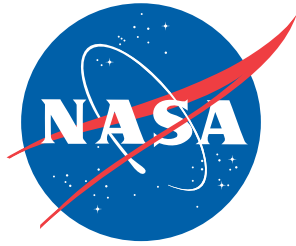


NASA/TM-2011-217151
NESC-RP-10-00629



Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)

*William H. Prosser/NESC
Langley Research Center, Hampton, Virginia*

*Eric I. Madaras
Langley Research Center, Hampton, Virginia*

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

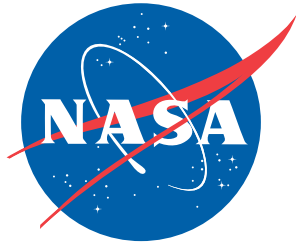
- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, and organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA STI Help Desk at 443-757-5803
- Phone the NASA STI Help Desk at 443-757-5802
- Write to:
NASA STI Help Desk
NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320

NASA/TM-2011-217151
NESC-RP-10-00629



Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)

*William H. Prosser/NESC
Langley Research Center, Hampton, Virginia*

*Eric I. Madaras
Langley Research Center, Hampton, Virginia*

National Aeronautics and
Space Administration


Langley Research Center
Hampton, Virginia 23681-2199

June 2011

The use of trademarks or names of manufacturers in the report is for accurate reporting and does not constitute an official endorsement, either expressed or implied, of such products or manufacturers by the National Aeronautics and Space Administration.


Available from:

NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320
443-757-5802

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 1 of 45	

**Development and Certification of Ultrasonic Background Noise Test
(UBNT) System for use on the
International Space Station (ISS)**

May 5, 2011

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 2 of 45	

Report Approval and Revision History

Approval and Document Revision History

Approved Version		
1.0	NESC Director	Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Dr. William Prosser, NASA Technical Fellow for Nondestructive Evaluation (NDE), LaRC	May 5, 2011



	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 3 of 45	

Table of Contents

Volume I: Technical Assessment Report

1.0	Notification and Authorization	5
2.0	Signature Page	6
3.0	Team List	7
4.0	Executive Summary	8
5.0	Assessment Plan	12
6.0	Proposed Solution	15
6.1	Proposed Hardware Solutions	16
6.2	Proposed Software Solutions	17
6.3	Proposed Certification Solutions	18
7.0	Implementation	19
7.1	UBNT Hardware Modification Implementation	19
7.1.1	RSU Transceiver Module	19
7.1.2	RSU Sensor Module	20
7.1.3	RTV142 Adhesive	24
7.2	UBNT Software Modification Implementation	25
7.2.1	RSU Flight Control Software GUI	25
7.2.2	Automatic Communications with the Transceiver.....	27
7.2.3	Verify Operations	27
7.2.4	Test Operations	28
7.2.5	Data Downloading Operations.....	29
7.2.6	Memory Management.....	30
7.3	UBNT Certification	32
7.3.1	Requirements	32
7.3.2	Certification Testing	33
7.3.3	Functional Testing	36
7.3.4	Documentation.....	37
8.0	Findings, Observation, and NESC Recommendations	39
8.1	Findings	39
8.2	Observation	39
8.3	NESC Recommendations.....	39
9.0	Alternate Viewpoints	40
10.0	Other Deliverables	40
11.0	Lessons Learned	40
12.0	Definition of Terms	40
13.0	Acronyms List	41
14.0	References	43

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 4 of 45	

List of Figures


Figure 5.0-1.	Test Concept	13
Figure 5.0-2.	Proposed Node 3 Sensor Configuration.....	14
Figure 5.0-3.	Proposed US Laboratory Sensor Configuration.....	15
Figure 7.1-1.	(a) UBNT RSU Transceiver Module, (b) UBNT USB Cable with Velcro Cable Wrap, and (c) UBNT USB Connectors	19
Figure 7.1-2.	RSU Transceiver Module Modified for an External Battery (top right) and External Antenna Connection (top left).....	20
Figure 7.1-3.	SSP WLEIDS L91 Battery Pack with External Connection.....	21
Figure 7.1-4.	RSU Module with the WLEIDS L91 External Battery and 2 m External Antenna.....	21
Figure 7.1-5.	RSU Low Frequency Response Connected to the B225.5 Sensors after 10 milli-g Acceleration Excitation.....	24
Figure 7.1-6.	RTV Syringe Dispenser	25
Figure 7.1-7.	RTV Loaded Syringe	25
Figure 7.2-1.	RSU Flight Control Software GUI	26
Figure 7.3-1.	EMI Test Results	35
Figure 7.3-2.	UBNT Drawing Tree	37

List of Tables

Table 7.1-1.	Gain/Frequency Values Model for the RSU Sensor Modules.....	23
--------------	---	----

Volume II: Appendices

Appendix A.	SDTO Flight Software Manual.....	45
-------------	----------------------------------	----

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 5 of 45	

Volume I: Technical Assessment Report


1.0 Notification and Authorization

Dr. William Prosser, NASA Technical Fellow for Nondestructive Evaluation (NDE), requested the NASA Engineering and Safety Center (NESC) to participate in the development of a Station Development Test Objective (SDTO) to characterize the ultrasonic background noise that exists in the International Space Station (ISS).

The requirement for this work was identified in the ISS Integrated Risk Management Application (IRMA), Watch Item #4669, which addresses the need for a leak detection/location system. The NESC was ideally situated to contribute to this investigation because of their history with pioneering the study of a compact, low power, high speed digitizing system known as the Distributed Impact Detection System (DIDS). These vehicle health monitoring devices were evaluated in a previous NESC assessment study and deemed to have significant potential for safety and space flight applications [ref. 1].

A joint NESC/ISS effort was proposed to the NESC as an out-of-board activity. Dr. Eric Madaras at Langley Research Center (LaRC) was selected to lead this assessment. The investigation plan was presented to the ISS Vehicle Control Board (VCB) and the NESC Review Board (NRB) and approved by the respective boards on March 31, 2010, and April 10, 2010. This report was presented to the NRB on May 5, 2011.

The key stakeholders for this assessment include the ISS Program (ISSP) and Exploration Systems Mission Directorate.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 6 of 45	

2.0 Signature Page

Submitted by:

Dr. William H. Prosser

Date


Dr. Eric I. Madaras

Date

Mr. Todd C. Hong


Date

Signatories declare the findings and observations compiled in the report are factually based from data extracted from Program/Project documents, contractor reports, and open literature, and/or generated from independently conducted tests, analysis, and inspections.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 7 of 45	

3.0 Team List

Name	Discipline	Organization
Core Team		
William Prosser	NESC Lead	LaRC/NESC
Eric Madaras	Principle Investigator	LaRC/NESB
Todd Hong	Investigation Engineering Lead	JSC/EV17
John P. Dempsey	UBNT Investigation Manager	JSC/OB
Ladessa Hicks-Jones	UBNT Investigation Lead	JSC/OB
David S. Havermalz	Investigation Engineer	JSC/EV4
Kornel Nagy	Structures and Mechanics Lead	JSC/ES
Jailin Tian	Analysis Lead	LaRC/FSSB
Aaron Trott	DIDS Lead Engineer	Invocon, Inc.
Roy Savage	MTSO Program Analyst	LaRC
Administrative Support		
Erin Moran	Technical Writer	LaRC/ATK


	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 8 of 45	

4.0 Executive Summary

As a next step in the development and implementation of an on-board leak detection and localization system on the International Space Station (ISS), there is a documented need to obtain measurements of the ultrasonic background noise levels that exist within the ISS. This need is documented in the ISS IRMA, Watch Item #4669. To address this, scientists and engineers from the Langley Research Center (LaRC) and the Johnson Space Center (JSC), proposed to the NASA Engineering and Safety Center (NESC) and the ISS Vehicle Office a joint assessment to develop a flight package as a Station Development Test Objective (SDTO) that would perform ultrasonic background noise measurements within the United States (US)-controlled ISS structure.

