Space Station Fluid Resupply

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Space Station Freedom

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Space Station Fluid Resupply

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- Requirements

  Resupply (PMC)
  ECLSS Fluids $\sim 3200 \text{ lbs } N_2 \text{ per year}$
  LAB Fluids $\sim 3500 \text{ lbs } O_2 \text{ per year}$
  Contingency
  ECLSS Fluids $\sim 1300 \text{ lbs } N_2 \text{ per year}$
  $\sim 700 \text{ lbs } N_2 \text{ on station}$
  $\sim 900 \text{ lbs } O_2 \text{ on station}$
Space Station Fluid Resupply

- Design Considerations:

  Resupply
  - Resupply Frequency: ~180 days
  - Transportation State: High pressure gas

  Contingency
  - Supply Frequency: On station @ PMC; as required thereafter
  - Transportation State: High pressure gas (3000 psi) Supercritical fluid
Space Station Fluid Resupply

Space Station Freedom

- Unpressurized Logistics Carrier

Outfitting
- Cargo Accommodations
  - Subcarrier Attach Mechanisms
  - Nor: Containerized Cargo Attachments

- Subsystems
  - EPS
  - DMS
  - TSS
  - MS
  - Passive Thermal Control System (PTCS)

Characteristics
- Empty Weight: 2,251 lbs
- Cargo Accommodation capability
  - Combinations of Subcarriers (FSC, OSC, HPSC, DCSC)
  - Seat Track on Member Faces for Oversized Cargo

Mechanisms
- Automated Umbilical Mechanism
- Subcarrier Attachment Mechanisms
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- Fluids Subcarrier (FSC)

Outfitting
- Cargo accommodations
  - 3 ECLSS Supercritical N₂ (SCN₂) tanks
  - 1 Lab SCN₂ tank

Subsystems
- MS
- FPS
- DMS
- TSS
- Passive Thermal Control System (PTCS)
- Tanks and Plumbing
- Mechanisms
  - Automated Umbilical Mechanism
  - U/C Attachment Mechanism
  - ITA Attachment Mechanism

Characteristics
- Total Dry Weight - 1940 lbs
- Cargo Accommodations Capability
  - ECLSS SCN₂ - 1434 lbs
  - Lab SCN₂ - 478 lbs
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- Oxygen Subcarrier (OSC)

**Outfitting**
- Cargo accommodations
  - 3 ECLSS Supercritical O₂ (SCO₂) tanks
- Subsystems
  - MS
  - EPS
  - DMS
  - TSS
  - Passive Thermal Control System (PTCS)
  - Tanks and Plumbing
  - Mechanisms
    - Automated Umbilical Mechanism
    - ULC Attachment Mechanism
    - ITA Attachment Mechanism

**Characteristics**
- Total Dry Weight - 1459 lbs
- Cargo Accommodations Capability
  - ECLSS SCO₂ - 2.75 lbs
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- High Pressure Subcarrier (HPSC)

Outfitting
- Cargo accommodations
  - 3 High Pressure N₂ (HPN₂) tanks
  - 2 HP O₂ tanks
- Subsystems
  - MS
  - EPS
  - DMS
  - TSS
  - Passive Thermal Control System (PTCS)
- Mechanisms
  - Automated Umbilical Mechanism
  - ULC Attachment Mechanism
  - ITA Attachment Mechanism

Characteristics
- Total Dry Weight - 3226 lbs
- Cargo Accommodations Capability
  - HPN₂ - 588 lbs
  - HPO₂ - 506 lbs
Space Station Fluid Resupply

- Transportation and Transfer Plan – Resupply
  - Prelaunch and post launch operations phases
    - Load fluids into supercritical tanks on the subcarriers
    - Transport fluids to the SS in a liquid state
  - On station operations phase
    - Change state of fluid from liquid to supercritical by turning on tank heaters
    - Transfer fluids from subcarriers to users
    - Complete unloading of subcarriers
  - Prelanding operations phase
    - Return subcarriers with residual gas
Space Station Fluid Resupply

Space Station Freedom

* Operations Phase Definitions
  * All LE's go through complete operations cycles consisting of 6 primary phases
  * Hab and US Lab go through operations cycles 1, 2 and 3 TOTAL CYCLE

**PHASE DEFINITIONS**

1. **Pre Launch Phase**
   Begins at start of preparations and processing for launch and ends at launch.

