IN-18

193054

NASA Technical Memorandum 107733

Soyuz/ACRV Accommodation Study

Jonathan Cruz
Marston J. Gould
Eric Dahlstrom

November 1993

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-0001

Abstract: Accommodation of a Soyuz TM as an ACRV
Authors: Marston Gould, Jonathan Cruz, Eric Dahlstrom

A study was conducted at the LaRC Space Station Freedom Office at the request of the Space Station Freedom Level 1 Program Office and the JSC ACRV project Office to determine the implications of accommodating two Soyuz TM spacecraft as Assured Crew Return Vehicles (ACRV) on the Space Station Freedom (SSF) at the Permanently Crewed Capability (PCC) stage. The study examined operational as well as system issues associated with the accommodation of the Soyuz for several potential configuration options. Operational issues considered include physical hardware clearances, worst case Soyuz departure paths, and impacts to baseline operations such as Pressurized Logistics Module (PLM) exchange, Space Station Remote Manipulator System (SSRMS) attachment, Extravehicular Activity (EVA), and automatic rendezvous and docking (AR&D). Systems impact analysis included determining differences between Soyuz interface requirements and SSF capabilities for the Electrical Power System (EPS), Thermal Control System (TCS), Communications and Tracking (C&T), Audio-Video Subsystem (A/V), Data Management System (DMS), and Environmental Control and Life Support System (ECLSS). Significant findings of this study have indicated that the current ΔV capability of the Soyuz will need to be increased to provide adequate departure clearances for a worst case escape from an uncontrolled SSF and that an interface element will be required to mate the Soyuz vehicles to station, provide for AR & D structural loads, and to house Soyuz-to-SSF system interfaces. Of the options considered, the placement of the pair of Soyuz on the nadir port of Node 1 and the zenith port of Node 2 or on the nadir and zenith port of Node 1 will have the fewest system interface modifications required for the Space Station and the Soyuz and can provide for the automatic rendezvous and docking and simultaneous departure of the Soyuz vehicles. However, since the option to use the nadir port of Node 2 will impact elements currently under critical design review (CDR), the recommended configuration is to place the Soyuz vehicles on the nadir and zenith ports of Node 1.

Soyuz/ACRV Accommodation Study

Agenda

- Introduction
- Options
- Systems Impacts
- Operational Impacts
- Comparison and Summary

Background

- This study was initiated on January 7,1993 at the request of the ACRV Project Office / Systems Engineering and Integration. The study was to assess the impact of accommodating two Soyuz vehicles during the PMC phase of the Space Station Freedom. Study results were completed on February 11,1993.

Soyuz/ACRV Accommodation Study

Background

- ACRV Project Office requested Langley to conduct accommodations study on January 7, 1993
- Langley Status Briefings held on January 14th, 21st, 28th, and February 4th
- Telecons with JSC/ACRV Project office held on January 29th and February 5th
- Study results completed on February 11th.

4

Objective

- The objective of the study was to evaluate the technical impacts of accommodating two Russian Soyuz vehicles as Assured Crew Return Vehicles on the Space Station Freedom during the PMC Phase.

Objective

- Assess and evaluate the technical impacts of accommodating two Soyuz-Assured Crew Return Vehicles on the Space Station Freedom

Focus of Study

- During the duration of the study, two sub-teams were identified and they focused their efforts on the system impacts and the operational impacts of accommodating the Soyuz vehicles

Focus of Study

- Identification of SSF - Soyuz system issues
- Analysis of SSF - Soyuz operational issues

Groundrules / Assumptions

- The groundrules and assumptions that were utilized during this study are shown on this chart.

Groundrules / Assumptions

- Only PMC phase considered
- U.S. Modules, Nodes, International Modules and PMA locations maintained from baseline
- Two Soyuz vehicles required for a 4 person crew
- Soyuz can be STS or ELV delivered
- Docking adapter interface between SSF - Soyuz required
- Single node failure tolerance not considered an issue
- Recommendations based on minimum impact to SSF and Soyuz systems

- This Page Intentionally Left Blank -

Options

12

PRECEDING PAGE BLANK NOT FILMED

Module Pattern Building Blocks

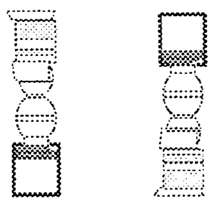
- Since the accommodation and location of the Centrifuge, which is part of the PMC program, has not been determined, three possible module pattern "building blocks" exist for the PMC phase. Only the Soyuz, PLM, and Airlock elements were considered for re-location. Assuming the Centrifuge is located in a mini-lab attached to Node 1's starboard side, the locations available for berthing the Soyuz vehicles, PLMs, and Airlock are the nadir and zenith porths of Nodes 1 and 2. The locations available when the Centrifuge is located in an additional Node are shown on the chart. While a large number of variations exist when a Centrifuge Node is utilzed, none are considered superior options. However they are shown here for completeness.

Module Pattern "Building Blocks"

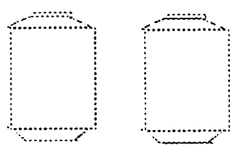
Locations Available

Elements to Accommodate

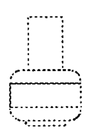
Soyuz/ACRV



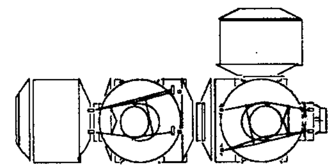
PLM



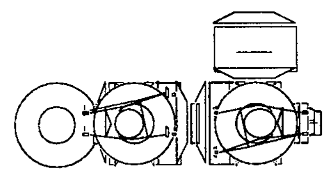
Airlock



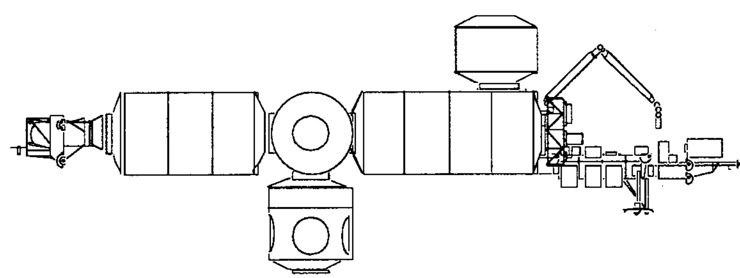
PMC Module Pattern - Centrifuge Pocket Lab



PMC Module Pattern - Centrifuge Node (Strb)



PMC Module Pattern - Centrifuge Node (Nadir)



* Node 1 Nadir
* Node 1 Zenith
* Node 2 Nadir
* Node 2 Zenith

12 Options

* Node 1 Nadir & Zenith
* Node 2 Nadir & Zenith
* Node 3 Nadir & Zenith
* Node 3 ±X

6000+ Options *

* Node 1 and 2 Zenith
* Node 1 or 2 Nadir
* Node 3 Nadir, Port or Stbd
* Node 3 ±X

800+ Options *

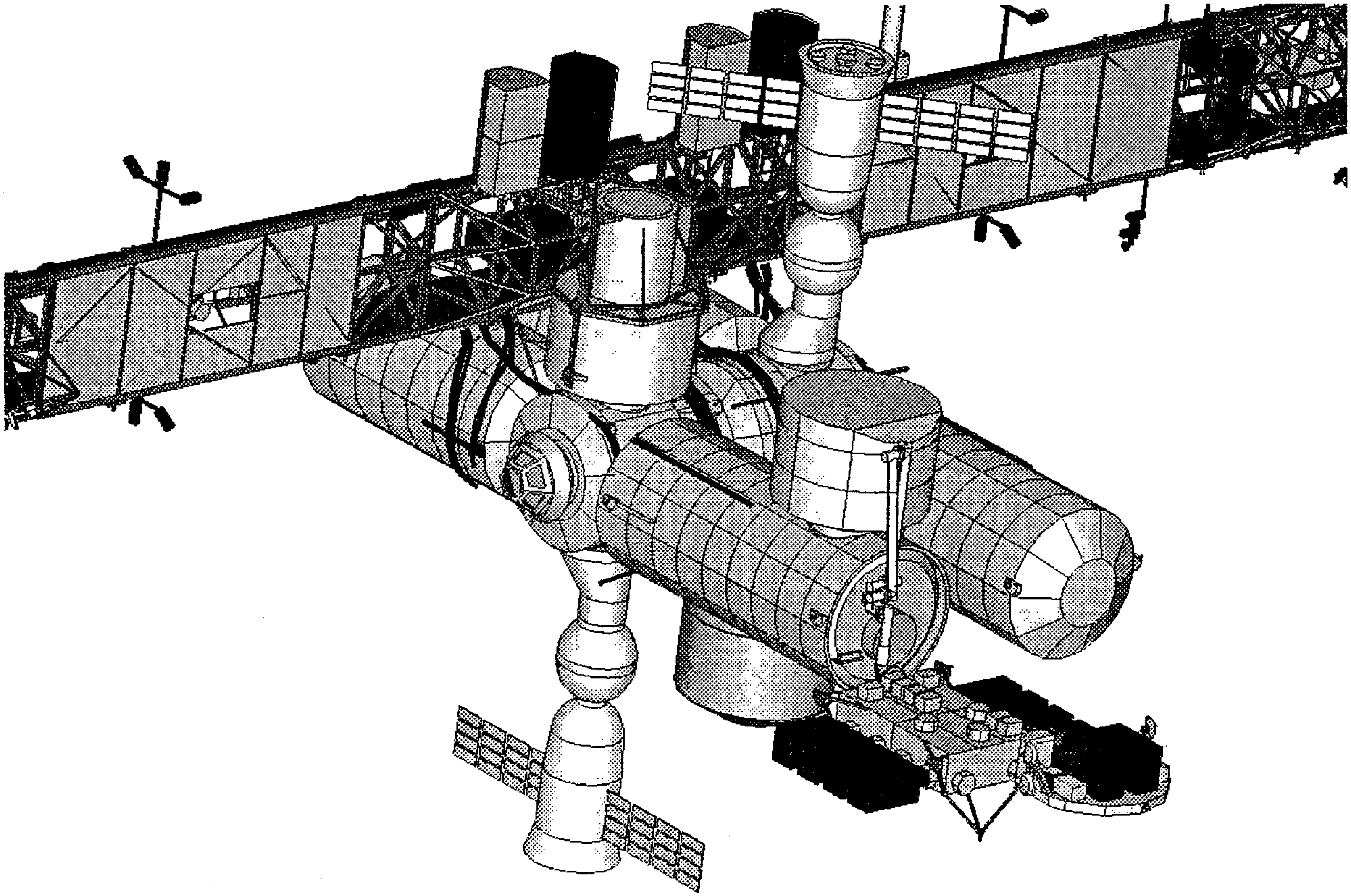
* Centrifuge Node was limited to two attached elements

Option 1

- Option 1, depicted in the figure below, utilizes the Node 1 zenith and Node 2 nadir berthing locations for the Soyuz vehicles. These positions are currently reserved for the ACRV and the secondary PLM.

Option 1

Node 1 Zenith, Node 2 Nadir

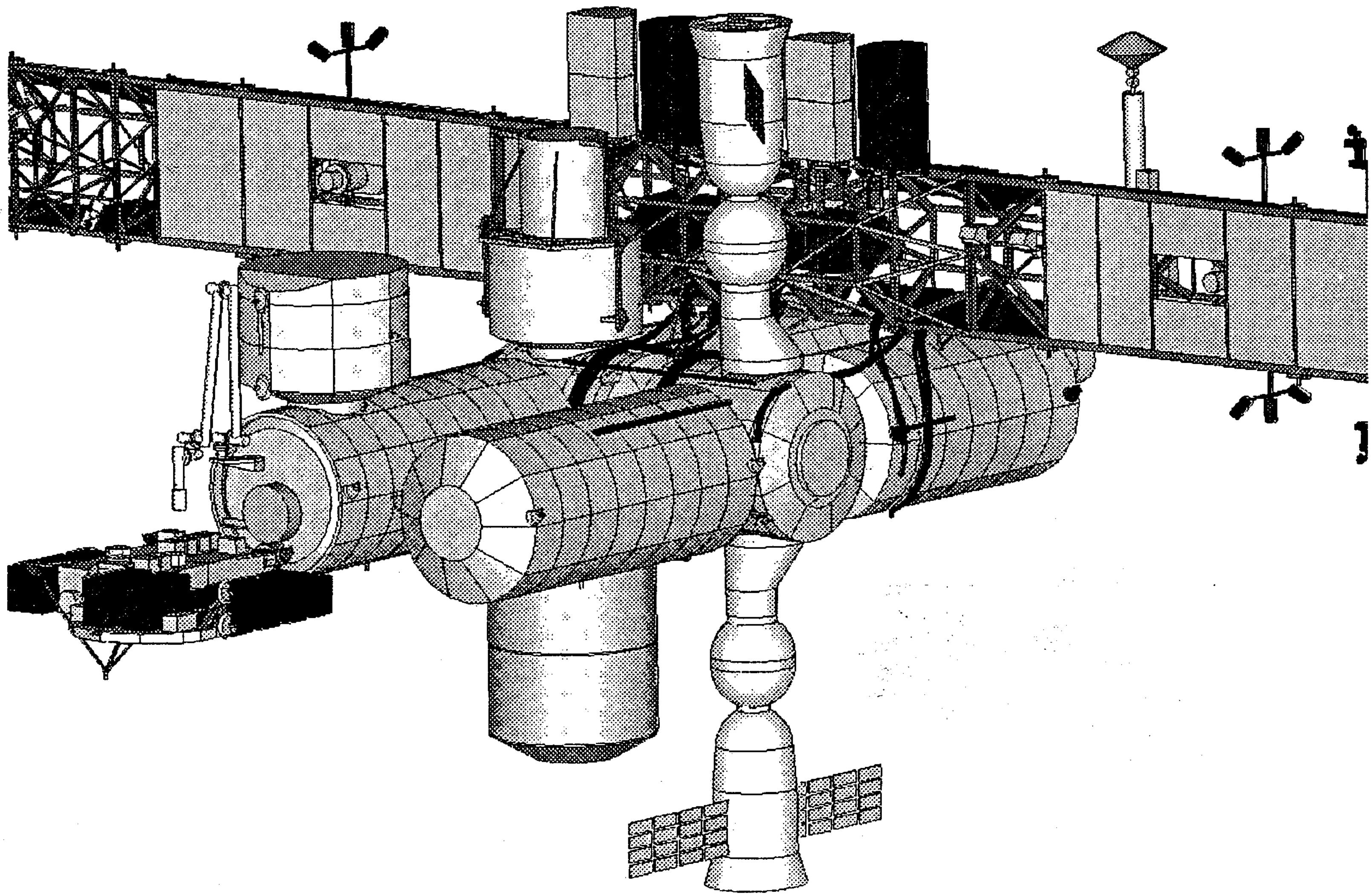


Option 2

- Option 2, depicted in the figure below, utilizes the Node 1 nadir and zenith berthing locations for the Soyuz vehicles. These positions are currently reserved for the ACRV and the primary PLM.

Option 2

Node 1 Zenith, Node 1 Nadir

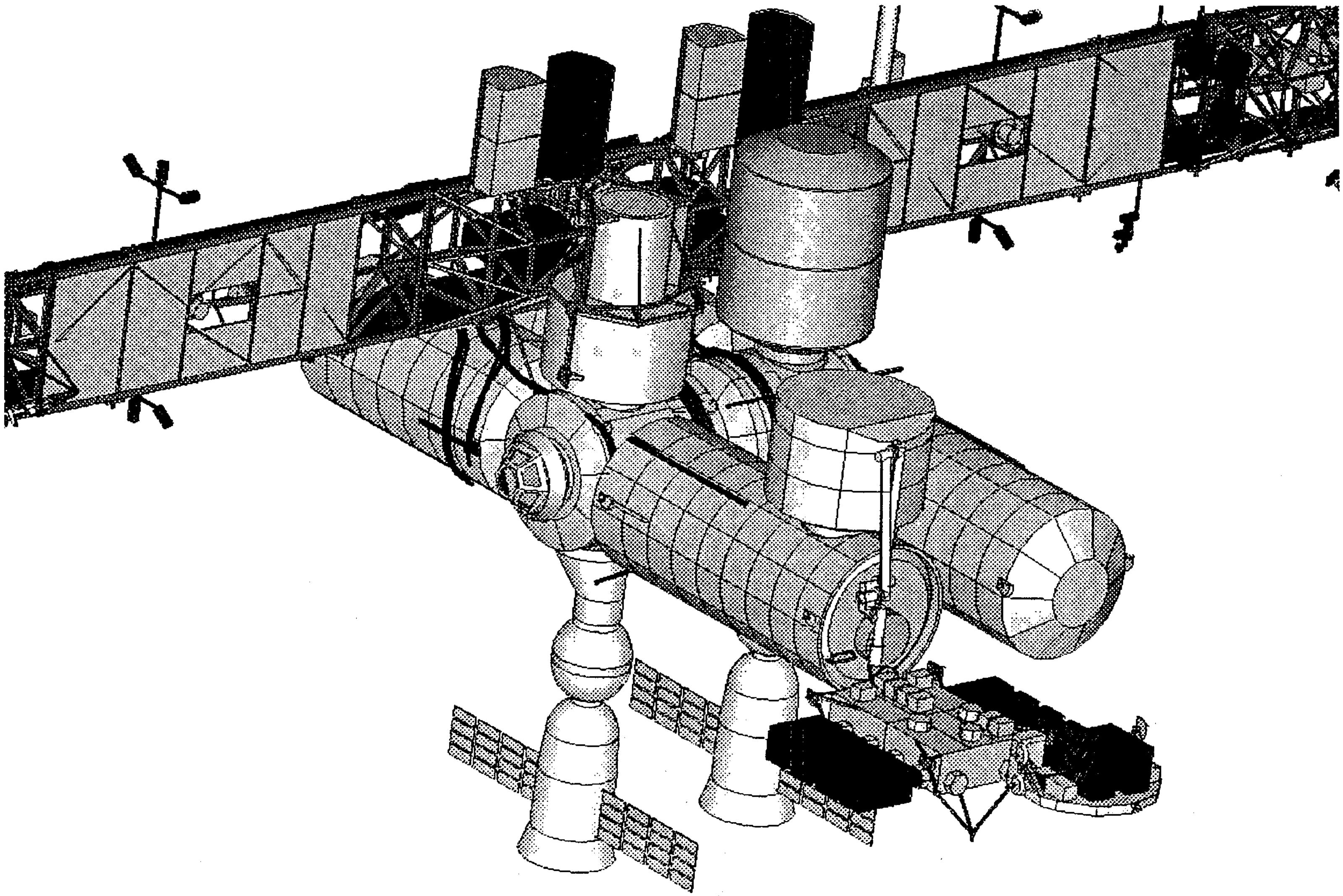


Option 3

- Option 3, depicted in the figure below, utilizes the Node 1 and 2 nadir berthing locations for the Soyuz vehicles. These positions are currently reserved for the primary PLM and secondary PLM. The primary PLM was relocated to the Node 1 zenith port.

Option 3

Node 1 Nadir, Node 2 Nadir

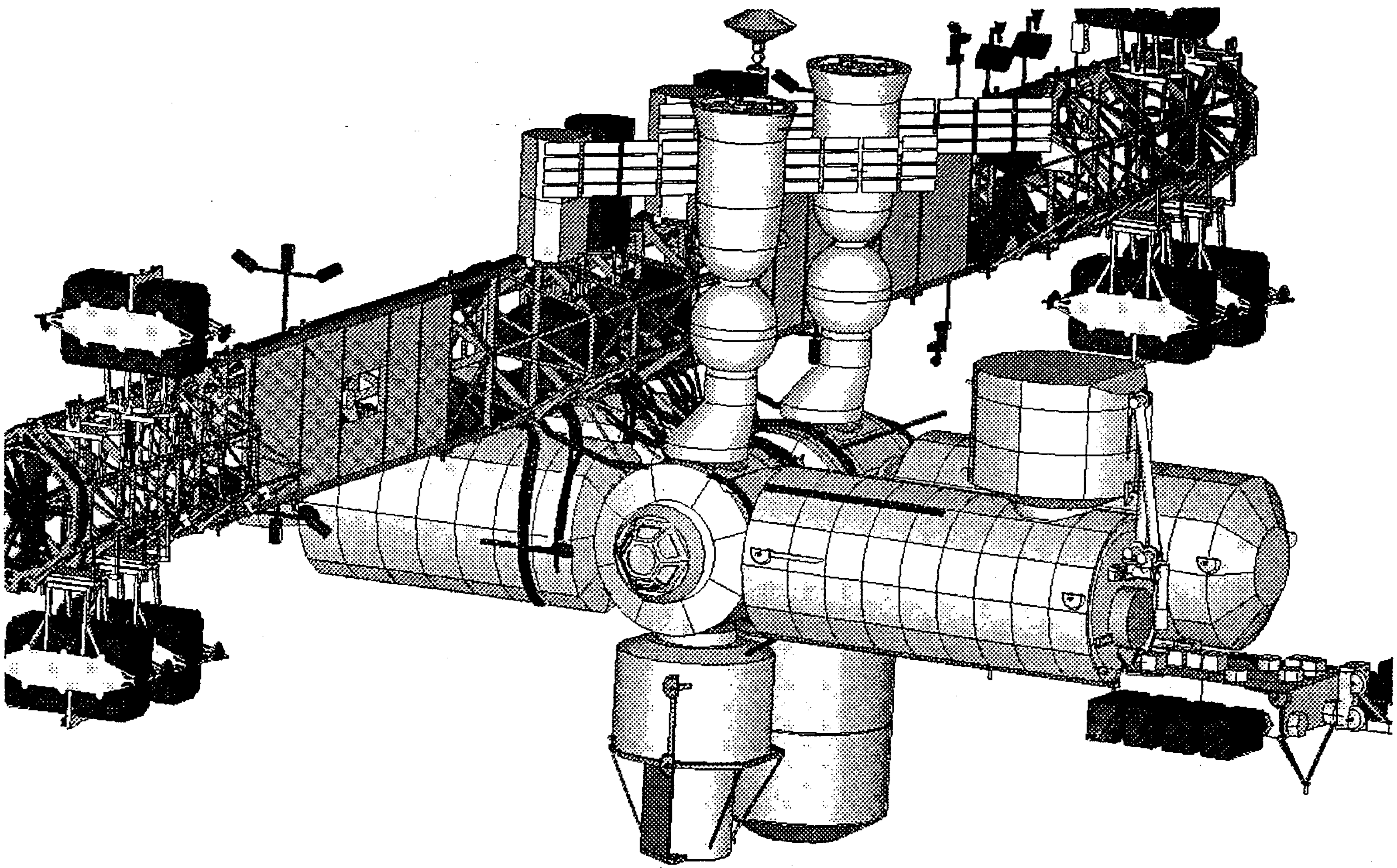


Option 4

- Option 4, depicted in the figure below, utilizes the Node 1 and 2 zenith berthing locations for the Soyuz vehicles. These positions are currently reserved for ACRV and the airlock. The airlock was relocated to the Node 2 nadir port.

Option 4

Node 1 Zenith, Node 2 Zenith

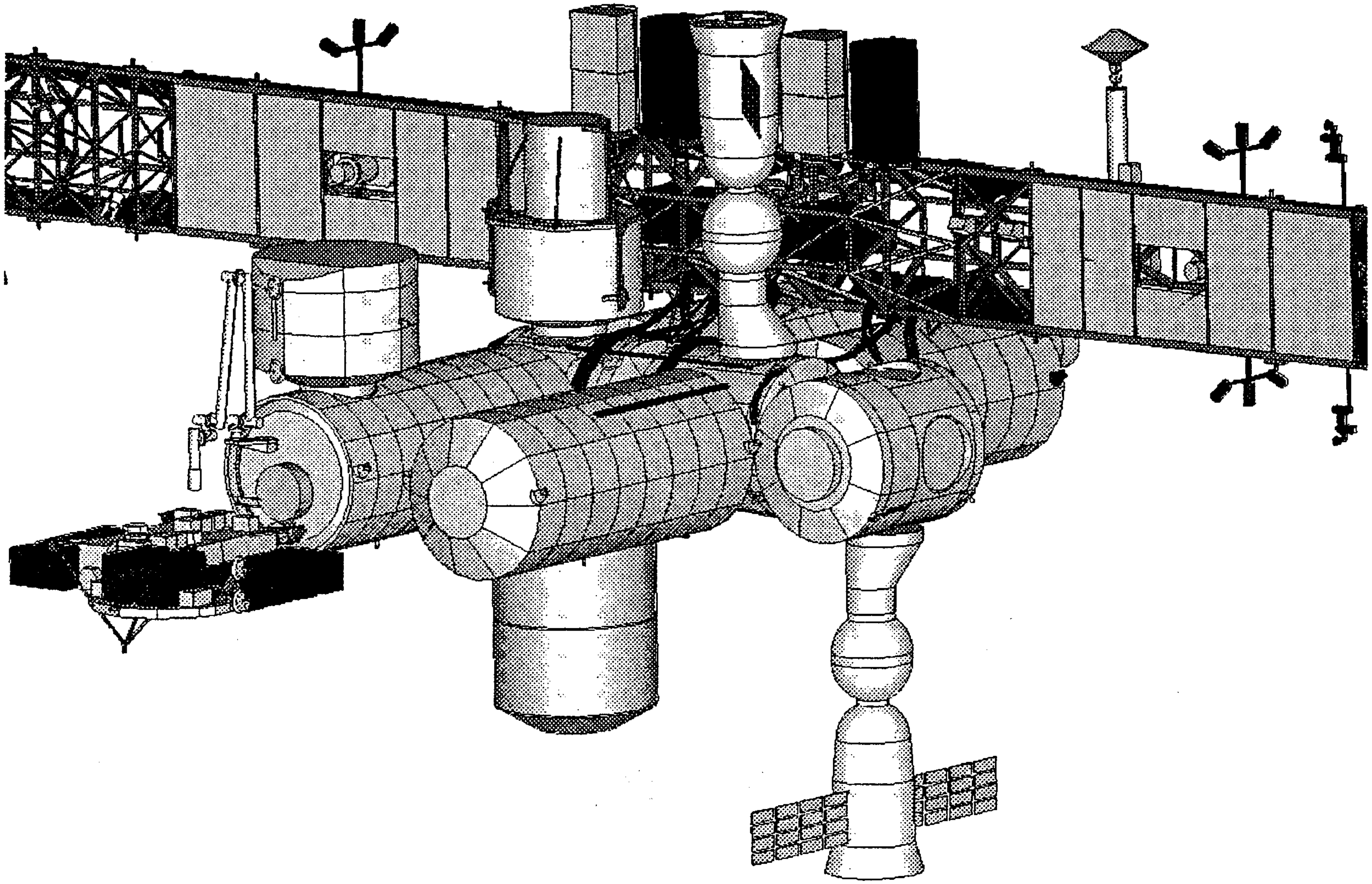


Option 5

- Option 5, depicted in the figure below, utilizes the nadir berthing location of the Centrifuge Node located on the Node 1 starboard which is currently unreserved and Node 1 zenith port which is reserved for the ACRV.