Formal investigation approval was received from the ISS Vehicle Control Board (VCB) and the NESC on March 31, 2010, and April 10, 2010, respectively. This investigation required the modification of existing Distributed Impact Detection System (DIDS) units (or Remote Sensor Units (RSUs)) and the acquisition of additional hardware, software modifications, and the hardware certification as a SDTO. The certification included meeting the Space Shuttle Program (SSP) 50835, *ISS Pressurized Volume Hardware Common Interface Requirements Document (CIRD)* certification, which allowed the SDTO package to be launched on any ISS-approved vehicle. A Change Request (CR) 012334 was submitted to the Space Station Program Control Board and approved on July 13, 2010, to support launching the SDTO and the operational support on the ISS once the SDTO was on orbit.

At the start of this investigation, the NESC team had six RSUs, two transceiver units, and 40 transducers that could be applied to the SDTO. The first phase involved purchasing additional hardware to satisfy the SDTO requirements. Three additional RSUs, two transceivers, and 38 flight sensor cables were procured. All of the RSU hardware and software were modified to improve their capabilities for the ISS application. The system hardware modifications made included: changing the RSU power source to allow operation on the L91 battery system that is currently in use on the SSP's Orbiter Wing Leading Edge Impact Detection System (WLEIDS) and employing an external antenna for more reliable communications. System software changes implemented included the ability to trigger the RSUs on a programmable time schedule along with a method to monitor the system's progress during the programmed triggering schedules. Other software changes involved: adding the capability to automatically open the universal serial bus (USB) port when the software's graphical user interface (GUI) was activated; increasing the number of files that could be saved in the memory by tenfold; adding a summary file handling capability to the sensor units; adding a software configuration file capability so ground-based developed files could be uploaded and executed; and developing a software application to streamline on-orbit operations.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 9 of 45	


In parallel with the hardware developments, flight unit certification was initiated to SSP 50835. Meeting SSP 50835 requirements implies by internal references meeting all the other necessary ISS certification documents. Initial tests included Offgas Testing for the hardware and adhesive materials, electromagnetic interference (EMI) emission, EMI susceptibility for the full system, and radiation susceptibility testing. Once all of the hardware was received, certification continued with Materials Certification; Thermal Analysis; Strength, Fracture, and Venting Assessment; Radio Frequency Authorization; Toxicology Assessment; Software and Hardware Support Station Computers (SSC) Integration Test; Wiring Continuity; Dielectric Withstanding Voltage and Insulation Resistance Testing; Circuit Derating Analysis; and Safety Certification.

The initial investigation plan targeted flight on SSP flight Space Transportation System (STS)-134. This required the SDTO be completed with all required certifications signed and shipped to the Kennedy Space Center (KSC) by December 19, 2010. This SDTO was ranked as a low priority, thus there was a possibility that another package with a higher priority could displace this SDTO from the flight. An opportunity was identified to make a late load on the European Space Agency's (ESA) Autonomous Transfer Vehicle (ATV)-2, scheduled to launch prior to STS-134. The remaining certification work was rescheduled, successfully accomplished, and the SDTO package was shipped to KSC on November 29, 2010, for Preship Review. The final certification documentation was signed on December 6, 2010, one week ahead of the ATV-2 late load deadline. The SDTO was shipped to Kourou, French Guiana on January 6, 2011, and was launched aboard ATV-2 on February 16, 2011. The SDTO is scheduled to start operations in the May 2011 time frame.

The initial SDTO testing will measure the noise levels in the Node 3 and the US Laboratory. Both ISS modules provide unique opportunities to characterize potential noise sources. The Node 3 module houses several life support functions: water purification system, oxygen regeneration system, air revitalization system, lavatory system, treadmill, and the standard airflow and thermal control systems. The US Laboratory has 23 rack bays that can house numerous ISS experiments including several zero gravity experiments and the standard life support systems. The systems housed within these two modules have the potential to generate ultrasonic noises into the structure. Measurements in these two modules should give a broad representation of many of the sources that might exist on other similarly manufactured US modules and future spacecraft. Subsequent to these measurements, plans are being developed to extend this SDTO (i.e., Phase II) to make similar measurements in the international partner modules.

The following NESC team findings were identified during this assessment development:

- (1) The RSU hardware and software necessary to perform an SDTO to characterize the ultrasonic background noise on the ISS was successfully acquired, modified, tested, and certified. It was installed onto ESA's ATV-2 and successfully launched on February 16, 2011. It is tentatively expected that the operational phase for the SDTO will

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 10 of 45	

begin in May 2011. Pending successful completion of this SDTO, this equipment can be re-utilized for Phase II measurements of the ultrasonic background noise in the modules of the international partners.


- (2) It was noted that there is a lack of instrumentation that can provide a controlled input signal, which can perform a simple quantitative assessment of the transducer and system's response on-orbit.
- (3) During certification testing, the RSU did not fully pass the EMI emissions and susceptibility testing.
- (4) The 2 GB Micro-Secure Data (SD) cards demonstrated radiation susceptibility during dynamic testing that translated into a mean time between failures (MTBF) of 54.6 to 473 days.
- (5) The Micro-SD cards are a pending RSU weak link as the 2 GB storage size will soon be obsolete. Obsolescence could happen within 2 years. In addition, it is noted that the RSU in its current configuration has reached numerous software, firmware, hardware, and operational limitations.

The following NESC team observations were identified in the investigation execution:

- (1) The RSUs originally procured in a previous NESC assessment [ref. 1] (two units) and the DIDS delivered under the original Small Business Innovation Research (SBIR) contract [ref. 2] (four units) were utilized for this SDTO to minimize fiscal year 2010 costs; and (2) There were requests to utilize the RSUs to support other NASA needs for Integrated Vehicle Health Monitoring (IVHM) efforts but which could not be supported because the hardware was dedicated for the flight SDTO.

