Space Station Fluid Resupply

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Space Station Fluid Resupply

Space Station Freedom

- Requirements

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

- Design Considerations:
  
  Resupply
  
  Resupply Frequency  ~ 180 days
  Transportation State  High pressure gas
                         Supercritical fluid
  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

Boeing

Pressurized Logistics Module (PLM)
(3 required)
- Cargo
- Crew Support
- Food
- Personnel supplies
- Housekeeping supplies
- Station Support
- Maintenance supplies
- Spares
- EVA support
- Customer Support
  - USL Equipment & supplies
  - JEM Equipment & supplies
  - Columbus equipment & supplies
- GSE Roller Floor

- Unpressurized Logistics Carrier (ULC) (4 required)
  - Carriers
    - Station spare
    - Platform and satellite supplies (resupply and ORU’s)
    - Attached payload
    - Intraocular launch storable fluid/propellant subcarriers
    - Direct mounting for a variety of non-commercial cargo configurations

- Subcarriers
  - Provides multiple combinations of subcarriers with the ULC
  - Efficient manifesting
  - Subcarriers are attached by automated mechanisms and umbilical mechanisms

High Pressure Gas subcarrier (HPSC)
(6 required)

Oxygen subcarrier (OSC)
(3 required)

Fluids subcarrier (FSC)
(3 required)

Dry Cargo subcarrier (DCSC)
(8 required)
Space Station Fluid Resupply

- Unpressurized Logistics Carrier

Outfitting
- Cargo Accommodations
  - Subcarrier Attach Mechanisms
  - Normal Containerized Cargo Attachments

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

Mechanisms
- Automated Umbilical Mechanism
- Subcarrier Attachment Mechanisms

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

Space Station Freedom

- 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
    - UL-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)

![Diagram of Oxygen Subcarrier](image)

**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
Space Station Fluid Resupply

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

* 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

Fluids State (N₂ and O₂)

Timeline Hrs/Days

Operations

Loaded @ - 20 psia and - 320°F (N₂) and TBD°F (O₂)

Liquid

Tank Pressure @ Launch ~ 31.5 psia

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

Note: 4 day contingency allowance included in this timeline

- 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)

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
(N₂ and O₂)

Timeline Hrs/Days

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

Critical Pressure
N₂: 493 psia
O₂: 736 psia

N₂ Delivered @ 550 - 700 psia and ~ -300°F (start) to -130°F (start + 180 days)
O₂ Delivered @ 840 - 950 psia and temperature TBD

Note: Heater cycles to increase pressure and expell gas

(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
- + TBD
- + TBD
- + TBD
- + 185.7 Days
- + 186.9 Days
- + 187 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

(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
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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