Option 5

Node 1 Zenith, Node 3 Nadir

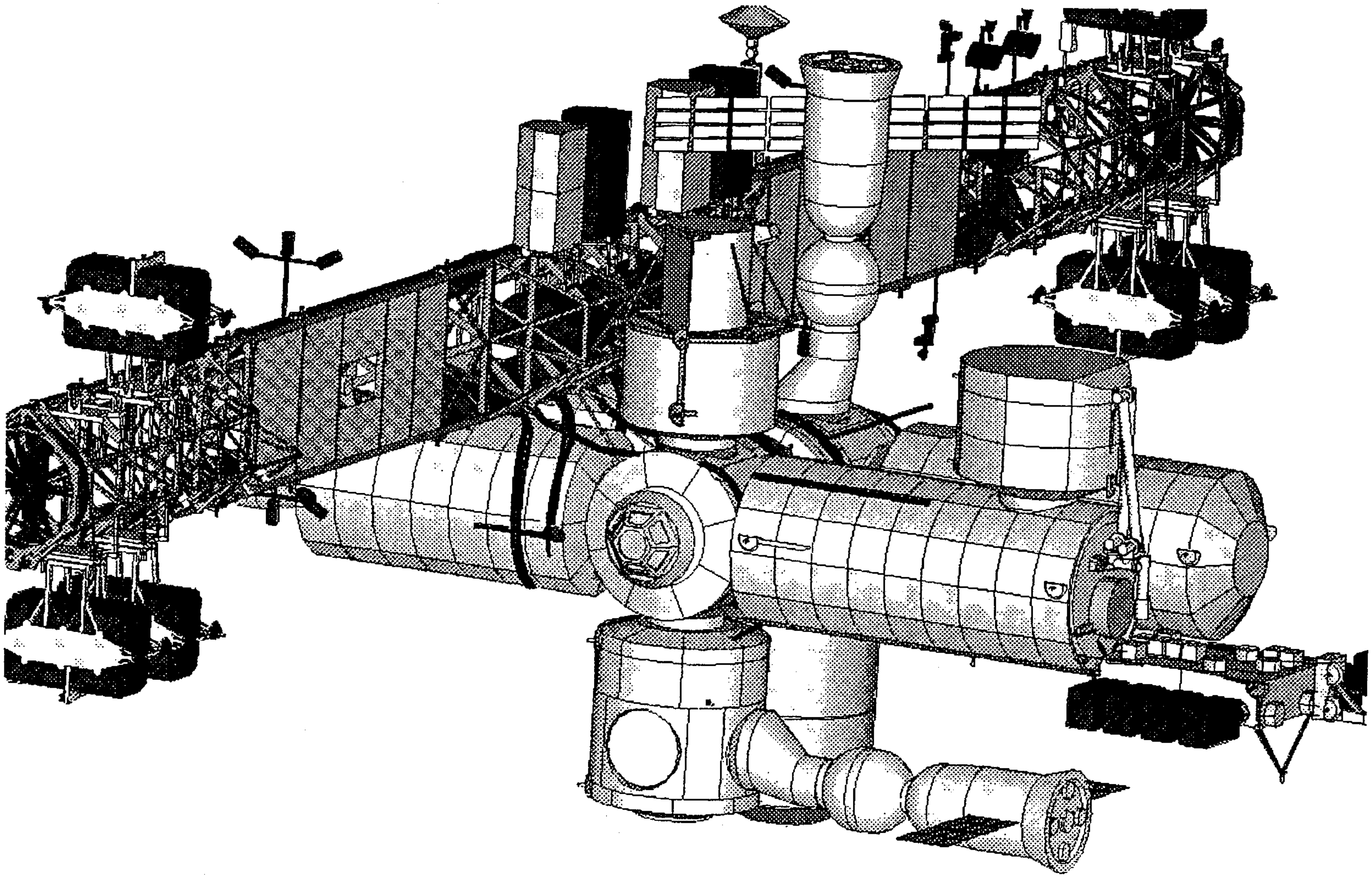


Option 6

- Option 6, depicted in the figure below, utilizes the -X berthing location of the Centrifuge Node located on the Node 2 nadir which is currently unreserved and the Node 1 zenith port which is reserved for the ACRV

Option 6

Node 1 Zenith, Node 3 Aft



Other Options

- **The other primary options, those which do not depend on the Centrifuge node, are listed below.**

Soyuz/ACRV Accommodation Study

Other Options

Node 1 Nadir	Node 1 Zenith	Node 2 Nadir	Node 2 Zenith	Note
Soyuz	Soyuz	Airlock	PLM	Option 2 with added A/L interface issues
Soyuz	Airlock	Soyuz	PLM	Option 3 with added PLM, A/L I/F issues
Soyuz	Airlock	PLM	Soyuz	Option 1 with added A/L I/F issues
Soyuz	PLM	Airlock	Soyuz	Option 1 with added PLM, A/L I/F issues
Airlock	Soyuz	Soyuz	PLM	Option 1 with added PLM, A/L I/F issues
Airlock	Soyuz	PLM	Soyuz	Similar to Option 4
Airlock	PLM	Soyuz	Soyuz	Option 2 with added PLM, A/L I/F issues
PLM	Airlock	Soyuz	Soyuz	Option 2 with added A/L I/F issues

- This Page Intentionally Left Blank -

SSF - Soyuz System Interfaces

PRECEDING PAGE BLANK NOT FILMED

SSF/Soyuz EPS Interfaces General Issues

- The general EPS issues associated with SSF-to-Soyuz interface include the power requirements of the Soyuz vehicles in comparison to the program allocation for the ACRV as well as the accommodation of a redundant set of power conversion units per Soyuz-ACRV vehicle.

General Issues

- Baseline ACRV power allocation is 318 watts keep-alive
- Soyuz power requirement is 250 watts keep-alive, 900 watts peak
- Additional 700 W may be required for heating of the Soyuz
- Redundant 120V-to-28V power conversion units will be required between Soyuz and Space Station Freedom interface

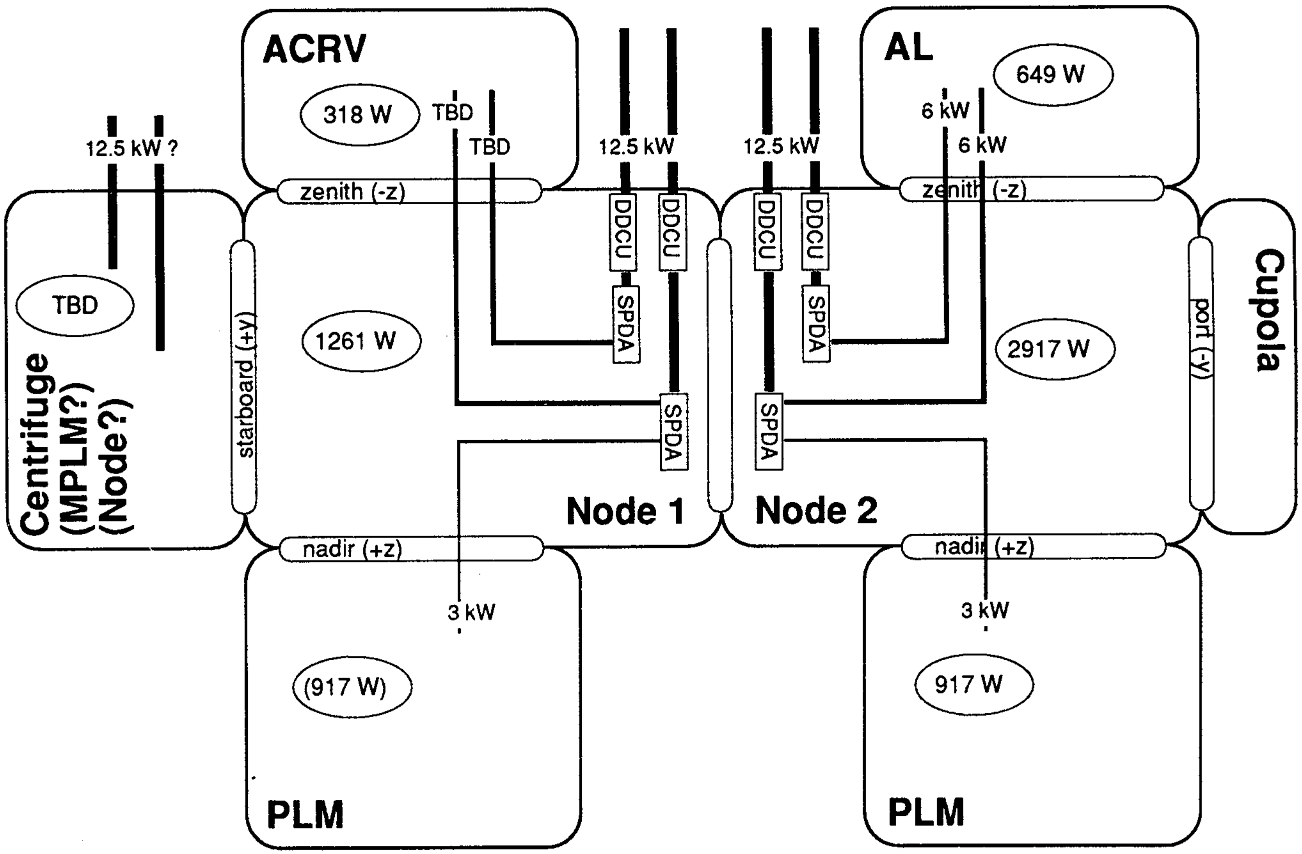
* Reference: SSP 30000 Sec 6 and discussions with JSC/ACRV Project Office

Node 1 & 2 Baseline Electrical Power Interfaces

- The diagram below illustrates the baseline Space Station Freedom Electrical Power Interfaces. Each Node is shown with a capability of 12.5 kW from the primary distribution assembly. The nadir ports of Node 1 and 2 are each designed with the capability of providing 3 kW of power through a single feed. Current allocations, for each of the PLMs, stand at 917 W. The zenith ports of Nodes 1 and 2 are designed with a redundant feed capable of providing 6 kW each. The baseline allocation for these systems is 649 W and 318 W for the Airlock and ACRV respectively.

Soyuz/ACRV Accommodation Study

Node 1 & 2 Baseline Electrical Power Interfaces



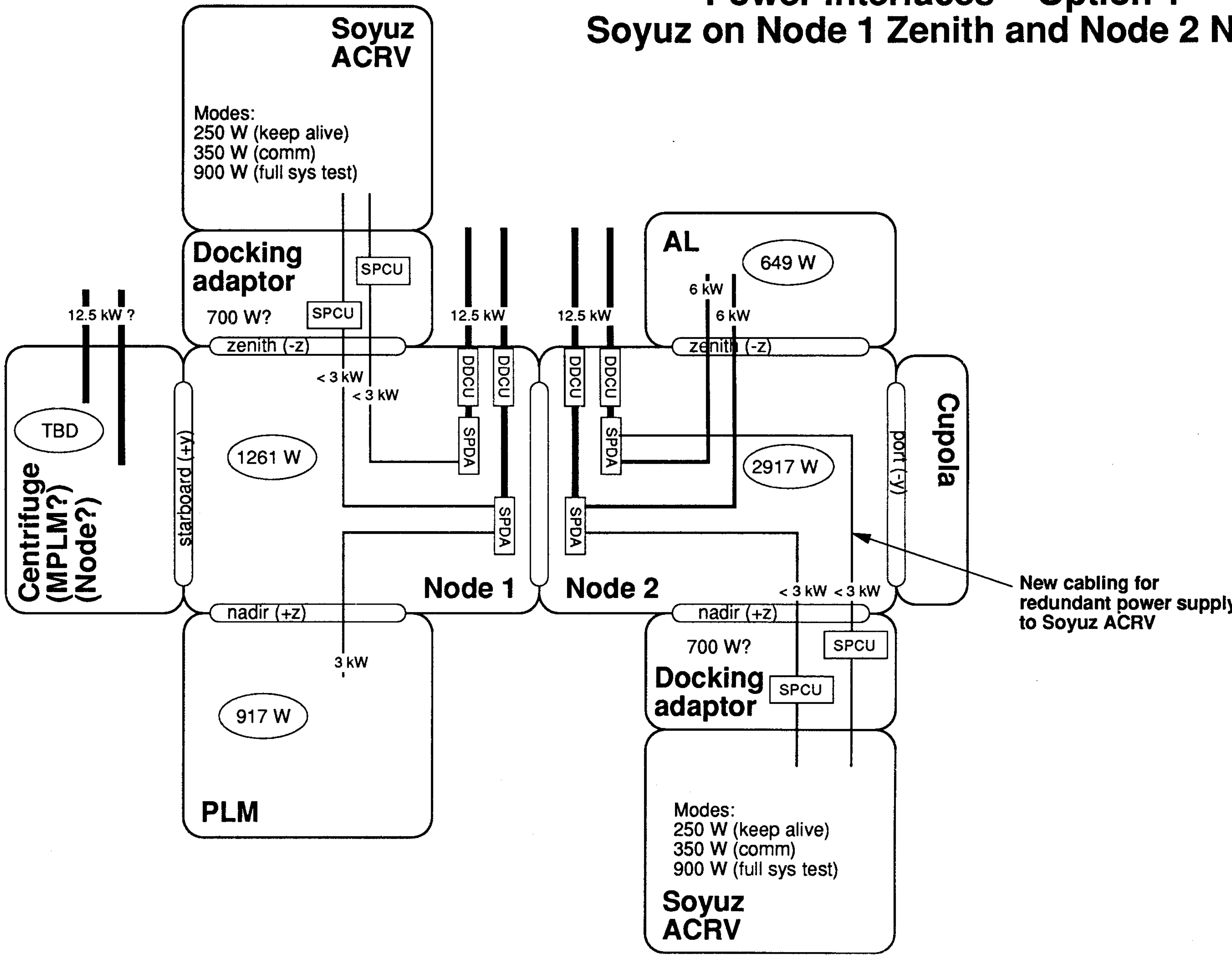
Key:
DDCU - DC to DC Conversion Unit
SPDA - Secondary Power Distribution Assembly
NPCU - NSTS Power Converter Unit (120V-28V, 6.25kW)
SPCU = Soyuz Power Converter Unit (120V-28V, ~1kW)

—kW— Power supply capacity labeled on lines (EPS ACD SSP 30263 RevD6)
(Watts) Ave power resource allocation in ovals (PDRD SSP 30000 Sec 6 RevF11)

Power Interfaces - Option 1

- This schematic shows the EPS impacts for option 1. This option will require minor changes to the EPS interface at the Node 2 nadir port. The Freedom - to - Soyuz power converter is shown located in the vehicle docking adapter.

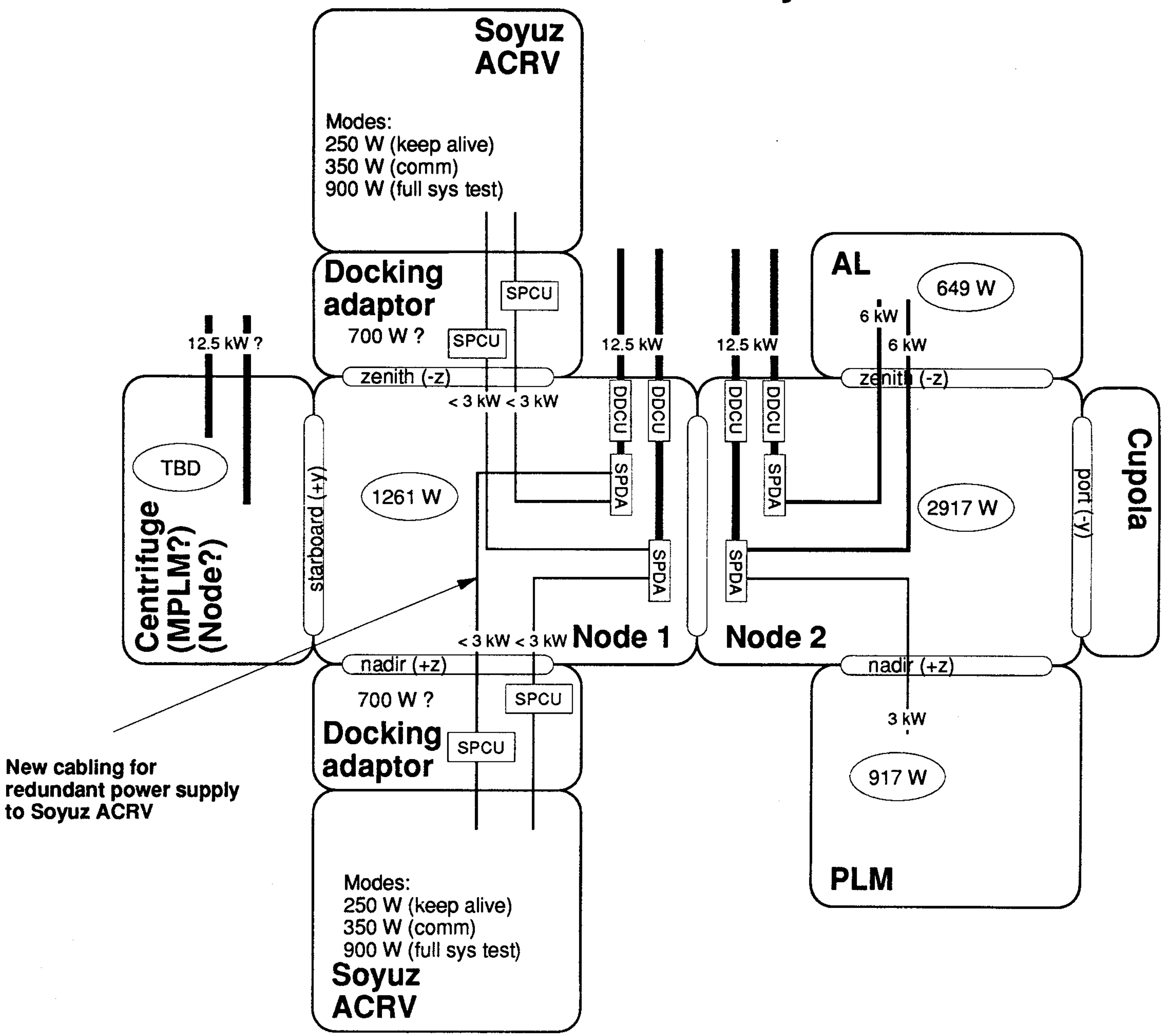
Power Interfaces - Option 1
Soyuz on Node 1 Zenith and Node 2 Nadir



Power Interfaces - Option 2

- This schematic shows the EPS impacts for option 2. This option will require minor changes to the EPS interface at the Node 1 nadir port. The Freedom - to - Soyuz power converter is shown located in the vehicle docking adapter.

Power Interfaces - Option 2
Soyuz on Node 1 Nadir and Zenith

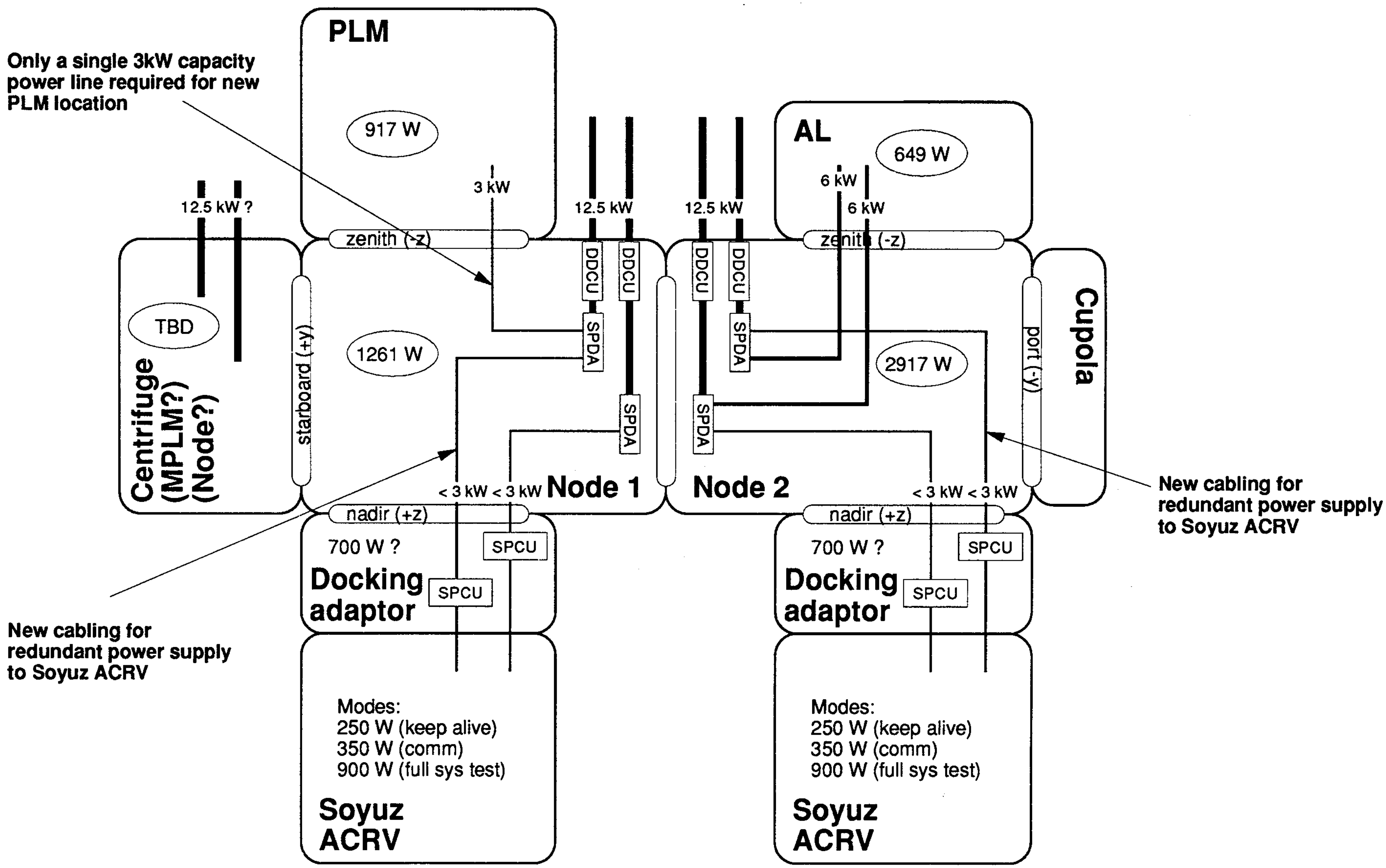


Power Interfaces - Option 3

- This schematic shows the EPS impacts for option 3. This option will require minor changes to the EPS interface at the Node 1 and 2 nadir ports. The Freedom - to - Soyuz power converter is shown located in the vehicle docking adapter.

Soyuz ACRV/SSF Accommodation Assessment

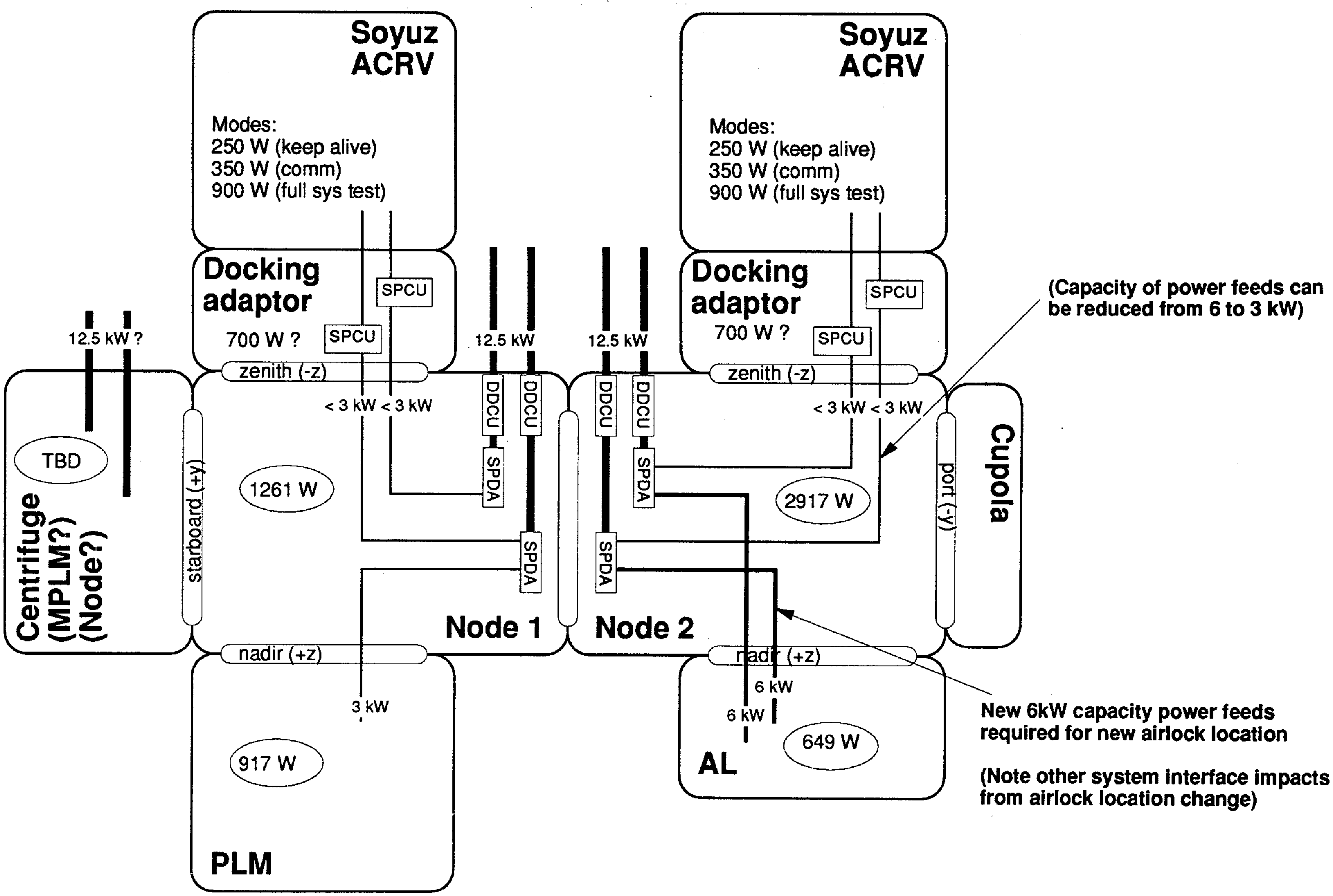
Power Interfaces - Option 3
Soyuz on Node 2 and Node 1 Nadir



Power Interfaces - Option 4

- This schematic shows the EPS impacts for option 4. This option will require minor changes to the EPS interface at the Node 1 and 2 zenith and Node 2 nadir port. The Freedom - to - Soyuz power converter is shown located in the vehicle docking adapter.