The NESC recommendations identified are: (1) The ISSP should complete the SDTO Phase I data acquisition and analysis, and plan for a Phase II effort to extend the SDTO for the Ultrasonic Background Noise Tests (UBNT) to international partner modules; (2) The ISSP should assess the results of this SDTO to determine the ability to detect and locate leaks and predict damage locations; (3) The ISSP, in preparation for leak location or impact detection operations, should plan to develop a quantitative method and instrumentation to verify system operation while on orbit; (4) Future NASA RSU acquisitions that utilize the external antenna should be made with a metal enclosure to provide EMI and radiation shielding; and (5) The NASA Program offices should continue RSU improvements to address the Micro-SD card obsolescence and operational/functional flexibility to support their program needs. These include:


1. Improve the RSU data storage system by either modifying the system to read larger capacity Micro-SD cards or by installing permanent memory that would replace the Micro-SD card.
2. Improve the system's wake-up time to be less than 10 μ sec to allow the system to capture faster events and help reduce power consumption.
3. Improve the analog front-end to increase RSU flexibility for other applications and avoid

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 11 of 45	

the use of “haywires” (i.e., miniature add-on circuit boards), and provide for better filtering and clamping when using other transducer types.

4. Increase RSU program memory to allow the addition of new features involved with advanced IVHM applications.
5. Implement the automatic triggered channel identification.
6. Refine the internode synchronization to enable multiple sensor units to be synchronized, which is useful for analyzing signals covered by multiple, independent sensor units.
7. Implement fully automated command file processing to minimize/eliminate on-orbit crew interaction and to enable ground support crew to perform all system operations remotely.
8. Increase the data file acquisition length to allow the ability to continuously write data to non-volatile memory.

Overall, these improvements would greatly extend the RSU IVHM capabilities, increasing the RSU flexibility and value for future space and aeronautic applications.


	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 12 of 45	

5.0 Assessment Plan

Ultrasonic methods have been used to help detect and locate leaks and predict damage locations within geometrically simple ground-based structures [ref. 3]. To extend these methods to applications on more geometrically complex structures that support operational functions (e.g., space flight structures), several key, fundamental elements must be addressed. One primary element is an understanding of the signal-to-noise levels that exist within an operating structure. Active (i.e., noisy) structures (pumps, turbines, high speed flowing liquids) will saturate (i.e., blind) measurement systems to the critical ultrasonic signals that arise from damage or leak generated signals. Although there are low frequency accelerometer data from spacecraft structures and audible airborne noise data, to date, there are no known measurements of the ultrasonic structural borne background noise levels that have been made on orbit due to the lack of operational instrumentation or systems. This lack of operational instrumentation and equipment is the second missing element that is required [ref. 3]. This involves the need for compact, ultra low power hardware that is able to function in a space environment. Most existing instrumentation is unsatisfactory for this need. Over the past few years, a compact DIDS data acquisition system was developed under an SBIR effort, which appears to meet most of the requirements for on-orbit use. The DIDS was studied in an earlier NESC assessment [ref. 1].

The ISS maintains an integrated risk management database, the IRMA, which documents the need for having a leak location method. It is understood that the measurement system designed for the purpose of locating atmospheric leaks must have an adequate signal-to-noise level to work satisfactorily. IRMA Risk 4669 specifies the requirement to make background ultrasonic noise measurements within the ISS to characterize the necessary signal-to-noise levels that might exist within the ISS. To address this need, scientists and engineers from LaRC and JSC developed a plan to fly a set of hardware capable of making the needed ultrasonic measurements within the ISS structural wall. The system would incorporate modified RSUs that would be appropriate for such a flight investigation. This report describes the efforts to prepare the flight package to address this need. Certification and functional testing of the hardware and software for flight would represent the necessary assessment plan. Data acquired by the on-orbit UBNT will aid in the development of future leak location systems.

The initial testing with this hardware will measure the noise levels present in the Node 3 and the US Laboratory. Figure 5.0-1 shows the concept of the UBNT SDTO in operation. Both ISS modules provide unique opportunities to characterize potential noise sources. The Node 3 currently houses several life support functions and standard airflow and thermal control systems. Figure 5.0-2 shows the present planned configuration for testing in the Node 3. The US Laboratory has 23 rack bays that can house numerous ISS experiments and standard life support systems. Figure 5.0-3 shows the present planned configuration for testing in the US Laboratory. The systems housed within these two modules have the potential to generate ultrasonic noises

	<p align="center">NASA Engineering and Safety Center Technical Assessment Report</p>	<p>Document #: NESC-RP-10-00629</p>	<p>Version: 1.0</p>
<p>Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)</p>		<p>Page #: 13 of 45</p>	

into the structure. Measurements in these two modules should provide a broad representation of many of the sources that might exist on other similarly manufactured modules and future spacecraft. Subsequent to these measurements, plans are being made to extend this SDTO (Phase II) to make similar measurements in the ISS international partner modules.

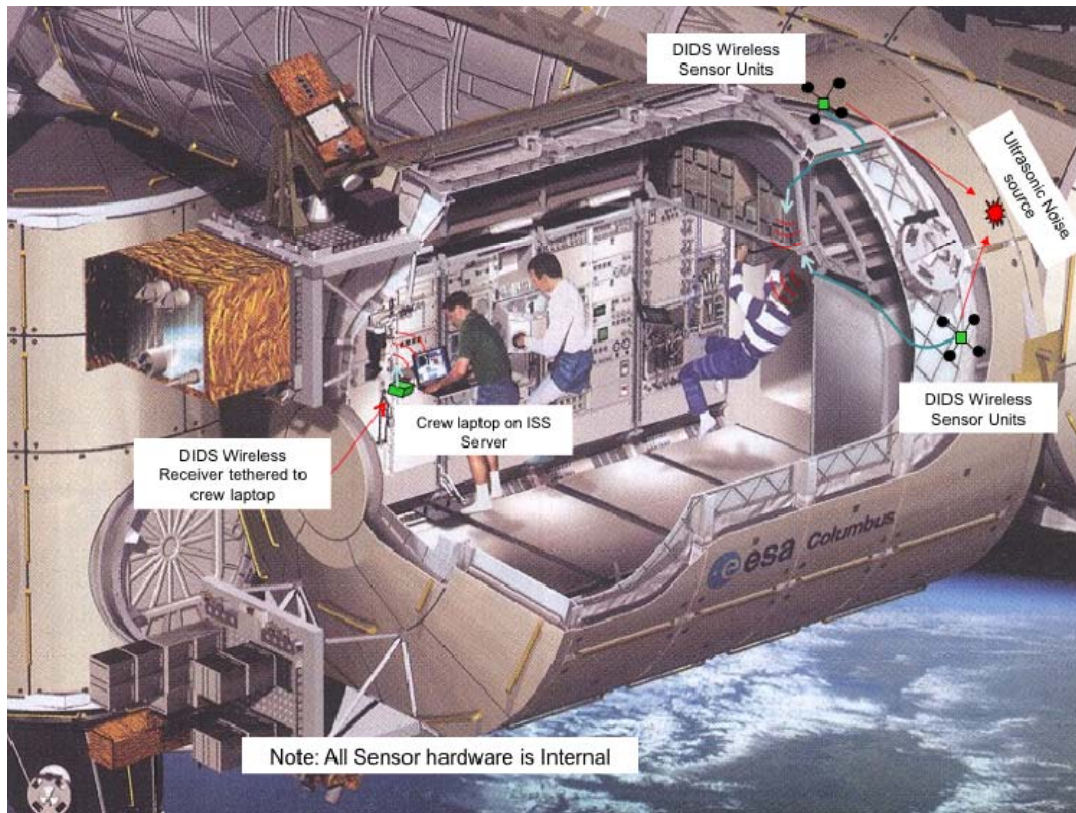


Figure 5.0-1. Test Concept



Title:

Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)

Page #:
 14 of 45

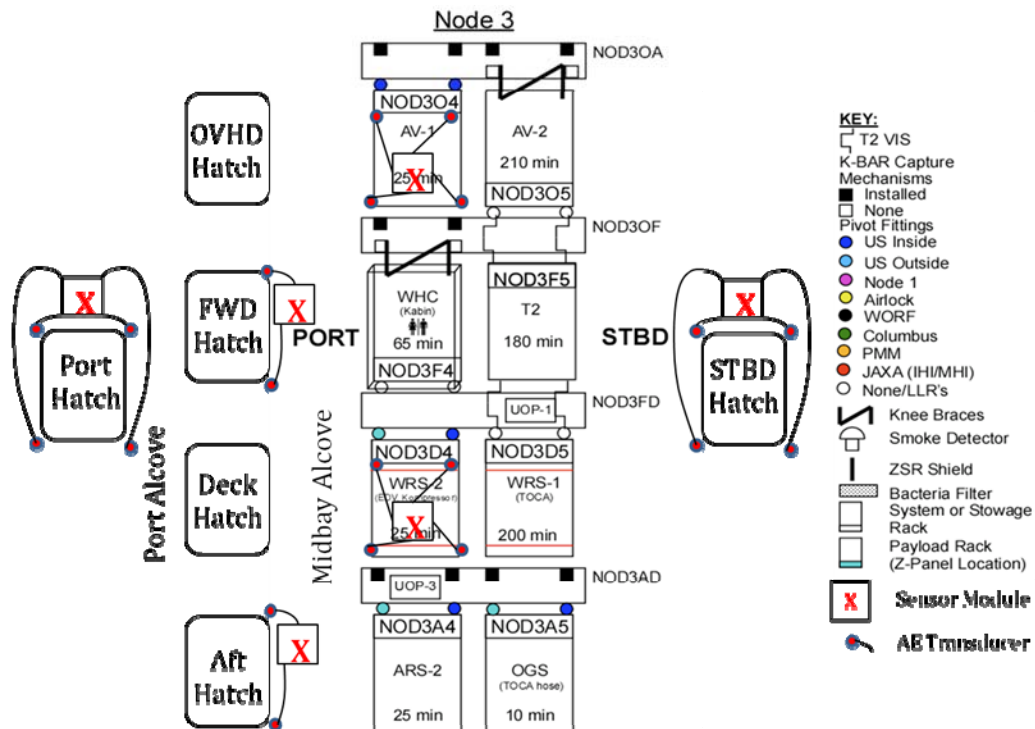



Figure 5.0-2. Proposed Node 3 Sensor Configuration

	<p align="center">NASA Engineering and Safety Center Technical Assessment Report</p>	<p>Document #: NESC-RP-10-00629</p>	<p>Version: 1.0</p>
<p>Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)</p>		<p>Page #: 15 of 45</p>	

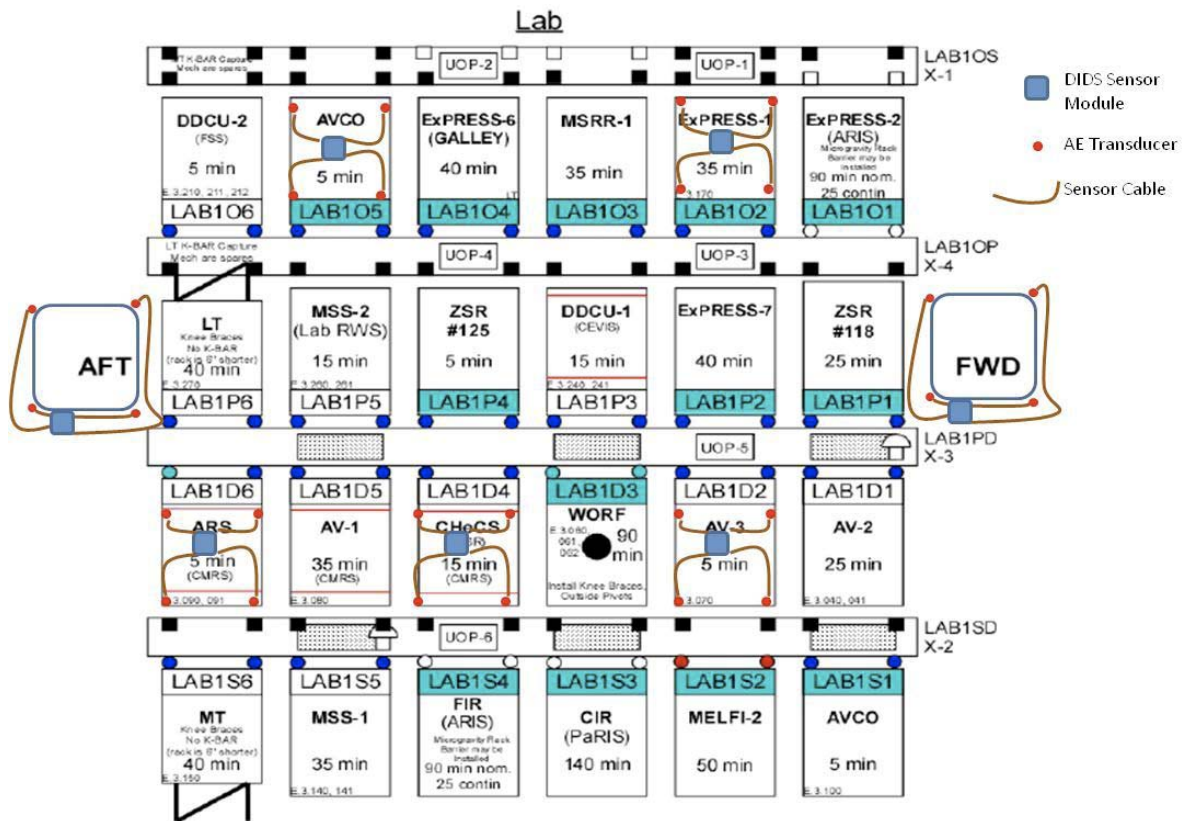



Figure 5.0-3. Proposed US Laboratory Sensor Configuration

6.0 Proposed Solution

The initial test plans for this SDTO called for nine RSUs, four transceiver units, and 38 transducers with the associated cabling. At the onset, the NESC team possessed six RSUs, two transceiver units, and 40 transducers, thus necessitating the procurement of additional hardware. In addition, modifications to the existing and new hardware were required to address several concerns. These concerns included: the safety of the internal battery (i.e., lithium (Li) thionyl chloride chemistry) used within the RSU; the internal antenna's ability to successfully transmit and receive signals from behind racks and panels; and a desire for larger memory storage capabilities and higher signal gains. There were software modifications required including more flexible triggering capability, automatic selection of the USB port on startup, and a simpler GUI. Other software modifications included the implementation of a summary data file that could be downloaded for a rapid initial evaluation, the ability to upload a configuration

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 16 of 45	

file that would automatically set test and download parameters, and increasing the number of files that could be addressed to more than 999. The configuration file was necessary to allow ground support personnel to set up tests and download data, thus reducing on-orbit crew time requirements.

