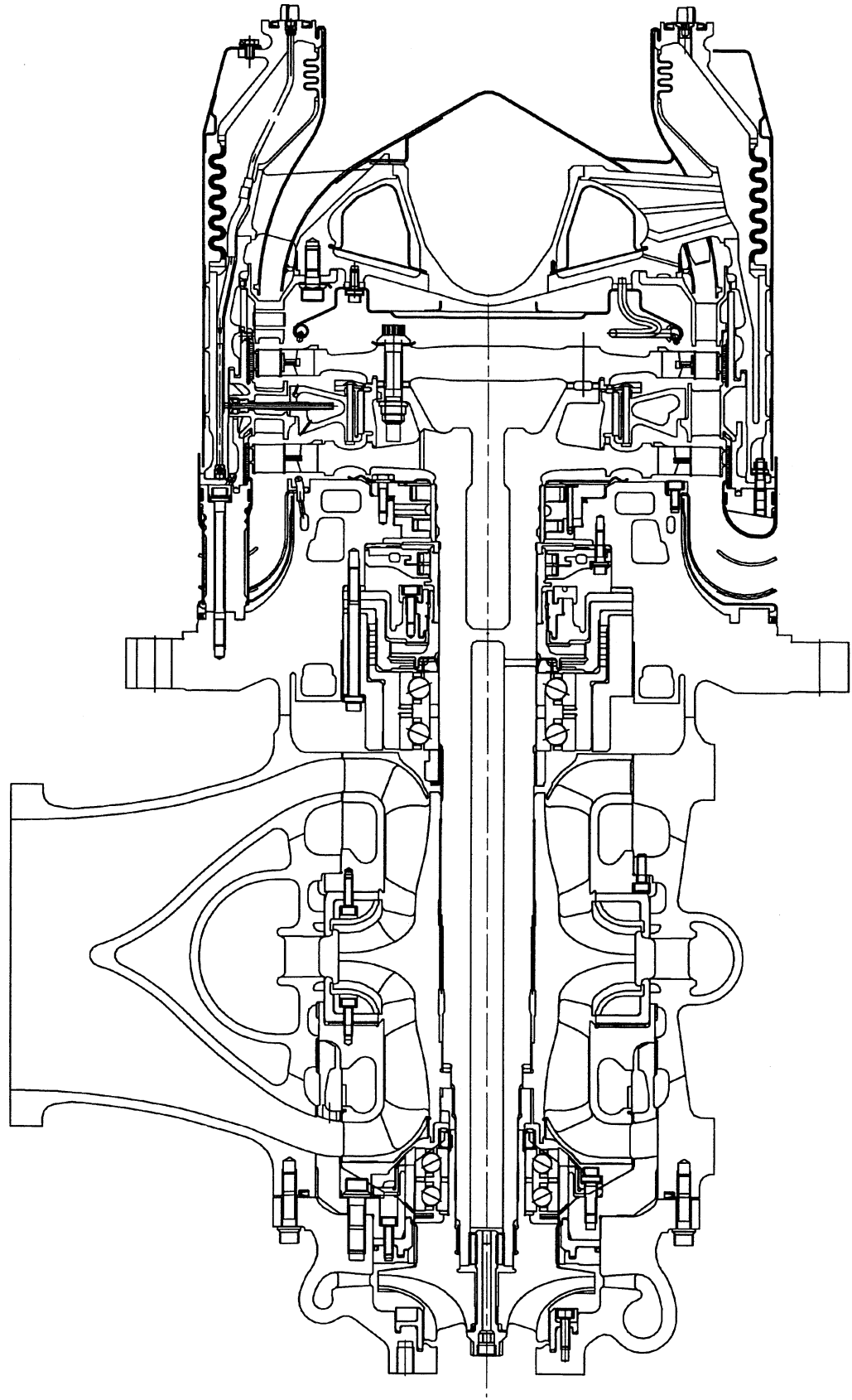
Inter-Propellant-Seal (IPS)

- **IPS Purpose**
 - **Separate incompatible fluids**
 - **Minimize propellant loss**
- **IPS Design Requirements**
 - **Reliable, Robust**
 - **Use minimal buffer gas**
 - **Use minimal axial pump length**

