

# International Space Station Temperature and Humidity Control Subsystem Verification for Node 1

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## ABSTRACT

The International Space Station (ISS) Node 1 Environmental Control and Life Support (ECLS) System is comprised of five subsystems: Atmosphere Control and Supply (ACS), Atmosphere Revitalization (AR), Fire Detection and Suppression (FDS), Temperature and Humidity Control (THC), and Water Recovery and Management (WRM). This paper provides a summary of the nominal operation of the Node 1 THC subsystem design. The paper will also provide a discussion of the detailed Element Verification methodologies for nominal operation of the Node 1 THC subsystem operations utilized during the Qualification phase.

## INTRODUCTION

Node 1 flew to ISS on Flight 2A. It was the first module of the United States On-Orbit Segment (USOS) that was launched to ISS. The Node 1 ISS ECLS design featured limited ECLS capability. The main purpose of Node 1 was to provide internal storage by providing four stowage rack locations within the module and to allow docking of multiple modules and a truss segment to it.

Of the five Node 1 ECLS subsystems this paper will only address the nominal operation of the THC subsystem. The nominal operation of the Node 1 THC subsystem capability can be subdivided into their sub-allocated functions. The Node 1 THC consists of: 1) intramodule ventilation, 2) particulate and microbe removal and disposal, and 3) intermodule ventilation (IMV) with adjacent elements including cooling of Node 1, the Cupola, and/or the Mini-Pressurized Logistic Module (MPLM) [the name for the MPLM was changed from Mini-Pressurized Logistic Module to Multi-Purpose Logistic Module later in the Program] with cold IMV air from the United States (U.S.) Laboratory Module.

The Verification of the ISS hardware is accomplished using a building block process. Verification starts at the Component Level and progresses until the Element Level Verification is complete. The primary objective of the Qualification Verification program is to ensure that the subsystems meet the section three requirements in the Prime Item Development Specifications (PIDS). The PIDS dictates whether a section three requirement is

verified by test, analysis, inspection, and/or demonstration, as documented in section four of the PIDS.

Node 1 is a Protoflight Test Article since no Element Qualification Test Article exists. Therefore, no additional ground testing or evaluations can be performed on Node 1 after it has been installed into the Space Shuttle Payload Bay and launched to ISS. Node 1 is shown in Figure 1 during processing at Kennedy Space Center (KSC) and in flight during the Flight 2A series of Flights (i.e., Flights 2A, 2A.1, 2A.2a, and 2A.2b).

## SUBSYSTEM OVERVIEWS

A general overview of the nominal operation of the Node 1 THC subsystem is provided below.

### THC:

The Node 1 THC hardware, as shown in Figure 2, consists of an Inlet Orbital Replacement Unit (ORU); four cabin air bacteria filter/housing assemblies; a plenum that holds the four bacteria filter/housing assemblies, two linear diffusers; four cabin air diffusers; nine IMV isolation valves; three IMV fans each with a set of mufflers; one Node 1 air temperature control rheostat; two variable air volume damper assemblies (VAVDAs); three IMV inlet screens; four manual THC isolation valves, flexible air ducting, and hard air ducting made from a composite material.

The Node 1 intramodule ventilation is predominately provided by the Inlet ORU blowing air out of the radial port area linear diffusers and the starboard rack bay area diffusers. It is also supplemented by the aft IMV fan blowing air out of the port rack bay area diffusers when the Russian Segment (RS) IMV air is not being transported to the U.S. Laboratory Module, and by the starboard IMV fan blowing air out of the radial port area linear diffusers after delivery of the Joint Airlock to ISS and when no extravehicular activities (EVA's) are being performed out of the Joint Airlock.

The particulate and microbial control in Node 1 is provided by the four Node 1 bacteria filters that are



**Node 1 Inlet ORU, Cabin Diffuser, and the Node 1 VAVDA**



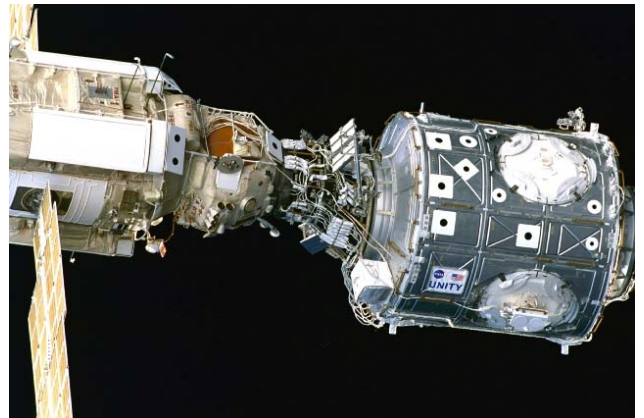
**Node 1 IMV Fan and Mufflers**



**Node 1 Linear Diffusers**

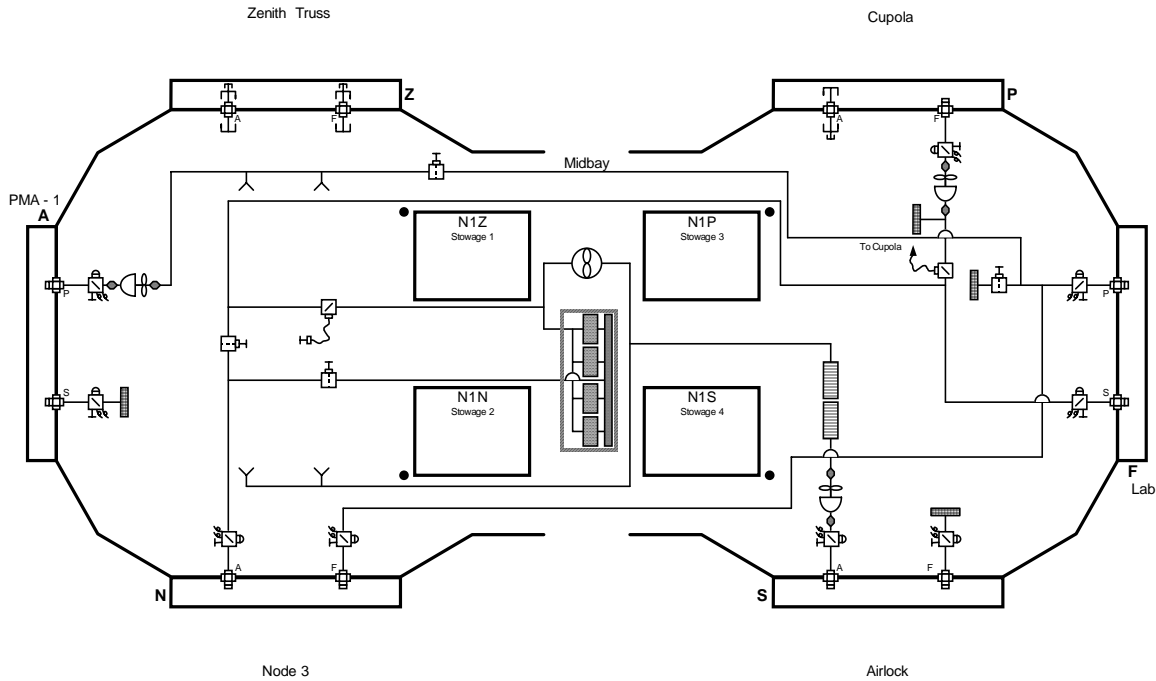


**Node 1 and PMA 1 at KSC**



**Node 1 attached to the early RS during Flight 2A**

**Figure 1 – Node 1 during processing at KSC and In Flight during the Flight 2A Series of Flights**



**Figure 2 – Node 1 Temperature and Humidity Control Schematic**

installed in the four bacteria filter housings which are contained in the Node 1 plenum. The bacteria filter was designed to remove 99.9% of all particulates 0.3 microns and larger. The airflow through the four bacteria filters is provided by the Inlet ORU. The four bacteria filters are prefiltered from large airborne debris by the return air grill at the top of the plenum and from smaller sized airborne debris by the screen on top of the bacteria filter housing. The crew cleans these two areas once a week as part of their nominal house cleaning task.

