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International Space Station Sustaining Engineering: A Ground-Based Test Bed for Evaluating Integrated Environmental Control and Life Support System and Internal Thermal Control System Flight Performance

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ABSTRACT

As the *International Space Station's (ISS)* various habitable modules are placed in service on orbit, the need to provide for sustaining engineering becomes increasingly important to ensure the proper function of critical onboard systems. Chief among these are the Environmental Control and Life Support System (ECLSS) and the Internal Thermal Control System (ITCS). Without either, life onboard the *ISS* would prove difficult or nearly impossible. For this reason, a ground-based ECLSS/ITCS hardware performance simulation capability has been developed at NASA's Marshall Space Flight Center. The ECLSS/ITCS Sustaining Engineering Test Bed will be used to assist the *ISS* Program in resolving hardware anomalies and performing periodic performance assessments. The *ISS* flight configuration being simulated by the test bed is described as well as ongoing activities related to its preparation for supporting ISS Mission 5A. Growth options for the test facility are presented whereby the current facility may be upgraded to enhance its capability for supporting future station operations well beyond Mission 5A. Test bed capabilities for demonstrating technology improvements of ECLSS hardware are also described.

INTRODUCTION

In order to ensure the habitability of the *International Space Station (ISS)* during its construction and on-orbit operations, a significant level of ground-based sustaining engineering must be maintained. As part of the ISS Program's sustaining engineering effort, the NASA Marshall Space Flight Center (NASA MSFC) is responsible for designing, constructing, and operating a test bed to facilitate evaluation of the Environmental Control and Life Support System (ECLSS) and Internal Thermal Control System (ITCS) in-flight performance. The ECLSS/ITCS Test Bed, which includes a complement of functionally flight-like ECLSS and ITCS equipment, serves as a key tool for investigating on-orbit contingency scenarios and in-flight anomalies. In addition it will be used for troubleshooting operational and performance problems, optimizing performance, verifying system modifications and upgrades, validating engineering analyses and models, and developing evolutionary ECLSS and ITCS technologies for the *ISS*.

The ECLSS/ITCS Test Bed provides a functionally flight-like, integrated ground test capability before and during the time the *ISS* becomes permanently inhabited. When completed, this test bed will include simulators for the U.S. Laboratory Module, Node 1, Node 3, and Habitation Module. Phased construction is being implemented with the Mission 5A configuration, comprised of the U.S. Laboratory and Node 1 elements, to be completed first followed by the addition of a Node 3/Habitation Module simulator.

Growth options are being considered that would enhance the fidelity of these ground-based simulators. They include better representation of element free volume, outfitting the facility with development and qualification hardware currently residing at Boeing subcontractor facilities and fabrication of Node 2 and Airlock simulators that would subsequently be outfitted with ECLSS hardware.

ISS FLIGHT CONFIGURATION DESCRIPTION

A schematic of the *ISS* U.S. Segment flight configuration, minus the Japanese and European laboratory modules, is provided in Figure 1. Node 1 and the Russian FGB are currently on orbit. According to the current Assembly Sequence, the U.S. Laboratory will be docked to Node 1 in August 2000 during Mission 5A. This will be followed by the Airlock in February 2001. Other elements such as Node 2 and Node 3 will be launched later.

FACILITY DESCRIPTION

The 1,860 square meter (20,000 square foot) ECLSS/ITCS Test Facility is located at NASA's Marshall Space Flight Center in Huntsville, Alabama. Reference 1 contains a detailed summary of the facility and its performance requirements. Figure 2 shows a simplified facility floor plan. This facility became operational in 1987 to support early ECLSS development testing. It has been used since 1987 for integrated ECLSS testing and subsystem development testing.

Currently, this facility is being used for development and life testing of *ISS* ECLSS hardware and will continue to be used for developmental testing of Node 3 ECLSS hardware. The facility includes a chemistry laboratory that can conduct limited chemical and microbial analyses. Facility services in place include gas and liquid supplies, monitoring and control, and data acquisition and analysis. Certified test subjects exercise and engage in personal hygiene activities in the End-use Equipment Facility (EEF) to generate wastewater which serves as the feed for water reclamation system testing.

In addition to its continued use in conducting development tests, the facility provides a functionally flight-like, integrated ground test capability before and during the time the *ISS* becomes fully operational. The facility construction is planned in two phases. During Phase I, simulators and facility capabilities will be put in place for supporting *ISS* assembly flight 5A. Upon completing the Phase I effort, the ECLSS/ITCS Test Bed will include a U.S. Laboratory Module Simulator (LMS), Node 1 Simulator (NS) and the U.S. Laboratory Module Engineering Development Article (USL EDA) outfitted with ITCS hardware. At the conclusion of Phase II, a Node 3/Habitation Module Simulator will be included.

PHASE I OVERVIEW: MISSION 5A CONFIGURATION – The Phase I test bed configuration is designed to simulate selected ECLSS and ITCS functions available onboard the *ISS* upon U.S. Laboratory module deployment during Mission 5A. It includes a LMS, Node 1 simulator, and the USL EDA outfitted with a low temperature ITCS loop as shown by Figure 3. The LMS will include primarily Atmosphere Revitalization System (ARS) and Temperature and Humidity Control system (THC) equipment while the

NS will be outfitted with a functionally flight-like THC system. Due to budget constraints, the moderate temperature ITCS loop will not be installed in the ITCS Simulator in time to support the 5A mission. However, it will be added as the facility construction progresses.

Laboratory Module Simulator – The LMS is comprised of a pressure vessel the Core Module Simulator, functionally flight-like hardware systems, and facility support hardware. Much of the LMS, such as the chamber and many functionally flight-like test articles already exist and have been used during previous integrated ECLSS tests. The 170 cubic meter (6,000 cubic foot) pressure vessel, known previously as the Core Module Simulator and used previously for ISS ECLSS development testing, is the primary structural element of the LMS. It should be noted that the LMS volume is approximately twice that of the flight U.S. Laboratory module. Figure 4 provides a schematic of the LMS and its major systems and subsystems. Major systems simulated in the LMS include the ARS, THC, and Atmosphere Control and Supply (ACS). Baseline U.S. Laboratory subsystems not included in the LMS is Fire Detection and Suppression (FDS) and the Vacuum System (VS). Facility support equipment includes a contaminant injection system: metabolic simulator: process sampling and monitoring equipment: and command, control, and data acquisition systems.

The baseline ISS ARS is comprised of the Four Bed Molecular Sieve Carbon Dioxide Removal Assembly (CDRA), the Trace Contaminant Control Subassembly (TCCS), and the Major Constituent Analyzer (MCA). All of these ARS subassemblies are included in the LMS. Also provided is low fidelity distributed ARS equipment, which simulates the Sample Delivery System (SDS) – a network of stainless steel tubing, valves, and fittings through which samples are pumped to the MCA. The high fidelity THC equipment includes a bacteria filter assembly, Common Cabin Air Assembly (CCAA), ducting, and an engineered interface with the CDRA. The ACS function is simulated using commercial hardware and software.

The CDRA used in the LMS is the Boeing Predevelopment Operational System Test (POST) unit that has been upgraded to be functionally flight-like. Enhancements that have been made include replacing all the sorbent and desiccant material with material taken from the actual manufacturer's lots used to pack the flight units, packing all beds with the same volume of sorbent used in the flight units, and replacing the original sorbent bed heater cores with a flight-like design. A commercial blower provides flight subsystem flow rates. Performance data from this subsystem is very similar to flight unit CDRA performance as has been shown by recent testing. [2]

The TCCS to be used in the LMS is the Regenerative Life Support System (RLSE) unit built by Lockheed Martin Missiles and Space Company. It has been used in numerous subsystem and integrated ECLSS tests over the last 15 years. The subsystem flow rates and bed materials are identical to the flight TCCS. Some variations in bed size relative to the flight design exist: however, the unit has been demonstrated by test to provide similar performance.

The MCA used in the LMS is a development unit built by Orbital Sciences Corporation. It was used previously in the Boeing POST and NASA MSFC Integrated Air Revitalization testing. This commercial unit uses a mass spectrometer to measure the partial pressures of oxygen, nitrogen, carbon dioxide, water vapor, methane, and hydrogen.

The low fidelity SDS uses a network of 6-mm (0.25-inch) Teflon tubing to collect samples from the LMS at approximately the same spatial location as the flight unit. The flight SDS is a network of 3-mm (0.125-inch) stainless tubing that allows the MCA to collect samples from remote locations throughout the *ISS*. The SDS simulator will mimic the ISS design's function for the U.S. Laboratory and Node 1 as configured for Mission 5A.

The THC equipment includes flight-like ducting removed from the USL EDA wrapped with flight insulation. The CCAA used in the LMS is comprised of a combination of a flight-like condensing heat exchanger core, development hardware, and functionally flight like commercial hardware. The development hardware consists of a manual/motorized by-pass valve, variable speed control fan, a differential pressure sensor, inlet and outlet temperature sensors, a collection system for the condensate, and commercial inlet and outlet transitions which are identical to the flight configuration. Although the flight design includes two CCAA units, there will be only a single CCAA in the LMS. A schematic of the CCAA installation is shown by Figure 5. The flexible process air duct from the outlet of the Condensing Heat Exchanger (CHX) to the CDRA is flight-like in terms of configuration and materials.

Node 1 Simulator – A connection between the LMS and the Node 3 Habitation Module simulator is provided in the form of the NS. A Boeing-constructed Structural Test Article (STA) was upgraded to the Node 1 flight configuration by the addition of an end-cone. Additional modifications such as the addition of longerons provide structural support for the THC system.