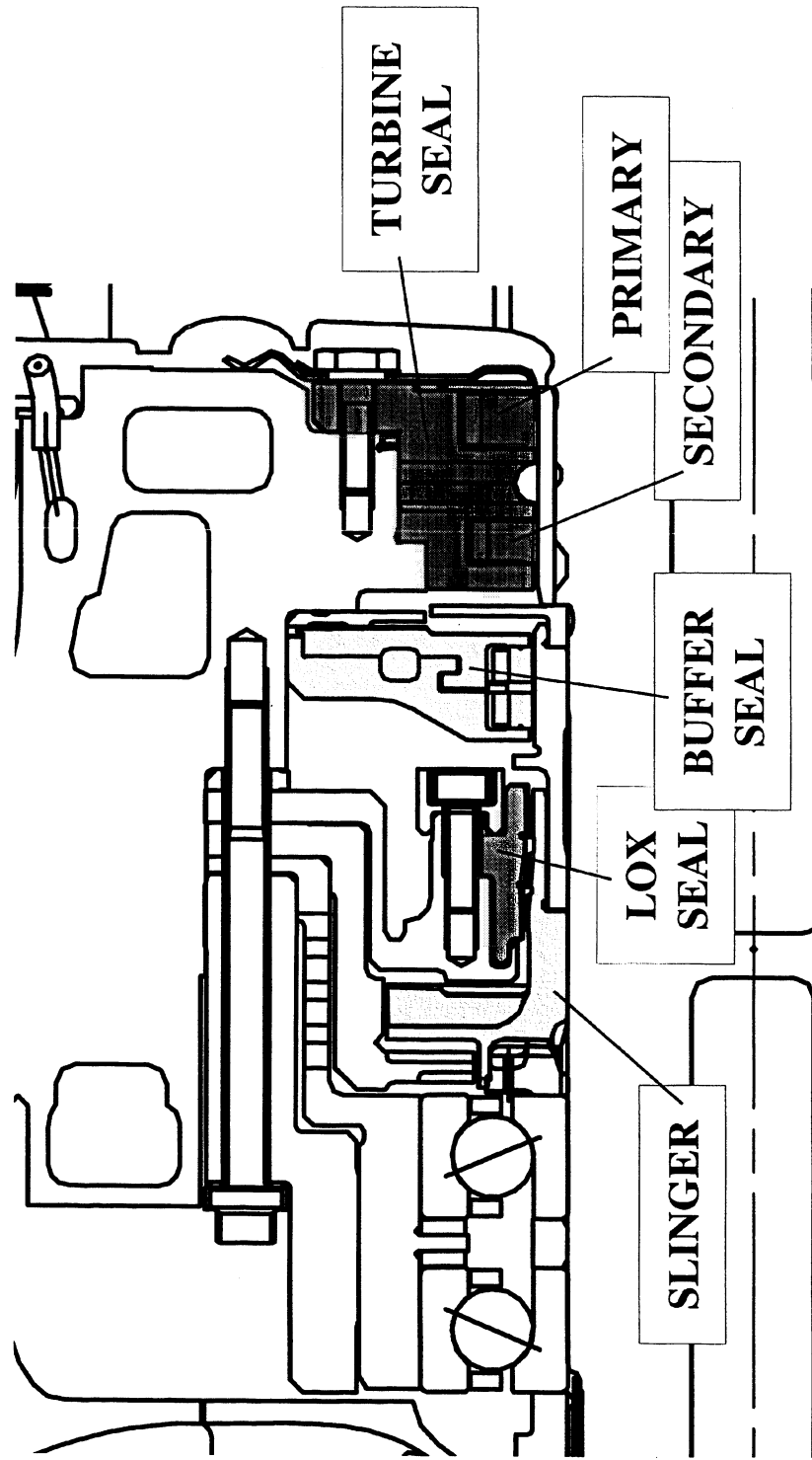
Inter-Propellant Seal System



SSME High Pressure Oxidizer Turbopump



SSME High Pressure Oxidizer Turbopump Inter-Propellant Seal System



Inter-Propellant Seal System Design Considerations

- **LOX Source**
 - **Supply Pressure and Temperature**
 - **Slinger (throttling, power)**
 - **Vent to pump inlet (suction performance, additional seal, porting)**
- **Fuel Source**
 - **Hot Gas**
 - **Staged seals**
 - **Transient thermal environment**
 - **Liquid (bearing sump or single shaft arrangement)**
 - **Inerting during chill, shutdown**