The purpose of the Node 1 IMV is to provide air exchange between Node 1 and the adjacent elements. It allows for centralized atmosphere revitalization and oxygen partial pressure control. The IMV in Node 1 is flexible to support the assembly operation by opening or closing the manual THC isolation valves and by enabling or disabling the IMV flow from an attached element by opening or closing the IMV valves at the Node 1 interfaces. The Node 1 IMV design has two configurations to minimize the partial pressure of carbon dioxide (ppCO<sub>2</sub>) in the U.S. Laboratory Module. One is to direct the RS IMV air from the Node 1 aft port IMV interface to the Node 1 forward port IMV interface. The other is to direct Node 3 IMV air from the Node 1 nadir forward interface to the Node 1 forward port interface. The IMV also has a secondary function of providing temperature and humidity control in Node 1; the MPLM when docked to Node 1 during assembly; and the Cupola (if it is attached to Node 1) by transferring cold air from the U.S. Laboratory Module Common Cabin Air Assembly (CCAA) to those elements. Temperature control in those elements is controlled by opening up or closing down the two VAVDA's in Node 1. This is accomplished by adjusting the appropriate rheostat in Node 1 or the Cupola. The rheostats are designed to

transmit a signal to the Node 1 Multiplexer/Demultiplexer (MDM) based on their position. The software in the MDM then interprets the rheostat position into a VAVDA position and then transmits a valve position command to the appropriate VAVDA, as required.

## ELEMENT LEVEL VERIFICATION PROGRAM

### NODE 1 THC QUALIFICATION METHODOLOGY:

#### Circulate Intramodule:

Requirement	Verification
<p>Node 1 shall provide an effective atmosphere velocity in its cabin aisleway in the range of 15 to 40 feet per minute in response to the input voltage at the PMA-1 interface as specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p> <p>During periods when intermodule atmosphere exchange with the Airlock is nonfunctional, effective velocity shall be 10-40 feet per minute.</p>	<p>The Node 1 capability to maintain an effective cabin aisleway circulation velocities in the range of 15-40 feet per minute (10-40 feet per minute during periods when intermodule atmosphere exchange with the Airlock is non functional) shall be verified by analysis. An analysis shall be performed considering the Node 1 internal geometric configuration with proper locations of diffusers and registers, and the effect of the intermodule ventilation velocities. The verification shall be considered successful when the analysis proves that the specified velocity ranges are met.</p>

The requirement references two ISS Interface Control Documents (ICDs). The relevant requirement from one of those documents is listed below. The data from SSP 50144-03 is not relevant to close this requirement.

SSP 42122	From/To PMA-1
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Interface Parameters	and Node 1
Node 1 ECLS Signals	<p>The Node 1 shall provide to and receive from PMA-1 instrumentation signals for the monitoring and control of the following ECLSS equipment by the N1-1 MDM: Atmosphere Revitalization valves, Smoke Detector, Node 1 Air Mixing Valve, Cabin Fan, Node 1 Aft IMV Fan, Node 1 Aft IMV Return and Supply Valves, Node 1 Starboard Return and Supply valves, Node 1 Port Supply valve, Node 1 Rheostat. The interface between the Node 1 ECLSS equipment and the N1-1 MDM shall be in compliance with SSP 30261:002.</p> <p>The Node 1 shall provide and receive from PMA-1 instrumentation signals for the monitoring and control of the following ECLSS equipment by the N1-2 MDM: Cabin Pressure sensor, Smoke Detector, Cupola Air Mixing Valve, Node 1 Port and Starboard IMV Fans, Node 1 Nadir IMV Return and Supply valves, Node 1 Forward Return and Supply valves, Cupola Rheostat. The interface between the Node 1 ECLSS equipment and the N1-2 MDM shall be in compliance with SSP 30261:002.</p>

Boeing – Huntington Beach analyzed the air circulation velocities for the two different areas in Node 1, i.e. the rack bay area including the aft hatch area and the radial port area that includes the four radial hatch areas and the forward hatch area, using equations from the Carrier Air Conditioning manual and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) handbook to show compliance for this requirement assuming a clean crew cabin closeout.

For the rack bay area they analyzed three different possible configurations. The three different configurations included: 1) the Inlet ORU providing 5.10 cubic meter/min [180 cubic feet per minute (cfm)] to the two starboard aft diffusers and the Node 1 aft port IMV fan providing 3.96 cubic meter/min [140 cfm] to the port aft diffusers; 2) the Inlet ORU providing 5.10 cubic meter/min [180 cfm] to the two starboard aft diffusers and the Node 1 aft port IMV fan providing 0 cubic meter/min [0 cfm] to the port aft diffusers; and 3) the Inlet ORU providing 0 cubic meter/min [0 cfm] to the two starboard aft diffusers and the Node 1 aft port IMV fan providing 3.96 cubic meter/min [140 cfm] to the port aft diffusers.

For the radial port area they analyzed two possible different configurations. The two configurations included 1) the Inlet ORU providing 3.40 cubic meter/min [120 cfm] to the linear diffusers and 2) the Node 1 starboard aft IMV fan providing 0 or 3.96 cubic meter/min [0 or 140 cfm] to the linear diffusers.

**Results:**

Based on the analysis the rack bay area has an average air velocity of 6.67 meter/min [21.88 feet per

minute (fpm)] with only the Inlet ORU providing air flow to that region; 11.86 meter/min [38.90 fpm] with the Inlet ORU and aft port IMV fan providing air flow to that region; and 5.19 meter/min [17.02 fpm] if only the aft port IMV fan was providing air flow to that region. Boeing – Huntington Beach also did a review of the impact of the Node 1 aft port IMV fan provided its integrated specified minimum flow rate of 3.82 cubic meter/min [135 cfm] instead of 3.96 cubic meter/min [140 cfm]. The result of this review showed that the air velocity would drop from 11.86 meter/min [38.90 fpm] to 11.58 meter/min [38 fpm] when the Inlet ORU and aft port IMV fan are providing air flow to that region.

For the radial port area the average air flow is 8.19 meter/min [26.86 fpm] with the Inlet ORU and the starboard aft IMV fan providing air flow to the radial port area and 3.78 meter/min [12.40 fpm] when only the Inlet ORU is providing air flow to the radial port area.

The analysis results are reasonable when compared to the results from a Space Station Freedom (SSF) cabin ventilation development test with similar cabin geometry, diffuser placement, and air flow rates from the diffusers. Also, the qualification data from the Inlet ORU showed that 8.49 cubic meter/min (300 cfm) is feasible with the variable speed fan that is contained in the Inlet ORU.