Figure 6 provides a schematic of the flight Node 1 THC system. The Node 1 THC equipment includes a cabin ventilation fan, supply duct, return air filter plenum, four bacteria filters, and a return duct. The system also includes one intermodule ventilation (IMV) fan and associated silencers (Mission 5A configuration), IMV valves, two variable air valves, and butterfly valves. Node 1 has no active cooling and, therefore, has no heat exchanger. Parasitic cooling from the LMS via IMV controls Node 1 heat loads.

A schematic of the NS configuration for ISS Mission 5A is provided by Figure 7. The NS is outfitted only with THC hardware, which is a combination of development, and flight-like hardware. The ductwork was fabricated from the same molds as the flight ducting by Microcraft - Ontario. The test ductwork is identical to the flight hardware except the test articles are made from fiberglass rather than the flight material, Kevlar. Using an alternate material resulted in significant cost savings. The cabin ventilation fan and IMV fan are development hardware but provide identical performance to the flight fans. The IMV fan silencers are Node 1 flight hardware made available when the silencers were changed out at NASA's Kennedy Space Center (NASA KSC). Other hardware items are either development or commercial units that are functionally identical to the flight articles. For instance, butterfly valves are commercial units that provide the same function as the flight solenoid operated valves.

U.S. Laboratory Module ITCS Simulator – The ITCS Simulator includes equipment for simulating the function and performance of the low temperature and moderate temperature single-phase coolant loops in the U.S. Laboratory module. The USL EDA is being outfitted with both the low and moderate temperature ITCS loops. The USL EDA is a high fidelity mockup used previously by Boeing to conduct fit and functional checks for the flight element and is ideally suited for housing the ITCS Simulator.

Figure 8 provides a schematic of the flight U.S. Laboratory module ITCS. The low temperature loop supplies coolant (water) in the range of 3.3-5.5 °C (38-42 °F) and the moderate temperature loop supplies coolant in the range of 16.1-18.3 °C (61-65 °F). These coolant loops provide a heat rejection source for subsystem and payload equipment. Key components of the ITCS include the Pump Package Assembly (PPA), System Flow Control Assembly (SFCA), Rack Flow Control Assemblies (RFCAs), and a loop crossover assembly. Nominally, the low temperature and moderate temperature loops operate independently of each other. However, the two loops can be cross-connected to allow either PPA with the two SFCA's to service the entire U.S. Laboratory. The heat collected from these two loops is rejected to the external thermal control system via two identical interface heat exchangers.

The U.S.Laboratory ITCS Simulator ultimately will be outfitted with both the low and moderate temperature loops. The test bed provides a high fidelity hydraulic and thermal simulation but the ability to troubleshoot hardware anomalies will be limited due to the unavailability of flight-like ITCS hardware. The connections between heat sources, line lengths and any insulation, and flow control devices are representative of the flight hardware. Key characteristics of the ITCS that will be simulated include the heat transfer characteristics and the coolant flow characteristics.

The heat loads of payloads and equipment are simulated with controllable water heaters rather than the actual equipment. ISS cold plates are not included in the system due to their unavailability as well as the complexity of mounting heating pads onto them. The ability to change heat loads, including the ability to timeline, add, and remove loads is provided. Heat gain or loss through the coolant supply and return lines is simulated by using flight-like tubing (material, size, etc.) where possible, and by using similar lengths as the flight ITCS.

A schematic of the ITCS Simulator's low temperature loop configured for Mission 5A is shown by Figure 9. The moderate temperature loop will not be installed in time to support Mission 5A because of funding constraints imposed in 1999. The ITCS services only three racks for Mission 5A – the two racks outfitted with THC CCAAs and the ARS rack. The ITCS Simulator's low temperature loop is outfitted with a combination of development and commercial hardware. All the development hardware was obtained from Boeing. It was used previously in a "brassboard" test facility used for an early ITCS development testing. The "brassboard" development hardware includes the PPA, SFCA, interface heat exchanger, and three-way mixing valve. The development unit loop crossover assembly will be added when the moderate temperature loop is installed. Insufficient development unit RFCAs were available to outfit all the rack simulators; therefore, commercial components were used which provide the same function and operability as the flight RFCAs.

Flight ITCS control software algorithms were obtained from Boeing and have been programmed using Labview. This software includes an overall supervisory code that allows for controlling the overall system as well as the individual components such as the RFCAs.

PERFORMANCE VALIDATION – Once construction and outfitting of the LMS, NS, and the ITCS Simulator low temperature loop is completed, checkout tests will be conducted where necessary to verify that the ground based system performance is consistent with flight system performance. Without this performance validation step, data from the ECLSS/ITCS test bed would be useless in troubleshooting on orbit anomalies

Performance validation for the LMS 4BMS and the TCCS has already been completed. Data from the US Laboratory flight article THC testing conducted in Building 4708 at MSFC has been obtained from Boeing. In addition, Boeing has supplied data from testing of the Node 1 flight article at NASA KSC. Hydraulic testing of the U.S. Laboratory ITCS was recently completed at NASA KSC and these data will be obtained from Boeing for comparison to ITCS test bed performance.

PHASE II OVERVIEW – The Phase II ECLSS ITCS test bed configuration is shown on Figure 10. The USL EDA will be outfitted with the ITCS moderate temperature coolant loop and additional ECLSS subsystems will be installed in the Node3 Habitation Module simulator, as they become available.

The ITCS Simulator's moderate temperature loop will be outfitted with commercial components unless higher fidelity hardware becomes available. The Node 3/Habitation Module Simulator, for which the test chamber has already been placed into position, will be outfitted with existing hardware currently located at NASA MSFC. This hardware includes ARS, THC, Water Processor (WP), Urine Processor Assembly (UPA), and end-use equipment from the EEF. The ARS hardware includes a high-fidelity Oxygen generator Assembly (OGA) used for development testing and a development unit Sabatier Carbon Dioxide Reduction subsystem. The THC CCAA used in the Node 3/Habiation Module Simulator is comprised of a combination of a flight-like condensing heat exchanger and development hardware very similar to the hardware installed in the LMS. Insufficient flight-like THC ductwork is available; therefore, the CCAA will be integrated with commercial ductwork with no attempt made to simulate the flight ducting. High fidelity Water Processor and Urine Processor units from Node 3 ECLSS development efforts will be used. The end-use equipment will be moved from the present EEF. It includes a shower, hand wash, exercise equipment, and urinal.

TEST BED GROWTH OPTIONS

Growth options to increase the ECLSS ITCS Test Bed's fidelity are listed by Table 1. They include simulation of actual flight free volumes, outfitting with high fidelity hardware, and addition of additional ISS elements.

Existing test chambers are used to house the ECLSS equipment for the LMS and Node 3/Habitation Module Simulator. The test chambers were fabricated before the U.S. Laboratory and Habitation Module lengths were reduced. As a result, the simulator volumes do not match flight element free volumes. This mismatch of free volumes requires transient predictions of flight environmental conditions, such as CO_2 partial pressures, be adjusted to achieve a valid comparison to test data. Although not an insurmountable task, it does present a challenge for analysts using predictive computer models in which the cabin free volume dictates the duration and magnitude of transient events. Several options are being examined to resolve this problem. They include installing closeout panels and using foam blocks to fill free spaces.

The ECLSS/ITCS Test Bed could be outfitted with hardware currently residing at Boeing subcontractor facilities or at NASA KSC. This hardware would serve to boost the test bed's fidelity thus providing improved functional simulations. Potential hardware that may become available of installation into the ECLSS ITCS Test Bed is listed in Table 2. These items are development quality hardware with the exception of the ARS 3-Way Process Air Valve and ITCS components that are qualification hardware. The bacteria filter assemblies are those that will be removed from the U.S. Laboratory flight article during final element closeout at NASA KSC. New bacteria filter assemblies will be installed in the U.S. Laboratory before flight thus the old ones will be available. The CDRA silencer is a development unit no longer needed for testing and is being stored by Boeing. Figure 11 depicts the approximate locations in the test bed that this additional hardware will be installed.

Additional ISS elements could be added to the ECLSS/ITCS Test Bed. Sufficient floor space is available in the building which houses the test bed to add Node 2 and Airlock simulators as shown by Figure 12. Simulators for both these elements would be fabricated and outfitted initially with THC hardware. Other ECLSS hardware would be added as funding became available.

TECHNOLOGY DEMONSTRATION CAPABILITIES

While the primary purpose for the ECLSS/ITCS Test Bed is to provide a ground-based, high-fidelity atmospheric and thermal control simulation capability for the *ISS* Program, its capabilities are also well-suited to demonstrating technological improvements of baseline systems and subassemblies which may lead to more efficient, less expensive station operations. Although bench-scale testing and performance demonstration can provide much useful information, experience has shown that the potential benefits of implementing a technology or process improvement cannot be fully understood without integrated testing under flight-like cabin conditions. Examples of technologies, which may be demonstrated in the ECLSS/ITCS Test Bed, include advanced process instrumentation and sensors, process control algorithms, subassembly components, and full subassemblies.

A recent technological development, which can make use of the ECLSS/ITCS Test Bed capabilities, is an advanced high temperature catalyst substrate for use in trace contaminant control applications. This technology, which was first developed for use in automotive exhaust and gas turbine applications, utilizes a series of high cell density, short channel length metal monoliths [3,4]. It has been shown during integrated testing in the precursor to the ECLSS/ITCS Test Bed to provide significant operational flexibility to the TCCS. [5]. While bench-scale testing of the metal monolith technology proved useful, its benefit to the TCCS and the *ISS* Program as a whole cannot be fully understood without integrated testing in a flight-like TCCS unit. The ECLSS/ITCS Test Bed provides the necessary resources to conduct such testing in a simulated *ISS* internal environment.