Power Interfaces - Option 4
Soyuz on Node 2 and Node 1 Zenith



SSF/Soyuz TCS Interfaces General Issues

- The general TCS issues associated with SSF-Soyuz interface are primarily concerned with the thermal heating requirement of the vehicle. When attached to the Mir space station, the Soyuz receives thermal transfer from an intermediate loop. This loop consists of an open hydraulic line with coolant and circulation provided by the Mir. The coolant, a silicone fluid, operates between 73.4 - 77° F.

- When attached to SSF, the station will be responsible for providing this heat. An intermediate loop between the Soyuz and SSF moderate temperature loop could be developed with major hardware, such as pump assemblies and heat exchanger located in the docking adapter. Neither pump power requirements or general station toxicity requirements have been quantified. In addition, the station may not be capable of providing water at a temperature to compensate for the temperature drop across the heat exchanger. An other option exist where the Soyuz TCS could be replaced with lines which meet SSF specifications and connected directly into the SSF TCS moderate temperature loop. However, this would require major changes to the Soyuz vehicles.

SSF/Soyuz Thermal Control System Interfaces

General Issues

- Soyuz receives heat from intermediate loop on Mir
  - Soyuz side is an open hydraulic line with coolant provided by Mir
  - Desired supply fluid temperature is 73.4 - 77° F
  - Loop working medium is silicone fluid
- Soyuz attached to SSF will require thermal transfer
  - Heating could be provided thru liquid/liquid heat exchange between SSF moderate temperature loop and silicone based system
  - Station water may not be hot enough to account for temperature drop across heat exchanger
  - Pump power required by silicone loop has not been determined
  - Working fluid may not meet SSF toxicity limits
- Option exists to replace Soyuz intermediate loop with SSF spec lines and connect directly to moderate temperature loops.

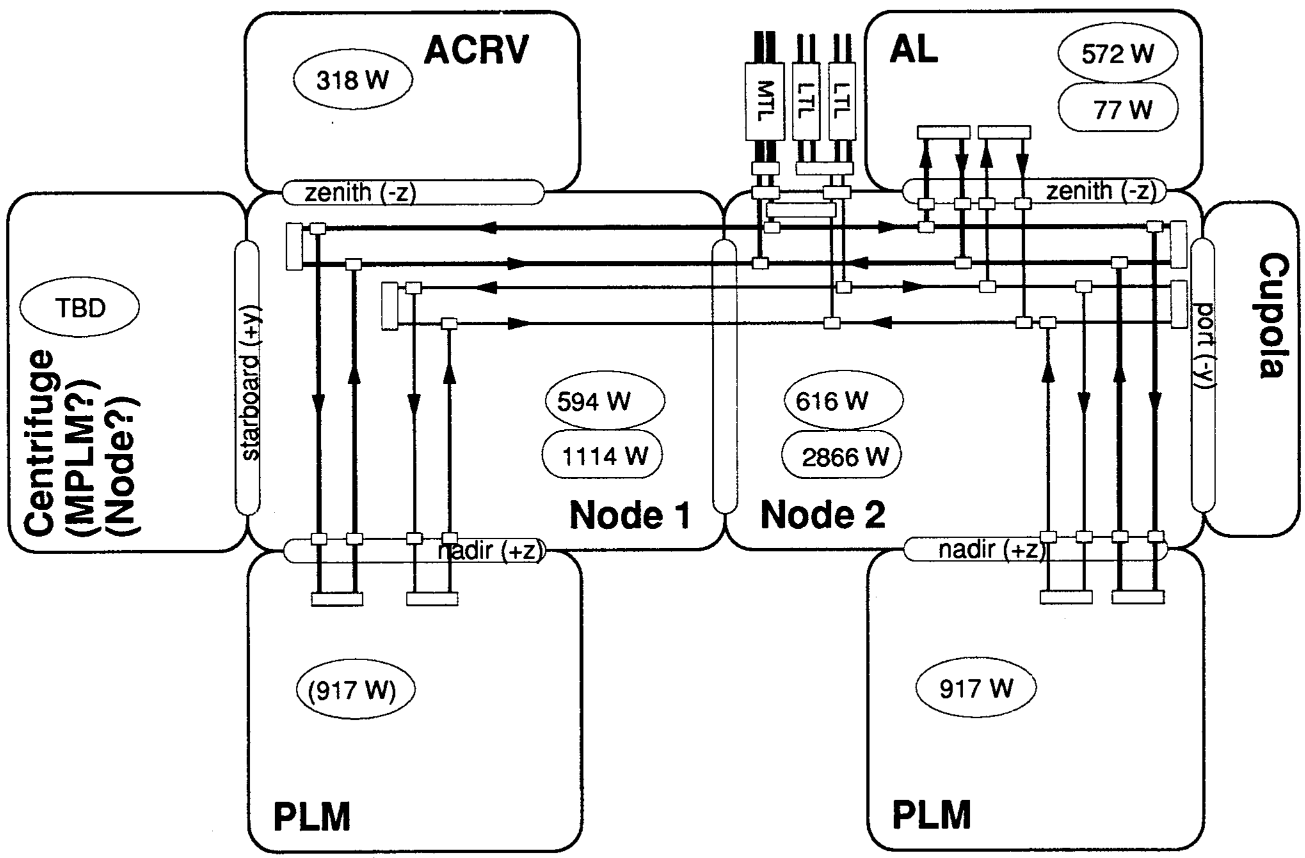
Node 1 & 2 Baseline Thermal Control System Interfaces

- The diagram below illustrates the baseline Space Station Freedom Thermal Control System interfaces for Nodes 1 and 2. While both the moderate and low temperature thermal loops exist in Nodes 1 and 2, the only interface between the internal and external TCS is in Node 2. In the baseline design, both the Node 2 nadir and zenith and Node 1 nadir ports have interfaces with both moderate and low temperature interfaces.

- In order to provide heat to the Soyuz , the vehicles will require access to the return side of the SSF moderate loop TCS. Access to the low temperature supply is unnecessary since that loop operates at a temperature below that capable of providing heat to the Soyuz. Redundancy must therefore be provided through air heaters.

Soyuz ACRV/SSF Accommodation Assessment

Thermal Interfaces
Current Reference with US ACRV

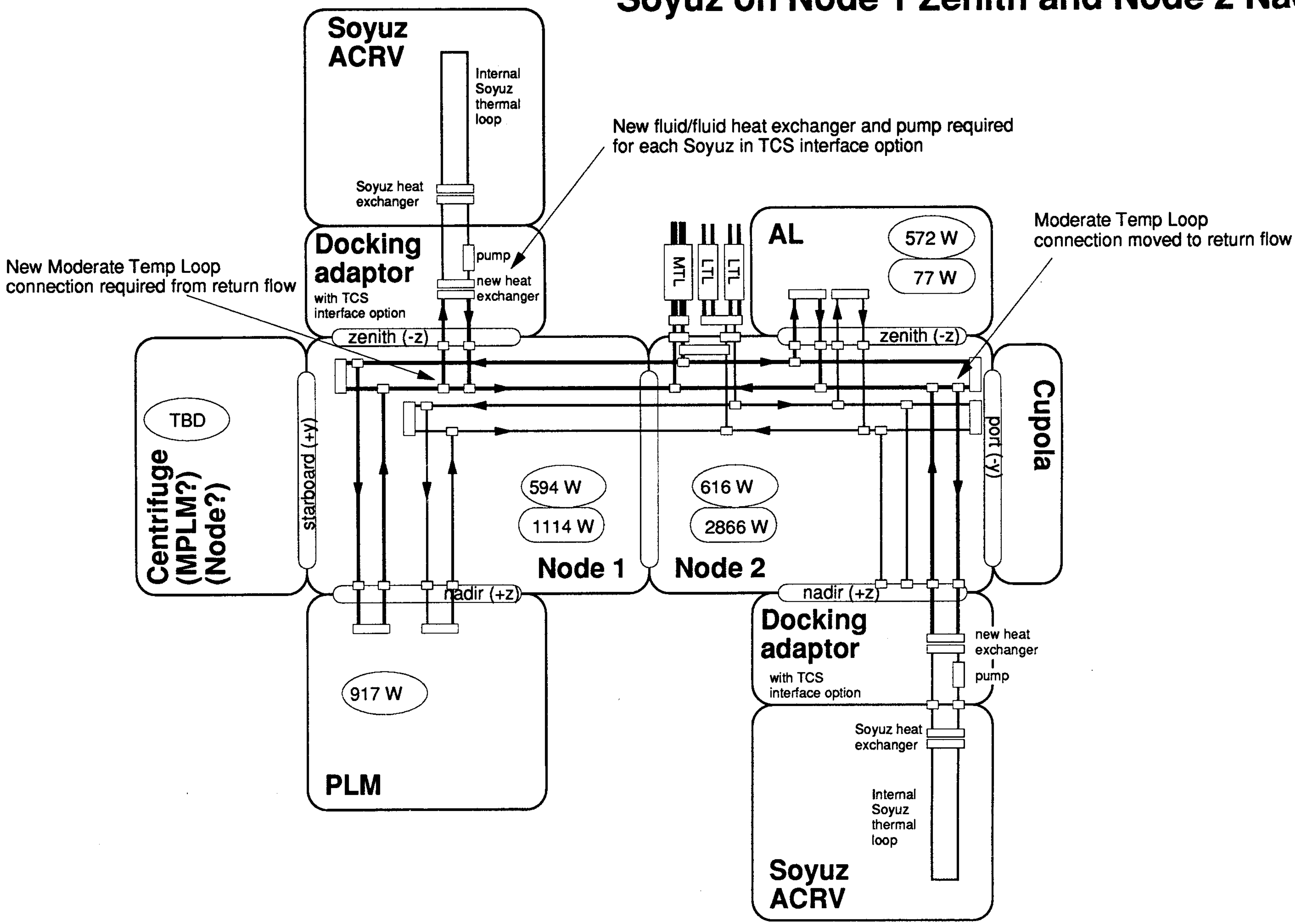


Moderate Temperature Loop
Low Temperature Loop
(Watts) Ave low temp loop thermal resource allocation in ovals (PDRD SSP 30000 Sec 6 RevF11)
(Watts) Ave moderate temp loop thermal resource allocation

TCS Interfaces - Option 1

- This schematic shows the TCS impacts for option 1. This option will require the addition of a moderate temperature loop connection to the zenith of Node 1 as well as the liquid/liquid heat exchangers and pump assemblies in Node 1 zenith and Node 2 nadir.

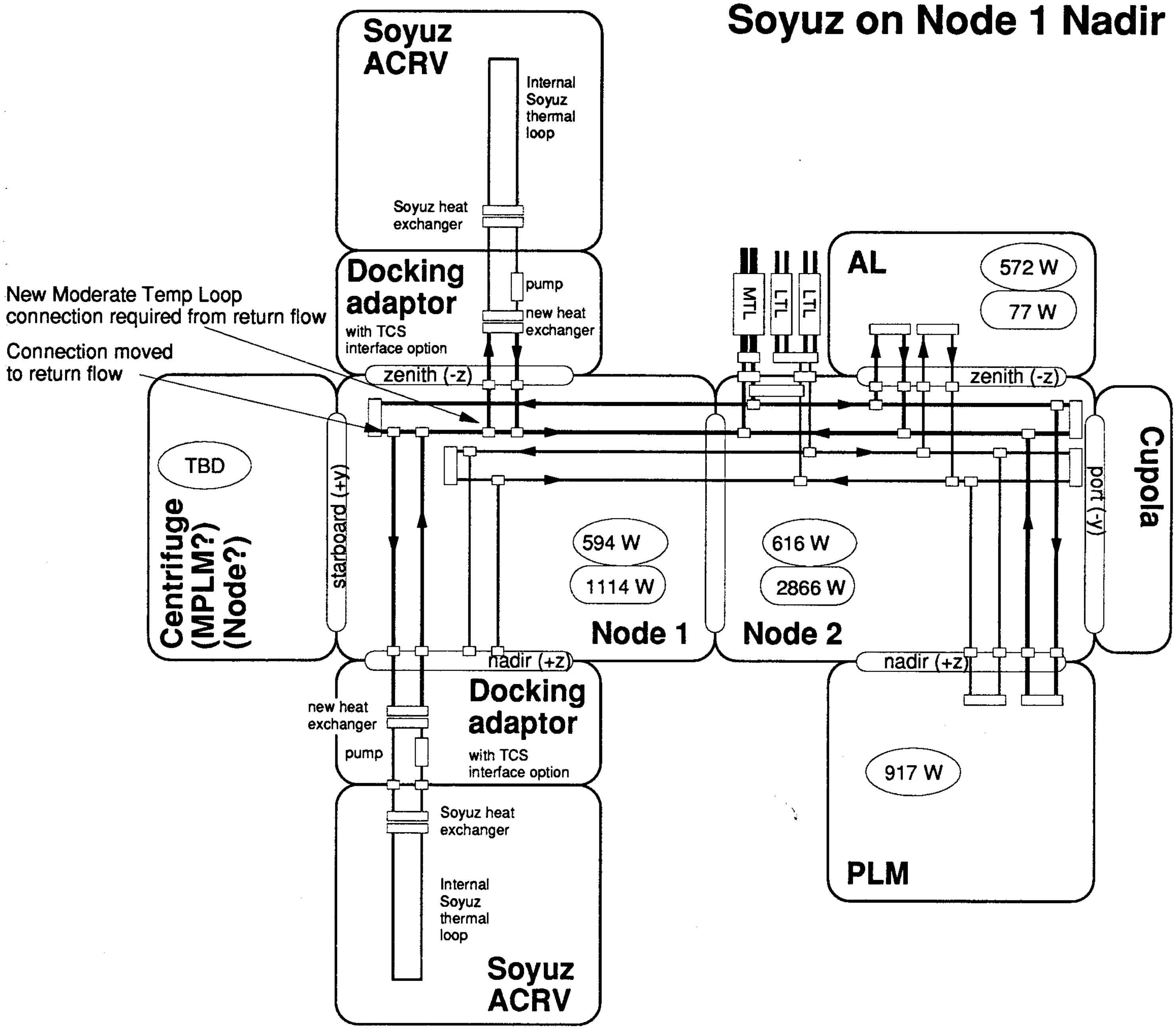
Thermal Interfaces - Option 1
Soyuz on Node 1 Zenith and Node 2 Nadir



TCS Interfaces - Option 2

- This schematic shows the TCS impacts for option 2. This option will require the addition of a moderate temperature loop connection to the zenith of Node 1 as well as the liquid/liquid heat exchangers and pump assemblies in Node 1 nadir and zenith.

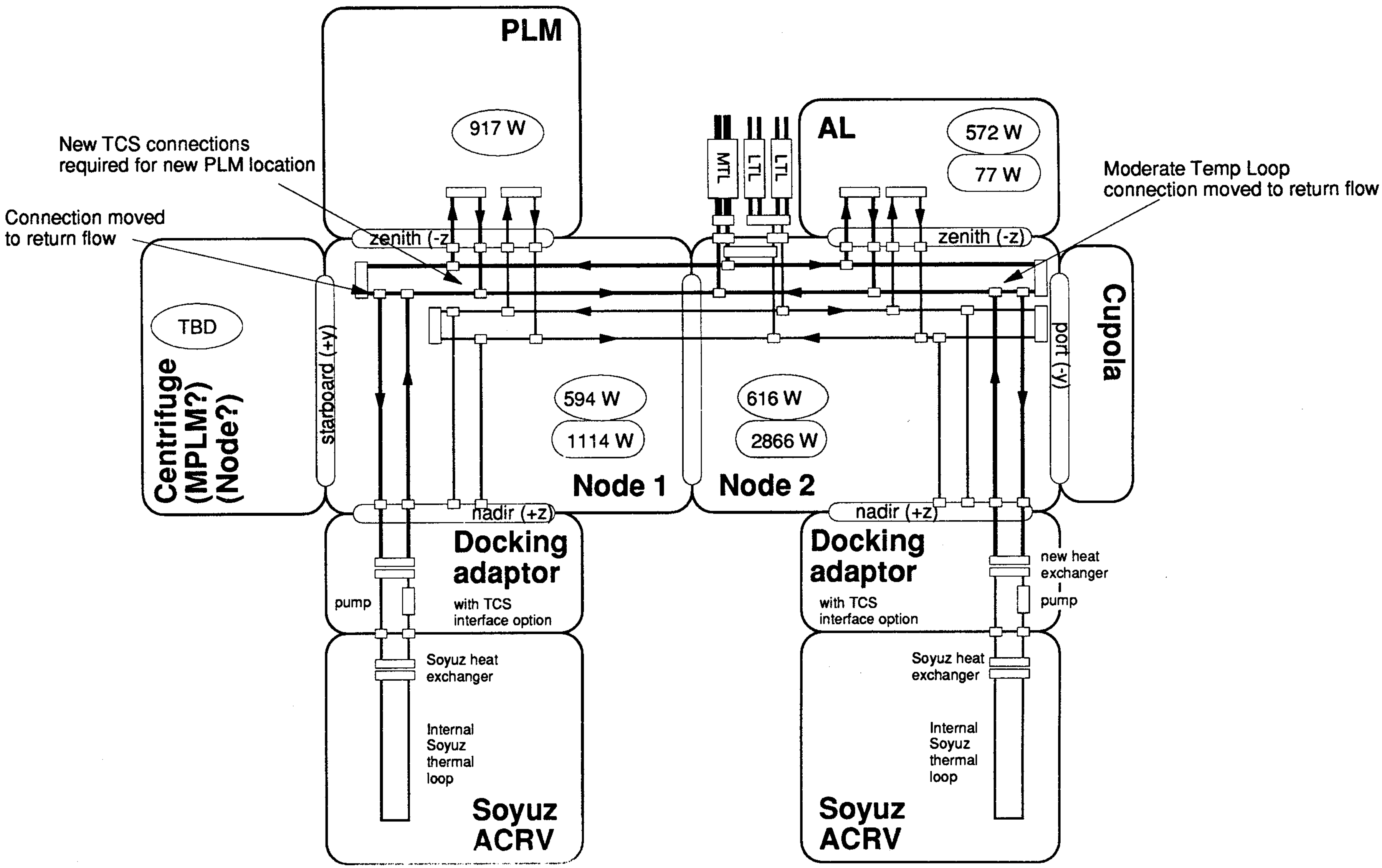
Thermal Interfaces - Option 2
Soyuz on Node 1 Nadir and Zenith



TCS Interfaces - Option 3

- This schematic shows the TCS impacts for option 3. This option will require the addition of a moderate and low temperature loop connections to the zenith of Node 1 for the PLM and a change to the Node 1 and 2 nadir ports such that Soyuz can be interfaced with the return side of the moderate temperature loops. Furhermore, liquid/liquid heat exchangers and pump assemblies must be added to the nadir ports of Nodes 1 and 2.

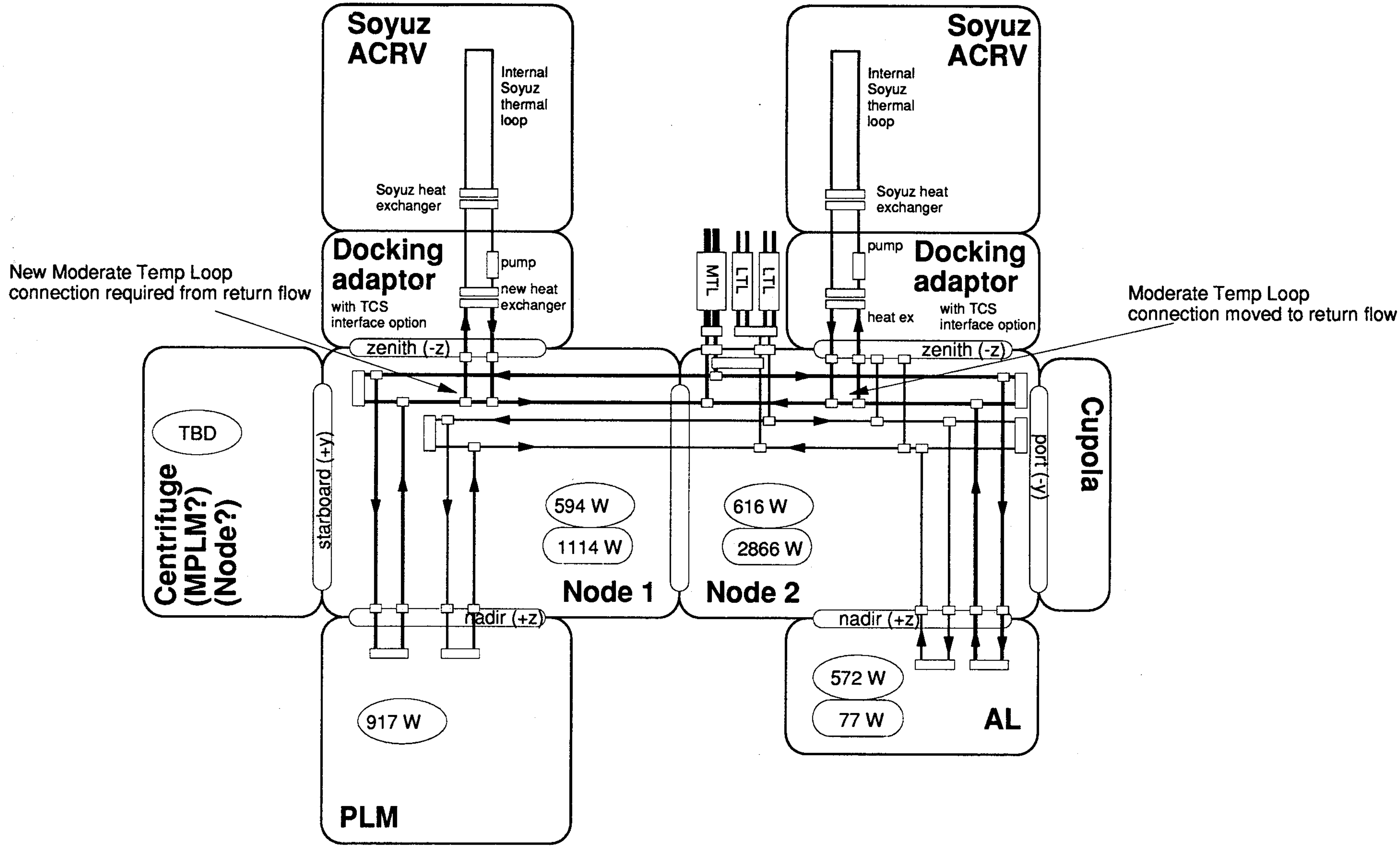
Thermal Interfaces - Option 3
Soyuz on Node 2 and Node 1 Nadir



TCS Interfaces - Option 4

- This schematic shows the TCS impacts for option 4. This option will require a new connection to the return side of the moderate temperature loop at the zenith of Node 1 and a change to the return side to Node 2 zenith. In addition the pump assemblies and liquid/liquid heat exchangers must be added to the zenith side of Nodes 1 and 2.

Thermal Interfaces - Option 4
Soyuz on Node 2 and Node 1 Zenith



SSF/Soyuz DMS Interfaces General Issues

- The SSF 1553B Core data bus interface is potentially compatible with the Soyuz GOST data bus interface. A link will be required to allow for data interchange and to effect data telemetry transfer

General Issues

- Two connections will be required between the SSF 1553B Core bus interface and the Soyuz GOST bus interface for data exchange and telemetry transfer.

SSF/Soyuz C/T Interfaces General Issues

The general issues associated with the SSF/Soyuz C/T Interface deal with the different protocals and ground link methodology. The Soyuz uses a direct VHF digitally coded transmission to ground at telemetry rates up to 256 Kbps or it uses the REGUL system to provide a digital link to ground via a satellite relay network at only 25.6 Kbps. SSF uses TDRSS S-Band single access service to provide 72 Kbps data uplink and 192 Kbps data downlink data downlink to support CC&T

General Issues

- Formats for the telemetry from the Soyuz and SSF may be incompatible
- Soyuz uses direct VHF digitally coded transmission to ground at 256 Kbps or a link to a satellite relay system via the REGUL control system at 25.6 Kbps
- SSF uses a direct link to ground via TDRSS S-Band single access service to provide 72 Kbps uplink and 192 Kbps data downlink

SSF/Soyuz A/V Interfaces General Issues

- The general issues associated with the Soyuz/SSF Audio/Video interfaces center around the incompatibility of the two system formats used. The Soyuz has a hardline audio and analog video connection. SSF uses a digital, fiber optic system with PFM signaling. Soyuz uses direct voice and analog video link to ground. SSF exclusively uses TDRSS network for digital transmission. UHF systems for Soyuz and SSF may be compatible.