To show compliance with the input voltage interface requirement Boeing – Huntington Beach summarized the power and data connection data for the Inlet ORU and the starboard aft IMV fan based on the Node 1 electrical and data drawings.

Based on these results, Node 1 met the air circulation requirements.

Remove Particulates:

Requirement	Verification
Node 1 shall limit the daily average atmosphere particulate level of the Node 1 to less than 0.05 mg per cubic meter (100,000 particles per cubic foot) with peak concentrations less than 1.0 milligrams per cubic meter (2 million particulates per cubic foot) for particles ranging from 0.5 microns to 100 microns, based on a particle generation rate of 1.4 million particles per minute. Whenever Node 1 is required to remove gaseous contaminants from the atmosphere, it is not required to simultaneously remove airborne particulate contaminants.	<p>The Node 1 capability to remove atmosphere airborne particulate contaminants shall be verified by analysis. An analysis shall be done to verify that the Node 1 circulation design is capable of removing atmosphere particulates in the range of 0.5-100 microns and it is able to maintain a daily average of 100,000 particles per cubic foot with peak concentrations less than 1.0 milligrams per cubic meter (2 million particulates per cubic foot) based upon generation rate of 1.4 million particles per minute.</p> <p>The verification shall be considered successful when the analysis results verify that the number of filters installed in the Node 1 can meet the particulate requirement as specified.</p>

Boeing – Huntington Beach analyzed the particulate removal rate based on the Inlet ORU provided 8.49 cubic

meter/min [300 cfm] of air flow through the four bacteria filters, a specified bacteria filter removal efficiency of 99.9%, five IMV interfaces at Assembly Complete (AC) that met their particulate requirements, a Node 1 cabin volume of 51.4 cubic meter [1814.4 cubic feet], and a particulate generation rate as specified.

Results:

Based on the analysis Node 1 would reach a steady state level of 2,022 particles/cubic meter [71,421 particles/cubic foot] if all of the adjacent elements were at their maximum daily average particulate level and Node 1 would reach a steady state of 39,689 particles/cubic meter [1,401,821 particles/cubic foot] if all of the adjacent elements were at their peak particulate level.

Based on these results Node 1 met its particulate removal requirement. Even if the Inlet ORU flow through the bacteria filter was reduced due to the maximum cold IMV flow from the U.S. Laboratory it still would meet its requirements.

Remove Microbes:

Requirement	Verification
Node 1 shall limit the daily average airborne microbes in the Node 1 atmosphere to no less than 1000 colony forming units per cubic meter. Whenever Node 1 is required to remove gaseous contaminants from the atmosphere, it is not required to simultaneously remove airborne microbes.	The Node 1 capability to remove airborne microbes from cabin atmosphere shall be verified by the analysis performed in 4.3.2.1.39.

Boeing – Huntington Beach analyzed the microbe removal rate based on the Inlet ORU provided 8.49 cubic meter/min [300 cfm] of air flow through the four bacteria filters, a microbe removal efficiency of 99.9% based on discussion with the filter element supplier, five IMV interfaces at AC that met their microbe requirements, a Node 1 cabin volume of 51.4 cubic meter [1814.4 cubic feet], and a microbe generation rate of 1643 colony forming units (CFU) per crew member based on data from the bacteria filter manufacture.

Results:

Based on the analysis Node 1 would reach a steady state level of 758 CFU/cubic meter [26,772 CFU/cubic feet] for one crew member in Node 1, 816 CFU/cubic meter [28,821 CFU/cubic feet] for two crew members in Node 1, 874 CFU/cubic meter [30,870 CFU/cubic feet]

for three crew members in Node 1, 932 CFU/cubic meter [32,981 CFU/cubic feet] for four crew members in Node 1, and 990 CFU/cubic meter [34,967 CFU/cubic feet] for five crew members in Node 1 if all of the adjacent

elements met their microbe requirements. It is assumed that post delivery of the U.S. Laboratory Module that no more than two crew members will be in Node 1 for any length of time so even if the Inlet ORU flow through the bacteria filter was reduced due to the maximum cold IMV flow from the U.S. Laboratory it still would meet its requirements.

Based on these results, Node 1 met its microbe removal requirement.

Dispose of Particulates:

Requirement	Verification
Particulate contaminant removal as specified in 3.2.1.39 shall incorporate replaceable filters with replacement intervals greater than or equal to 90 days.	The Node 1 capability to dispose of the removed particulate contaminants shall be verified by analysis. An analysis of the Node 1 drawings shall be performed to evaluate filters installations for compliance with SSP 50005 for crew interface requirements for ease of replacement. The analysis shall verify the operability of hinges, knobs, and brackets as appropriate for crew to remove and replace the filters. The analysis of 4.3.2.1.39 shall be executed through the end of the 90 day interval and evacuated for mass accumulation in the filter. The verification shall be considered successful when analysis of drawings shows that replaceable filters are in full compliance with SSP 50005, section 13.2.3.1 requirements for removal and disposal by crew, and the analysis shows that at the end of the 90 day period, daily average particle densities remain below 100,000 particles per cubic foot, and instantaneous densities below 2 million particles per cubic foot for particles ranging from 0.5 to 100 microns.

Dispose of Microbes:

Requirement	Verification
Airborne microbe removal as specified in 3.2.1.41 shall incorporate replaceable filters with replacement intervals greater than or equal to 90 days.	The Node 1 capability to dispose of airborne microbes from cabin atmosphere shall be verified by the analysis performed in 4.3.2.1.40.

Boeing – Huntington Beach analyzed the life of the filters to make sure that they could last at least 90 days based on the specified filter end of life requirement of filtering 32 grams of airborne debris without dropping the filter delta pressure from  $\leq 8.4$  mm-H<sub>2</sub>O (0.33 in-H<sub>2</sub>O) to  $\leq 0.5$  in-H<sub>2</sub>O (12.7 mm-H<sub>2</sub>O). The analysis used the average particulate level in Node 1 of 0.05 mg/cubic meter (100,000 particles/cubic feet) to calculate an average density of particles, the filter qualification data removal efficiency of 99.97%, the inlet ORU providing

8.49 cubic meter/min (300 cfm) through the filters, the results from the steady state particulate level of 2,022 particles/cubic meter [71,421 particles/cubic foot] in Node 1 if all of the adjacent elements were at their

maximum daily average particulate level, and the fact that there are four filters in Node 1. They also analyzed what would happen to the filter life if all of the adjacent elements were at their peak particulate levels and the Node 1 steady state level was at 39,689 particles/cubic meter [1,401,821 particles/cubic foot].

The access and removal of the filter per SSP 50005 will not be addressed in this paper. It was addressed during the requirement closure process for Node 1 as part of the Flight Crew System and Integration (FCS&I) requirements and not by the ECLS team.

**Results:**

Based on the analysis the filters will last 293 days if the adjacent elements were at their maximum daily average particulate levels and 14.9 days if the adjacent elements were at their peak particulate levels to collect 32 grams of material. It is assumed that the peak level in the adjacent elements is only a short term transient condition so the filters should easily last  $\geq 90$  days.