Once these issues were addressed, the hardware had to undergo required flight certifications steps, which are identified in ISSP SSP 50835. Meeting these requirements would give NASA the most flexibility for launching the SDTO and simplifying the future development and certification of a leak location system based on this type of hardware.

6.1 Proposed Hardware Solutions


To satisfy hardware needs, three RSUs, two transceivers, and 38 flight sensor cables (2-meter nominal length) were purchased. In parallel with the acquisition of additional hardware, modifications to address battery, radio frequency (RF) communications, higher gain levels, and memory concerns were pursued.

The original RSUs utilized a Li thionyl chloride battery, which is prohibited from use on the ISS. To satisfy the concerns about the battery chemistry, it was decided that the RSUs would be converted to use the battery type used in SSP Orbiter WLEIDS, which are model L91 Li iron disulfide chemistry AA batteries. This battery change had several advantages. Most important, the L91 batteries meet SSP flight certification and safety requirements, making certification for the ISS easier. Secondly, the L91 batteries offer twice the battery power over the Li thionyl chloride battery. The only disadvantage to the L91 batteries was their size being too large to fit inside the RSU case. This required a modification to bring the power connector outside the case.

To improve RF communications within the ISS, it was decided to replace the internal antenna with a connector that passed through the RSU case allowing the use of a small, unobtrusive external antenna. A 2-meter long cable was specified to make the antenna connection between the RSU mounted behind a rack and the antenna mounted within the ISS corridors. This allowed near line of sight to the transceiver in the ISS module. An antenna mount was developed that would orient the antenna perpendicular to the mounting surface. Testing conducted in ISS mockups demonstrated that this orientation provided the optimum signal within ISS mockups.

The RSUs utilize Micro-SD cards for memory storage. Increasing the memory capacity consisted of replacing the existing Micro-SD cards (250 MB capacity) with a card with a larger capacity. The RSU software had, in principle, the capability to address a Micro-SD card with a 2 GB capacity, although the software had not been certified to that level.

The final hardware modification was the need for higher signal amplification (gain). The existing RSUs had a maximum low frequency gain of 15, which is sufficient for impact detection. Field tests with laboratory equipment showed that gains of 200 were a more optimal gain level for leak signals. In addition, those field tests indicated that the frequency of the leaks

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 17 of 45	

ranged from below 40 kHz to above 500 kHz, with the greatest signal levels at the lower frequency range. The gain-bandwidth product (i.e., functional constant for a given amplifier related to the power of that amplifier) occurred near 1 MHz for the gain setting of 15. The gain-bandwidth product dropped to about 700 kHz for a gain of about 25. Since the sensors being used had a bandwidth limit of about 330 kHz, the required Nyquist sampling frequency would have to be above 660 kHz. The RSU sampling rate is typically near 800 kHz, so the 700-kHz range for the gain-bandwidth product should produce an undistorted signal. Since the RSUs are based on a 16-bit digitizer (with about 14 bits of true dynamic range), their dynamic range made a gain of 25 adequate for the ISS application. This level of signal resolution along with the gain level should allow adequate detection of small and large noise levels ranging between the noise floor of the RSUs and the RSU's saturation level.

In addition to the instrumentation and software, the materials, mechanisms, and processes to install the sensors, hardware, and cabling were developed and evaluated. Materials and Processing personnel at JSC suggested that room temperature vulcanizing (RTV142) be investigated, which exhibited a low volatile organic compound (VOC) character.


6.2 Proposed Software Solutions

The DIDS was originally designed with the purpose of triggering unscheduled impact sounds. For the purposes of this SDTO, it was required that the units be configured to allow time scheduled measurements during various on-orbit activities. Hence, it was requested that Invocon, Inc. modify the software to allow the system to execute a series of triggers during specific time windows. It was decided to allow up to 16 windows of data acquisition time. In addition, the windows could be of variable time length to allow either short or long data acquisition windows, with variable times between windows. During a data acquisition window, the time between the individual triggers could be adjusted. Measurements within the Node 3 during ground certification testing indicated that a 15-second spacing minimum would be adequate for detecting mechanical noise sources. It was considered a possibility that the ISS crew might not be able to start the software in a timely manner (i.e., a scheduled test might be targeted for a specific time, but due to higher priority activities the crew might not activate the software when planned). To deal with this contingency, a software filter was added to allow a test to proceed at the next appropriate time for acquiring data.

Another issue highlighted during early testing with the RSU software was the need to manually select a USB port for the transceiver operation. Instead of manually activating the USB port, this task should be performed automatically during software startup.

The original RSUs were limited to 999 files to be acquired. With the upgraded triggering capabilities, it was desired to expand the number of files to 9,999. This accompanied the hardware modification of using a larger Micro-SD card.

The original RSU software only allowed for downloads of raw data files. If there were a

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 18 of 45	


thousand files on six or seven RSUs, downloading that amount of data would approach 6 to 7 GBs if the Micro-SD cards were nearly full. This would be a significant burden on the ISS's down link bandwidth. A method was needed to download summary data that was a fraction of the total data but could provide ground personnel a way to prioritize the files that were required for download.

In the first RSU software version, the operator set the operational steps and functions manually. For the type of testing that was being planned for the SDTO with the new triggering capabilities, manually setting the software was determined to be an unreasonable time burden for the ISS crew. This required the ability to upload a configuration file that would automatically set all of the parameters for a test or download. This configuration file could be written on ground and then uploaded to the ISS computer server so the ISS crew would only have to run the configuration file to start a test, download raw data, or download summary data.

Finally, the project required an astronaut-friendly GUI. A GUI that had only a few buttons for the ISS crew to activate was needed. When activated, the crew would see a limited number of configuration files to choose from. Once selected, the desired configuration file would open and the selected operation would be implemented automatically. The selection buttons involved were: **Verify/End Verify**, which was used for verifying the RSU hardware during installation per a configuration file; **Test/End Test**, which started a series of data taking windows per a configuration file; **Summary Download**, which downloaded the specified summary files via a configuration file; **Data Download**, which downloaded the specified data event files via a configuration file; a **Status** query to update the GUI on the system's status; and **Erase**, which allowed for the memory cards to be erased and reset. The **Erase** function was included in case there was a need to clear the memory card for more measurements, although it had the additional advantage of resetting a RSU in case a system malfunction occurred. In addition to operation of the SDTO functions, the GUI needed to provide the status of the various RSU functions.