General Issues

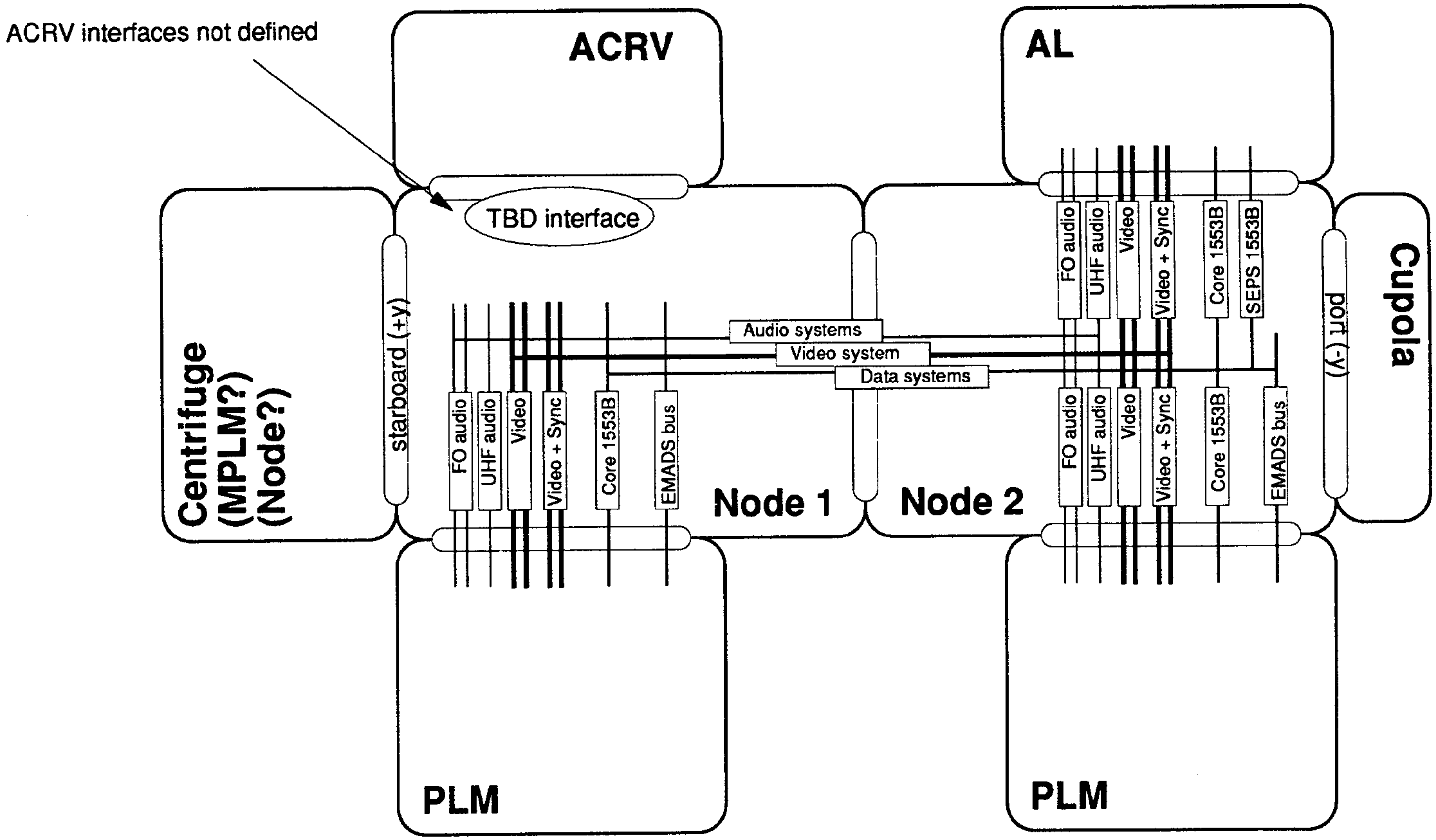
- Soyuz uses direct voice link to ground or Mir. SSF exclusively uses TDRSS network
- Potential may exist to utilize UHF systems for both Soyuz and SSF audio/voice transfers.
- Video signal formats for SSF and Soyuz are 494 lines @ 30 frames/sec and 625 lines at 25 frames/sec respectively
- Soyuz uses hardline analog video connetion, SSF connections are fiber optic, PFM signaling
- Soyuz uses direct analog transmission of video to ground, SSF uses TDRSS for digital transmission of video.

Node 1 & 2 Baseline DMS,C&T, A/V Interfaces

- The diagram below illustrates the baseline Space Station Freedom Data Management System, Communications and Tracking, and Audio / Video interfaces for Nodes 1 and 2. Node 2 nadir and zenith and Node 1 nadir port are all outfitted with a Core 1553B local data bus connection, a F.O. audio (2) connection, wireless UHF audio cabling, and F.O. PFM video (2) connection to Video Switch Units and F.O. PFM video(1) + Sync (1) to Video Switch Units. Nodes 1 and 2 nadir are additionally outfitted with an EMADS bus connection. Node 2 zenith also has an SEPS 1553B User bus connection. No DMS, C/T, or A/V interfaces have been defined at the zenith port of Node 1.

Soyuz ACRV/SSF Accommodation Assessment

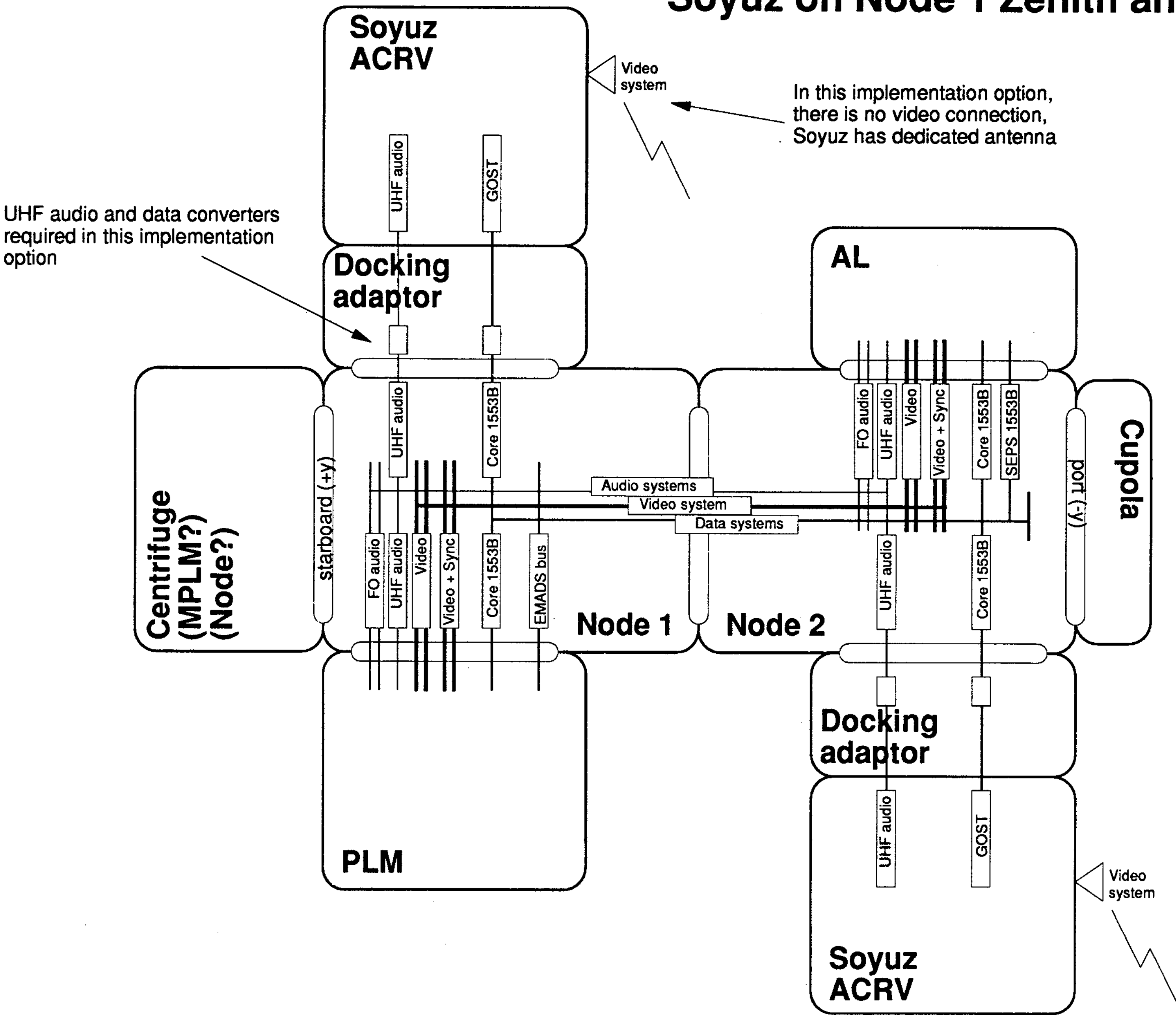
C&T, DMS and A/V Interfaces Current Reference with US ACRV



DMS,C/T, A/V Interfaces - Option 1

- This schematic shows the DMS, C/T, and A/V impacts for option 1. This option will require UHF audio and DMS coverters be added to the zenith port of Node 1

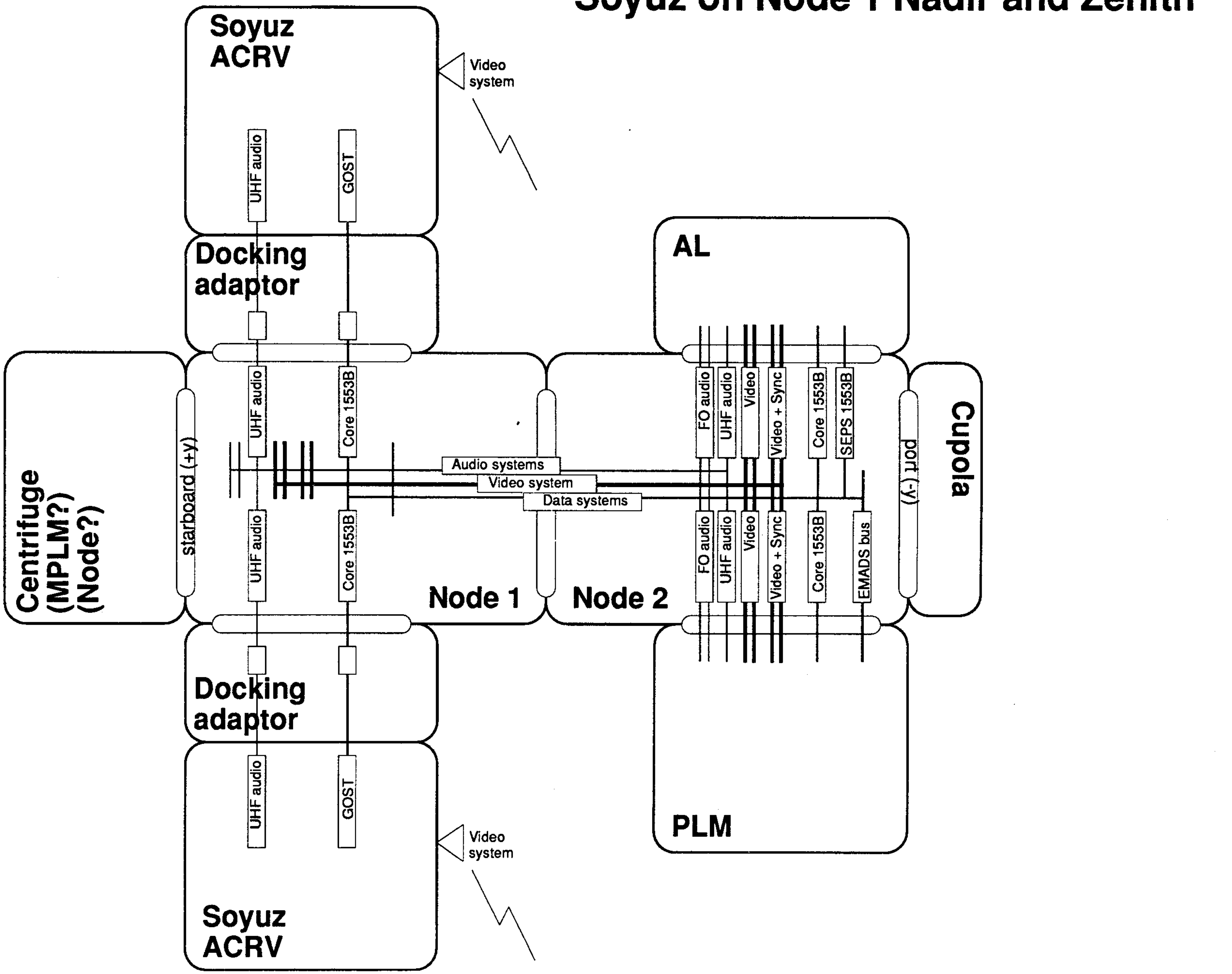
C&T, DMS and A/V Interfaces - Option 1
Soyuz on Node 1 Zenith and Node 2 Nadir



DMS,C/T, A/V Interfaces - Option 2

- This schematic shows the DMS, C/T, and A/V impacts for option 2. This option will require UHF audio and DMS coverters be added to the zenith port of Node 1

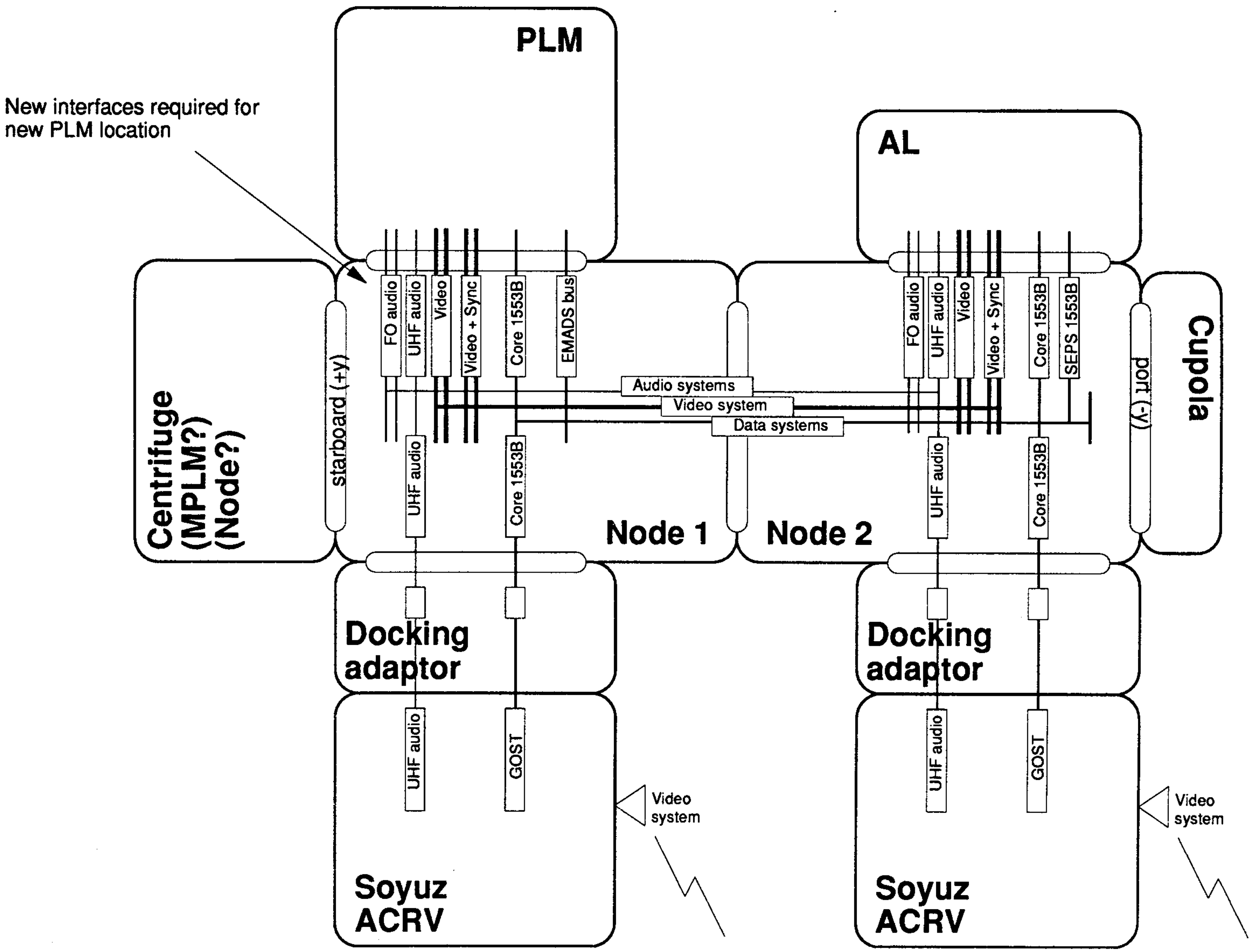
C&T, DMS and A/V Interfaces - Option 2
Soyuz on Node 1 Nadir and Zenith



DMS,C/T, A/V Interfaces - Option 3

- This schematic shows the DMS, C/T, and A/V impacts for option 3. This option will require UHF audio and DMS coverters be added to the zenith port of Node 1

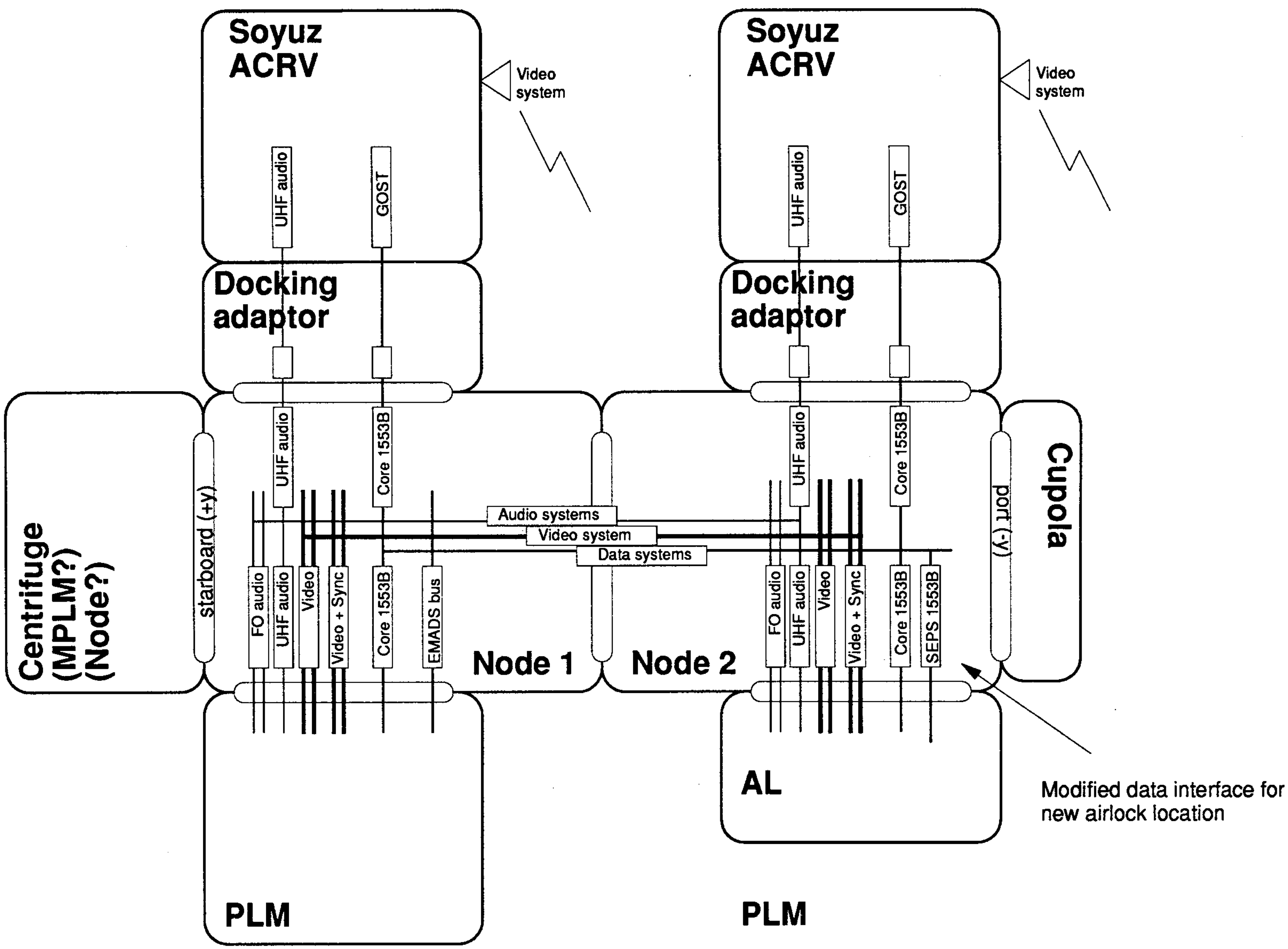
C&T, DMS and A/V Interfaces - Option 3 Soyuz on Node 2 and Node 1 Nadir



DMS,C/T, A/V Interfaces- Option 4

- This schematic shows the DMS, C/T, and A/V impacts for option 4. This option will require UHF audio and DMS coverters be added to the zenith port of Node 1 and modification to the data interface for the airlock at the Node 2 nadir port.

C&T, DMS and A/V Interfaces - Option 4
Soyuz on Node 2 and Node 1 Zenith



SSF/Soyuz ECLSS Interfaces General Issues

- The general issues associated with the SSF/Soyuz ECLSS interfaces deal with the exchange of air between station and the Soyuz. The Soyuz is designed to receive air at a rate of 100CFM with a temperature of 68°F and 50% relative humidity. Station can provide, thru intermodule ventilation, air at 135 CFM with a temperature range of 65° - 80°F and with a range of relative humidty from 24% - 84%.

SSF/Soyuz Environmental Control and Life Support System Interfaces

General Issues

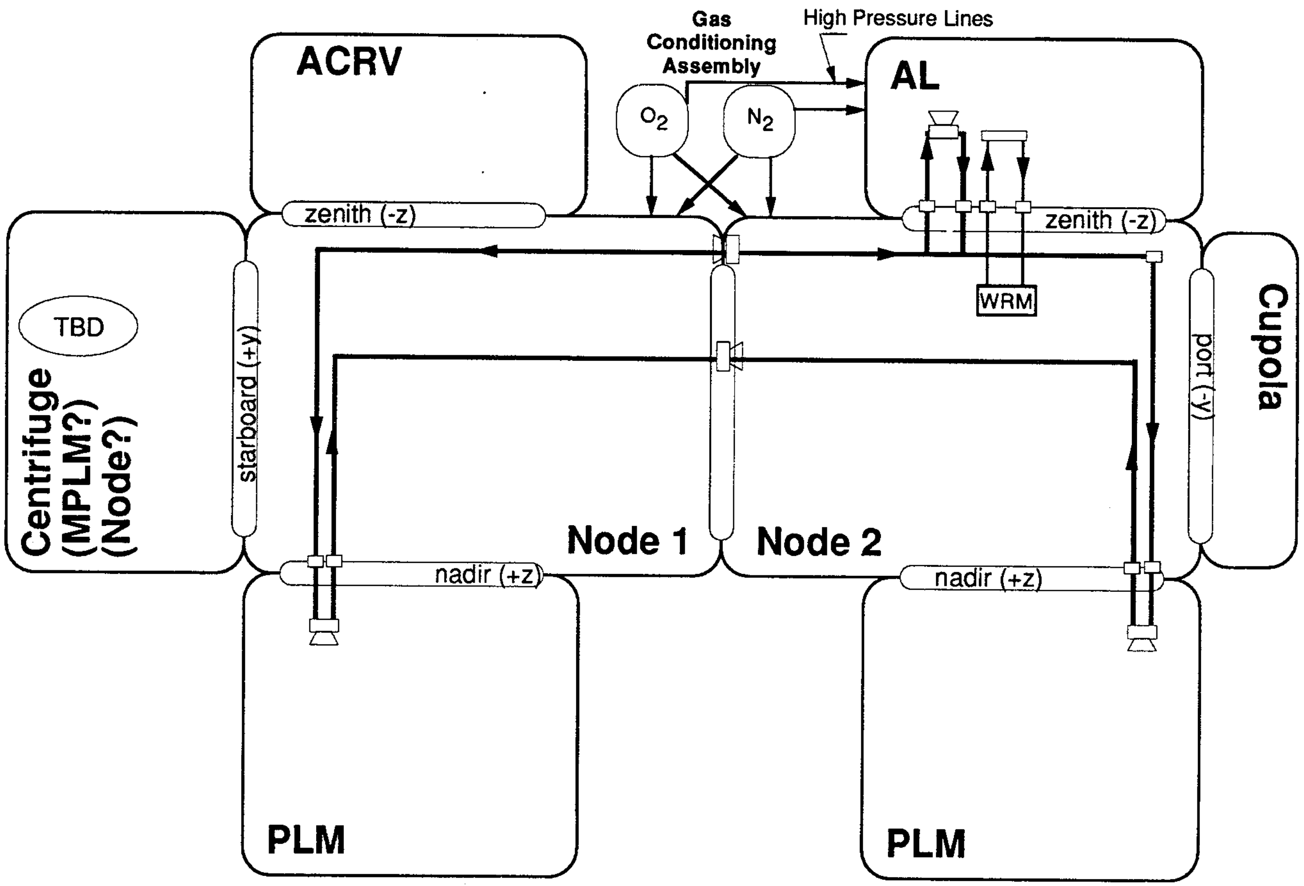
- Soyuz vehicle provides complete ECLSS during manned ascent and decent
- Soyuz has been designed to receive 100 CFM of air at 68°F, 50% relative humidty from Mir
- SSF is designed to provide 135 CFM of air at 65-80° F, 24% - 84% relative humidity through intermodule ventilation

Node 1 & 2 Baseline ECLSS Interfaces

- The diagram below illustrates the baseline Space Station Freedom ECLSS interfaces for Nodes 1 and 2. The SSF ECLSS is designed to provide temperature and humidity control and intermodule air circulaiton for those elements attached to the nadir of Nodes 1 and 2 and the zenith of Node 2. CO2, particulate, and bacterial control and handeled through the air exchange system. Fire Detection and Suppression is handled at each element individually. In addition, pressure control in the nodes support all attached elements. The airlock is provided with high pressure oxygen and nitrogen from the Gas Conditioning Assembly and potable water from the Node.

Soyuz ACRV/SSF Accommodation Assessment

ECLSS Interfaces
Current Reference with US ACRV



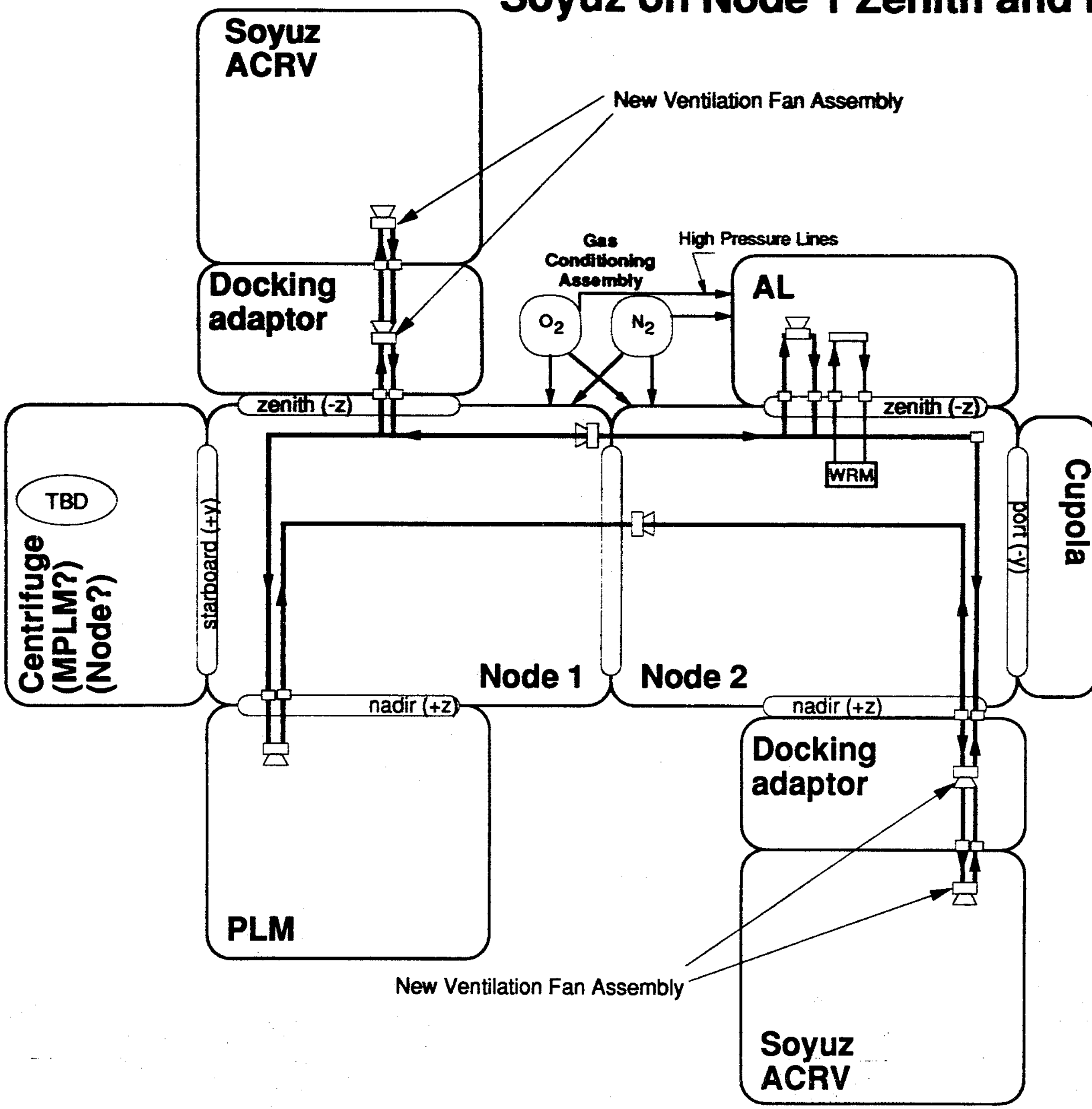
Intermodule Ventilation
O2/N2 and H20 lines

WRM Water Recovery & Management

ECLSS Interfaces - Option 1

- This schematic shows the ECLSS impacts for option 1. This option will require additional fans and ducting at the zenith port of Node 1 and the nadir port of Node 2.