2. **Post Launch Phase**
   Begins at launch and ends at completion of element installation on SS.

3. **On Station Operations Phase**
   Begins at completion of element installation on SS and ends at start of transfer of returning LE from SS to the orbiter.

4. **Prelanding Phase**
   Begins at start of transfer of returning LE from SS to the orbiter and ends at landing.

5. **Post Landing Phase**
   Begins at landing and ends at completion of LE offload operations.

6. **LE Turnaround**
   Begins at completion of LE unloading operations and ends at start of LE prelaunch operations.
Space Station Fluid Resupply

- Operations Flow - FSC and OSC

### Timeline

**Fluids State**
- **N₂** and **O₂**
- Loaded @ ~ 20 psia and ~ 320°F (N₂) and TBD°F (O₂)
- Tank Pressure @ Launch ~ 31.5 psia

**Note:** While in the liquid state, pressure and temperature will slowly rise in the tanks.

**Timeline Hrs/Days**
- - 568 Hrs (1)
- - 560 Hrs (1)
- - 544 Hrs (1)
- - 400 Hrs (1)
- - 72 Hrs (1)
- 0
- + 1.5 Hrs (2)
- + 31 Hrs (2)
- + 45 Hrs (2)

**Operations**
- Start Loading
- Complete Loading Fluids
- Emplace Subcarriers into ULC
- Emplace ULC into Orbiter
- Close PLB Doors
- Launch Orbiter
- Open PLB Doors
- Dock Orbiter on-Station
- Connect SSRMS to ULC

(1) Preliminary timeline estimate
(2) Preliminary timeline estimate from NSTS Integration and Operations Office
Space Station Fluid Resupply

- Operations Flow - FSC and OSC (continued)

**Fluids States (N\textsubscript{2} and O\textsubscript{2})**

- Liquid
- Critical Pressure
  - N\textsubscript{2}: 493 psia
  - O\textsubscript{2}: 736 psia
- Liquid to Supercritical Transformation
- Supercritical
- Residual Gas

**Timeline Hrs/Days**

- + 46 Hrs (1)
- + 47 Hrs (1)
- + 49 Hrs (1)
- + 49.5 Hrs (1)
- + 73.5 Hrs (1)
- + 180 Days (2)
- + 182 Days (2)
- + TBD

**Operations**

- Connect ULC to ITA
- Parking and C/O Complete for ULC on ITA
- Parking and C/O Complete for subcarriers on ITA
- Start subcarrier heater duty cycle
- Start transfer of fluids from subcarriers to User
- Launch next Orbiter
- Dock Orbiter On-Station
- Parking and C/O Complete for second subcarrier set on ITA
- Complete Unloading of first subcarrier set

(1) Preliminary timeline estimate
(2) Preliminary timeline estimate NSTS Integration and Operations Office
Space Station Fluid Resupply

- Operations Flow - FSC and OSC (continued)

Timeline

Hrs/Days

Operations

Emplace first subcarrier set into ULC
Start Transfer of ULC from ITA to Orbiter
Emplace ULC into Orbiter
Unlock Orbiter from Station
Close PLB doors
Land

Fluids State

(N₂ and O₂)

Residual Gas

Returned @ 120 psia and -130°F (N₂ and O₂)

(1) Preliminary timeline estimate

(2) Preliminary timeline estimate from NSTS Integration and Operations Office
Space Station Fluid Resupply

- Transportation and Transfer Plan – Contingency
  - Prelaunch and post launch operations phases
    - Load fluids into high pressure tanks on the HPSC
    - Transport fluids to the SS in a gaseous state
  - On station operations phase
    - Transfer fluids as required
    - Replace HPSC as required
Space Station Fluid Resupply

Summary

- SSF is resupplied with supercritical $O_2$ and $N_2$ for the ECLSS and USL on a 180 day resupply cycle
- Resupply fluids are stored in the subcarriers on station between resupply cycles and transferred to the users as required
- ECLSS contingency fluids ($O_2$ and $N_2$) are supplied and stored on station in a gaseous state
- Efficiency and flexibility are major design considerations
- Subcarrier approach allows multiple manifest combinations
- Growth is achieved by adding modular subcarriers