6.3 Proposed Certification Solutions

Once the hardware/software/materials were delivered, the system had to undergo certification for flight. To minimize development costs, only the minimum safety certification tasks were proposed. An SDTO should represent a minimum level of ISS risk and those certifications required for that purpose had to be performed. Beyond that requirement, additional certifications related to environmental performance and launch survivability become trades between costs, schedule, and risks. These certifications included: EMI susceptibility; radiation susceptibility; electrical, electronic, and electromechanical (EEE) parts assessment; workmanship reviews; thermal testing; vibration testing; detailed hardware and software verification testing; and hardware and software integration testing. It was initially decided to focus on the certifications required for ISS safety and to accept the risks for the other certifications. During the development of the ISS CR to support the launch and implementation of the SDTO, it was advocated by the ISSP that, at a minimum, EMI susceptibility and radiation susceptibility testing

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP-10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 19 of 45	

be included. The ISSP requested the EMI susceptibility testing to ensure that there were reasonable expectations that the wireless systems would function in the ISS environment. The ISSP was concerned about the issue of radiation susceptibility in part because the Micro-SD memory cards had no previous ISS history. If these devices should be susceptible to radiation effects, then this vulnerability could thwart data acquisition efforts. The ISSP felt the cost of the SDTO installation and operations was sufficient to justify verifying these issues in addition to the minimum ISS safety certifications. Finally, by meeting SSP 50835 requirements for certification, the RSU system could be launched on any vehicle traveling to the ISS. This reduced schedule risks by allowing the SDTO to launch on the next available vehicle traveling to the ISS. Meeting SSP 50835 requirements implies by internal references meeting all other necessary ISS certification documents.

7.0 Implementation

7.1 UBNT Hardware Modification Implementation

7.1.1 RSU Transceiver Module

The RSU transceiver modules (Figure 7.1-1 (a)) did not require hardware modifications. The USB cable that connected the transceiver modules to the SSC (Figure 7.1-1 (b)) was a 2.62 feet USB 2.0 cable. This cable incorporates a five-pin USB Mini-B connector (Figure 7.1-1 (c)) versus the more common four-pin Mini-B connector. In addition, this cable was wrapped with Teflon[®] tape as required for flight.

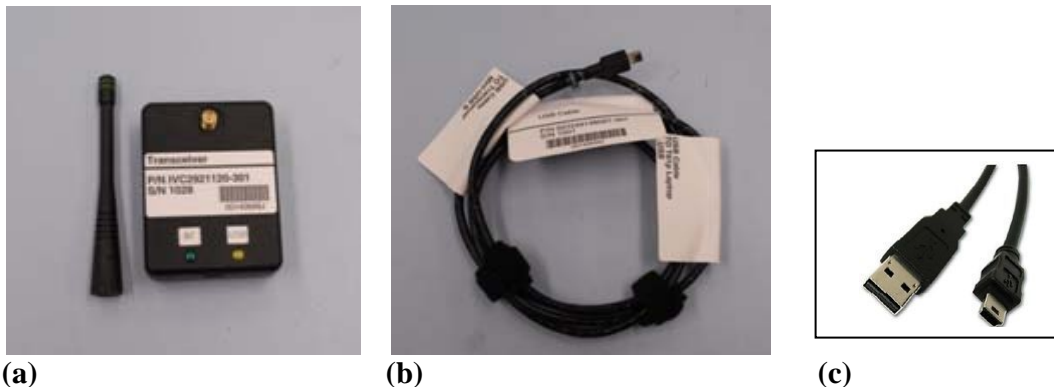



Figure 7.1-1. (a) UBNT RSU Transceiver Module, (b) UBNT USB Cable with Velcro Cable Wrap, and (c) UBNT USB Connectors

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 20 of 45	

7.1.2 RSU Sensor Module

The RSUs were modified to allow the attachment of the L91 SSP Orbiter WLEIDS batteries and the attachment of an external antenna (Figures 7.1-2, 7.1-3, and 7.1-4).

The NESC team calculated that two L91 batteries should be able to power a RSU to record and transmit approximately 10,000 event files. Each event file contains approximately 65 kB of data. Laboratory testing using commercial (Li iron disulfide type AA) batteries succeeded in recording and transmitting over 13,000 files. During ISS use, it is expected that the number of files recorded and transmitted will be fewer than calculated and demonstrated during laboratory testing. The first reason is because of the battery de-rating as a result of the required certification testing. The second reason is that some power will be consumed while in standby mode for extended time periods. A program was implemented to track the power used during the UBNT SDTO so power management and reliable data scheduling can be performed.



Figure 7.1-2. RSU Transceiver Module Modified for an External Battery (top right) and External Antenna Connection (top left)


	<p align="center">NASA Engineering and Safety Center Technical Assessment Report</p>	<p>Document #: NESC-RP-10-00629</p>	<p>Version: 1.0</p>
<p>Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)</p>		<p>Page #: 21 of 45</p>	



Figure 7.1-3. SSP WLEIDS L91 Battery Pack with External Connection

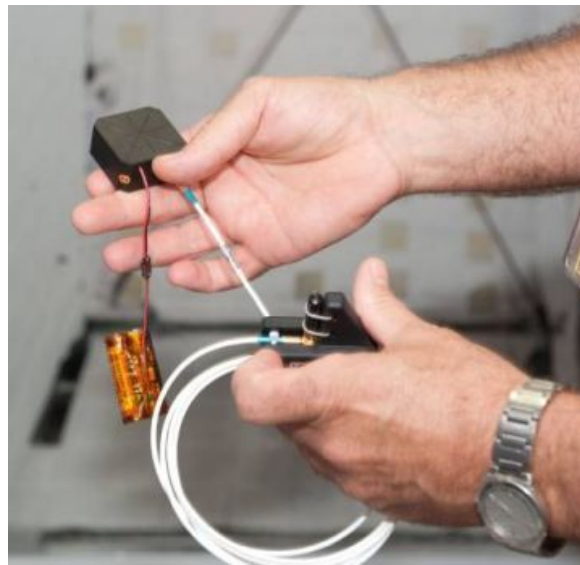



Figure 7.1-4. RSU Module with the WLEIDS L91 External Battery and 2-m External Antenna


Initial external antenna functional testing was performed with a range of relative orientations and distances between the transceiver and the external antenna to develop guidelines for the antenna installation. It was determined the optimum antenna orientation was perpendicular to a wall. A mounting bracket was developed to orient the antenna in this configuration (Figure 7.1-4). A high fidelity functional test was also performed in the Node 2 mockup. The RSU was mounted on the Node 2's pressure wall, while the antenna was installed in the corridor between two racks. Several relative transceiver and RSU antenna orientations were tested, which successfully demonstrated the RSU communications capability.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP-10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 22 of 45	

In addition, the Micro-SD card was changed to a 2 GB capacity. During functional testing, it was determined there were significant variations in the writing speed capabilities of Micro-SD cards from different manufacturers and manufacturing locations. When Micro-SD cards from different manufacturers were tested, it was found the Micro-SD cards from SanDisk[®] proved to be the most reliable in this application. It is believed that differences in data writing speeds caused the problems observed in initial testing in which some cards did not reliably store data from the system. These Micro-SD cards would hang-up during data transfer or, if writing the file took too long, the RSU software would change from trigger back to idle mode. Even with the SanDisk[®] Micro-SD cards chosen for flight, infrequently a specific Micro-SD card might not work reliably with a specific RSU. For that reason, additional functional testing was performed to verify that each Micro-SD card and each RSU worked together reliably. The testing involved writing 9,999 files onto each Micro-SD card to certify it for use with a specific RSU. These Micro-SD cards' serial numbers were recorded so that they could be assigned to their corresponding RSU on orbit.