Demonstrating new technologies in the ECLSS/ITCS Test Bed also provides the opportunity to better compare a proposed new technology's performance to the existing *ISS* design under nearly identical environmental conditions more quickly and economically compared to a flight demonstration. Such a demonstration would be both expensive and difficult to carry out onboard the *ISS* as it would require fabricating flight hardware, coordinating on-orbit operations to accommodate the demonstration test, and attempting to regulate the crew's activities to minimize effects on the test results. By conducting integrated performance testing in the ECLSS/ITCS Test Bed, the technology's capabilities can be screened in a controlled, simulated *ISS* cabin environment. As such, its technology readiness level can be elevated to at least 6 and possibly as high as level 8 as defined by Table 3. [6]. For those technologies with no microgravity sensitivities, a minimum technology readiness level 7 may be achieved via integrated testing in the ECLSS/ITCS Test Bed. Of course, testing technologies having suspected microgravity sensitivities requires the unique environment that can only be attained during in-flight evaluation. Such sensitivities are rare for atmosphere revitalization, supply, and control technologies; however, water processing technologies have more risk for microgravity sensitivity. [7]

TEST BED CONSTRUCTION SCHEDULE

The current ECLSS/ITCS Test Bed schedule is shown by Figure 13. This schedule includes only the construction and outfitting for the approved elements (Node 1, LMS, Node 3, and Lab ITCS) and not the growth options discussed previously. According to this development plan, the Node 1 and LMS ECLSS will be operational in time to support a Mission 5A launch date of August 2000. In addition, the ITCS Simulator's low temperature loop will be operational at the same time. The ITCS Simulator's moderate temperature loop will be operational by October 2001. Outfitting of the Node 3 Simulator will begin in September of 2000. It should be operational by December 2001. Should the growth option for adding the airlock and Node 2 simulators be approved, work on these elements could be done where activities are currently planned for Node 3 and the

Node 3 work moved to the right. The current assembly sequence shows a Node 3 launch in May 2004.

SUMMARY

An overview of work currently being accomplished at NASA MSFC on the ECLSS/ITCS Sustaining Engineering Test Bed for the *ISS* Program Office has been provided. The first use of this facility will be *ISS* Mission 5A (U.S. Laboratory) currently scheduled to fly in August 2000. The NASA MSFC facility, for which NASA has made a considerable investment during space station development, will be utilized for *ISS* flight support, development of evolutionary ECLSS hardware, and continued development of Node 3 ECLSS hardware. In addition, this facility and the experienced personnel at NASA MSFC have the capability to support both technology development and sustaining engineering activities in parallel. This capability is an asset to the program that has resulted from years of experience in ECLSS hardware design, development, and testing.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Blaine Salyer and Andy Jenkins of ION Corporation for their contributions to this paper.

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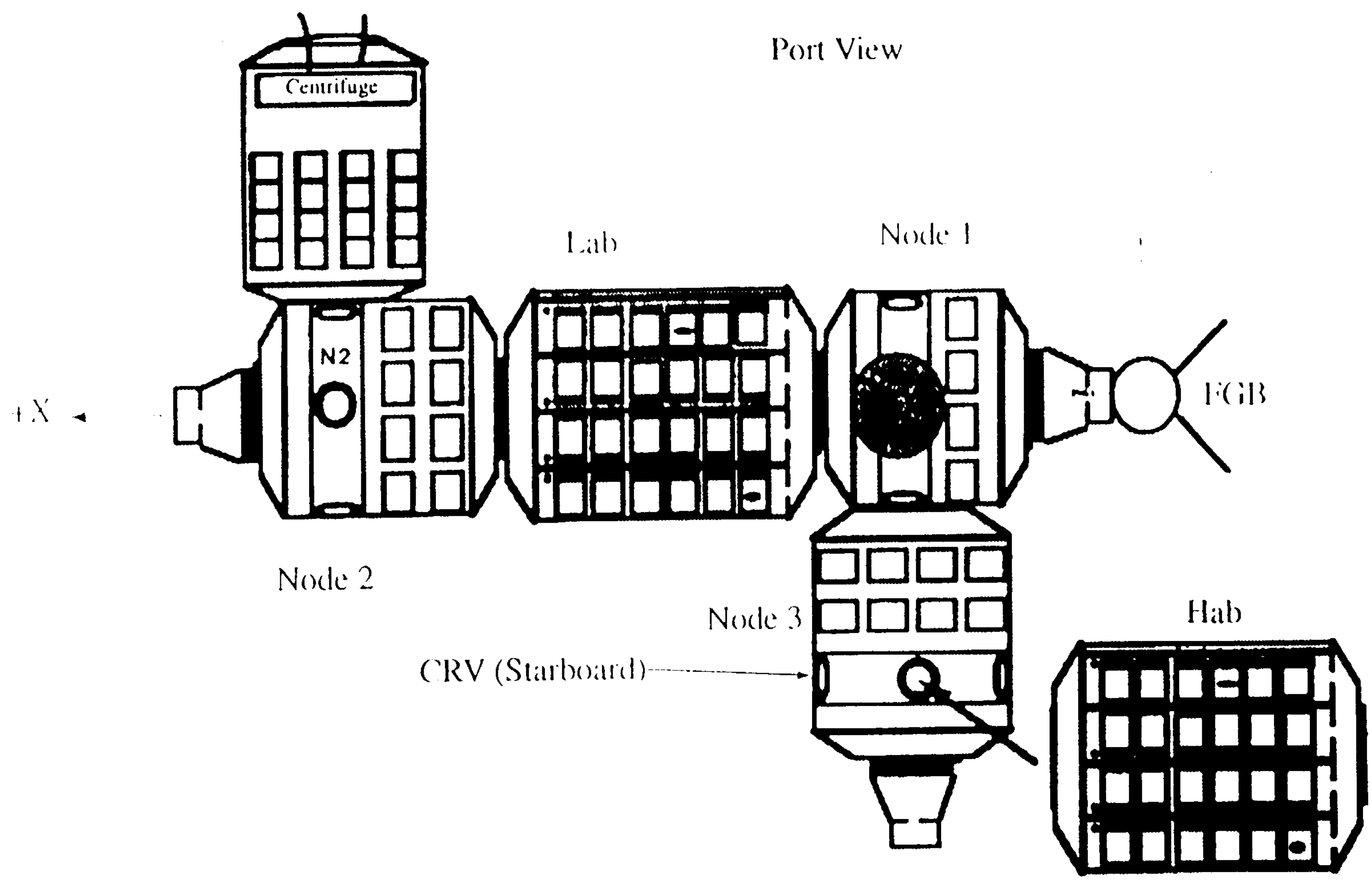
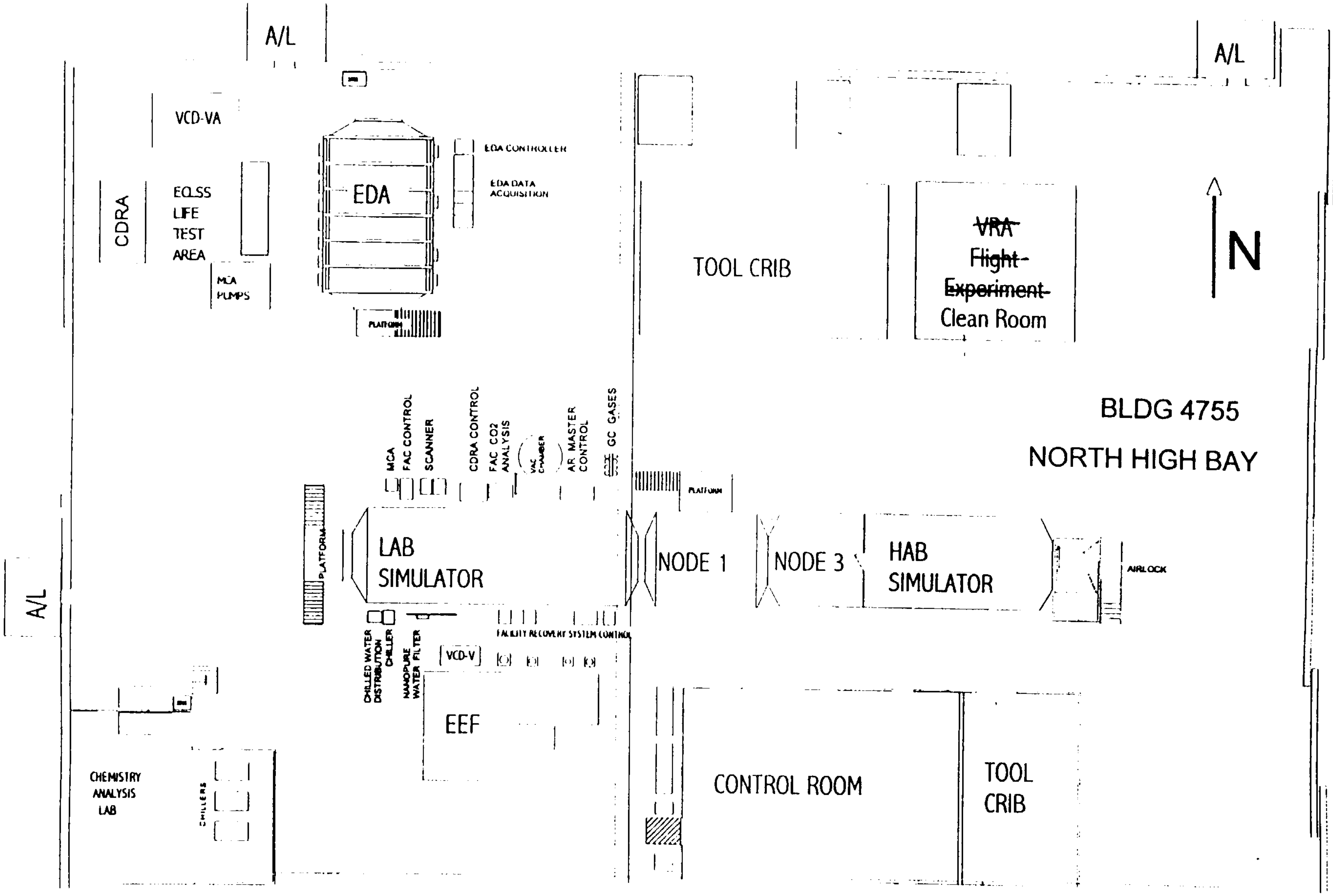
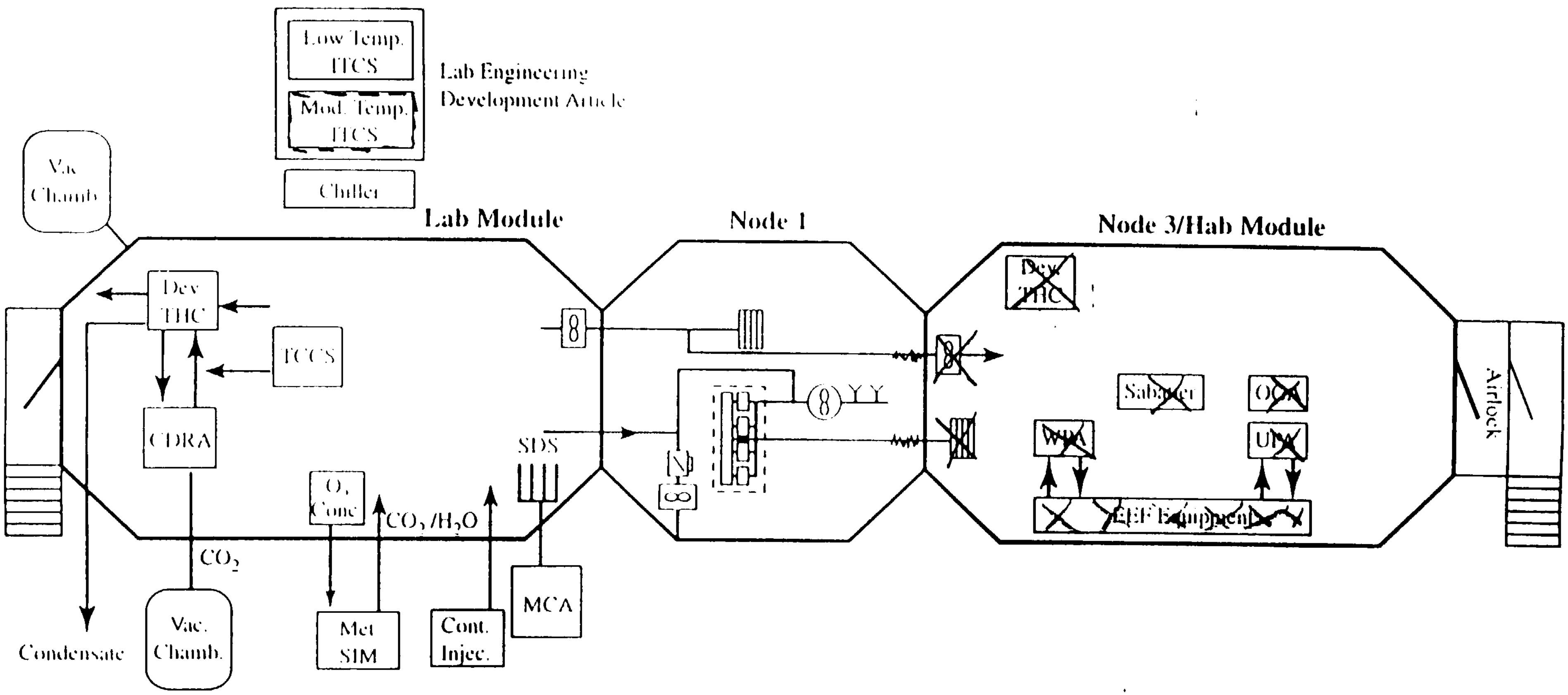
ISS Flight Configuration