This analysis is conservative since the filter qualification showed that it would take 250 grams of material to have a delta pressure of 12.2 mm-H<sub>2</sub>O (0.48 in-H<sub>2</sub>O) versus the specified value of 32 grams of material with a pressure loss of  $\leq 12.7$  mm-H<sub>2</sub>O (0.5 in-H<sub>2</sub>O). Therefore the ECLS part of the disposal requirements was met.

**Circulate Intermodule:**

42122, paragraph 3.2.1.5.4.1, Node 1 shall receive intermodule atmosphere from the Airlock, at flow rates as	the valves, fans, etc, necessary for the activation of the flows to and from the USL interface junctions can be activated by the defined combinations of the interface signals
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Requirement (cont'd)	Verification (cont'd)
<p>specified in SSP 41145, paragraph 3.2.1.3.5.</p> <p>Note: Intermodule atmosphere flow to the Airlock will be through the open hatch.</p> <p>When directed from the PMA-1 MDM control signals as specified by SSP 50144-03, and SSP 42122, paragraph 3.2.1.5.4.1, Node 1 shall provide intermodule atmosphere to the Cupola at flow rates as specified in SSP 41142, paragraph 3.2.1.2.3.1.5.</p> <p>Note: Return atmosphere from the Cupola will be through the open hatch.</p> <p>When directed from the PMA-1 MDM control signals as specified by SSP 50144-03, and SSP 42122, paragraph 3.2.1.5.4.1, Node 1 shall receive intermodule atmosphere from the PMA-1 at flow rates as specified in SSP 42122, paragraph 3.2.1.3.1.1.3.</p>	<p>specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p> <p>The circulate atmosphere intermodule Node 1/Node 3 requirement shall be verified by analysis. Analysis of the Node 1 ducts, valves, fans, etc. involved in the performance of the Node 1/Node 3 intermodule atmosphere exchange shall be performed to determine the dynamic flow capability between the internal ambient atmosphere and the Node 3 interface junctions. Analysis of the interface signals specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1 and their connections to the Node 1 devices shall be performed to determine the combinations of interface signals that cause activation of those devices providing for circulation of Node 1 ambient atmosphere to the Node 3 interface junction, and the combinations that provide for circulation of ambient atmosphere from the Node 3 interface junction to the Node 1 internal atmosphere. Verification shall be considered successful when (1) analysis shows that the Node 1 ducts, valves, fans, etc. that are in-line to the flow of ambient atmosphere to and from the Node 3 interface junctions can provide the flow rates specified in SSP 41140, paragraph 3.2.1.2.6.1.4 and 3.2.1.2.5.1.4; and (2) the valves, fans, etc, necessary for the activation of the flows to and from the Node 3 interface junctions can be activated by the defined combinations of the interface signals specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p>
<p>When directed from the PMA-1 MDM control signals as specified by SSP 50144-03, and SSP 42122, paragraph 3.2.1.5.4.1, Node 1 shall exchange intermodule atmosphere with the USL at the flow rates specified in SSP 41141, paragraphs 3.2.1.2.6.1.4 and 3.2.1.2.5.1.4.</p> <p>When directed from the PMA-1 MDM control signals as specified by SSP 50144-03, and SSP 42122, paragraph 3.2.1.5.4.1, Node 1 shall exchange intermodule atmosphere with the Node 3 at flow rates specified in SSP 41140, paragraphs 3.2.1.2.6.1.4 and 3.2.1.2.5.1.4.</p> <p>When directed from the PMA-1 MDM control signals as specified by SSP 50144-03, and SSP</p>	<p>The circulate atmosphere intermodule Node 1/Airlock requirement shall be verified by analysis. Analysis of the Node 1 ducts, valves, fans, etc. involved in drawing atmosphere from the Airlock interface to the Node 1 ambient atmosphere shall be performed to determine the dynamic flow capability between the internal ambient atmosphere and the Airlock interface junction. Analysis of the interface signals specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1 and their connections to the Node 1 devices shall be performed to determine the combinations of interface signals that cause activation of those devices providing for circulation of Node 1 ambient atmosphere to the Airlock interface junction. Verification shall be considered successful when (1) analysis shows that the Node 1 ducts, valves, fans, etc. that are in-line to the flow of ambient atmosphere from the Airlock interface junction can provide the flow rates specified in SSP 41145, paragraph 3.2.1.2.6.1.3; and (2) the valves, fans,</p>
<p>When directed from the PMA-1 MDM control signals as specified by SSP 50144-03, and SSP</p>	<p>The Node 1 shall accommodate the transfer of a minimum of 140 cubic feet per minute of parasitic air from the USL to the MPLM without dropping the pressure more than 1.04 inches of water, including the jumper duct in the MPLM vestibule, excluding the jumper duct in the USL vestibule.</p>
<p>When directed from the</p>	<p>When directed from the</p>

PMA-1 MDM control signals as specified by SSP 50144-03, and SSP 42122, paragraph	etc, necessary for the activation of the flows from the Airlock interface junction can be activated by the defined combinations of the interface signals
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	The circulate atmosphere intermodule Node 1/MPLM requirement shall be
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Requirement (cont'd)	Verification (cont'd)
<p>3.2.1.5.4.1, Node 1 shall receive Intermodule atmosphere from the PMA-3 at flow rates as specified in SSP 42097, paragraph D3.2.1.3.1.1.3 and D3.2.1.3.2.1.3.</p> <p>Note: Intermodule atmosphere flow to the PMA-3 will be through the open hatch.</p> <p>Node 1 shall provide for manual adjustment of intermodule atmosphere flow rate from the USL by resident crewmembers, and conversion of the adjustment selection to a proportional voltage applied to the PMA-1 interface as specified by SSP 42122, paragraph 3.2.1.5.4.1, for the purpose of temperature control of the Node 1 atmosphere.</p>	<p>specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p> <p>The circulate atmosphere intermodule Node 1/Cupola requirement shall be verified by analysis. Analysis of the Node 1 ducts, valves, fans, etc. involved in providing Nod 1 ambient atmosphere to the Cupola interface shall be performed to determine the dynamic flow capability between the internal ambient atmosphere and the Cupola interface junction. Analysis of the interface signals specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1 and their connections to the Node 1 devices shall be performed to determine the combinations of interface signals that cause activation of those devices providing for circulation of Node 1 ambient atmosphere to the Cupola interface junction. Verification shall be considered successful when (1) analysis shows that the Node 1 ducts, valves, fans, etc. that are in-line to the flow of ambient atmosphere to the Cupola interface junction can provide the flow rates specified in SSP 41142, paragraph 3.2.1.2.3.1.5; and (2) the valves, fans, etc, necessary for the activation of the flows to the Cupola interface junction can be activated by the defined combinations of the interface signals specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p> <p>The circulate atmosphere intermodule Node 1/PMA-1 requirement shall be verified by analysis. Analysis of the Node 1 ducts, valves, fans, etc. involved in performance of the Node 1/PMA-1 intermodule atmosphere exchange shall be performed to determine the dynamic flow capability between the internal ambient atmosphere and the PMA-1 interface junction. Analysis of the interface signals specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1 and their connections to the Node 1 devices shall be performed to determine the combinations of interface signals that cause activation of those devices providing for circulation of Node 1 ambient atmosphere to the PMA-1 interface junction to the Node 1 internal atmosphere. Verification shall be considered successful when (1) analysis shows that the Node 1 ducts, valves, fans, etc. that are in-line to the flow of ambient atmosphere from the PMA-1 interface junction can provide the flow rates specified in SSP 42122, paragraph 3.2.1.3.1.1.3 and 3.2.1.3.2.1.3; and (2) the valves, fans, etc, necessary for the activation of the flows from the PMA-1 interface junctions can be activated by the defined combinations of the interface signals specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p>