Micro-SD card manufacturers are increasing card capacity while discontinuing cards with smaller memory. The 2 GB card size is at the limit of the RSU firmware's ability. Therefore, improving the RSU data storage system by either modifying it to read larger Micro-SD sized cards or installing permanent memory is necessary.

The final RSU modification involved increasing the system's gain. Ground testing showed that the gains achieved were 27.8 dB at the low end of the sensor's frequency range to about 25 dB at the upper end of the frequency range. Table 7.1-1 shows the modeled values of expected gains. The second column shows the ratio of the output to input, while the third column is the dB range of the second column. In addition, a test was performed with the transducers attached to a vibration table to measure the low frequency effects. Although these transducer elements are designed to work in a plate expansion mode and to operate from about 40 to 330 kHz, sometimes transducers show responses from unexpected modes at low frequencies. This could present an issue since structural vibration displacement amplitudes tend to be greater at lower frequencies. Hence, an unknown low frequency transducer response mode could lead to the capture of spurious large amplitude low frequency signals, which are not related to leak events. The RSU has a 1-kHz single pole, high-pass filter, so signals between 1 and 40 kHz were characterized to ensure that the system would be operated in the linear regime. Accelerometer testing on the ISS has measured 1 milli-g forces in the vicinity of 60 Hz, with the accelerations diminishing above approximately 200–500 Hz [ref. 4]. The results of the low frequency testing are shown in Figure 7.1-5, which shows there is an elevated sensitivity near 10 kHz, but it would require a 0.1 g acceleration to approach RSU amplifier saturation. At 10 kHz, 0.1 g acceleration is not anticipated since above 500 Hz the measured accelerations were below 0.001 g and decrease in amplitude rapidly with higher frequency. Hence, low frequency effects are not expected to be an issue.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 23 of 45	

It should be reiterated that the DIDS was initially designed as an impact detection system. It was selected for the current application because it had capabilities and flexibilities that could meet the SDTO needs. Some of DIDS limitations (e.g., the system's 10 μ sec wake-up time from the idle to active data acquisition mode (to better identify a signals phase) and the analog front-end is limited to only a few sensor types) impact its possible usage for other applications, such as piezo polymer materials (piezo-patches), and these limitations could be addressed by further modifications. Shorter activation times would allow the system to capture faster events without the interference of transient waveforms inherent in the data acquisition electronics.

Table 7.1-1. Gain/Frequency Values Model for the RSU Sensor Modules

Freq (kHz)	Gain (V_{out}/V_{in})	Gain, dB
10	24.6	27.82
20	24.8	27.89
50	24.7	27.85
100	24	27.60
200	22	26.85
300	19.6	25.85
400	17.2	24.71
500	15.4	23.75
600	13.6	22.67
700	12	21.58
800	11.1	20.91
900	10	20.00
1000	9.1	19.18



Title:

Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)

Page #:
24 of 45

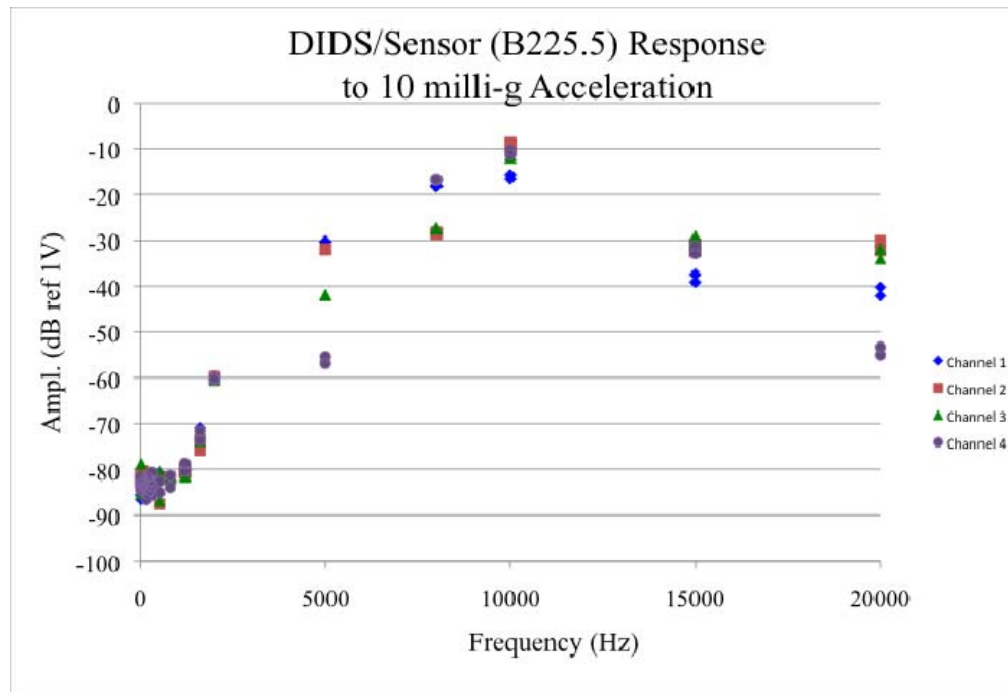



Figure 7.1-5. RSU Low Frequency Response Connected to the B225.5 Sensors after 10 milli-g Acceleration Excitation

This may help to reduce power consumption when capturing either fast or slow events because the sensor unit can wake up, gather data, and shut down faster (i.e., operate in the higher-power mode for less time). Improvements to the analog front-end to increase the unit flexibility for other applications could enable the use of additional types of transducers without having to use haywires. It could provide for better filtering and clamping for other types of transducers (e.g., piezo-patch transducers).

7.1.3 RTV142 Adhesive

In order to detect acoustic signals through the wall structure, adequate acoustic coupling between the transducer and the pressure wall is required. However, for this SDTO, a temporary transducer installation was required that would not damage the wall or leave residue. The approach developed was to first place a thin layer of Kapton[®] tape on a clean area of the pressure wall structure and then to adhesively bond the sensor to the tape. In laboratory tests, the thin layer of tape did not produce a measurable effect with this instrumentation. This approach has been successfully used for ground-based tests on SSP and ISS structural components. Kapton[®] tape was selected based on its approved use on the ISS and it does not leave adhesive residue. Materials and Processing personnel at JSC suggested that RTV142 be used to bond the sensor to

	<p align="center">NASA Engineering and Safety Center Technical Assessment Report</p>	<p>Document #: NESC-RP- 10-00629</p>	<p>Version: 1.0</p>
<p>Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)</p>		<p>Page #: 25 of 45</p>	

the tape. This RTV has a low VOC rating during the 4-hour cure, which made it more attractive than most adhesives for use on the ISS.

To control the amount of adhesive that was used for each bond and to simplify the installation procedure for the astronaut, a syringe-dispensing system was utilized. Figures 7.1-6 and 7.1-7 show the syringe dispenser and the syringe filled with RTV142, respectively. Removal of the transducer involved twisting the sensor to break this adhesive bond and then removing the tape.

Timed installation tests in the Node 2 mockup indicated that one crew member could mount and verify the hardware system with four transducers behind a rack bay in less than 25 minutes.