~~Figure 1. BITF Floor Plan~~

ECLSS/ITCS Sustaining Engineering Test-Bed Baseline



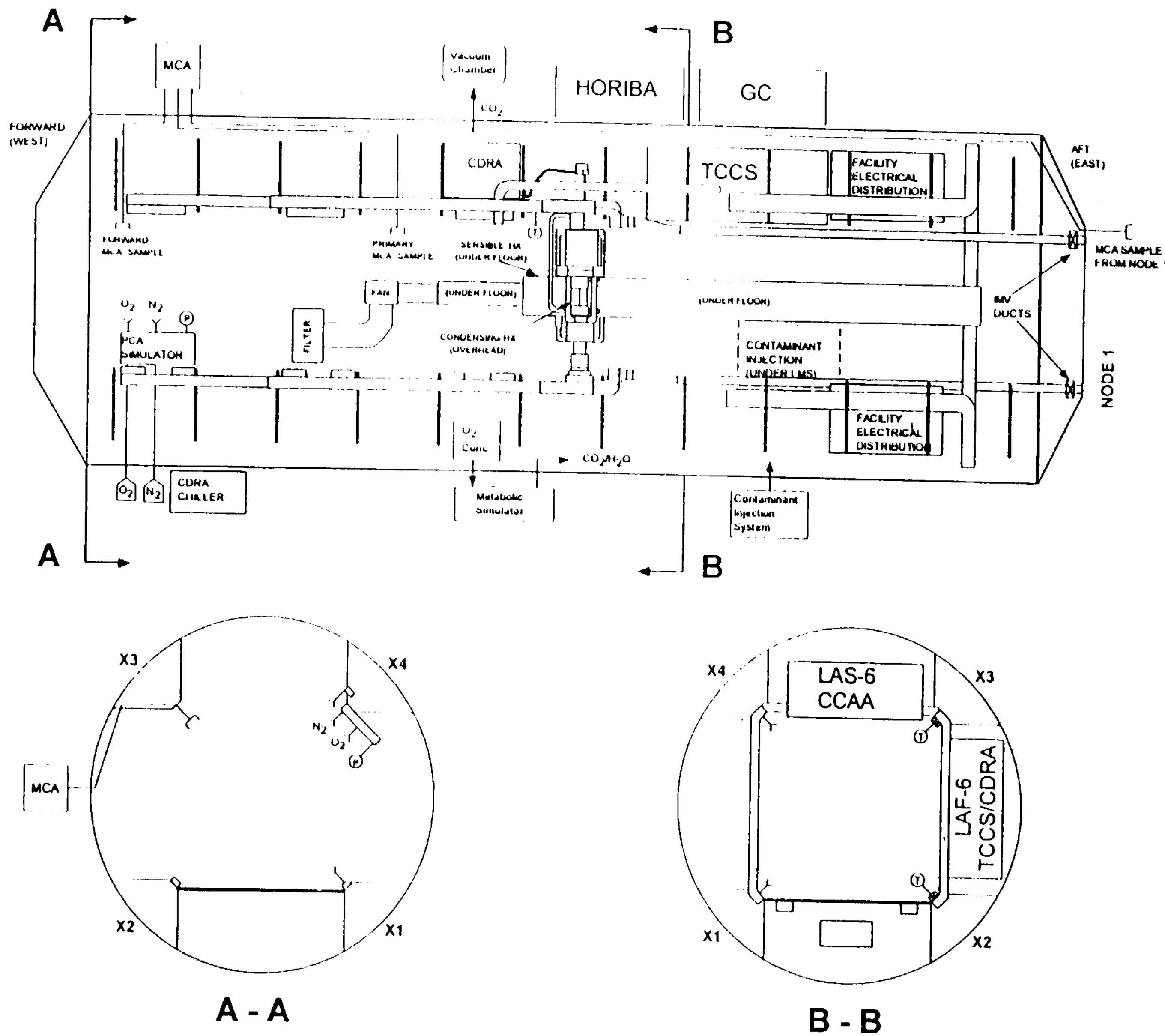


Figure 2. Simplified LMS Facility Schematic