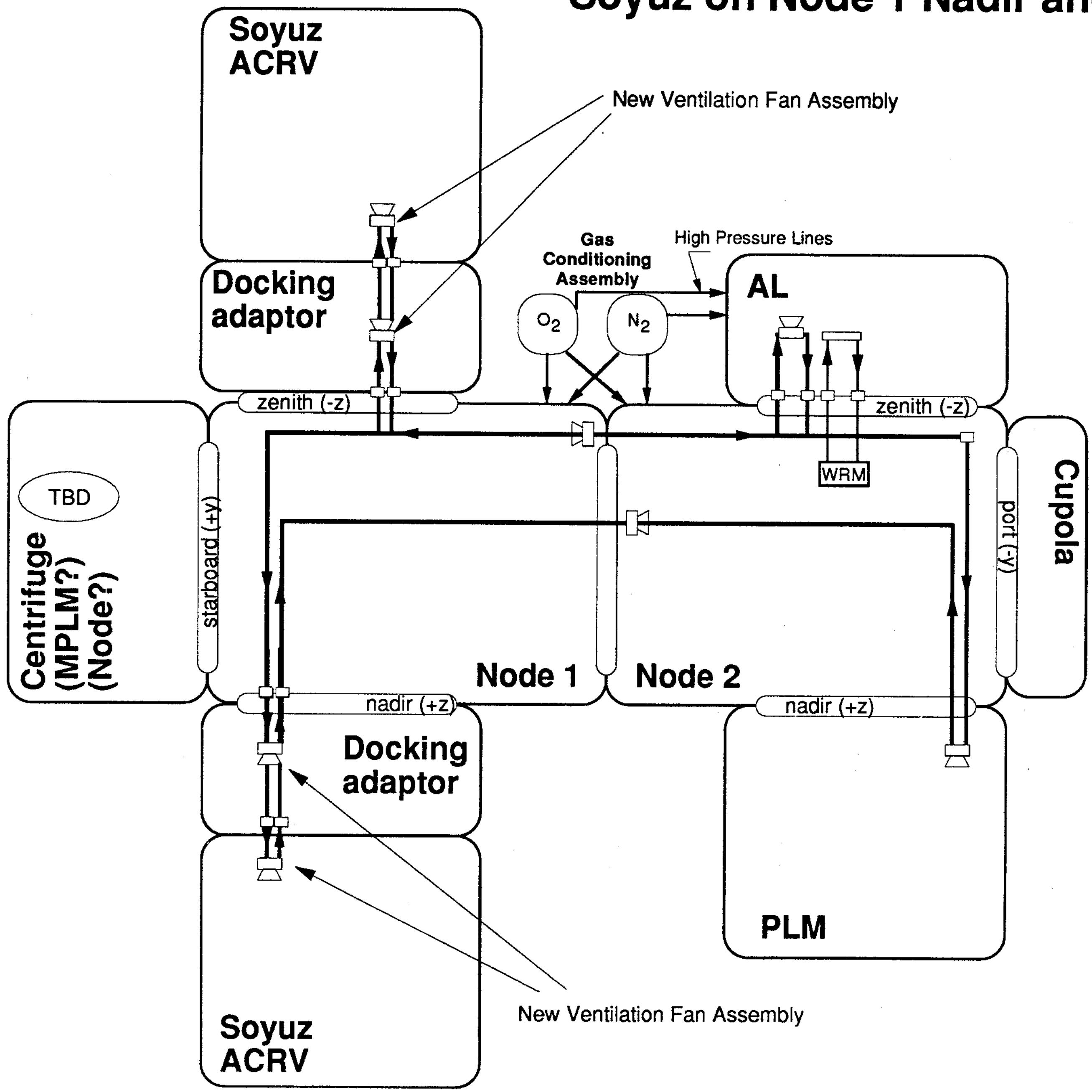
ECLSS Interfaces - Option 1
Soyuz on Node 1 Zenith and Node 2 Nadir



ECLSS Interfaces - Option 2

- This schematic shows the ECLSS impacts for option 2. This option will require additional fans and ducting at the nadir and zenith ports of Nodes 1.

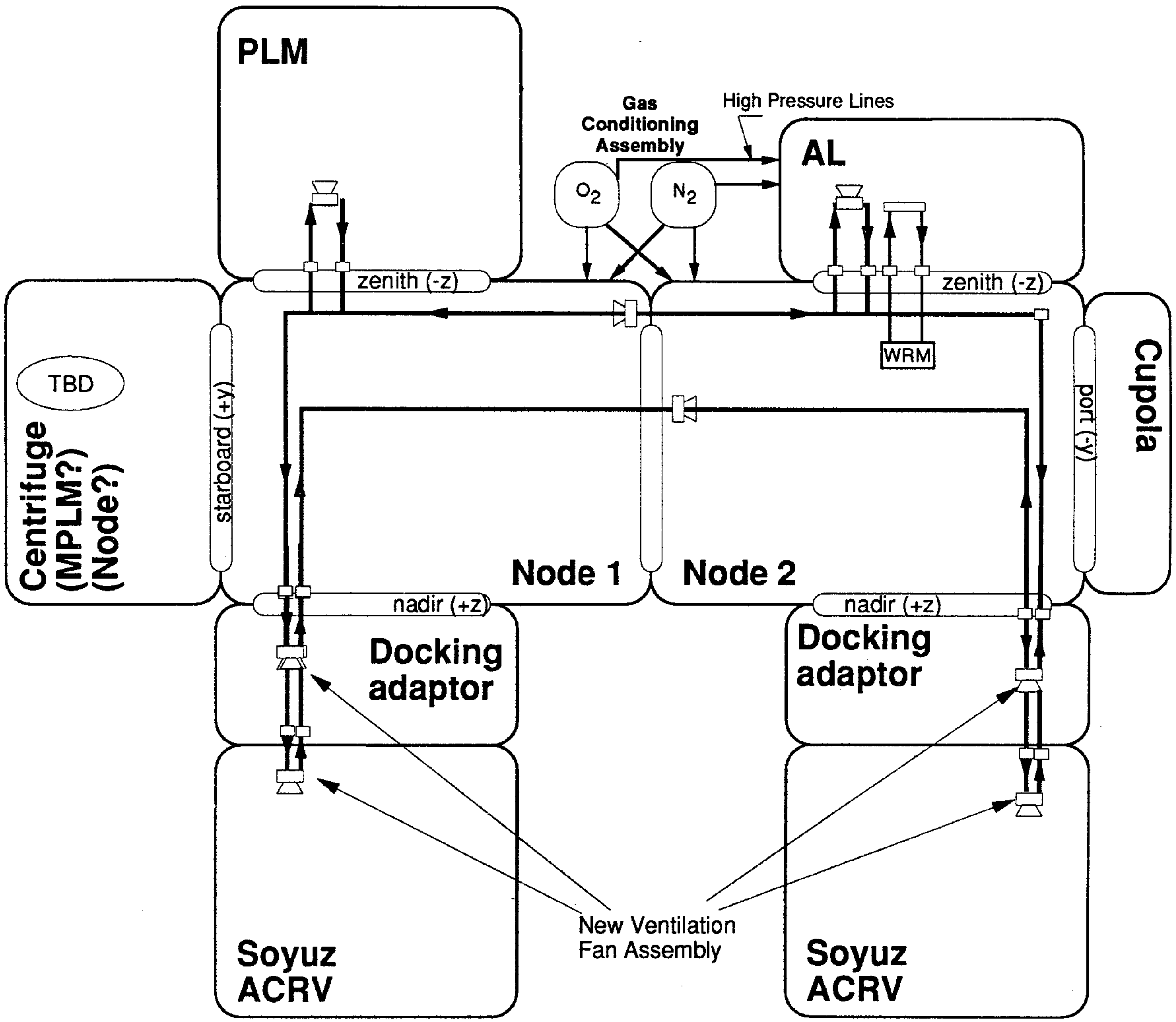
ECLSS Interfaces - Option 2
Soyuz on Node 1 Nadir and Zenith



ECLSS Interfaces - Option 3

- This schematic shows the ECLSS impacts for option 3. This option will require additional fans and ducting at the nadir ports of Nodes 1 and 2 and the zenith port of Node 1.

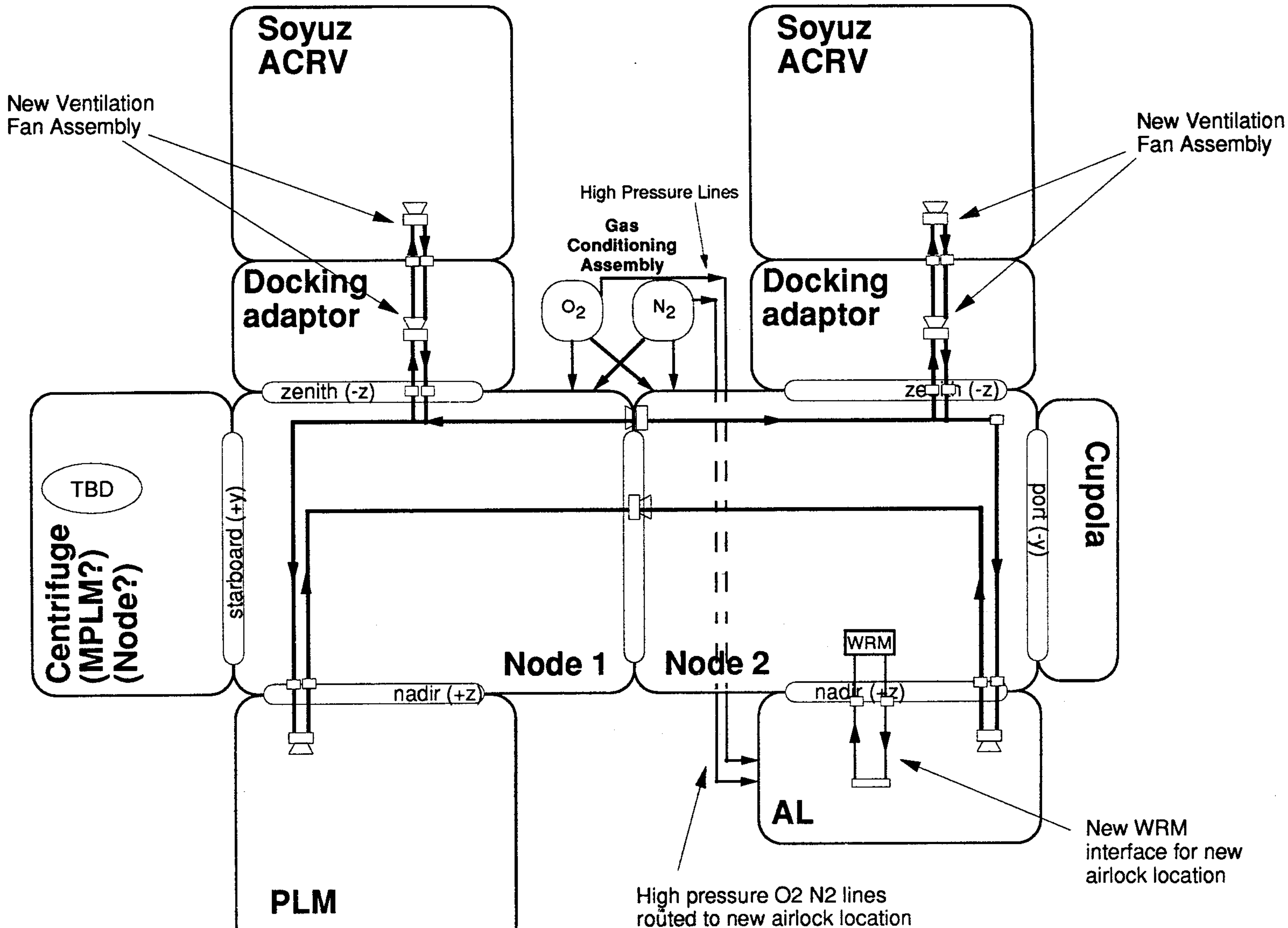
ECLSS Interfaces - Option 3
Soyuz on Node 2 and Node 1 Nadir



ECLSS Interfaces - Option 4

- This schematic shows the ECLSS impacts for option 4. This option will require additional fans and ducting at the zenith ports of Nodes 1 and 2. In addition, high pressure oxygen and nitrogen and potable water lines must be relocated to the nadir port of Node 4 for the airlock.

ECLSS Interfaces - Option 4
Soyuz on Node 2 and Node 1 Zenith



Option Summary

- Show below is a summary of the system impacts for each of options studied

Soyuz/ACRV Accommodation Study

Systems Impacts Option Summary

System	Option 1	Option 2	Option 3	Option 4
EPS	N1-Zenith (2) N2-Nadir (1)	N1-Zenith (2) N1-Nadir (1)	N1 & N2-Nadir (2) N1-Zenith (1)	N1- Zenith (1) N2 -Nadir (2)
TCS	N1 - Zenith (1) N2 - Nadir (1)	N1-Zenith (1) N1-Nadir (1)	N1 Zenith (2) N1 & N2-Nadir (2)	N1 & N2-Zenith (2)
DMS, C/T, A/V	N1 - Zenith (2) N2 - Nadir (2)	N1-Zenith (2) N1-Nadir (2)	N1 Zenith (6) N1 & N2-Nadir (4)	N1 & N2-Zenith (4) N2- Zenith (1)
ECLSS	N1 - Zenith (1) N2 - Nadir (1)	N1-Zenith (1) N1-Nadir (1)	N1 Zenith (1) N1 & N2-Nadir (2)	N1 & N2-Zenith (2) N2 Nadir (2)
	11	11	20	14

N1 = Node 1, N2 = Node 2 : Indicate which interfaces change
Numbers in () indicate total number of interface changes

- This Page Intentionally Left Blank -

SSF - Soyuz Operational Issues

PRECEDING PAGE BLANK NOT FILMED

- This Page Intentionally Left Blank -

SSF-Soyuz Operational Issues

- Clearance Issues
- SSRMS Reach Assumptions
- SSF PLM Exchange Issues
- Departure Path Analysis
- Soyuz Delivery Assumptions

SSF/Soyuz Clearances General Issues

- For each option considered, determine minimum clearances provided to Soyuz and all SSF elements which could potentially interfere with Soyuz. Furthermore, Orbiter Payload Bay clearances for options that include Soyuz on the nadir port must be considered.

Soyuz/ACRV Accommodation Study

General Issues

- Determine minimum clearances provided to Soyuz and all SSF elements
- Determine Orbiter PLB clearances for options that include Soyuz on nadir port

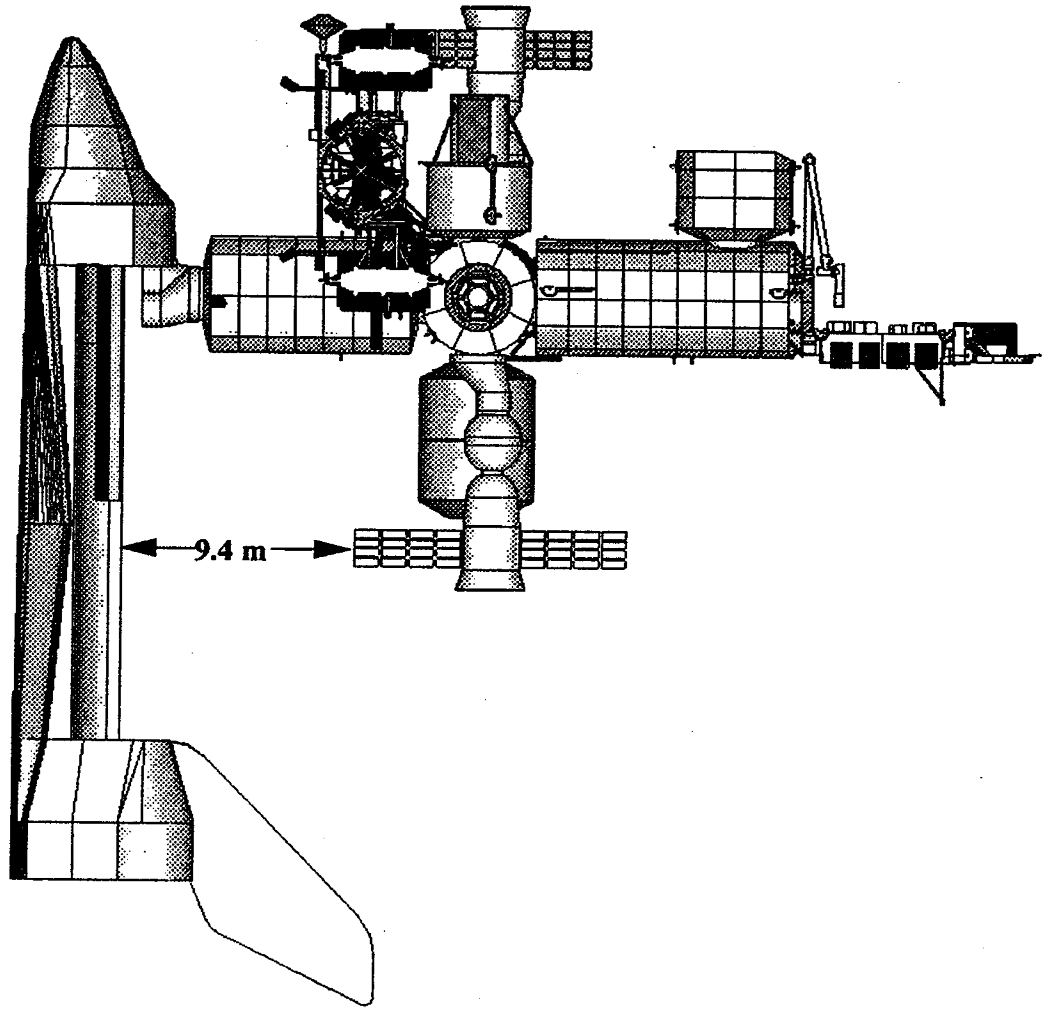
Options 1,2,3, & 5 - Soyuz on nadir port(s)

Orbiter to Soyuz Clearance

- **Minimum clearance between orbiter and Soyuz on nadir port is 9.4 meters**
  - Occurs between leading edge of Soyuz PV array and top edge of orbiter PLB

Orbiter to Soyuz Clearance

Soyuz on nadir port



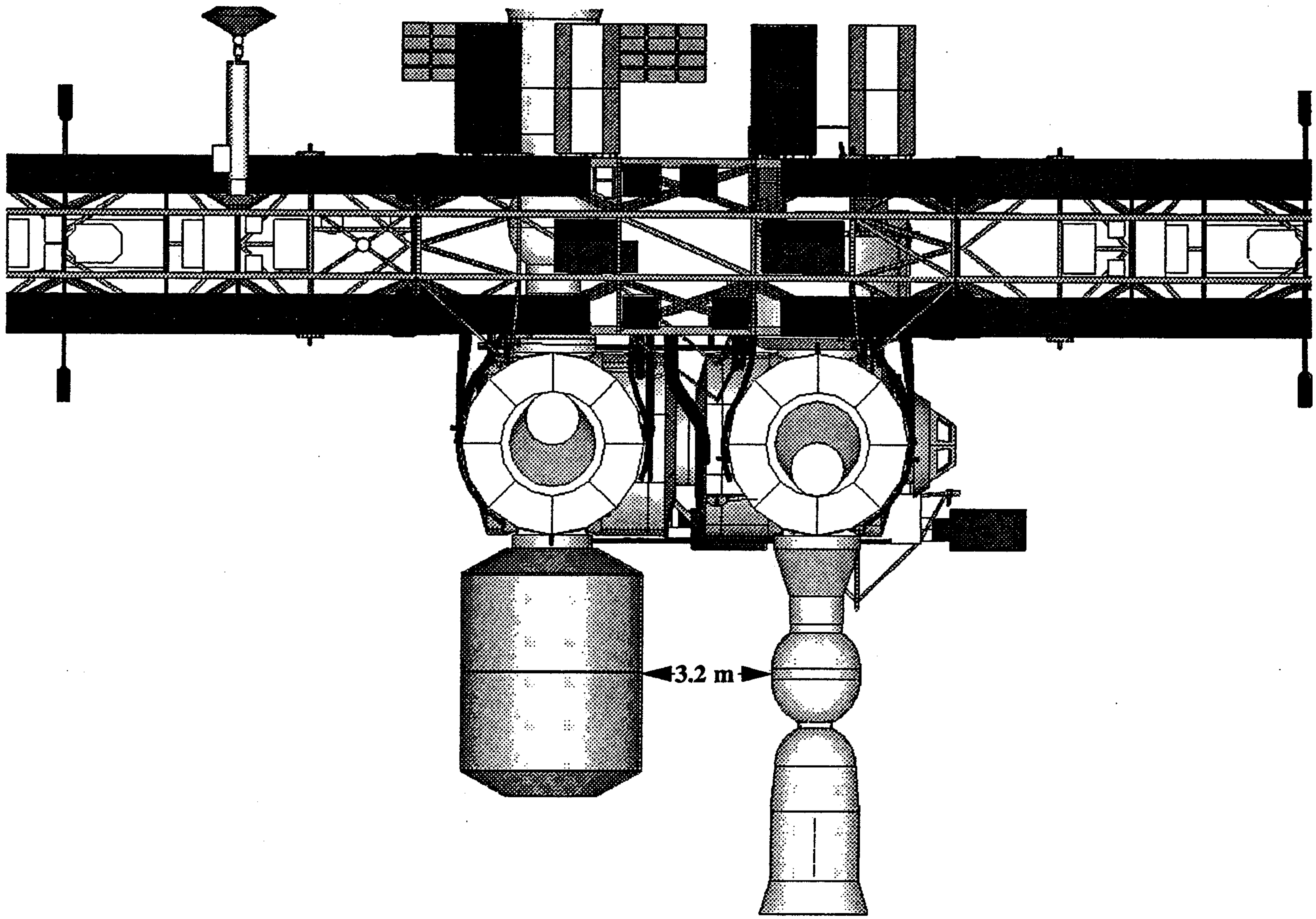
Options 1 &2, Single Soyuz on nadir port

Soyuz to PLM Clearance

- **Minimum clearance between Soyuz on nadir port and PLM is 3.2 meters**
  - Occurs between orbital module and PLM shell
- **Need to determine if this clearance precludes consideration of AR & D of Soyuz**
  - Can assume Soyuz is brought up prior to PLM
  - However, still have problem when need to replace Soyuz at end of lifetime

Soyuz to PLM Clearance

Soyuz on nadir port



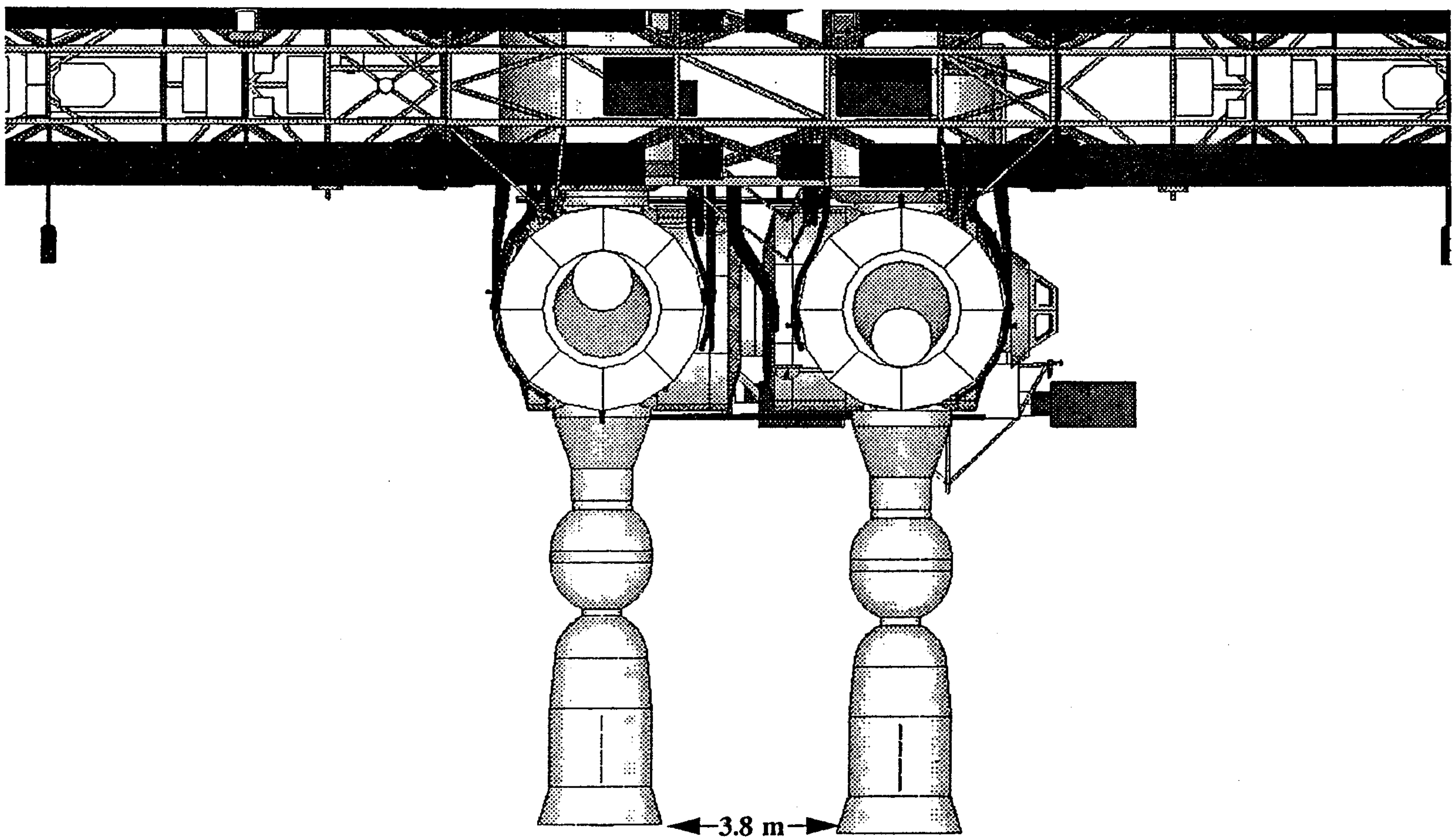
Option 6 - Both Soyuz on nadir port

Soyuz to Soyuz Clearance

- **Minimum clearance between the two Soyuz is 3.8 meters**
    - Occurs at outer edge of flaring at bottom of each vehicle
- **Need to determine if this clearance precludes consideration of AR &D of second Soyuz to nadir port if first Soyuz already occupies one of the nadir ports.**