Requirement (cont'd)	Verification (cont'd)
	<p>verified by analysis. Analysis of the Node 1 ducts, valves, fans, etc. involved in the performance of the Node 1/MPLM intermodule atmosphere exchange shall be performed to determine the dynamic flow capability between the USL junction and the MPLM interface junction. Analysis of the interface signals specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1 and their connections to the Node 1 devices shall be performed to determine the combinations of interface signals that cause activation of those devices providing for circulation of Node 1 ambient atmosphere to the MPLM interface. Verification shall be considered successful when (1) analysis shows that the Node 1 ducts, valves, fans, etc. that are in-line to the flow to the MPLM interface junction can provide the flow rates specified in SSP 42007, paragraphs 3.2.1.3.3.1.3 and 3.2.1.3.4.1.2; (2) the valves, fans, etc, necessary for the activation of the flows to and from the MPLM interface junctions can be activated by the defined combinations of the interface signals specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1; and (3) the valves, fans, etc. accommodate the transfer of a minimum of 140 CFM of parasitic air from the USL to the MPLM without dropping the pressure more than 1.04 inches of water, including the jumper duct in the MPLM vestibule but excluding the jumper duct in the USL vestibule.</p> <p>The circulate atmosphere intermodule Node 1/PMA-3 requirement shall be verified by analysis. Analysis of the Node 1 ducts, valves, fans, etc. involved in the performance of the Node 1/PMA-3 intermodule atmosphere exchange shall be performed to determine the dynamic flow capability between the internal ambient atmosphere and the PMA-3 interface junction. Analysis of the interface signals specified in SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1 and their connections to the Node 1 devices shall be performed to determine the combinations of interface signals that cause activation of those devices providing for circulation of Node 1 ambient atmosphere from the PMA-3 interface junction. Verification shall be considered successful when (1) analysis shows that the Node 1 ducts, valves, fans, etc. that are in-line to the flow of ambient atmosphere from the PMA-3 interface junction can provide the flow rates specified in SSP 42097, paragraphs D3.2.1.3.1.1.3 and D3.2.1.3.2.1.3; and (2) the valves, fans, etc, necessary for the activation of the flow from the PMA-3 interface junction can be activated by the defined combinations of the interface signals specified by SSP 50144-03 and SSP 42122, paragraph 3.2.1.5.4.1.</p>

Requirement (cont'd)	Verification (cont'd)
	The Node 1 adjustment of intermodule atmosphere flow rate requirement shall be verified by analysis. Analysis of the Node 1 electrical drawings shall be performed to determine the device providing crew desired flow adjustments, its specifications, and its electrical terminal interfaces. Analysis of the device specifications and the Node 1 installation shall be performed to determine the relationship between the manual setting of the device and the voltage presented to the PMA-1 interface. Verification shall be considered successful when the integrated analysis shows that there is a device for manually adjusting the intermodule ventilation flow rate and the voltage presented to the PMA-1 interface specified in SSP 42122, paragraph 3.2.1.5.4.1, is proportional to the position selected by the crew.

The requirement references nine ISS Interface Control Documents (ICDs). The relevant requirements from eight of those documents are listed below. The data from SSP 50144-03 is not relevant to close this requirement.

SSP 42122 Interface Parameters	From/To PMA-1 and Node 1
Node 1 ECLS Signals	<p>The Node 1 shall provide to and receive from PMA-1 instrumentation signals for the monitoring and control of the following ECLSS equipment by the N1-1 MDM: Atmosphere Revitalization valves, Smoke Detector, Node 1 Air Mixing Valve, Cabin Fan, Node 1 Aft IMV Fan, Node 1 Aft IMV Return and Supply Valves, Node 1 Starboard Return and Supply valves, Node 1 Port Supply valve, Node 1 Rheostat. The interface between the Node 1 ECLSS equipment and the N1-1 MDM shall be in compliance with SSP 30261:002.</p> <p>The Node 1 shall provide and receive from PMA-1 instrumentation signals for the monitoring and control of the following ECLSS equipment by the N1-2 MDM: Cabin Pressure sensor, Smoke Detector, Cupola Air Mixing Valve, Node 1 Port and Starboard IMV Fans, Node 1 Nadir IMV Return and Supply valves, Node 1 Forward Return and Supply valves, Cupola Rheostat. The interface between the Node 1 ECLSS equipment and the N1-2 MDM shall be in compliance with SSP 30261:002.</p>

SSP 41140 Interface Parameters	From Node 3 to Node 1	To Node 3 from Node 1
Flow Rate	120 cfm (3.40 cubic meter/min)	≥ 120 cfm (≥ 3.40 cubic meter/min)
Temperature	65 - 85°F (18.3 – 29.4°C)	65 - 85°F (18.3 – 29.4°C)
Pressure Drop	≤ 0.29 in-H <sub>2</sub> O (≤ 7.4 mm-H <sub>2</sub> O)	≤ 0.47 in-H <sub>2</sub> O (≤ 11.9 mm-H <sub>2</sub> O)

SSP 41141 Interface Parameters	From U.S. Laboratory Module to Node 1	To U.S. Laboratory Module from Node 1
Flow Rate	≥ 140 cfm (≥ 3.96 cubic meter/min)	≥ 125 cfm (≥ 3.54 cubic meter/min) pre-AC and 120 cfm (3.40 cubic meter/min) at AC
Temperature	45 - 85°F (7.2 – 29.4°C)	65 - 85°F (18.3 – 29.4°C)
Dew Point in XPOP Flight Attitude	40 - 53°F (4.4 – 11.7°C)	40 - 53°F (4.4 – 11.7°C)
Dew Point	40 - 60°F (4.4 – 15.6°C)	40 - 60°F (4.4 – 15.6°C)
Pressure Loss	≤ 0.5 in-H <sub>2</sub> O (≤ 12.7 mm-H <sub>2</sub> O)	≤ 0.35 in-H <sub>2</sub> O (≤ 8.9 mm-H <sub>2</sub> O) pre-AC and ≤ 0.29 in-H <sub>2</sub> O (≤ 7.4 mm-H <sub>2</sub> O) at AC

SSP 41142 Interface Parameters	From Cupola to Node 1	To Cupola from Node 1
Flow Rate	N/A	≥ 130 cfm (≥ 3.68 cubic meter/min)
Temperature	N/A	45 - 85°F (7.2 – 29.4°C)
Head Pressure	N/A	≥ 0.17 in-H <sub>2</sub> O at 130 cfm (≥ 4.3 mm-H <sub>2</sub> O at 3.68 cubic meter/min)