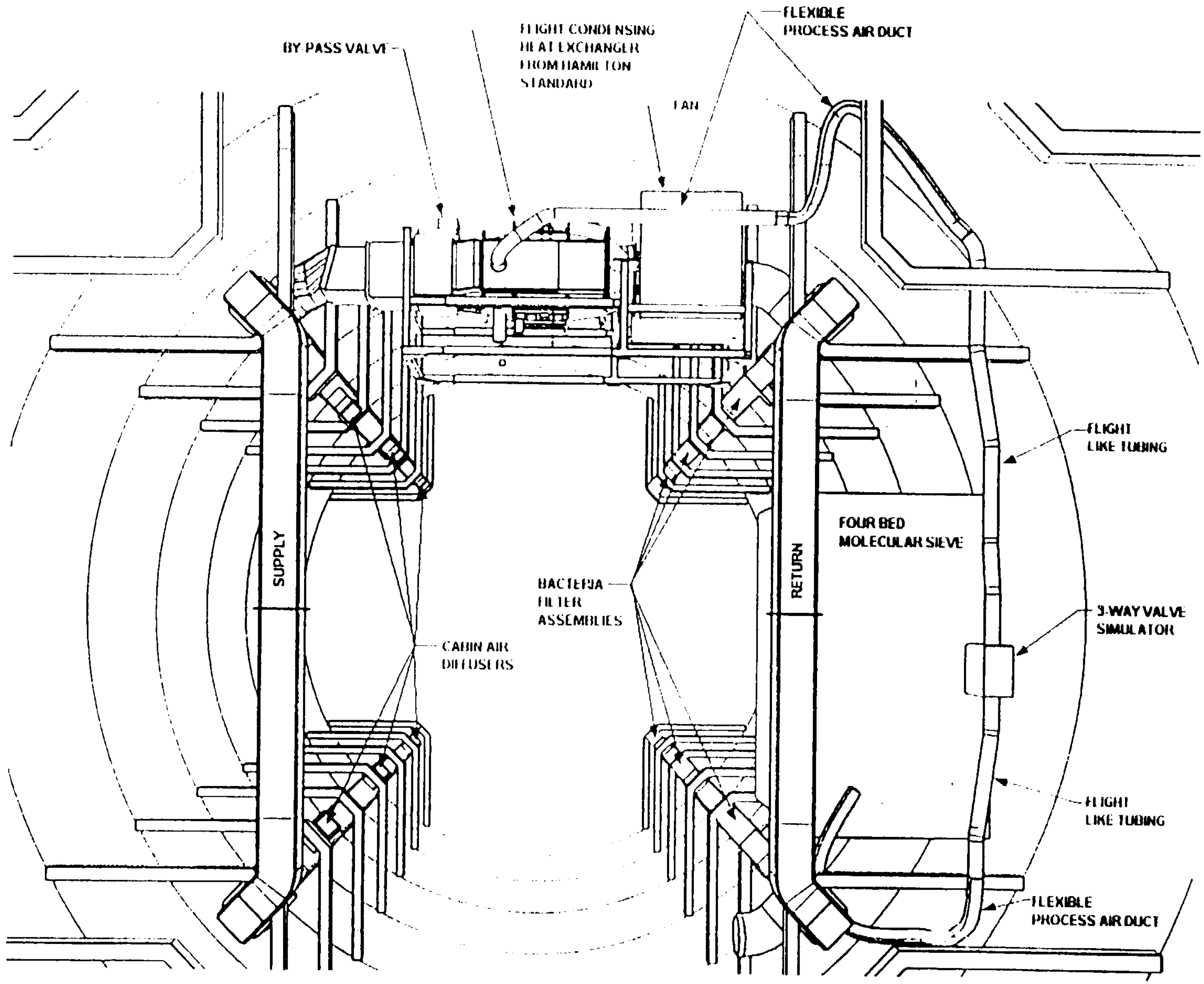


Figure 3 COMMON CABIN AIR ASSEMBLY INSTALLED IN LMS

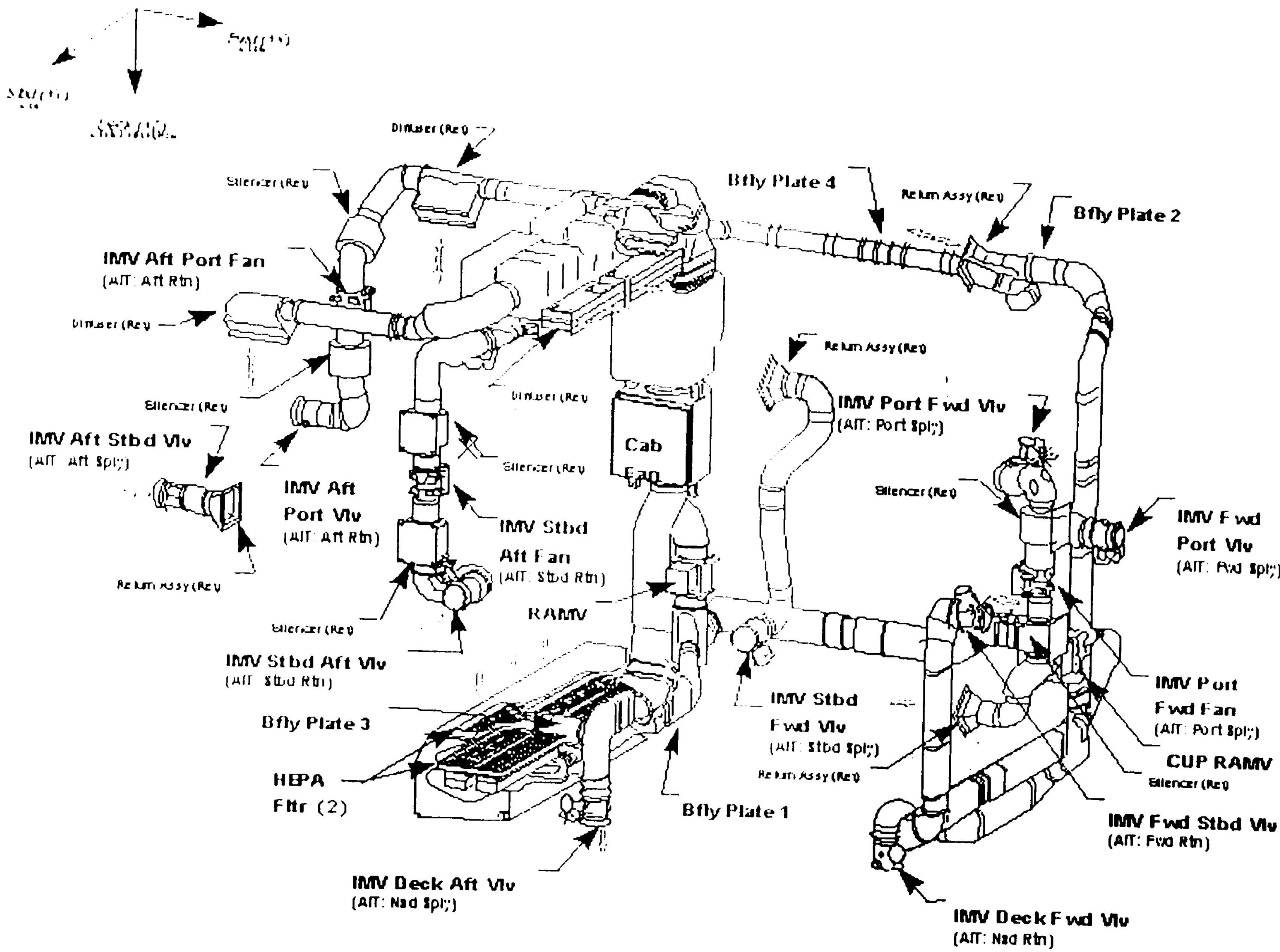
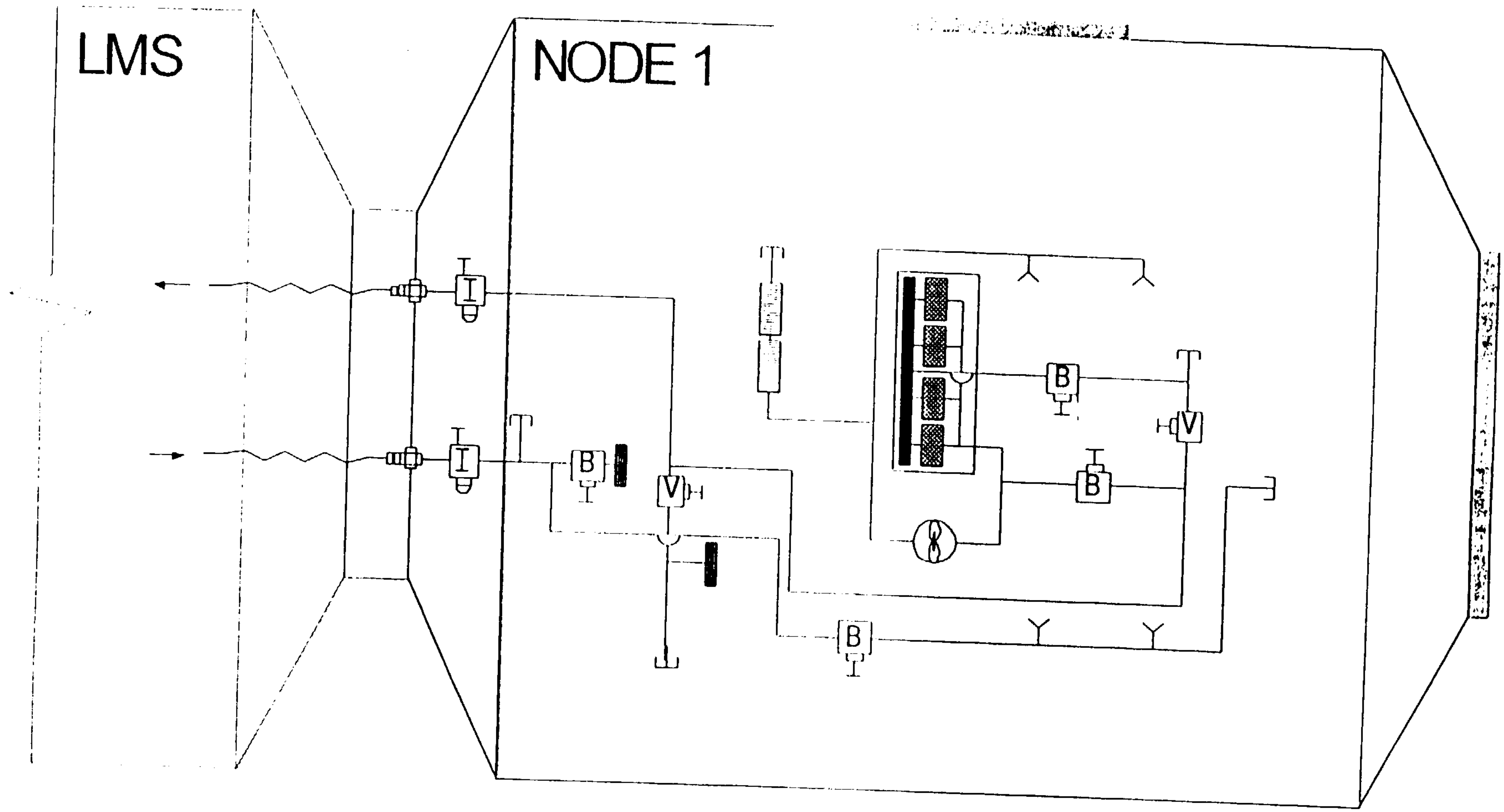