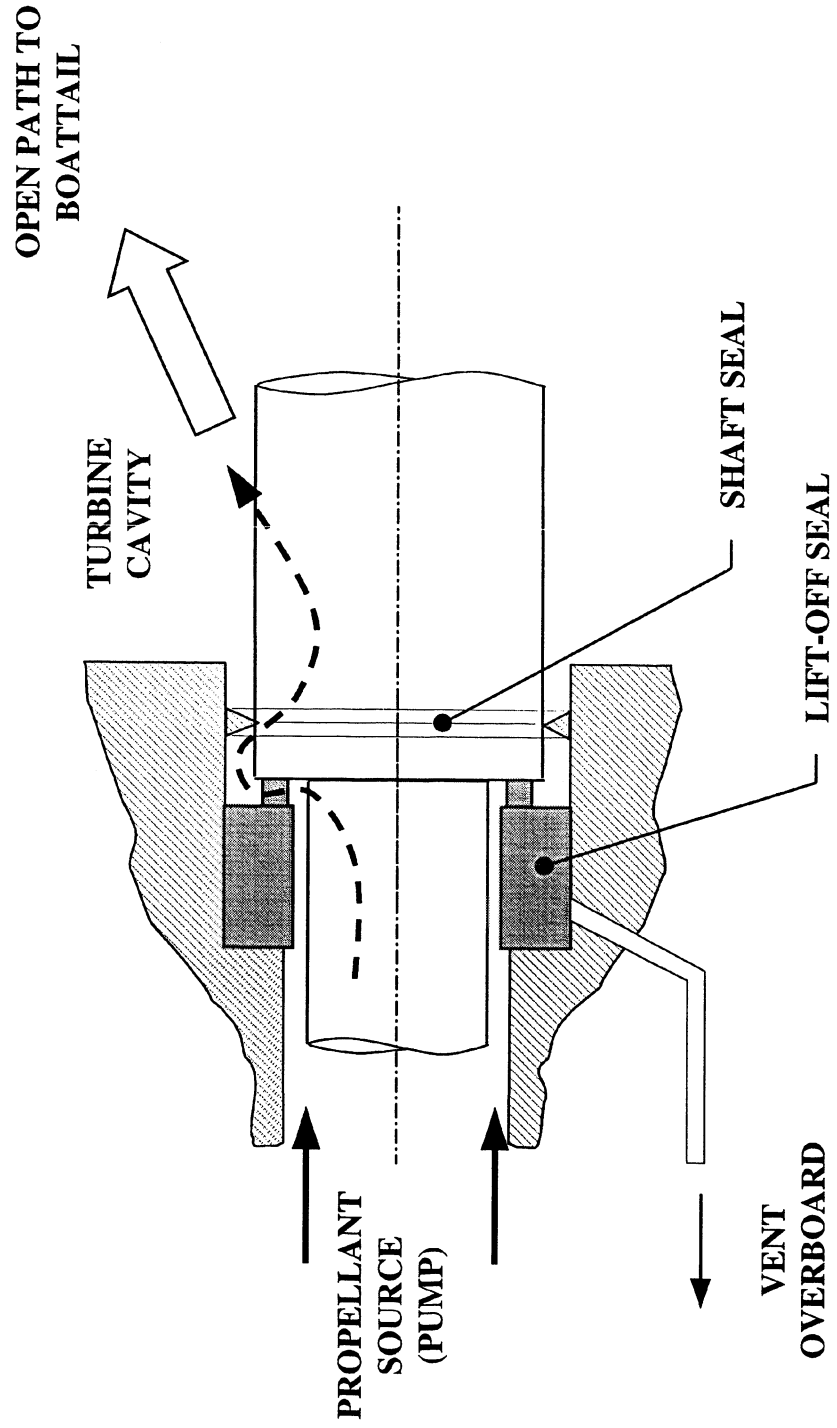
Inter-Propellant Seal System Design Considerations

- **Drains**
- **Low sump pressure**
- **Routing**
 - **Internal passages**
 - **External lines -- Engine or Vehicle mounted pump**
 - **Weight including support structure**
- **Buffer Gas Supply System (Helium)**
 - **Sources**
 - **Other users**
 - **Pressure control versus mass flow control**

Inter-Propellant Seal System Design Considerations

- **Shaft Seals**
- **Materials**
 - **LOX Compatibility, Hydrogen Environment Embrittlement**
 - **Hard vacuum**
 - **Failure Mode Effects, Fail-Safe requirements**
 - **Thermal environment - large transient and steady-state gradients**
 - **Length -- significant effect on rotordynamics**
- **Wear**

Lift-off Seal System



Lift-off Seal System Design Considerations

- **Propellant Source**
- **Supply Pressure and Temperature**
- **Pressure must always be greater than turbine pressure**
- **Usually cryogenic fluid**
- **Turbine Cavity**
- **Pressure set by engine cycle and turbine flow direction**

Lift-off Seal System Design Considerations

- **Lift-Off Seal**
 - **Closed under maximum pump inlet pressure during chill and shutdown**
 - **Open before minimum steady state operating point**
 - **Accommodate shaft axial travel**
 - **May require overboard vent line (low pressure sink)**
- **Shaft Seal**
 - **Leakage onto hot turbine components troublesome**
 - **Generally limited length available**
 - **Position upstream or downstream of lift-off seal influenced by turbine disc cooling requirements**

Technology Development Needs

- **Inter-Propellant Seals**
 - **Reduced leakage seals**
 - **Robust Seals - reduce buffer margin**
- **Lift-Off Seal System**
 - **Combine lift-off seal with turbine shaft seal and eliminate overboard vent**