SSP 41145 Interface Parameters	From Joint Airlock to Node 1	To Joint Airlock from Node 1
Flow Rate	≥ 115 cfm (≥ 3.26 cubic meter/min)	≥ 115 cfm (≥ 3.26 cubic meter/min)
Temperature	65 - 80°F (18.3 – 26.7°C)	65 - 85°F (18.3 – 29.4°C)
Dew Point in XPOP Flight Attitude	40 - 53°F (4.4 – 11.7°C)	40 - 53°F (4.4 – 11.7°C)
Suction Pressure	≥ .45 in-H <sub>2</sub> O (≥ 11.4 mm-H <sub>2</sub> O)	N/A

SSP 42007 Interface Parameters	From MPLM to Node 1	To MPLM from Node 1
Flow Rate	135 - 210 cfm (3.82 – 5.95 cubic meter/min)	135 - 210 cfm (3.82 – 5.95 cubic meter/min)
Temperature	N/A	45 - 85°F (7.2 – 29.4°C)
Dew Point	N/A	40 - 60°F (4.4 – 15.6°C)
Heat Load	≤ 650 W	N/A
Delta Pressure including IMV Jumper	N/A	≤ 0.9 in-H <sub>2</sub> O (≤ 22.9 mm-H <sub>2</sub> O) at ≥ 135 cfm (3.82 cubic meter/min)



SSP 42097 Appendix D Interface Parameters	From PMA-3 to Node 1	To PMA-3 from Node 1
Flow Rate	≥ 120 cfm (≥ 3.40 cubic meter/min)	N/A
Temperature	65 - 85°F (18.3 – 29.4°C)	65 - 85°F (18.3 – 29.4°C)
Suction Pressure	≥ 1.2 in-H <sub>2</sub> O at 120 cfm (≥ 30.5 mm-H <sub>2</sub> O at 3.40 cubic meter/ min)	N/A

SSP 42122 Interface Parameters	From PMA-1 to Node 1	To PMA-1 from Node 1
Flow Rate	127 – 148 cfm (3.60 – 4.19 cubic meter/min)	127 – 148 cfm (3.60 – 4.19 cubic meter/min)
Dew Point	40 - 57°F (4.4 – 13.9°C)	40 - 60°F (4.4 – 15.6°C)
Suction Pressure	≥ 0.13 in-H <sub>2</sub> O at 135 cfm (≥ 3.3 mm-H <sub>2</sub> O at 3.82 cubic meter/ min)	N/A

Boeing – Huntington Beach analyzed the IMV pressure loss, suction pressure, or head pressure at each of the five Node 1 IMV interfaces during assembly and at AC. The analysis is based on the results from the Boeing – Huntington Beach flow balance development test with a 10% margin added to the pressure loss for the ducting and manual THC isolation valves in Node 1 for manufacturing variance between the Boeing – Huntington Beach provided test hardware and the Boeing – Huntington Beach provided flight hardware. The analysis also used the specified IMV valve pressure loss, the specified IMV fan performance data, vendor provided Inlet ORU performance data, Boeing – Huntsville estimated pressure loss for the IMV muffler plus 15% margin, Boeing – Huntsville estimated pressure loss for the IMV jumper plus 20% margin, development test results for the pressure loss versus flow rate for the charcoal filters that were installed in Node 1 instead of bacteria filters for temporary trace contaminant control prior to docking of the U.S. Laboratory Module to ISS and activation of the U.S. Laboratory Module trace contaminant control subsystem (TCCS), and Boeing – Huntsville estimated pressure loss for the IMV inlet screens plus 10% margin. The different Node 1 IMV configurations that were analyzed are summarized below:

- Node 1 to Node 3 Interface: The analysis calculated the pressure drop for this interface starting at the Node 1 plenum duct inlet to the Node 1 nadir aft interface. The analysis includes the pressure drop from some ducting, a manual THC isolation valve, and an IMV valve. It assumed the Node 1 nadir midbay manual THC isolation valve is closed.
- Node 3 to U.S. Laboratory Module Interface (at AC): The analysis calculated the pressure drop for this

interface starting at the Node 1 nadir forward interface to the Node 1 forward port interface. The analysis includes the pressure drop from two IMV valves and ducting. It assumed the Node 1 port and forward manual THC isolation valves are closed.

- Node 1 to U.S. Laboratory Module Interface (during assembly): The analysis calculated the pressure drop for this interface starting at the Node 1 forward IMV inlet screen and exits Node 1 at the Node 1 forward port feedthrough. The analysis includes the pressure drop from the IMV inlet screen, a manual THC isolation valve, some ducting, and an IMV valve. It assumes the Node 1 port manual THC isolation valve and the Node 1 nadir forward IMV valve are closed.
- Node 1 to Cupola Interface: The Node 1 port forward interface was analyzed to determine the head pressure provided by the Node 1 port IMV fan. The circuit in Node 1 includes an IMV inlet screen, an IMV fan, two IMV mufflers, an IMV valve, and some ducting. The analysis calculates the head pressure when the Node 1 to Cupola VAVDA is closed and the Node 1 port IMV fan is providing ≥ 3.68 cubic meter/min (130 cfm) to the Cupola.
- Node 1 to Airlock Interface: The Node 1 starboard aft interface was analyzed to verify the suction pressure the Node 1 starboard aft IMV fan will supply to the Joint Airlock ducting. The circuit in Node 1 contains an IMV valve, two mufflers, an IMV fan, some ducting, and a linear diffuser. The Node 1 starboard forward interface was not analyzed by Boeing – Huntington Beach since that interface was not planned to be used nominally for intermodule ventilation since the return path to the Joint Airlock will be normally through the hatch opening.
- U.S. Laboratory Module to MPLM at the Node 1 Nadir Interface (during assembly): The analysis calculated the pressure loss from the Node 1 forward starboard interface to the Node 1 nadir aft interface including the IMV jumper duct. The analysis includes the pressure drop from two IMV valves, a manual THC isolation valve, and ducting. The analysis assumes both VAVDAs and the Node 1 plenum manual THC isolation valve are closed.
- Node 1 to Pressurized Mating Adapter (PMA) 1 Interface: The Node 1 aft port interface was analyzed to verify the suction pressure the Node 1 aft IMV fan will supply to the PMA 1 ducting. The circuit in Node 1 contains an IMV valve, two mufflers, an IMV fan, and two cabin air diffusers. The Node 1 port manual THC isolation valve is assumed closed for this verification. The Node 1 aft starboard interface was not analyzed by Boeing – Huntington Beach since that interface was not planned to be used nominally for intermodule ventilation since the return path will be normally through the hatch opening.
- Node 1 to PMA 3 at the Node 1 Nadir Interface (during assembly): The analysis calculated the required Inlet ORU fan speed to provide ≥ 30.5 mm-H<sub>2</sub>O (1.2 in- H<sub>2</sub>O) suction pressure at the Node 1

nadir aft interface at 3.40 cubic meter/min (120 cfm). Since the plenum and the IMV leg providing suction to PMA 3 are parallel the flow split for the two legs was determined by an iteration process. The PMA 3 suction leg included the pressure loss from an IMV valve, a manual THC isolation valve, the Node 1 VAVDA, and ducting. It assumed that the Node 1 forward starboard IMV valve and the Node 1 to Cupola VAVDA were closed. The charcoal filter suction leg included the pressure loss from the four charcoal filters, the bacteria filter/housing assembly and ducting. Since the configuration included the Inlet ORU the analysis had to consider the performance capability of the Inlet ORU and the pressure drop from ducting, the cabin air diffusers, and the linear diffusers that the Inlet ORU is blowing air out.