Figure 6. NODE 1 FLIGHT THC LAYOUT



B = Butterfly Valve
V = Variable Air Damper
I = IMV Valve

Figure ~~14~~. ~~Node 1 Phase 5A Schematic~~

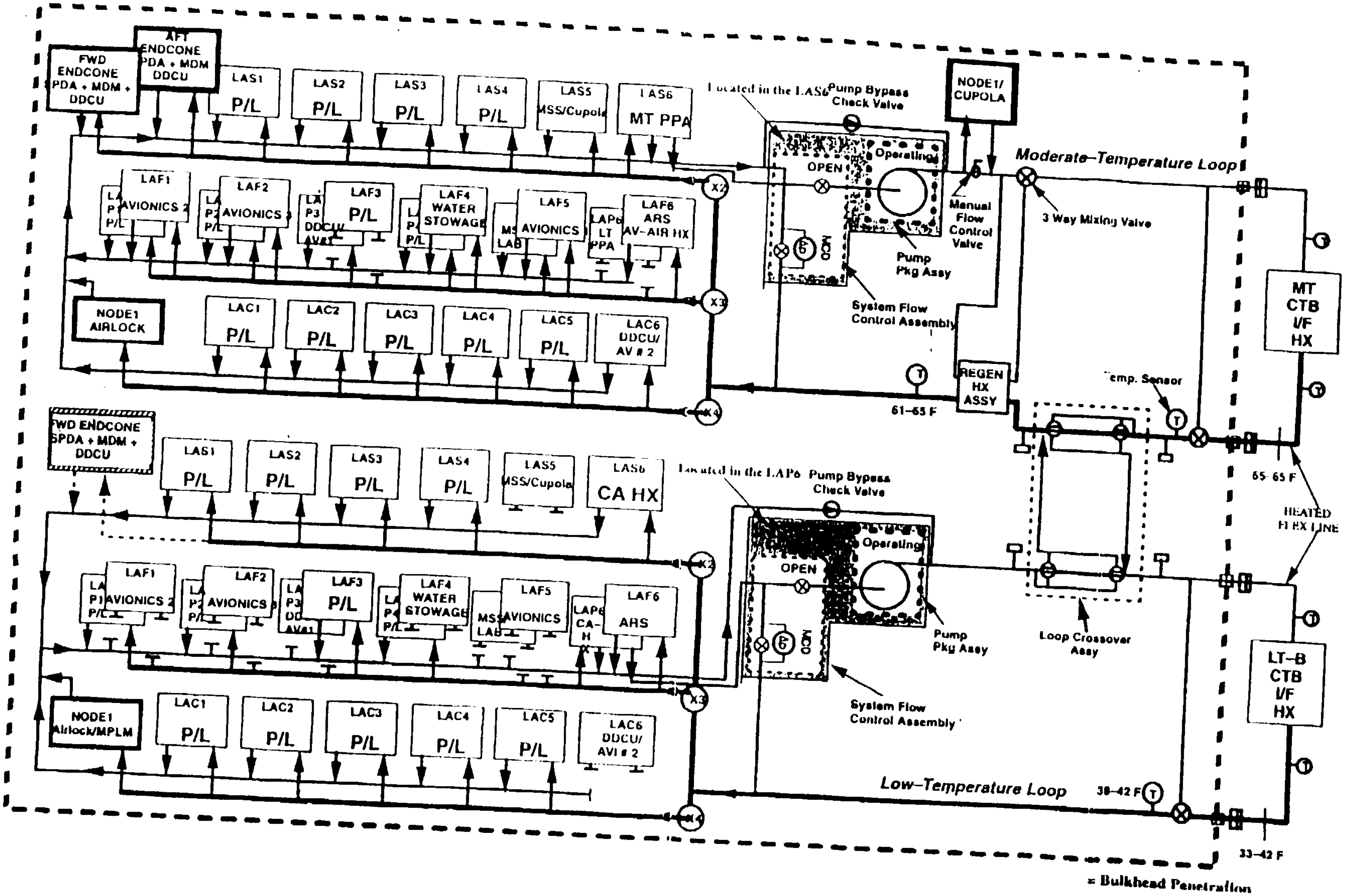


Figure 15.-ITCS in the U.S. Laboratory

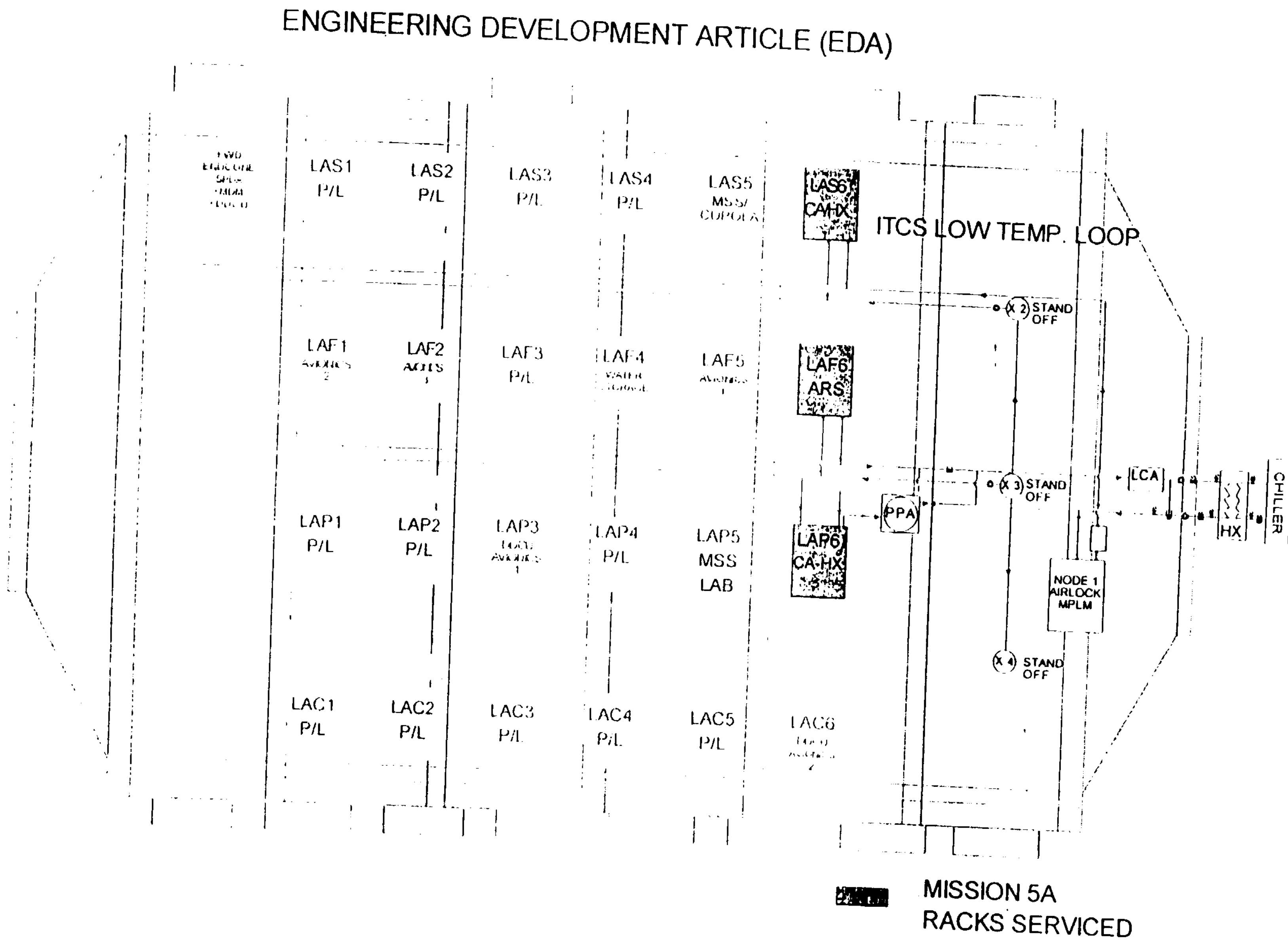


Figure [illegible]. ITCS Schematic

~~ECLSS/ITCS~~ Sustaining Engineering ~~Test-Bed~~
~~Baseline~~

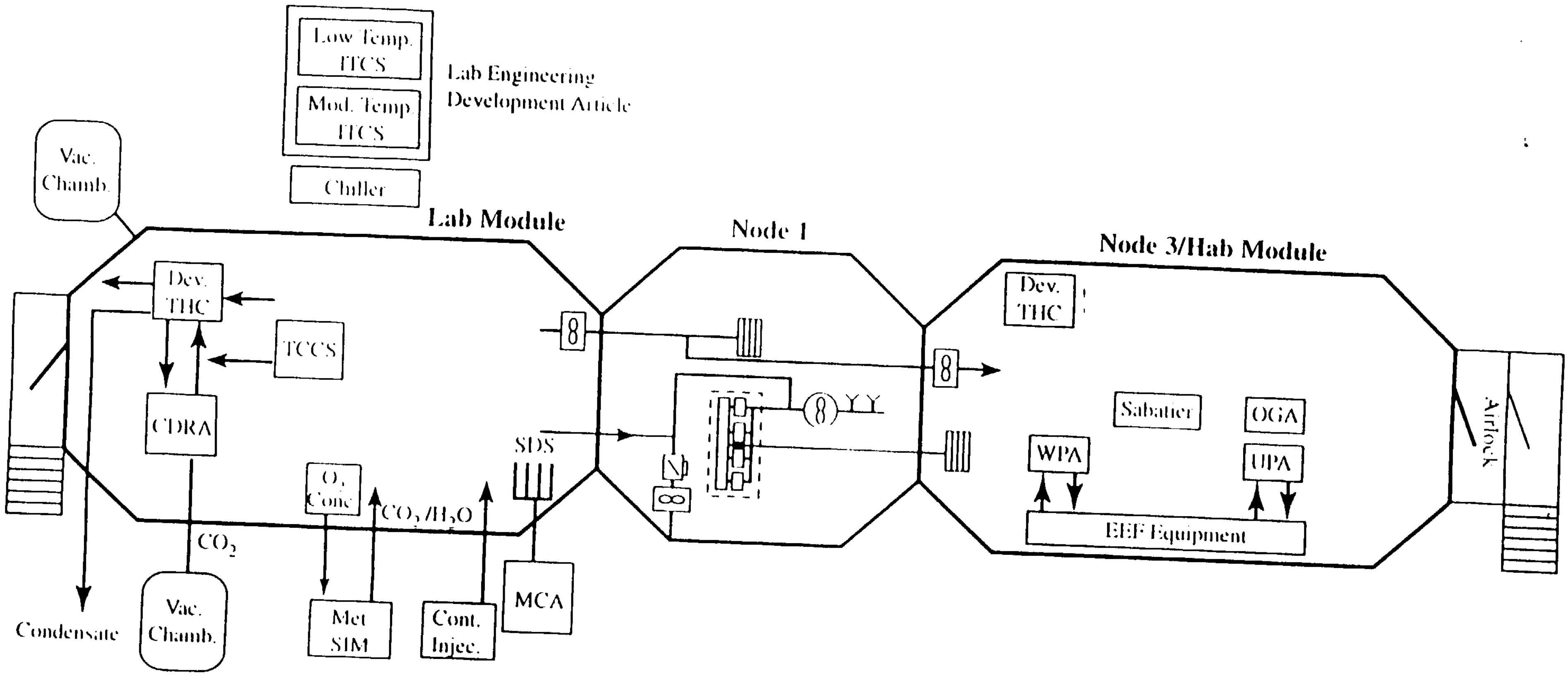


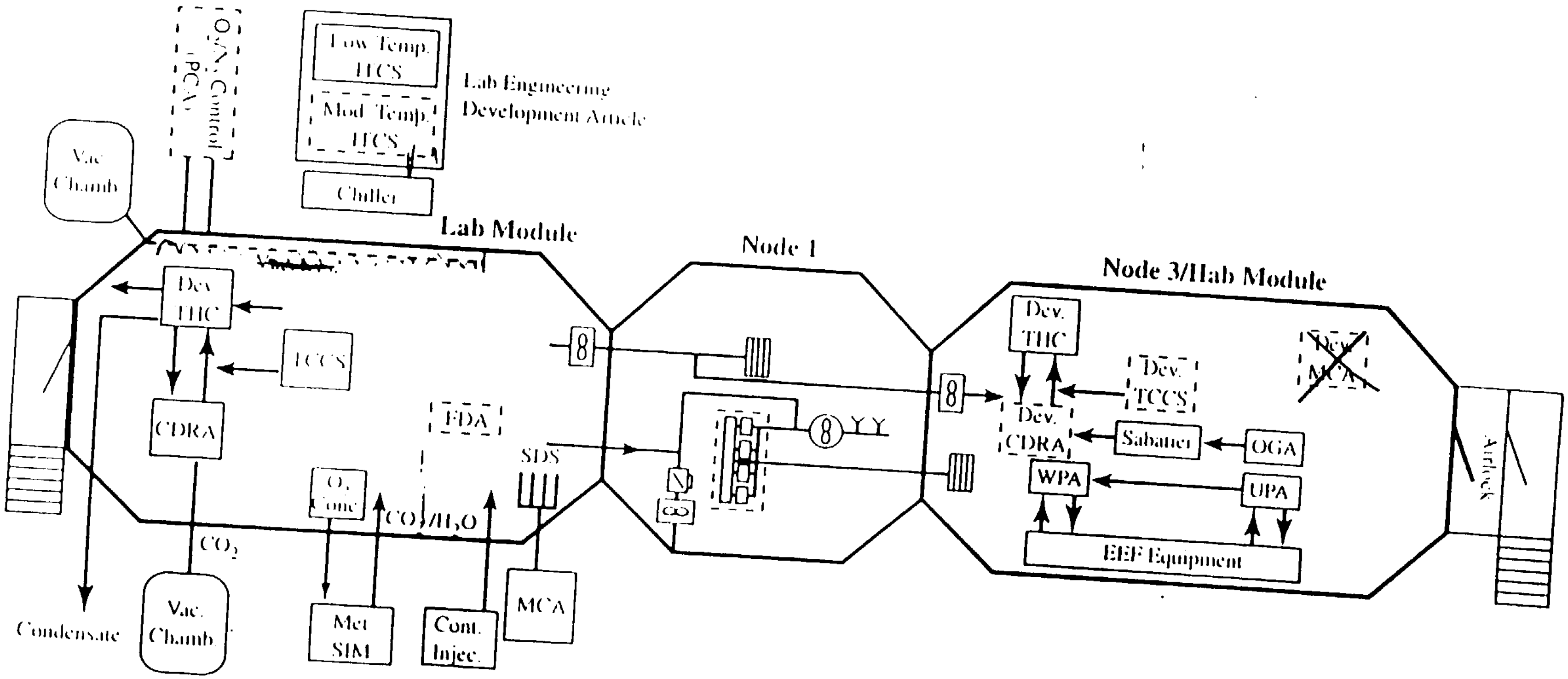
TABLE 1. ECLSS/ITCS TEST BED GROWTH OPTIONS

OPTION	DESCRIPTION
1	SIMULATION OF ACTUAL FLIGHT FREE VOLUMES
2	OUTFIT WITH BOEING DEVELOPMENT AND QUALIFICATION HARDWARE CURRENTLY ATSUBCONTRACTOR FACILITIES
3	FABRICATE NODE 2 AND AIRLOCK SIMULATOR (OUTFIT WITH THC)

TABLE 2. POTENTIAL HARDWARE OUTFITTING ITEMS

SUBYSYSTEM	OUTFITTING LOCATION
TCCS	NODE 3
CDRA	NODE 3
BACTERIA FILTER ASSEMBLIES	LMS THC
ARS 3-WAY PROCESS AIR VALVE	LMS THC
CDRA SILENCER	LMS THC
SMOKE SENSORS	LMS
PRESSURE CONTROL SYSTEM	LMS
ITCS QUAL HARDWARE • PUMP PACKAGE ASSEMBLY • RACK FLOW CONTROL ASSEMBLY • SYSTEM FLOW CONTROL ASSEMBLY • THREE WAY MIX VALVE • LOOP CROSSOVER ASSEMBLY	ITCS MOD TEMP LOOP