Soyuz to Soyuz Clearance

Both Soyuz on nadir ports



Option 6 - Soyuz on aft port of Node 3

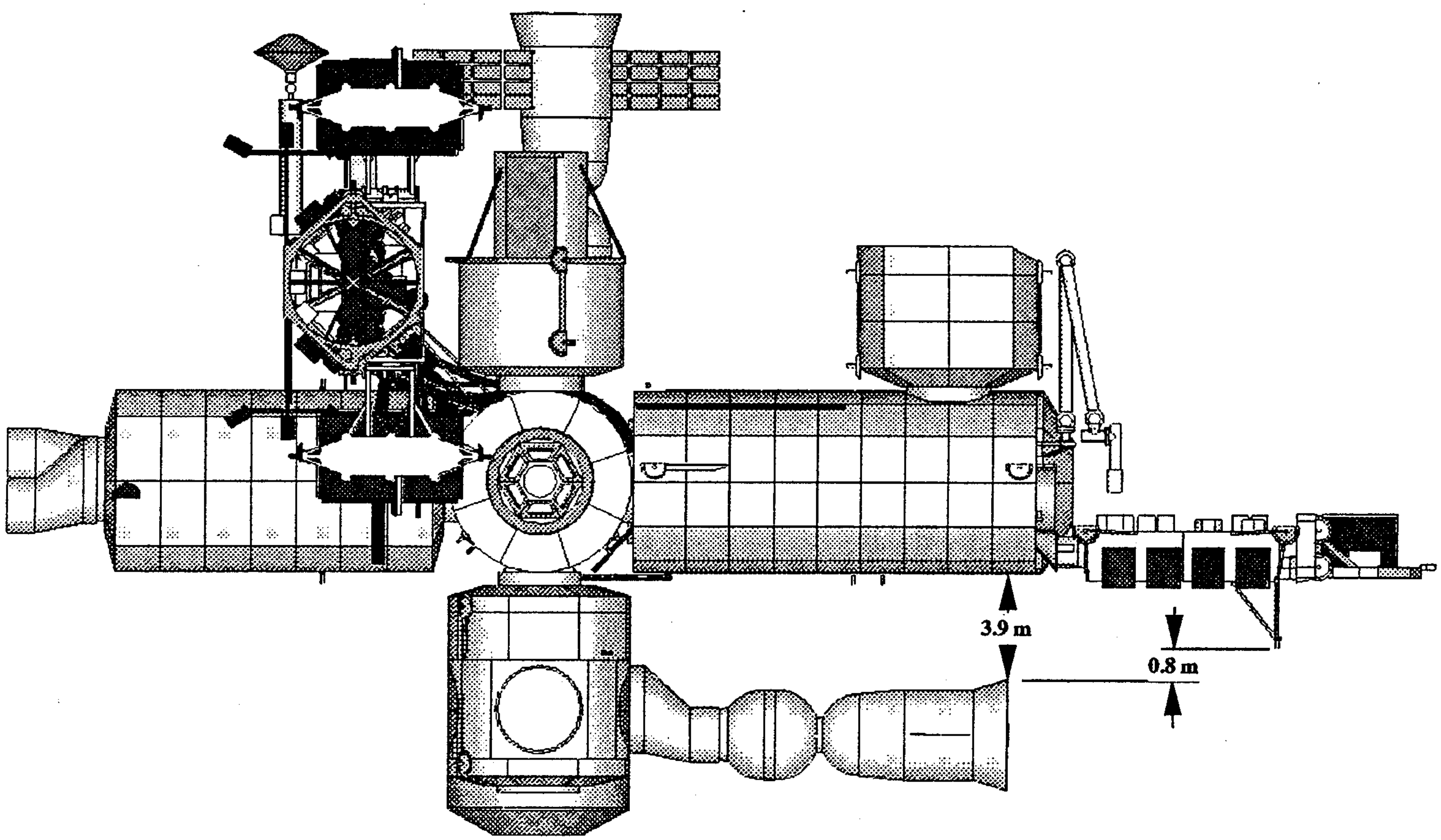
Soyuz to JEM Clearance

- **Minimum clearance between Soyuz and JEM module is 3.9 meters**
    - Occurs between outer shell of JEM module and flare of Soyuz module
- **Minimum clearance along z-axis of Soyuz and JEM exposed facility is 0.8 meters**
    - Occurs between keel fitting of JEM EF and flare of Soyuz module
    - This small clearance could interfere with escape path of vehicle

FREEDOM

Soyuz to JEM Clearance

Soyuz on aft port of Node 3



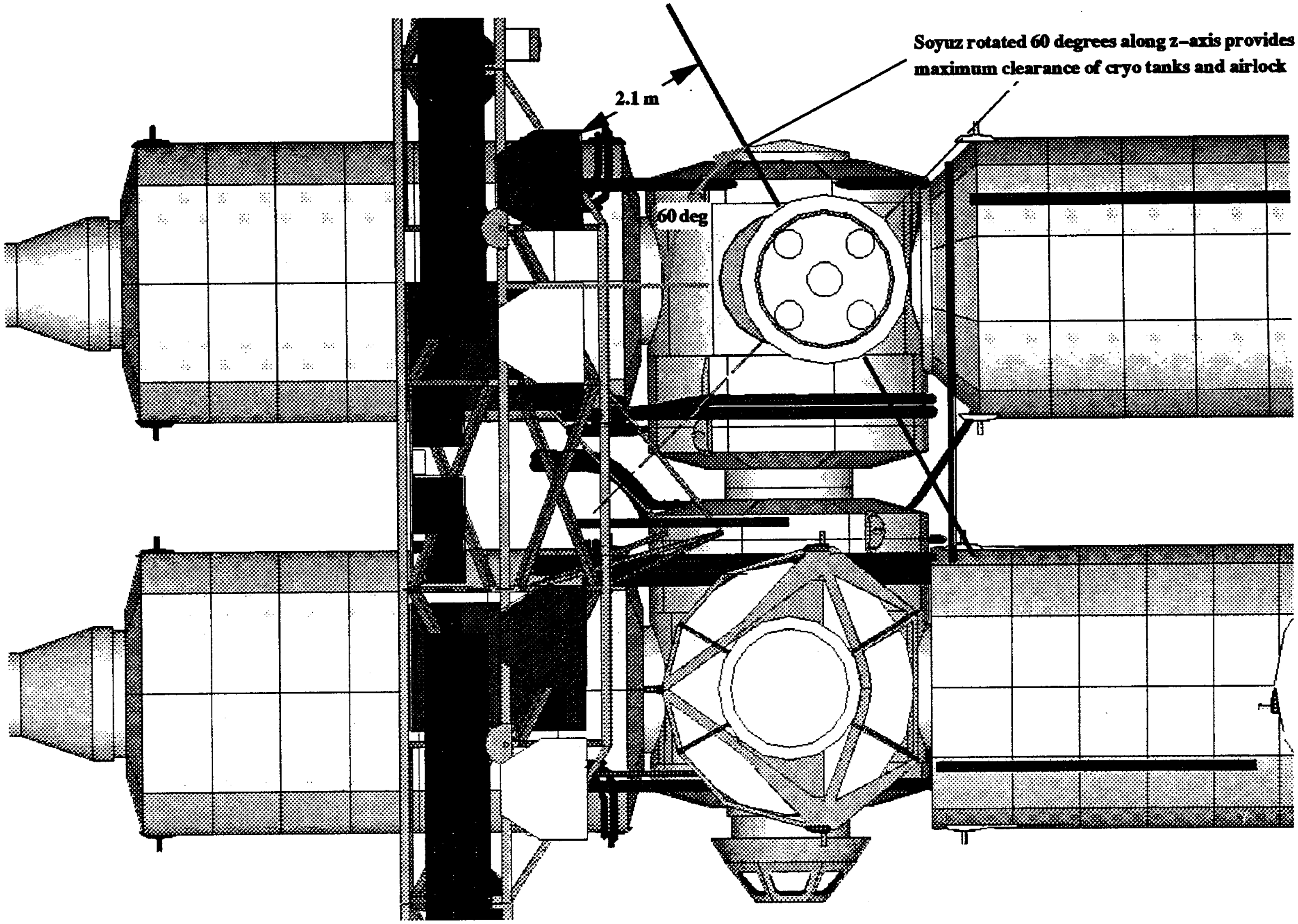
Options 1,2,4,5, & 6

Soyuz PV Array Clearance

- **Parametric study performed to identify preferred docking rotation of Soyuz to zenith port**
  - Studied rotating Soyuz in 15 degree increments about z-axis
  - Determined minimum clearance between Soyuz and cryo tanks, airlock
- **Determined that best angle of docked Soyuz to maximize clearance is 60 degrees about z-axis**
  - Arrays along x-axis considered initial orientation
  - Provides a minimum of 2.1 meters clearance - occurs between PV array and cryo tank
- **Ability to retract Soyuz PV arrays would make this orientation unnecessary as well as increase clearances.**

Soyuz PV Array Clearance

Soyuz on zenith port



Soyuz/SSRMS Placement Issues

- The placement of the Soyuz on either of the nadir or zenith berthing locations on Nodes 1 and 2 should present no problems. Currently program has other pressurized elements designated to be placed at ports where proposed to place Soyuz. These elements (PLM, Airlock, U.S. ACRV) are currently placed in their final position by SSRMS. Further study is required to determine current and/or potential position of grapple fixture on Soyuz. These positions would likely correspond to positions similar to that of PLM or the Airlock. Furthermore, study is necessary to determine if grapple fixtures need to be relocated on other elements. In some options, propose placing a PLM on a zenith port. This may require relocation of its grapple fixture. Final analysis of actual Soyuz placement process is required. In some options, could require handoff between STSRMS and SSRMS or placement at a temporary postion while SSRMS relocates.

Soyuz/ACRV Accommodation Study

SSRMS Reach Assumptions

- Should present no problems
  - Currently have other pressurized elements designated to be placed at ports where propose to place Soyuz
  - These elements (PLM, U.S. ACRV, etc.) are currently placed in their final position by SSRMS
- Further study required
  - Determine current and/or potential position of grapple fixture on Soyuz
    - Could correspond to position of grapple fixture on pressurized element currently occupying that particular port
  - Determine if grapple fixtures need relocating on other elements
    - In some options, propose placing a PLM on a zenith port. This may require relocation of its grapple fixture.
  - Determine actual process for placement of Soyuz
    - In some options, could require handoff between STSRMS and SSRMS or placement at a temporary position while SSRMS relocates.

SSF PLM Exchange Issues

- In most options, the process for exchanging the PLM must be re-examined. In Options 1,2,4, and 6, only a single nadir port is available for PLMs. Therefore, an additional attachment point for PLM changeout will be required. This could be either an interim attachment point on PIT, MT PDA, or a hold by SSRMS. Another proposed solution would be to use the closet module concept. In option 3, the only port available for PLMs is on a zenith port. This will also required and interim attach point. Furthermore, a new path for placement of PLM must be analyzed

Soyuz/ACRV Accommodation Study

SSF PLM Exchange Issues

- Both ports on nadir available for PLMs
  - Option 5
  - Changeout operations normal - one port used for old PLM while other port for replacement PLM
- Single port available on nadir for PLMs
  - Options 1,2,4, & 6
  - Requires additional attachment point for PLM changeout
    - Interim attachment point (store on PIT, MT PDA, or hold with RMS)
    - Closet module concept
- Single port available on zenith for PLMs
  - Option 3
  - Requires additional attachment point for PLM changeout
    - Interim attachment point (store on PIT, MT PDA, or hold with RMS)
    - Closet module concept
  - Requires new path for placement for PLM - may require hand-off or interim attachment point for even first PLM

Soyuz Departure Path Analysis General Issues

- Several impacts to the Soyuz escape trajectory requirements were studied. They included an assessment of the atmospheric density effects, configuration ballistic coefficient, departure direction, and the loss of Freedom attitude control

General Issues

- Determine Soyuz escape trajectory requirements for candidate locations studied
  - Assess atmospheric density effects
  - Assess configuration dependent ballistic coefficient effects
  - Assess departure direction
  - Assess Freedom loss of attitude control

Assumptions

• The assumptions for this study are shown below

Assumptions

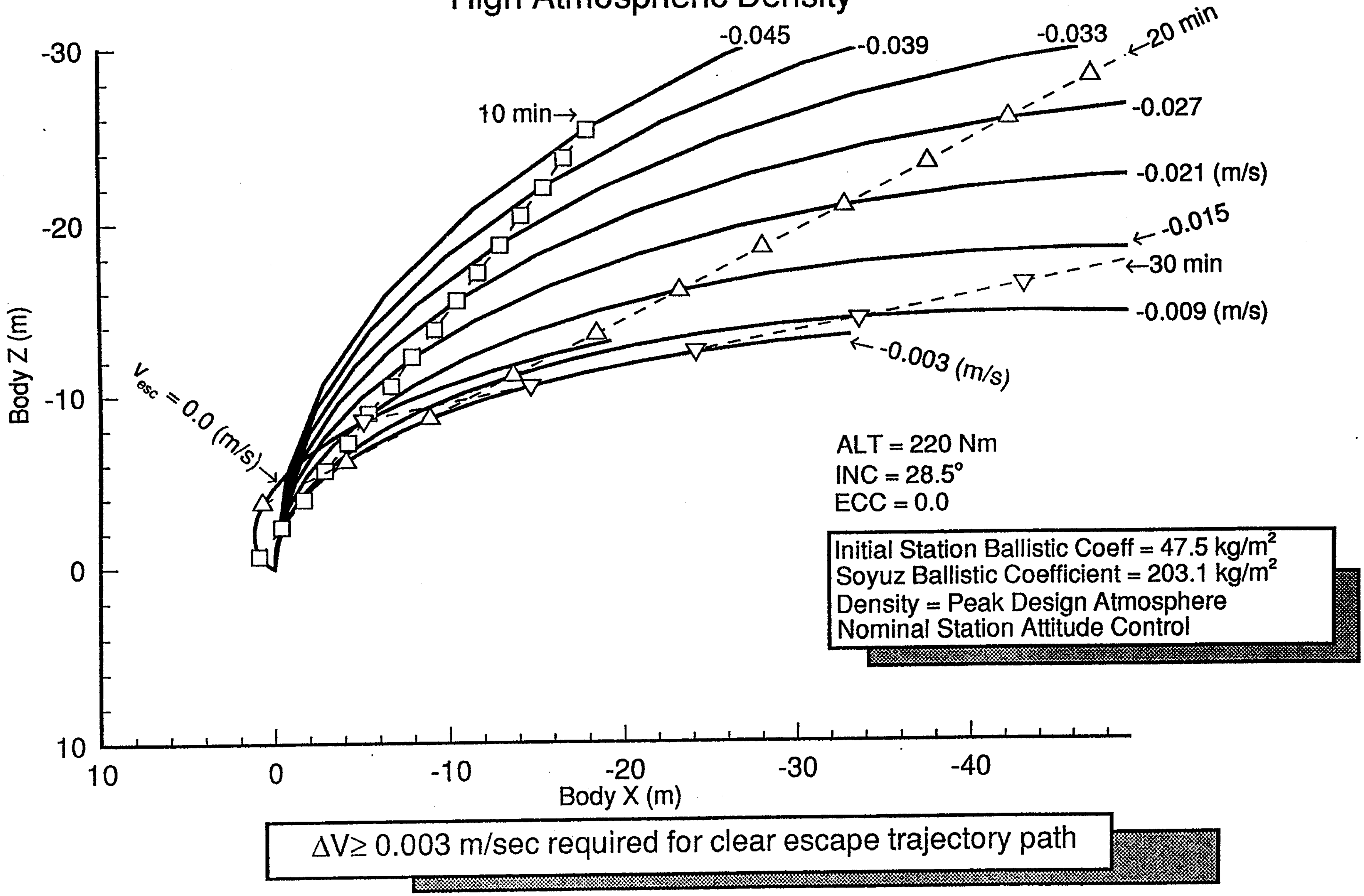
- 3 atmosphere density profies studied
  - Design atmosphere @ 220 Nm
  - -2s min solar cycle @ 220 Nm
  - Design atmosphere @ 229 Nm (180 day lifetime above 150 Nm)
- 2 configuration dependent ballistic coefficient profiles studied
  - Feathered Soyuz (203.1 kg/m^2) vs "full array" Soyuz (125.5 kg/m^2)
  - Sun tracking Freedom PV arrays
    - initially feathered
    - initially max area into velocity
  - Blockage effects of Freedom on Soyuz neglected
- 3 departure directions studied
  - zenith (body -z)
  - nadir (body +z)
  - minus vbar (body -x)
  - Impact of canted departures considered
- 2 Freedom attitude control modes
  - Nominal CMG control
  - Contingency 0.65 deg/sec pitch rate
- Negligible Soyuz rotation rate during departure
- Initial Station pitch attitude: -13 degrees

Soyuz Zenith Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. A velocity of at least 0.003 m/sec was required for a clear escape trajectory path. This is well within the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ ZENITH ESCAPE TRAJECTORY PATHS
High Atmospheric Density



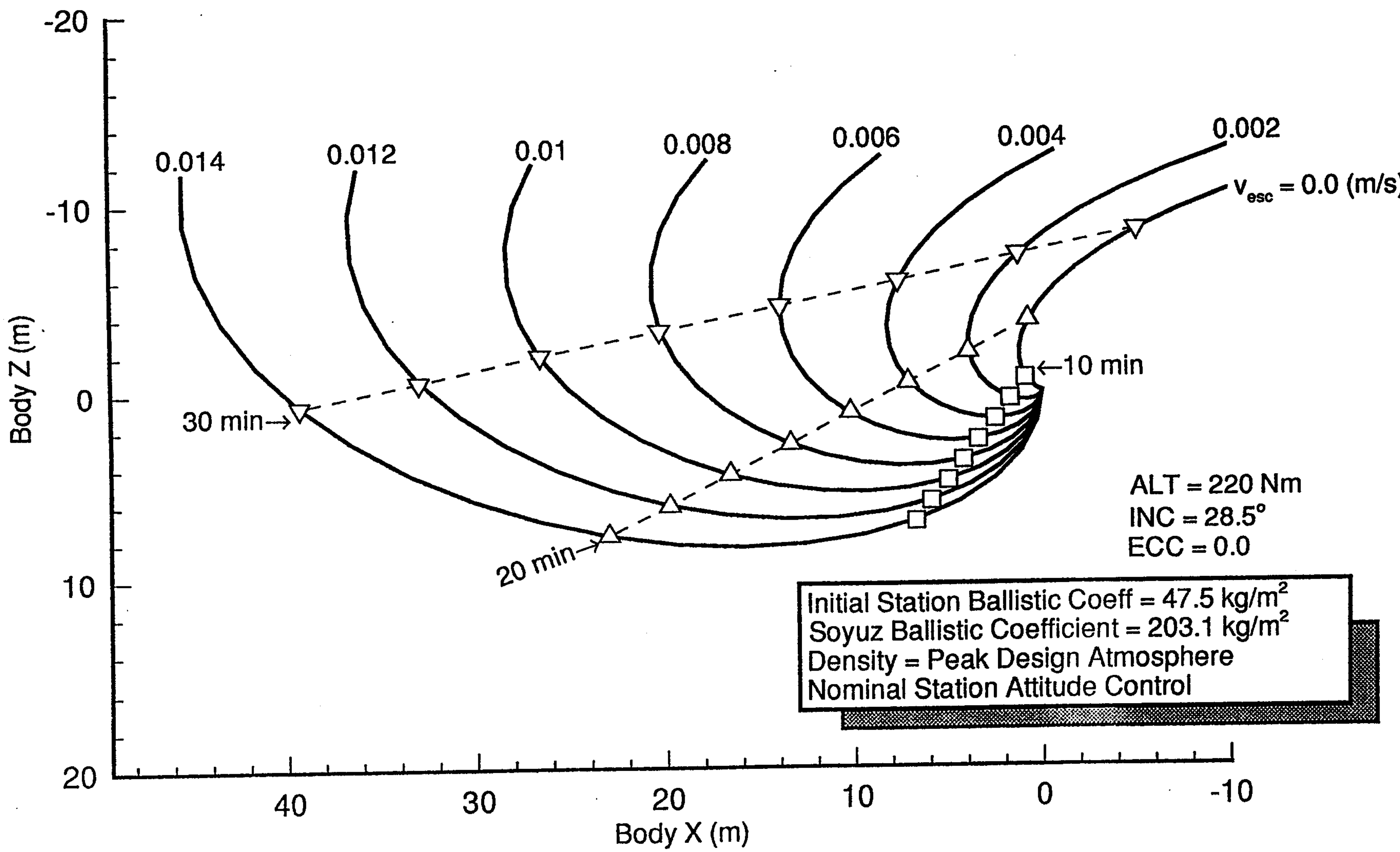
Soyuz Nadir Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. A velocity of at least 0.008 m/sec was required for a clear escape trajectory path. This is well within the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ NADIR ESCAPE TRAJECTORY PATHS

High Atmospheric Density



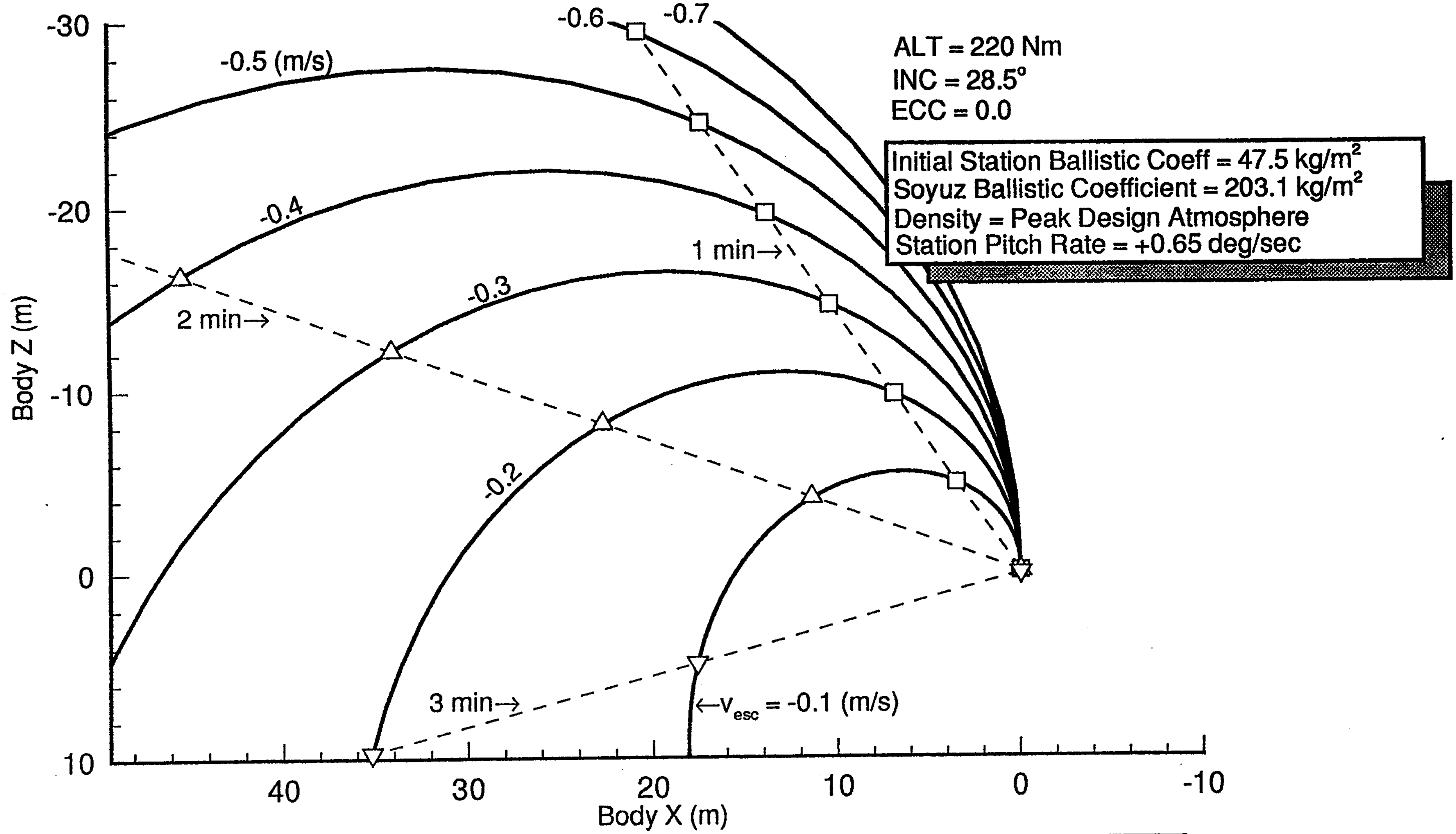
$\Delta V \geq 0.008$ m/sec required for clear escape trajectory path

Soyuz Zenith Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. An uncontrolled mode with a station pitch rate of +0.65 deg/sec was assumed. A velocity of at least 0.7 m/sec was required for a clear escape trajectory path. This is well above the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ ZENITH ESCAPE TRAJECTORY PATHS
High Atmospheric Density