- U.S. Laboratory Module to Cupola Interface: The analysis calculated the flow split of cold air from the U.S. Laboratory Module and ambient temperature Node 1 air and still meet the specified flow rate and head pressure requirements. Since the Node 1 IMV inlet screen leg and the Node 1 Cupola IMV leg have a common tee with the same pressure level and the flow versus pressure loss through both legs based on different Node 1 Cupola VAVDA positions the flow split can be determined by an iteration process. The U.S. Laboratory Module IMV leg included the pressure loss from an IMV valve, the Node 1 to Cupola VAVDA, and some ducting. It assumed that the Node 1 forward manual THC isolation valve, port manual THC isolation valve, and the Node 1 nadir forward IMV valve are closed. The IMV inlet screen leg included the pressure loss from the IMV inlet screen and ducting. The Node 1 Cupola IMV leg included the pressure loss from an IMV valve, two mufflers and some ducting and the pressure rise from the IMV fan. For the analysis the resistance of the Cupola was estimated based on the new flow rate at the interface using the following equation:

$$\text{Calculated Cupola} = 0.17 \left( \frac{\text{new flow rate in}}{\text{Resistance}} \text{ cfm}/130 \right)^{**2}$$

- U.S. Laboratory Module to Node 1 Interface: Since the plenum and the IMV leg from the U.S. Laboratory Module are parallel the flow split for the two legs must be calculated such that they have the same pressure loss just prior to the inlet of the Inlet ORU. Also, for a given Inlet ORU speed the suction pressure at the inlet of the Inlet ORU must be equal to the pressure loss from the two inlet legs. The analysis determined by an iterative process correct flow split of the two inlet legs and the Inlet ORU flow rate required to arrive at a steady state solution. The U.S. Laboratory suction leg included the pressure loss from an IMV valve, the Node 1 VAVDA, and ducting. It assumed that the Node 1 nadir midbay manual THC isolation valve was

closed. The bacteria filter leg suction leg included the pressure

loss from the four bacteria filters, the bacteria filter/housing assembly and ducting.

- For the Node 1 cabin temperature analysis Boeing – Huntington Beach looked at best case and worst case Node 1 heat loads of 500 W and 1542 W; worst case and best case IMV exchange rate with the U.S. Laboratory Module of 3.11 cubic meter/ min (110 cfm) and 3.96 cubic meter/min (140 cfm); and an IMV supply temperature from the U.S. Laboratory Module between 7.2°C and 18.3°C (45°F and 65°F).

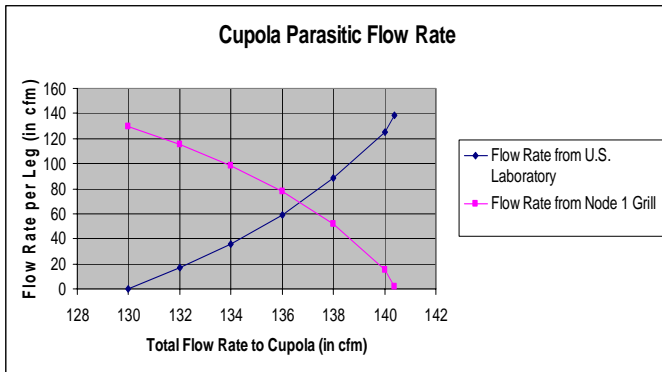
Results:

- Node 1 to Node 3 Interface: At 3.40 cubic meter/min (120 cfm) the calculated pressure loss was 11.4 mm-H2O (0.45 in-H2O), which is less than the specified maximum level of 11.9 mm-H2O (0.47 in-H2O).
- Node 3 to U.S. Laboratory Module Interface (at AC): At 3.40 cubic meter/min (120 cfm) the calculated pressure loss was 7.1 mm-H2O (0.28 in-H2O), which is less than the specified maximum level of 7.4 mm-H2O (0.29 in-H2O).
- Node 1 to U.S. Laboratory Module Interface (during assembly): At 3.54 cubic meter/min (125 cfm) the calculated pressure loss was 8.6 mm-H2O (0.34 in-H2O), which is less than the specified maximum level of 8.9 mm-H2O (0.35 in-H2O).
- Node 1 to Cupola Interface: At 3.68 cubic meter/min (130 cfm) the calculated head pressure was 4.3 mm-H2O (0.17 in-H2O), which meet the specified level.
- Node 1 starboard aft to Airlock Interface: At 3.26 cubic meter/min (115 cfm) the calculated suction pressure at the Node 1 starboard aft interface was 11.9 mm-H2O (0.47 in-H2O), which is greater than the specified minimum level of 11.4 mm-H2O (0.45 in-H2O).
- U.S. Laboratory Module to MPLM at the Node 1 Nadir Interface (during assembly): At 3.96 cubic meter/min (140 cfm) the calculated pressure loss was 25.9 mm-H2O (1.02 in-H2O), which is less than the Node 1 Requirement specified maximum level of 26.4 mm-H2O (1.04 in-H2O). It should be noted that the ICD and the Node 1 Requirement are in disagreement for the pressure loss requirement but the Node 1 Requirement is the controlling requirement per the ICD.
- Node 1 aft port to PMA 1 Interface: At 3.82 cubic meter/min (135 cfm) the calculated suction pressure was 3.3 mm-H2O (0.13 in-H2O), which meet the specified level.
- Node 1 to PMA 3 at the Node 1 Nadir Interface (during assembly): The iterative process calculated that the suction pressure at the Node 1 to PMA 3 interface would be 39.1 mm-H2O (1.54 in-H2O) at 3.40 cubic meter/min (120 cfm). The flow rate for

the charcoal filter leg at 39.1 mm-H<sub>2</sub>O (1.54 in-H<sub>2</sub>O) was calculated to be 6.66 cubic meter/min (235.4 cfm). The Inlet ORU outlet pressure loss was calculated to be 29.7 mm-H<sub>2</sub>O (1.17 in-H<sub>2</sub>O) at the

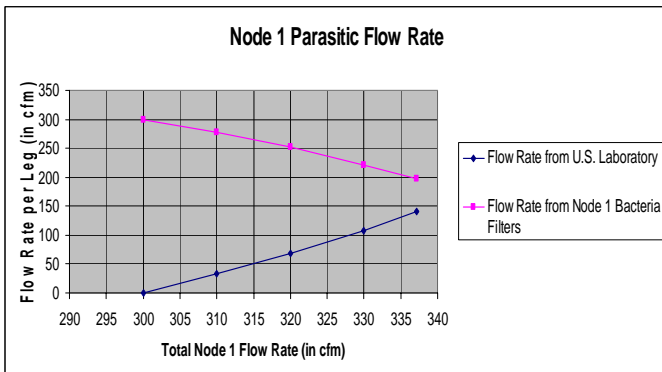
combined flow rate from the two suction legs of 10.06 cubic meter/min (355.4 cfm). To provide the flow rate of 10.06 cubic meter/min (355.4 cfm) and a head pressure of the combined inlet and outlet legs of 68.8 mm-H<sub>2</sub>O (2.71 in-H<sub>2</sub>O) the Inlet ORU has to be commanded to a speed of 4951 revolutions per minute (rpm).