ECLSS/ITCS Sustaining Engineering Test-Bed Option 2

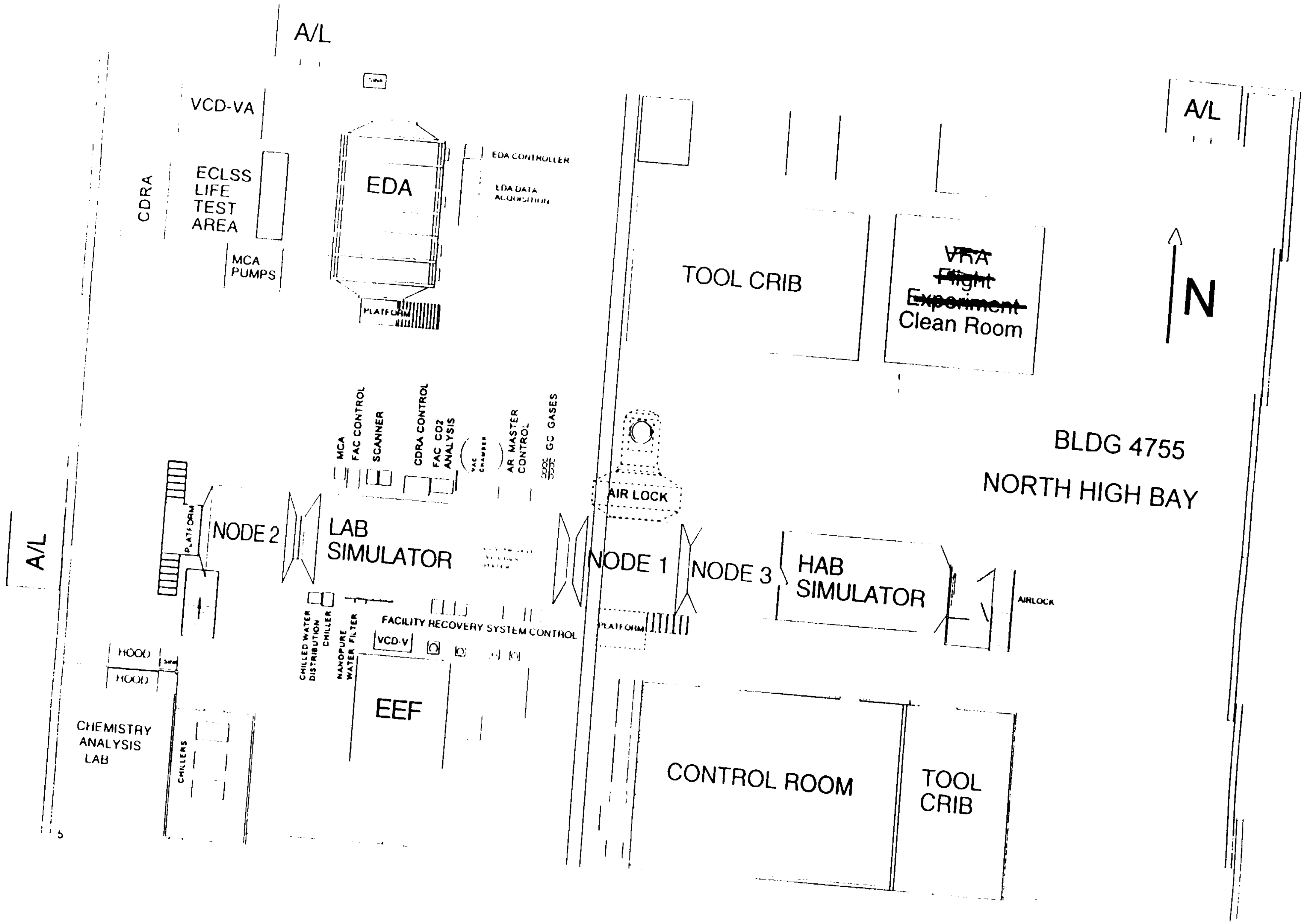


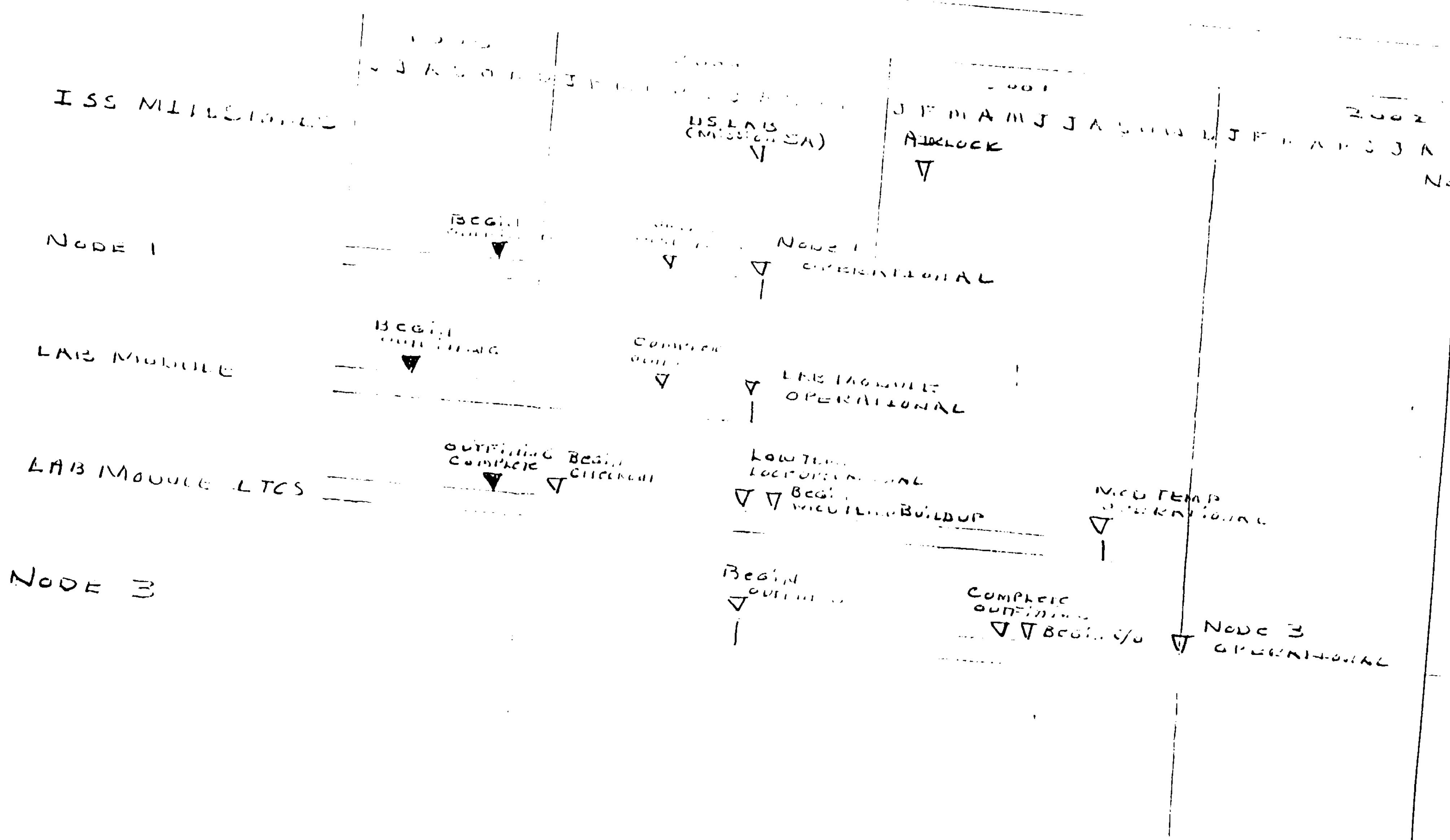
Legend:

- - - - Outfitted if released by Boeing

Table 3. Technology Readiness Levels

LEVEL	DESCRIPTION
1	Basic principals observed and reported
2	Conceptual design formulated
3	Analytical or experimental proof-of-concept
4	Concept demonstrated in a laboratory environment
5	Concept demonstrated in a relevant environment
6	Prototype demonstrated in a relevant environment
7	Prototype demonstrated in space environment
8	Flight qualified
9	Flight proven


A/L
VCD-VA
CDRA
ECLSS
LIFE
TEST
AREA
MCA
PUMPS
EDA
PLATFORM
EDA CONTROLLER
EDA DATA
ACQUISITION
TOOL CRIB
VRA
Flight
Experiment
Clean Room
A/L
N
BLDG 4755
NORTH HIGH BAY
MCA
FAC CONTROL
SCANNER
CDRA CONTROL
FAC CO2
ANALYSIS
VAC
CHAMBER
AR MASTER
CONTROL
GC GASES
AIR LOCK
A/L
PLATFORM
NODE 2
LAB
SIMULATOR
NODE 1
NODE 3
HAB
SIMULATOR
AIRLOCK
PLATFORM
CHILLED WATER
DISTRIBUTION
CHILLER
NANOPURE
WATER FILTER
FACILITY RECOVERY SYSTEM CONTROL
VCD-V
HOOD
HOOD
CHEMISTRY
ANALYSIS
LAB
CHILLERS
EEF
CONTROL ROOM
TOOL
CRIB
5



ISS MILESTONES
NODE 1
LAB MODULE
LAB MODULE LTCS
NODE 3
2001
2002
J F M A M J J A
US LAB
AIRLOCK
BEGIN
NODE 1
OPERATIONAL
BEGIN
LAB MODULE
OPERATIONAL
OUTFITTING COMPLETE
BEGIN CHECKOUT
BUILDUP
BEGIN
COMPLETE
NODE 3

National Aeronautics and Space Administration

Facsimile Transmission Cover Sheet

FROM			
NAME AND TITLE Helen Lambert		INSTALLATION HQ	OFFICE CODE
TELEPHONE NUMBER (202) 358-1859	FAX NUMBER (202) 358-3099	TOTAL PAGES *(Including lead sheet)* 34	DATE 04/26/2000

TO			
NAME AND TITLE Cynthia A. Vemmer		INSTALLATION MSFC	OFFICE CODE FD21
TELEPHONE NUMBER (256) 544-3250	FAX NUMBER (256) 544-0920		

REMARKS/ADDITIONAL ADDRESSEES

Pursuant with your conversation with Kathe Buford, I am forwarding th paperwork necessary to approve the conference attedance for ICES in Toulouse, France.

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13113	4-26	09:35	CODE ID NASA HQ	34	0°15'42"	NORMAL	OK
				34	0°15'42"		