ΔV ≥ 0.7 m/sec required for clear escape trajectory path

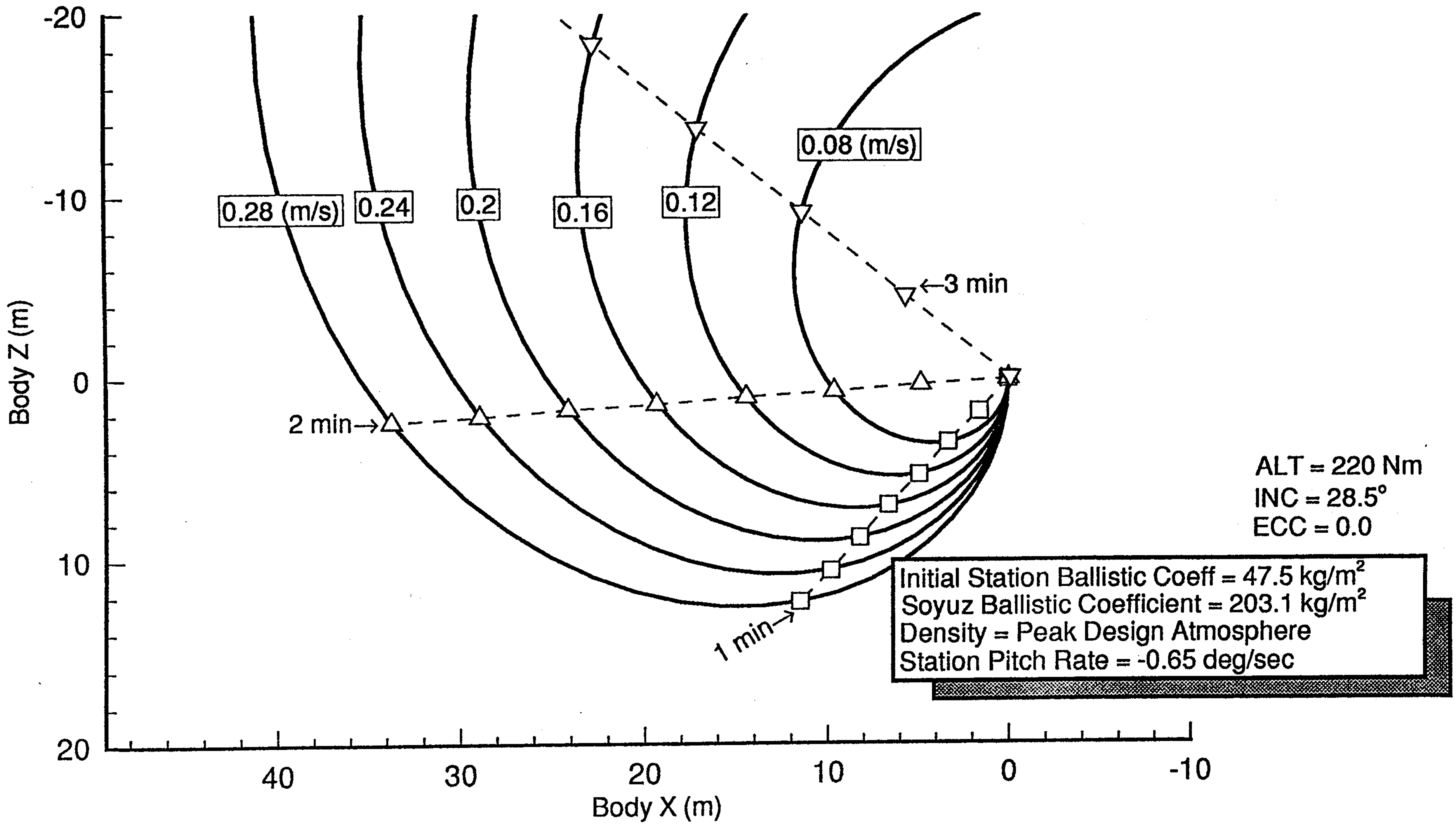
Soyuz Nadir Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. An uncontrolled mode with a station pitch rate of –0.65 deg/sec was assumed. A velocity of at least 0.15 m/sec was required for a clear escape trajectory path. This is below the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ NADIR ESCAPE TRAJECTORY PATHS

High Atmospheric Density



$\Delta V \geq 0.15$ m/sec required for clear escape trajectory path

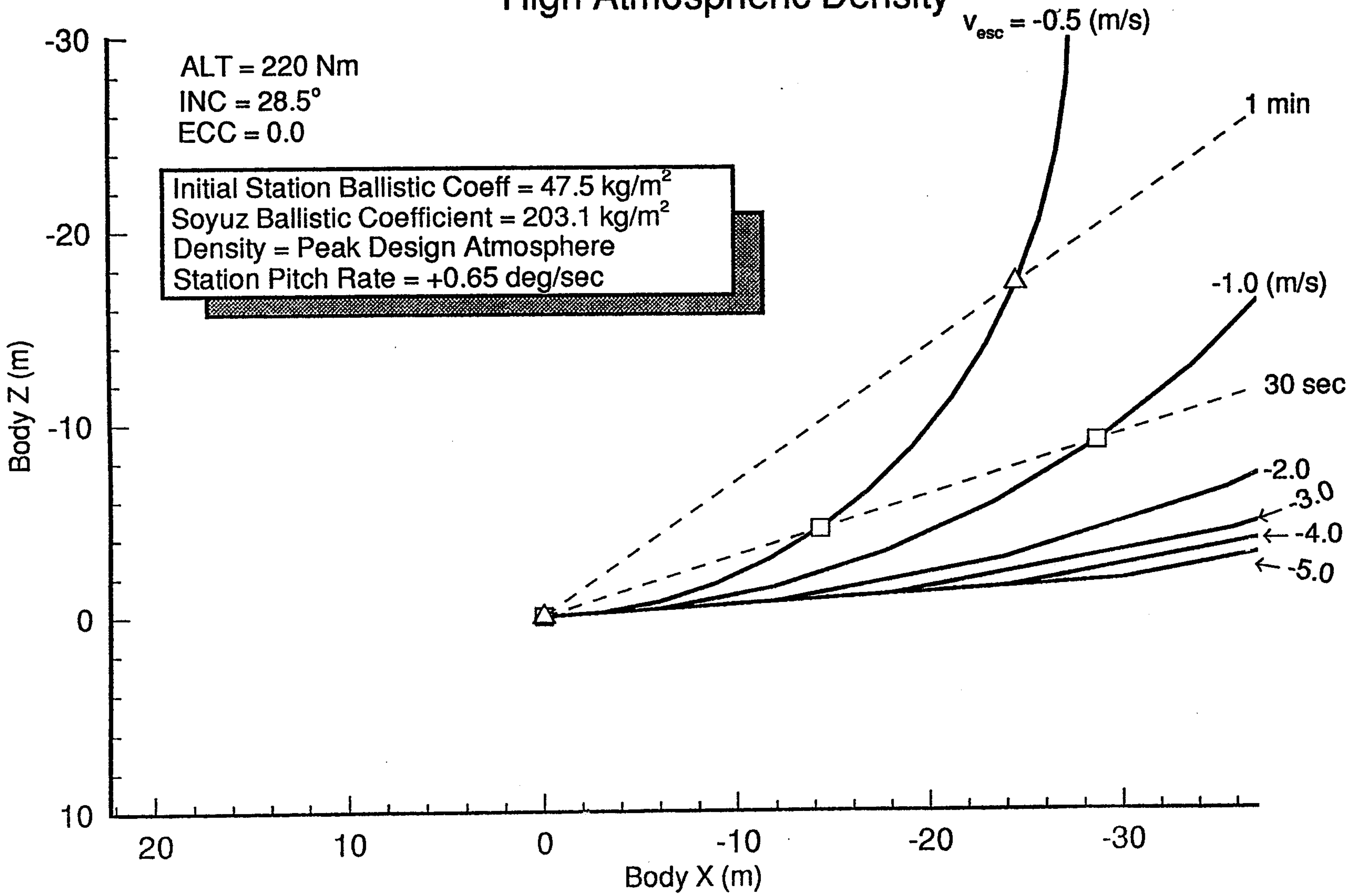
Soyuz –V Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. An uncontrolled mode with a station pitch rate of +0.65 deg/sec was assumed. A velocity of at least 4 m/sec was required for a clear escape trajectory path. This is well above the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ -V ESCAPE TRAJECTORY PATHS

High Atmospheric Density



$\Delta V \geq 4$ m/sec required for clear escape trajectory path

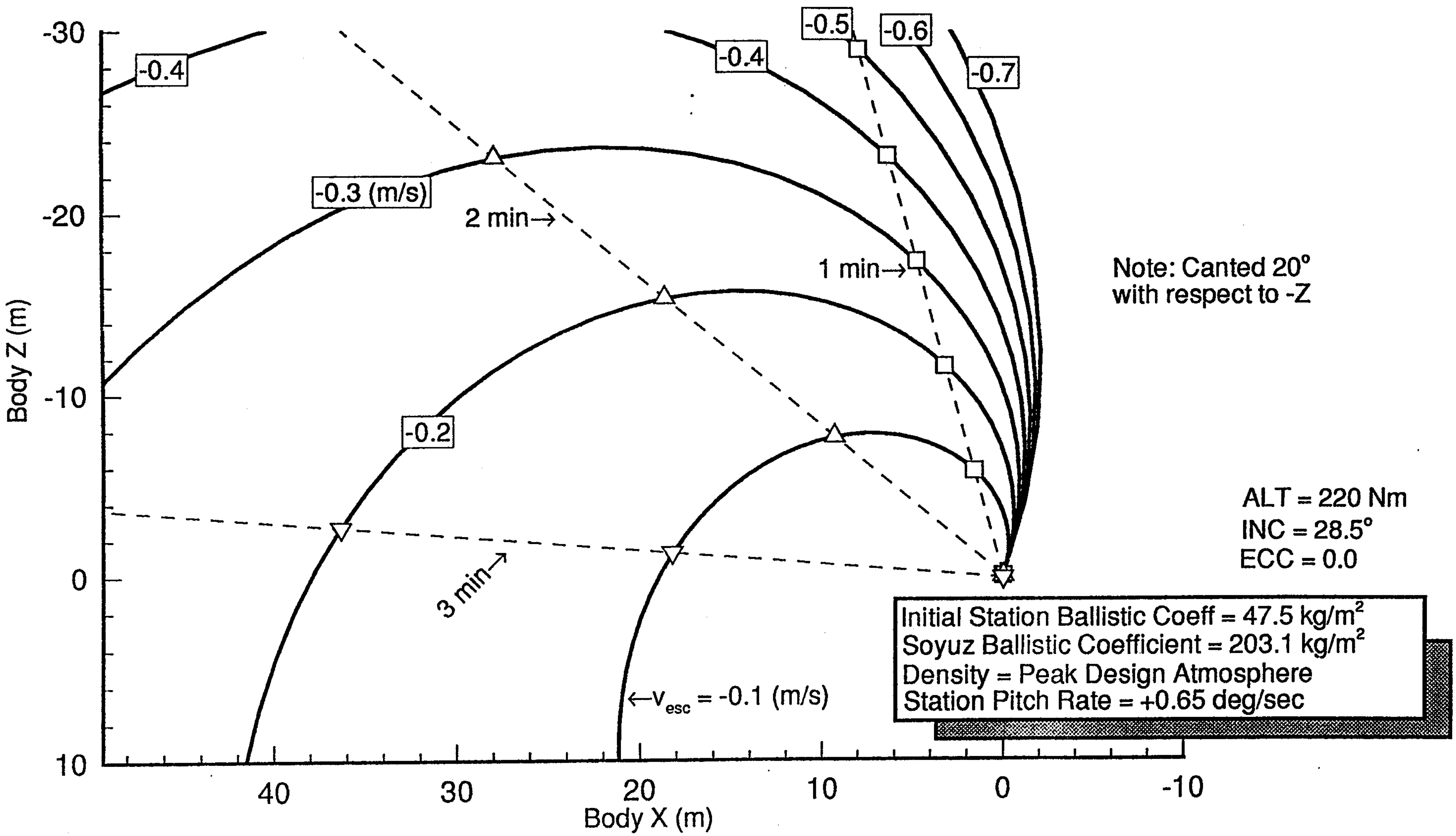
Soyuz Zenith Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. An uncontrolled mode with a station pitch rate of +0.65 deg/sec was assumed. In addition, an initial departure angle of 20 degrees with respect to –Z (to simulate a canted docking adapter) was assumed in an attempt to reduce the velocity required for a clear escape trajectory path, A velocity of at least 0.3 m/sec was required for a clear escape trajectory path. This is above the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz, but shows a vast improvement over the 0.7 m/sec required without the use of a canted docking adapter..

SOYUZ ZENITH ESCAPE TRAJECTORY PATHS

High Atmospheric Density



$\Delta V \geq 0.3$ m/sec required for clear escape trajectory path

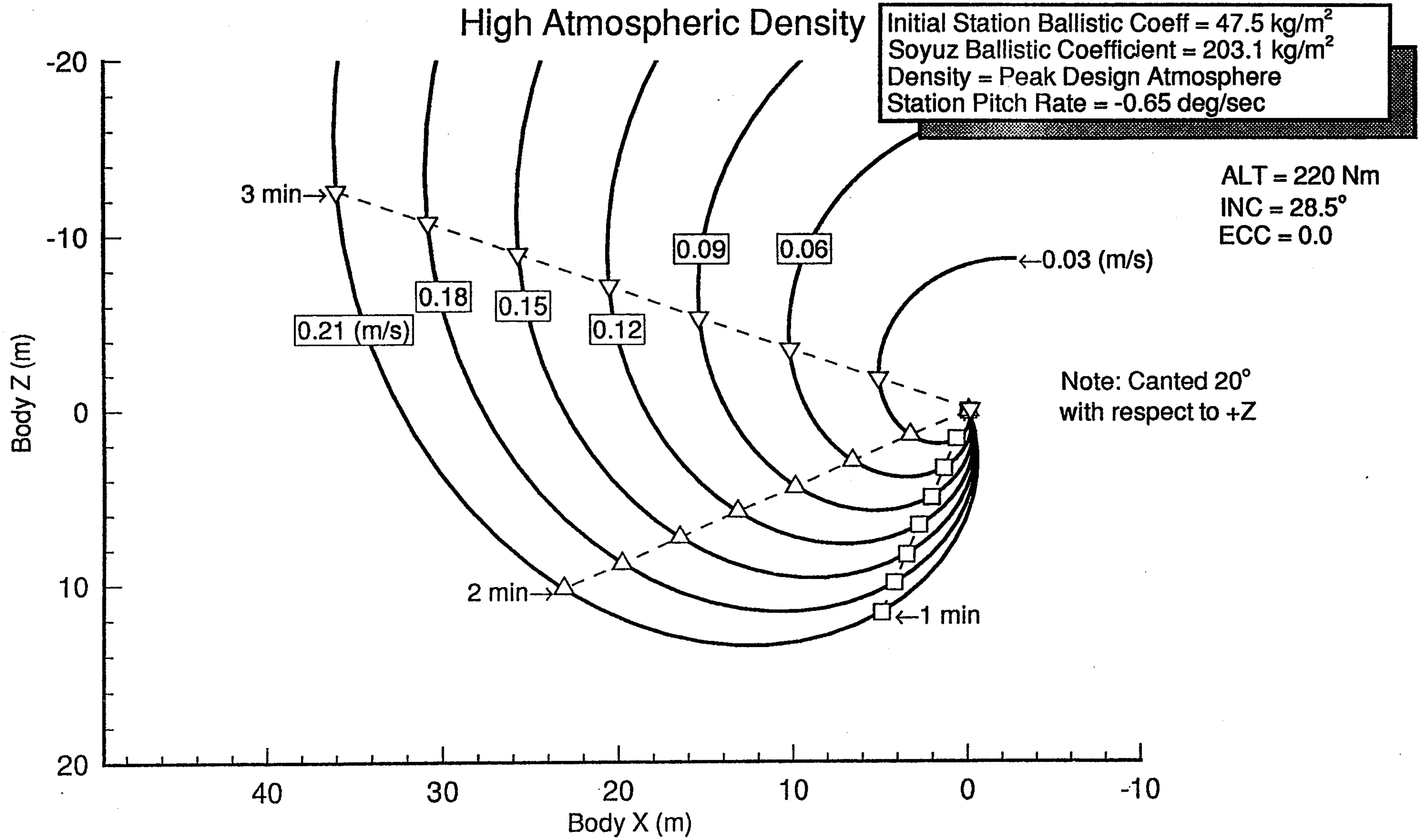
Soyuz Nadir Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. An uncontrolled mode with a station pitch rate of –0.65 deg/sec was assumed. In addition, an initial departure angle of 20 degrees with respect to +Z (to simulate a canted docking adapter) was assumed in an attempt to reduce the velocity required for a clear escape trajectory path, A velocity of at least 0.12 m/sec was required for a clear escape trajectory path. This is below the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ NADIR ESCAPE TRAJECTORY PATHS

High Atmospheric Density



$\Delta V \geq 0.12$ m/sec required for clear escape trajectory path

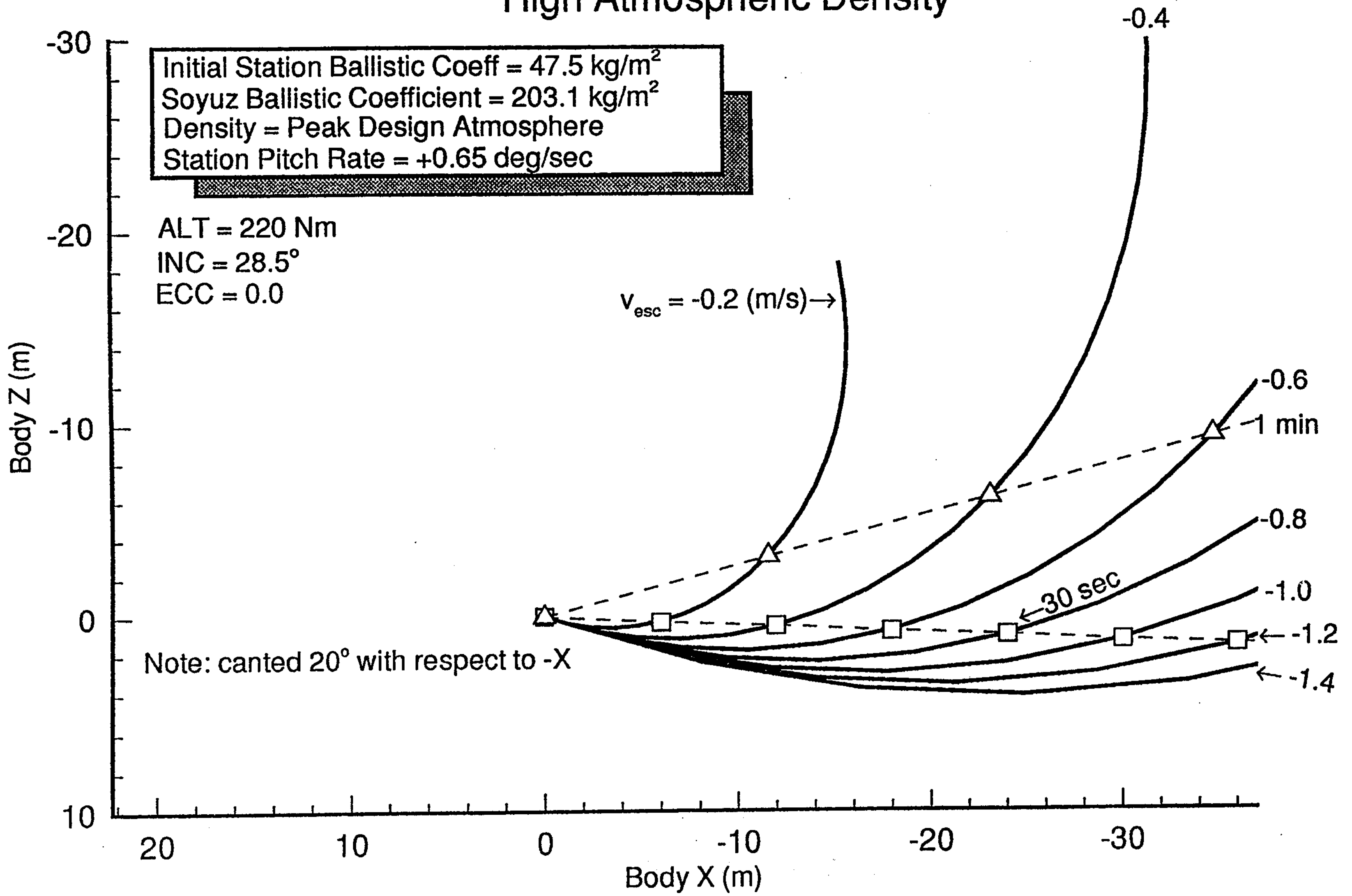
Soyuz –V Escape Trajectory Paths

High Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A design atmosphere was assumed, along with a minimum SSF ballistic coefficient and a maximum Soyuz ballistic coefficient. An uncontrolled mode with a station pitch rate of +0.65 deg/sec was assumed. In addition, an initial departure angle of 20 degrees with respect to –X (to simulate a canted docking adapter) was assumed in an attempt to reduce the velocity required for a clear escape trajectory path, A velocity of at least 0.6 m/sec was required for a clear escape trajectory path. This is well above the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz, but does show a vast improvement over the 4 m/sec required without the canted docking adapter.

SOYUZ -V ESCAPE TRAJECTORY PATHS

High Atmospheric Density



$\Delta V \geq 0.6$ m/sec required for clear escape trajectory path

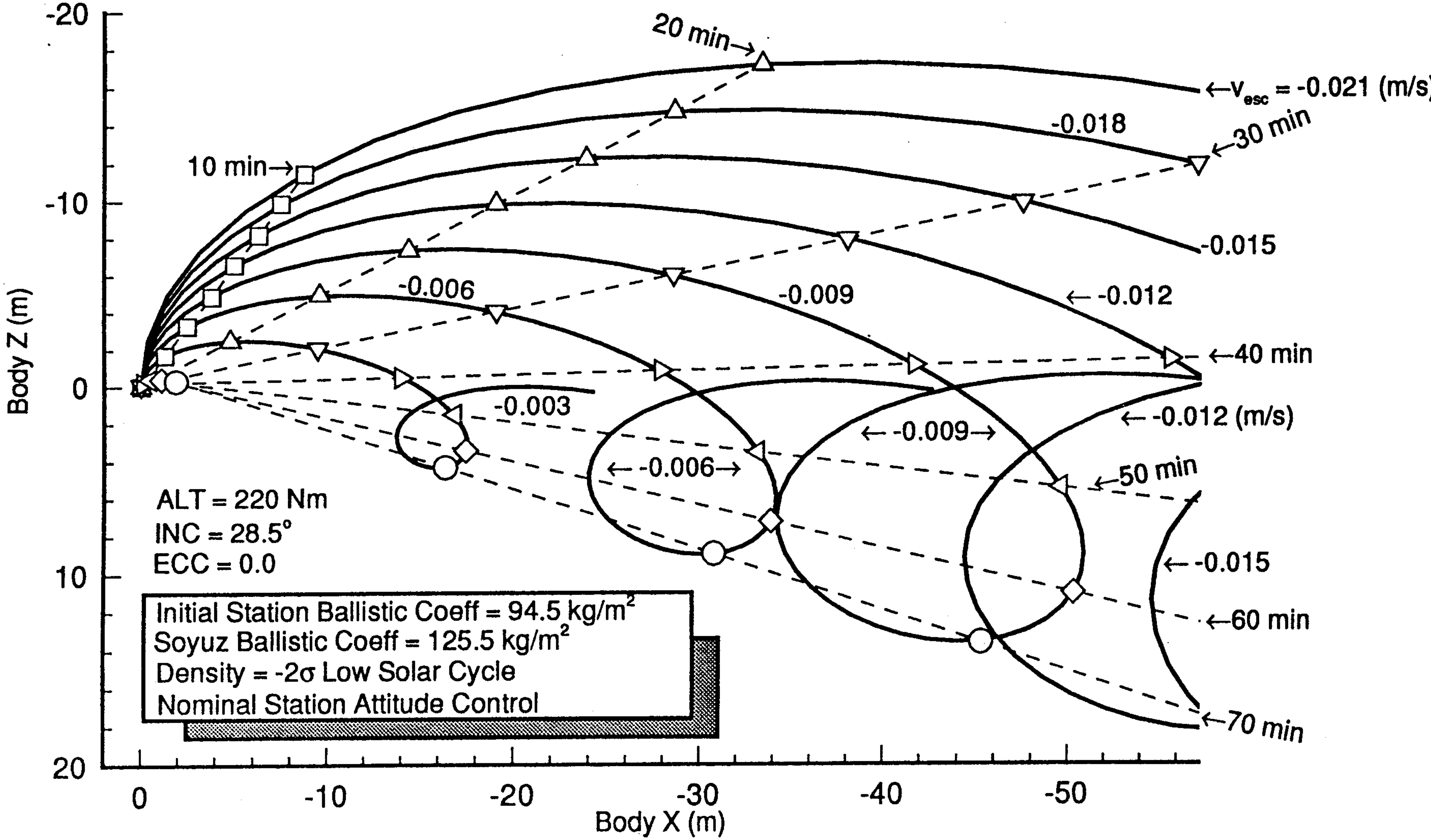
Soyuz Zenith Escape Trajectory Paths

Low Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A –2–sigma atmosphere was assumed, along with a maximum SSF ballistic coefficient and a minimum Soyuz ballistic coefficient. A velocity of at least 0.006 m/sec was required for a clear escape trajectory path. This is well below the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ ZENITH ESCAPE TRAJECTORY PATHS