- U.S. Laboratory Module to Cupola Interface: The calculated flow split of cold air from the U.S. Laboratory Module and ambient temperature Node 1 air with the Node 1 Cupola VAVDA being fully closed (the far left side of the graph) to fully open (the far right side of the graph) and all positions in between is shown in the figure 3:



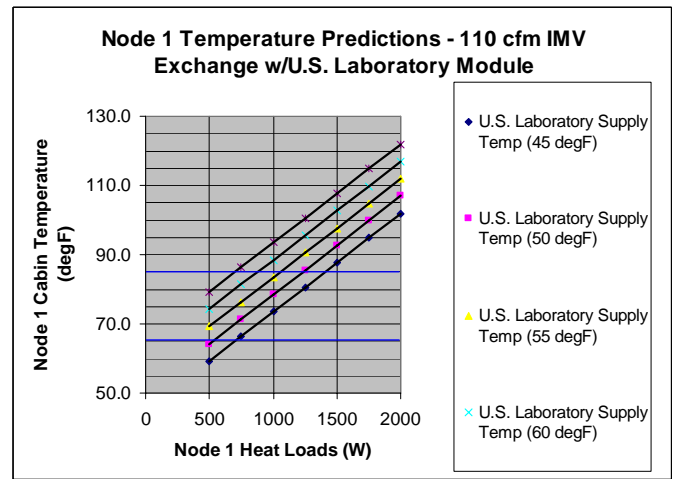
**Figure 3 – Cupola Parasitic Flow Rate when Node 1 Cupola VAVDA is Fully Closed**

- U.S. Laboratory Module to Node 1 Interface: The calculated flow split of cold air from the U.S. Laboratory Module and ambient temperature Node 1 air going through the four Node 1 bacteria filters with the Node 1 VAVDA being fully closed (the far left side of the graph) to fully open (the far right side of the graph) and all positions in between with a Inlet ORU speed of 4078 rpm is shown in the figure 4:

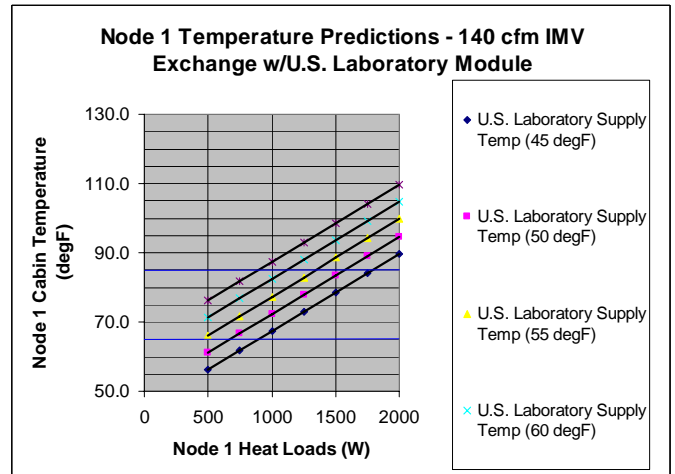


**Figure 4 - Node 1 Parasitic Flow Rate Based on Node 1 VAVDA Position**

- The calculated Node 1 cabin temperature based on the two different IMV exchange rates with the U.S. Laboratory Module are shown in figure 5a and 5b:



**Figure 5a – Node 1 Temperature with 110 cfm IMV Exchange with U.S. Laboratory Module**



**Figure 5b – Node 1 Temperature with 140 cfm IMV Exchange with U.S. Laboratory Module**

To show compliance with the input voltage interface requirement Boeing – Huntington Beach referenced the electrical and data line drawing in their verification report for the IMV fans, IMV valves, the VAVDAs, and the Inlet ORU.

## CONCLUSION

The verification of Node 1 utilized a building block approach from the Component Qualification data through to the Element Level Verification. This paper provides a general overview of the nominal operation of the THC subsystem in Node 1 and of the ISS ECLS

Element Level Verification program for the THC subsystem in Node 1. It also showed that nominal operation of the Node 1 THC subsystem that was discussed in this paper met all of its Element requirements.

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## REFERENCES

1. "Prime Item Development Specification for Node 1"; S684-10102, Revision J; November 20, 2002.
2. "Space Station Program Node Element 1 to Node Element 3 Interface Control Document, Part 1"; SSP 41140, Revision E; August 24, 2005.
3. "Node 1 Element to U.S. Laboratory Element Interface Control Document, Part 1"; SSP 41141, Revision F; December 10, 2004.
4. "Node 1 Element to Airlock Element Interface Control Document, Part 1"; SSP 41145, Revision E plus IRN 41145-0074A; January 5, 2002.
5. "United States On-Orbit Segment to Italian Mini Pressurized Logistics Module Interface Control Document, Part 1"; SSP 42007, Revision H; December 31, 2002.
6. "Pressurized Mating Adapter 2 & 3 to United States Pressurized Elements (Node 1 to PMA-3) Interface Control Document, Part 1, Appendix D"; SSP 42097, Revision E, June 30, 2006.
7. "Resource Node 1 to Pressurized Mating Adapter-1 Interface Control Document, Part 1"; SSP 42122, Revision D plus IRN 0019, 0016, and 0020; December 20, 2002.
8. Boeing – Huntington Beach; "International Space Station Node 1 Cabin Ventilation ECLSS Verification Analysis Report"; MDC 97H0453A; April 1, 1998.
9. Boeing – Huntington Beach; "International Space Station Particulate and Microbe Removal ECLSS Verification Analysis Report"; MDC 96H0682B; January 30, 1998.
10. Boeing – Huntington Beach; "International Space Station Node 1 Intermodule Ventilation and Temperature Control ECLSS Verification Analysis Report"; MDC 96H0512B; February 6, 1998.

## CONTACT

## ACRONYMS

°C:	degree celsius
°F:	degree fahrenheit
AC:	Assembly Complete
ACS:	Atmosphere Control and Supply
AR:	Atmosphere Revitalization
ASHRAE:	American Society of Heating, Refrigerating and Air Conditioning Engineers
CCAA:	Common Cabin Air Assembly
cfm:	cubic feet per minute
CFU:	Colony Forming Unit
ECLS:	Environmental Control and Life Support
EVA:	Extravehicular Activity
FCS&I:	Flight Crew System and Integration
FDS:	Fire Detection and Suppression
fpm:	feet per minute
H2O:	water
ICD:	Interface Control Document
IMV:	Intermodule Ventilation
ISS:	International Space Station
in:	inch
KSC:	Kennedy Space Center
MDM:	Multiplexer/Demultiplexer
mg:	milligram
min:	minute
mm:	millimeter
MPLM:	Mini-Pressurized Logistic Module or Multi-Purpose Logistic Module
ORU:	Orbital Replacement Unit
PIDS:	Prime Item Development Specifications
PMA:	Pressurized Mating Adapter
ppCO2	partial pressure of carbon dioxide
rpm:	revolution per minute
RS:	Russian Segment
SSP:	Space Station Program
SSF:	Space Station Freedom
TCCS:	Trace Contaminant Control Subsystem
THC:	Temperature and Humidity Control
U.S.:	United States
USL:	United States Laboratory
USOS:	United States On-Orbit Segment
VAVDA:	Variable Air Volume Damper Assembly
W:	Watts
WRM:	Water Recovery and Management