Low Atmospheric Density



ΔV ≥ 0.006 m/sec required for clear escape trajectory path

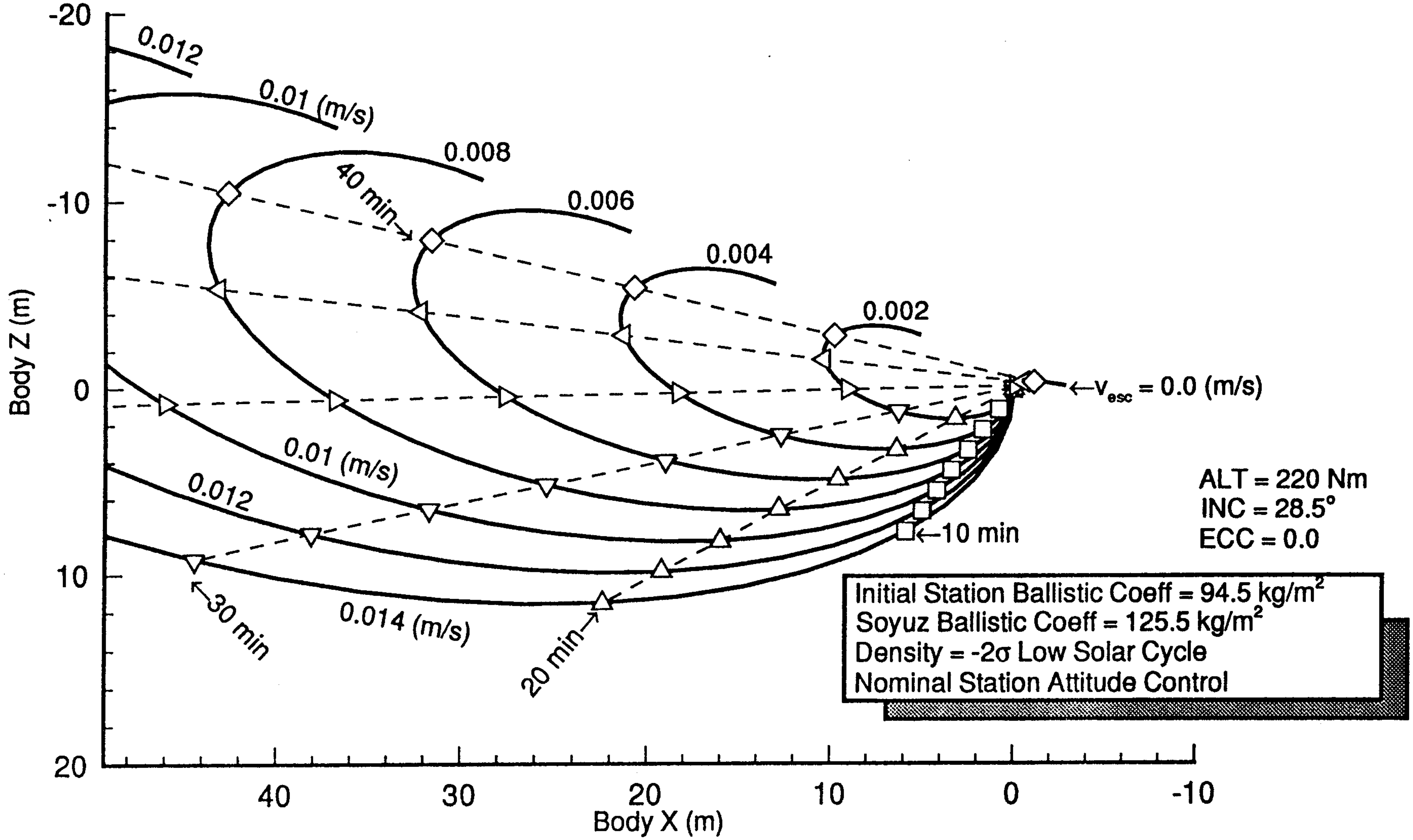
Soyuz Nadir Escape Trajectory Paths

Low Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A –2–sigma atmosphere was assumed, along with a maximum SSF ballistic coefficient and a minimum Soyuz ballistic coefficient. A velocity of at least 0.006 m/sec was required for a clear escape trajectory path. This is well below the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ NADIR ESCAPE TRAJECTORY PATHS

Low Atmospheric Density



$\Delta V \geq 0.006$ m/sec required for clear escape trajectory path

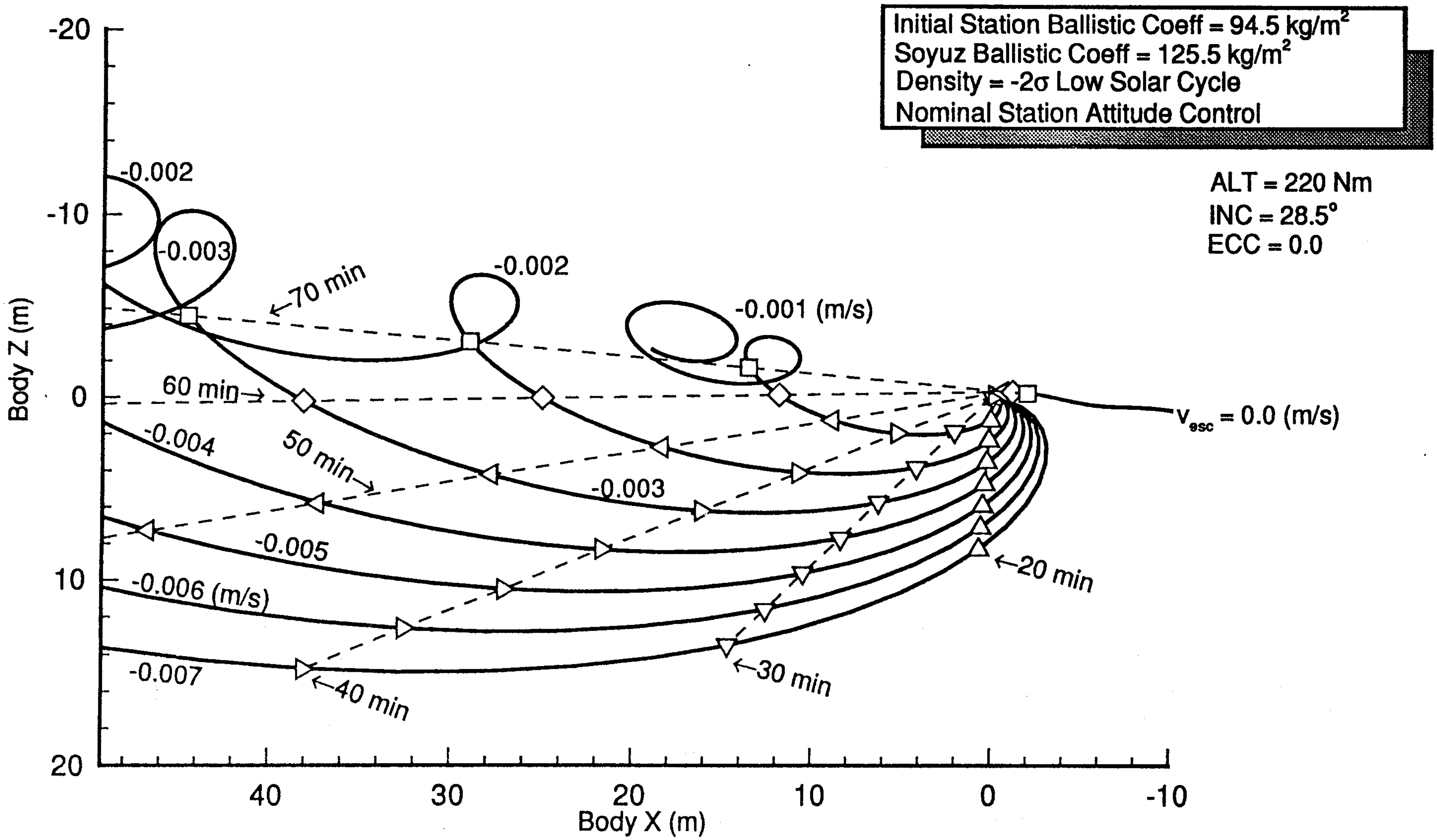
Soyuz –V Escape Trajectory Paths

Low Atmospheric Density

This chart shows a parametric study of the escape velocity (assumed to be achieved by an initial impulse that accelerates the Soyuz up to a constant velocity). The graph is in body coordinates of the Space Station Freedom. A –2–sigma atmosphere was assumed, along with a maximum SSF ballistic coefficient and a minimum Soyuz ballistic coefficient. A velocity of at least 0.002 m/sec was required for a clear escape trajectory path. This is well below the 0.20 m/sec maximum escape velocity currently achievable by the Soyuz.

SOYUZ -V ESCAPE TRAJECTORY PATHS

Low Atmospheric Density



ΔV ≥ 0.002 m/sec required for clear escape trajectory path

Soyuz ΔV Required for Clear Escape Trajectories

The results from the previous graphs are summarized in this table. For all cases studied with nominal station attitude control, the required velocities were all well below the capabilities of the Soyuz TM. When an uncontrolled station with a high pitch rate was assumed, problems arose with the required escape velocities, but these were somewhat alleviated by the use of a canted docking adapter.

SOYUZ ΔV Required for Clear Escape Trajectories

	High Atmospheric Density (Design atmosphere) 220 Nm Init Station BC = 47.5 kg/m^2 *SOYUZ* BC = 203.1 kg/m^2 (feathered)			Low Atmospheric Density (–2σ min solar cycle) Init Station BC = 94.5 kg/m^2 *SOYUZ* BC = 125.5 kg/m^2 ("full" arrays)
	Nominal Station Attitude Control	0.65 deg/sec Station pitch rate	0.65 deg/sec Station pitch rate 20 deg Cant	Nominal Station Attitude Control
–Z (Zenith)	0.003	0.7	0.3	0.006
+Z (Nadir)	0.008	0.15	0.12	0.006
–X (minus vbar)	0.008	4.0	0.6	0.002

Units are met/sec

Soyuz Escape Path

Conclusions

The best location for the Soyuz ACRV in terms of a clear departure path is the +Z body, or nadir, of the space station. The biggest driver in determining the necessary escape velocity is the attitude rate of the station, in this case the contingency pitch rate. The differences in atmospheric density assumptions and in relative ballistic coefficient assumptions had only minor effects on the resulting required escape velocity, especially when compared to the effect of the contingency pitch rate.

SOYUZ Escape Path
CONCLUSIONS

- Biggest driver is contingency pitch rate of 0.65 deg/sec
  - essentially eliminates –X escape departure (Option 6)
- Atmospheric density and relative ballistic coefficient not a factor (< 1 cm/sec impact)
- **Best location for clear path departure is Nadir (+Z body)**
  - 15 cm/sec required for contingency pitch rate
  - < 1 cm/sec required for nominal station attitude
- Canted docking mechanisms reduce zenith and minus v departures (not very beneficial to nadir)

SSF/Soyuz Automated Rendezvous and Docking General Issues

- No specific assumption was made during the study as to the method of Soyuz delivery. The Soyuz could be ELV delivered or STS delivered. With ELV delivery, AR & D capability required. This will be the addition of the KURS radar system on SSF as well as qualification of docking location and loads. Furthermore, the AR & D corridor will need to be determined. Autodocking is feasible for nadir or forward ports. For forward port use, a man-in-the-loop will be required to operate the SSRMS to place the Soyuz in final destination. Autodocking not feasible for zenith ports. Cryo tanks, Airlock, PIT, etc. create too many obstructions. For STS delivery, the Soyuz must be STS flight approved. This mode will also require a man-in-the-loop to operate SSRMS.

Automated Rendezvous and Docking General Issues

- ELV delivery
  - AR &D capability required
    - Requires inclusion of KURs radar system(s) on SSF
    - Requires qualification of docking location for docking loads
  - AR & D corridor required
    - Autodocking feasible for nadir ports
    - Autodocking feasible for forward ports - requires man in the loop to operate SSRMS to place on final destination port
    - Autodocking not feasible for zenith ports - cryo tanks, airlock, PIT, etc. create too many obstructions
- STS delivery
  - Soyuz must be STS flight approved
  - Requires man in loop to operate SSRMS to place on final destination port

- This Page Intentionally Left Blank -

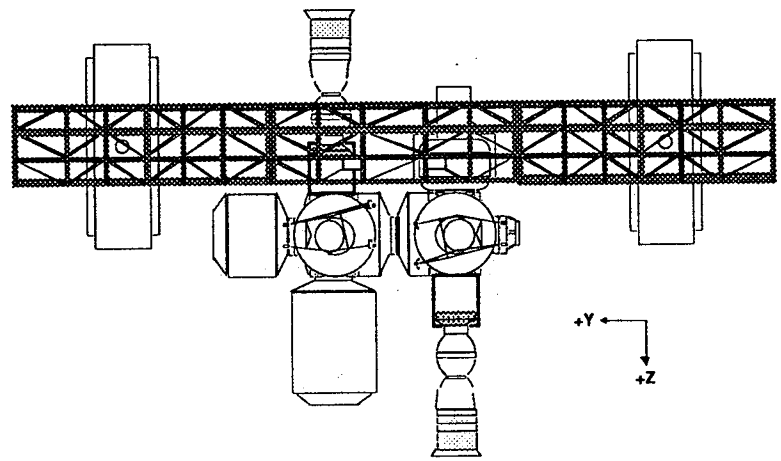
Comparison and Summary

Option 1 - Pro's and Con's

- The following figure lists the pros's and con's for option 1

Option 1 - Pro's and Con's

Soyuz on Node 1 Zenith and Node 2 Nadir



PROs

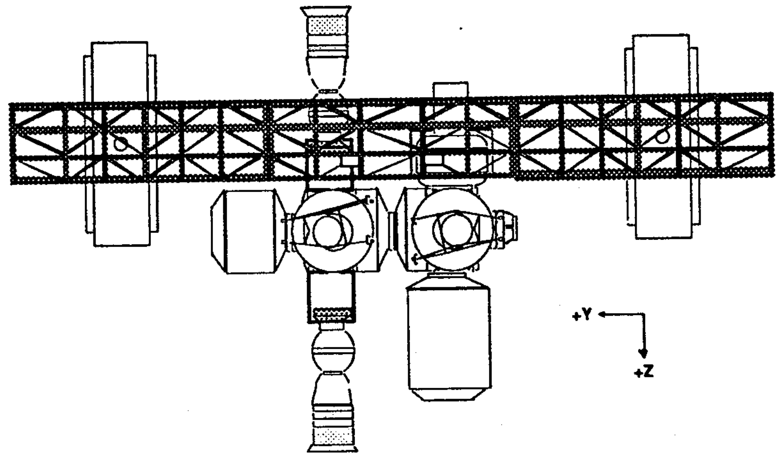
- Fewest System Impacts
- Simultaneous Departure
- AR & D for 1 vehicle

CONs

- Impacts Node 2 (part of MTC phase)
- No secondary PLM berthing port
- Non-identical departure path

Option 2 - Pros's and Con's

Soyuz on Node 1 Nadir and Zenith



PROs

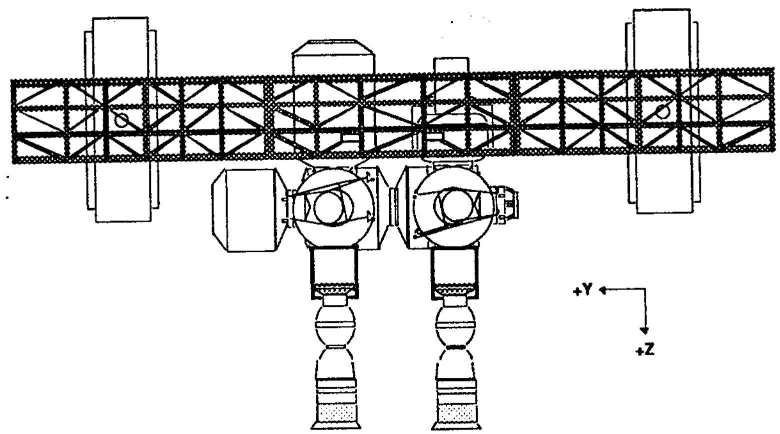
- Fewest System Impacts
- Simultaneous Departure
- AR & D for 1 vehicle
- Impacts Node 1 (post-MTC phase)

CONs

- No secondary PLM berthing port
- Non-identical departure path

Option 3 - Pro's and Con's

Soyuz on Node 2 and Node 1 Nadir



PROs

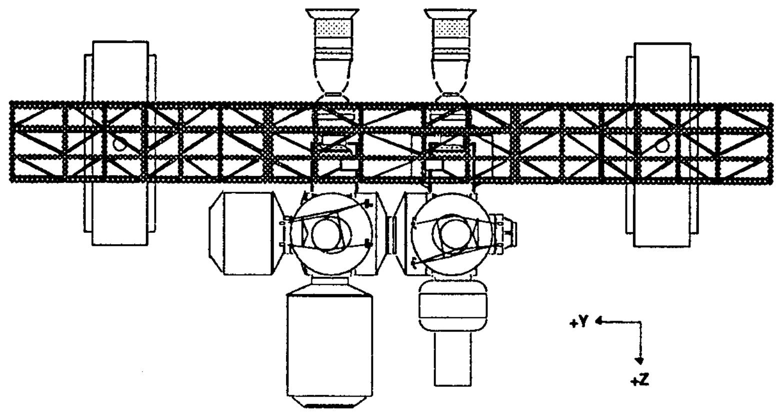
- Identical Departure Path
- AR & D for both vehicles
- Optimal escape trajectory

CONs

- No secondary PLM berthing port
- Non-simultaneous departure
- Added system impacts to TCS,C/T, DMS, A/V, and ECLSS
- PLM relocated
- Impacts Node 2 (part of MTC phase)

Option 4 - Pro's and Con's

Soyuz on Node 2 and Node 1 Zenith



PROs

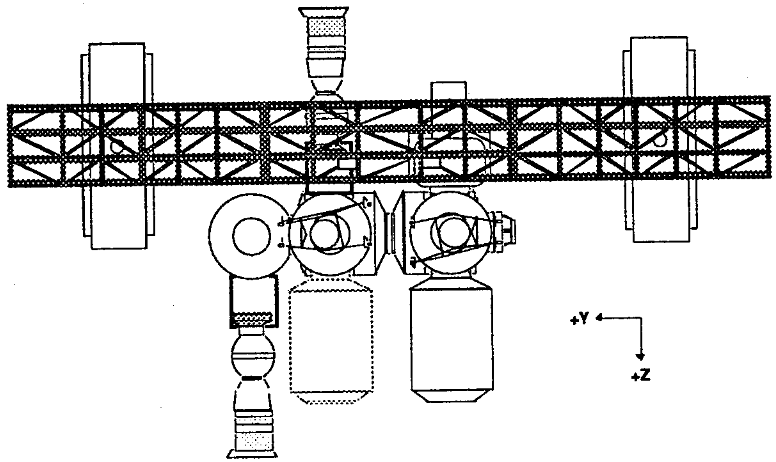
- Identical Departure Path

CONs

- No secondary PLM berthing port
- Non-simultaneous departure
- Added system impacts to C/T, DMS, A/V, and ECLSS
- Airlock relocated, EVA from A/L to PIT distance
- AR & D for neither vehicle
- Impacts Node 2 (part of MTC phase)

Option 5 - Pro's and Con's

Soyuz on Node 1 Zenith and Third Node Nadir



PROs

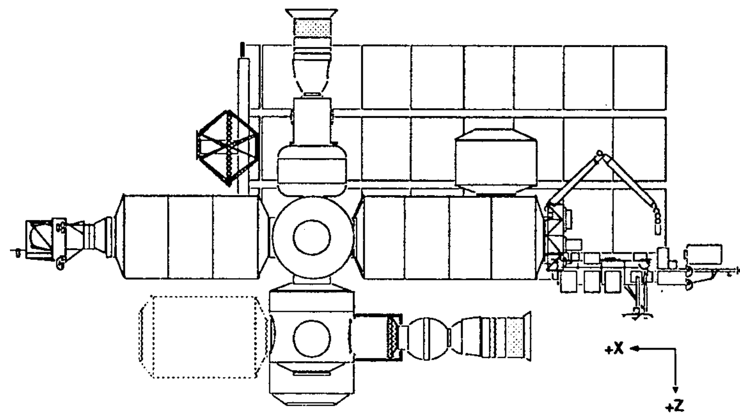
- Simultaneous Departure
- AR & D for 1 vehicle
- Impacts Node 1 (post - MTC phase)
- Maintain PLM secondary berthing port

CONs

- Non-identical Departure Path
- Added system impacts to TCS,C/T, DMS, A/V, and ECLSS
- Requires Third Node (delays 4-man PMC)
- Soyuz - to PLM clearance

Option 6 - Pro's and Con's

Third Node on Node 2 Nadir -
Soyuz on -X of Third Node and Node 1 Zenith



PROs

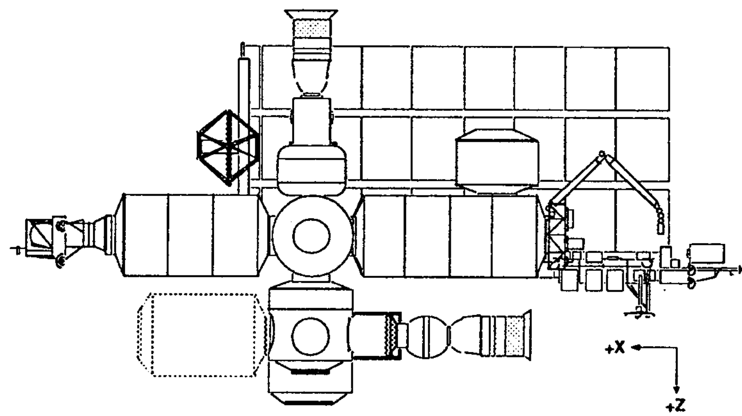
(Not Applicable)

CONs

- Eliminated Due to Unexceptable Departure Path

Option 6 - Pro's and Con's

Third Node on Node 2 Nadir -
Soyuz on -X of Third Node and Node 1 Zenith

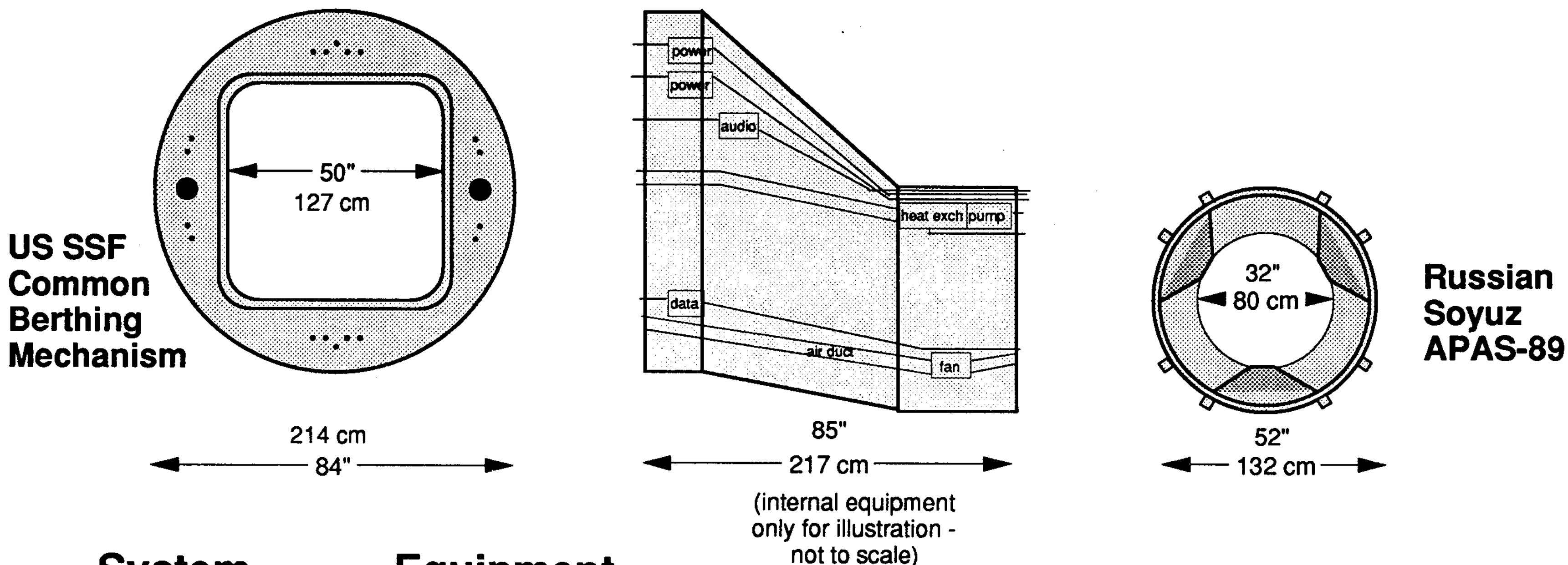


Ports: Utilize ports reserved for ACRV and (Centrifuge Operations)

Pros:

Cons: Eliminated due to unexceptable departure path escape trajectory

Example SSF/Soyuz Docking Adaptor
(Derived from SSF Level II Pressurized Mating Adaptor (PMA) Solid Model)



System	Equipment
Power	**Two 120V-to-28V power converters** (similar to NPCU)
Thermal	**Fluid/fluid heat exchanger and pump**
ECLSS	**Fans and ducting for cabin air flow**
Audio	**Converter for connection to internal wireless audio**
Data	**Data converter for SSF core 1553B to Soyuz GOST bus**
Video	**(Option) Video signal converter**

Summary

- From the systems impact and operation analysis, the prefered option is Option 2 with the Soyuz on zenith node 1 and nadir node 1. This option had the fewest systems impacts and least modification to SSF schedule since it did not impact Node 2, the first pressurized element to be lauched to orbit.

Soyuz/ACRV Accommodation Study

Summary

- Option 2 (zenith node 1, nadir node 1) is the most viable option studied
  - Least impacts to current SSF PMC
  - Least impacts to current schedule
    - Avoids/minimizes modification to Node 2 (first pressurized element delivered)
- Operational issues not a discriminator between the options
  - Clearance, escape paths, placement of elements provided no obvious best option

Acknowledgement

• The authors would like to acknowledge the guidance of Buddy DeRyder, Richard Russell, and Karen Brender and the efforts of Pat Cosgrove, Fred Stillwagon, Washito Sasamoto, Michael Heck, and Martin Henry.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 1993

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Soyuz/ACRV Accommodation Study

5. FUNDING NUMBERS
476-14-06

6. AUTHOR(S)
Jonathan Cruz, Marston J. Gould, and Eric Dahlstrom

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-0001

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-107733

11. SUPPLEMENTARY NOTES
Jonathan Cruz and Marston J. Gould: Langley Research Center, Hampton, VA
Eric Dahlstrom: Lockheed Engineering & Sciences Company, Hampton, VA

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited

Subject Category 18

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A study was conducted at the LaRC Space Station Freedom Office at the request of the Space Station Freedom Level 1 Program Office and the JSC ACRV Project Office to determine the implications of accommodating two Soyuz TM spacecraft as Assured Crew Return Vehicles (ACRV) on the Space Station Freedom (SSF) at the Permanently Crewed Capability (PCC) stage. The study examined operational as well as system issues associated with the accommodation of the Soyuz for several potential configuration options. Operational issues considered include physical hardware clearances, worst case Soyuz departure paths, and impacts to baseline operations such as Pressurized Logistics Module (PLM) exchange, Space Station Remote Manipulator System (SSRMS) attachment, Extravehicular Activity (EVA), and automatic rendezvous and docking (AR&D). Systems impact analysis included determining differences between Soyuz interface requirements and SSF capabilities for the Electrical Power System (EPS), Thermal Control System (TCS), Co9mmunications and Tracking (C&T), Audio-Video Subsystem (A/V), Data Management System (DMS), and Environmental Control and Life Support System (ECLSS). Significant findings of this study have indicated that the current ΔV capability of the Soyuz will need to be increased to provide adequate departure clearances for a worst case escape from an uncontrolled SSF and that an interface element will be required to mate the Soyuz vehicles to station, provide for AR&D structural loads, and to house Soyuz-to-SSF system interfaces.

14. SUBJECT TERMS
Soyuz
ACRV (Assured Crew return)
Space Station
Departure Path
Interfaces

15. NUMBER OF PAGES
151

16. PRICE CODE
A08

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		