Figure 7.1-6. RTV Syringe Dispenser




Figure 7.1-7. RTV Loaded Syringe

7.2 UBNT Software Modification Implementation

The UBNT software application is entitled DIDSFlight.exe. This software application will be loaded on an ISS server. Any ISS SSC will be able to install and operate the software by locating and then activating the installer.

7.2.1 RSU Flight Control Software GUI

It was decided early in the investigation to update the software's GUI to simplify ISS crew operations. Figure 7.2-1 shows the RSU Flight Control Software GUI. There are two major functions visible in the streamlined GUI: the **Commands** and the **RSU** sections. The **Command** section consists of eight buttons for operating the UBNT. The **RSU** section shows the sensor

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
		Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)	

status. The original RSU software had numerous buttons that opened pull down menus that provided various options and steps that required activation or selection to start RSU testing.

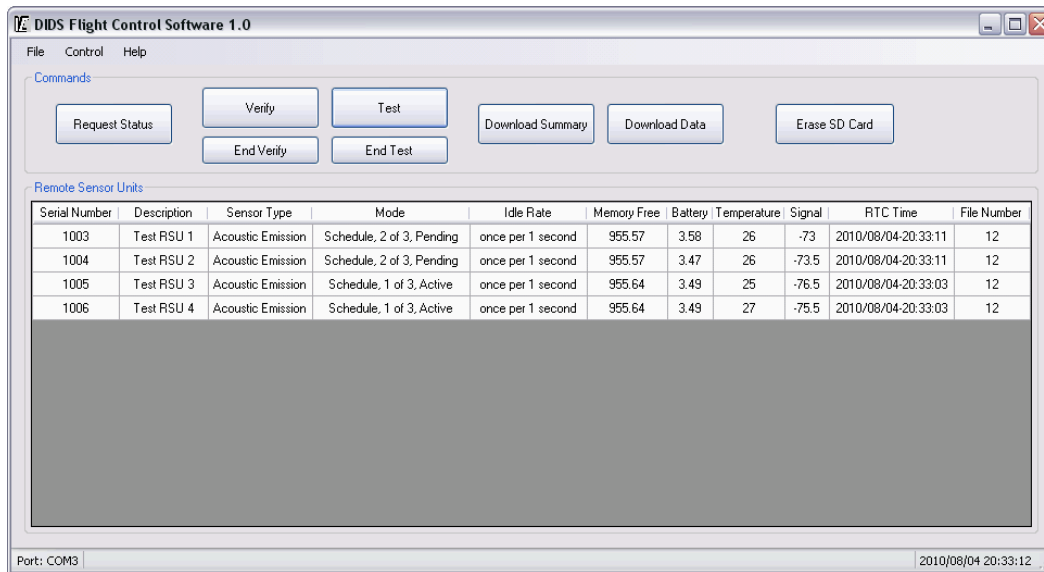



Figure 7.2-1. RSU Flight Control Software GUI

Under the **Command** section, the **Request Status** button will command selected RSUs to return their status information. The **Verify** button will put selected RSUs into the threshold trigger mode. Using this operation, the ISS crew can show that the system is operating properly by manually triggering the transducers. The crew will perform this function only during sensor installation. The **End Verify** button will change the RSUs from the trigger mode to the idle mode. The **Test** button will program selected RSUs into scheduled trigger mode for performing data acquisition. Once activated, the RSUs will run independent of the computer system and will perform their scheduled data acquisition without further computer control. The **End Test** button will allow the crew to stop the operations of the selected RSUs and return them to idle mode. The **Download Summary** button will allow summary data to be downloaded to a SSC. This data will be down linked for initial data analysis. The **Download Data** button will allow selected event data files to be downloaded to a SSC for subsequent down link to ground for detailed analysis. The **Erase SD Card** button will allow the crew to erase the memory card. Most commands will execute within a few seconds, while select commands (e.g., **Download Data**) may take a significant amount of time depending on the amount of data requested. When any of these **Command** buttons is activated, smaller status dialog windows will appear to indicate the command status as the communications with the RSUs are progressing. When the command is complete, the status dialog window will automatically disappear.

Under the **RSU** section, the status of various modes and systems are displayed for the listed RSUs. The **RSU** section's first column refers to the RSU's serial numbers, which is how

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 27 of 45	

specific RSUs are addressed. The second column refers to a **Description**, which supplies information about the test or operations underway, and will be included in the data file header for future reference. The **Sensor Type** will always be listed as **Acoustic Emission** for this UBNT SDTO since the amplifier's impedance was set up only for Acoustic Emission sensor types. The fourth column shows the **RSUs Mode**, which refers to whether the RSU is idle, in trigger mode (threshold trigger), or in scheduled trigger mode (programmed schedule trigger). The **Idle Rate** column indicates how frequently (in seconds) the RSUs will be checking RF communications. The **Memory Free** column shows the available memory (MB) on the Micro-SD card. The **Battery** column gives a measure of the battery voltage (volts), which can be an indication of the remaining battery life. The **Temperature** column indicates the RSU temperature (°C). The **Signal** column indicates how strong (dBm) of a communication link signal has been detected. The **RTC Time** is a date and time stamp indicating the latest event's date and time. Certain operations (**Verify**, **Test**, **Erase SD Card**) will reset the time to the current SSC time. The **File Number** indicates the number of files that a RSU has written on the Micro-SD card.


7.2.2 Automatic Communications with the Transceiver

In earlier RSU software versions, once the software was activated, the user first needed to manually determine which USB port was being used and then activate the port from the software. In the current version, when the software is activated, it automatically searches the USB ports to determine which one is connected to the transceiver unit. If the transceiver is not connected, then an error message will be displayed. Connecting the transceiver will clear this error message. If the transceiver is correctly connected, then the USB port number will be displayed at the bottom left side of the application's status bar for quick reference and verification that the transceiver is operating. If the transceiver should be disconnected at some point during testing, then reconnecting the transceiver will automatically allow the software to relocate the correct USB port for proper communications.

7.2.3 Verify Operations

On orbit, qualitative verification of the RSUs, transceivers, and transducer operation is performed by exciting the transducers with a signal produced by physically tapping the sensing face with a hard object. The resultant signal causes the RSU to trigger and record a signal, which can then be transmitted to the computer. This verifies: the transducer can produce an adequate signal to trigger the RSU, the RSU can successfully record data, and the RF communications are working. A controlled input signal, not available on ISS, is required to perform a quantitative assessment of the transducer and system's response. Plus, the availability of an astronaut's time to do additional verification testing steps is very limited. For these reasons, in this SDTO, it is assumed that if the system is operational, then it is performing as calibrated on the ground.

Activation of the **Verify** command will allow the ISS crew to set RSUs into the trigger mode. After selecting the **Verify** button, an open file dialog window will be available to select a **RSU**

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 28 of 45	

Configuration file. The **RSU Configuration** files contain the programming information for setting up the RSU. These files will be written on the ground and uploaded to the SSC for crew selection. Once selected, the RSUs will be displayed in the **Remote Sensor Units** section and a **RSU Status** dialog window will be opened to provide the operation status during setup. The command includes three operations: Set RTC, Program acquisition setup, and Set trigger mode. This last operation includes setting the idle rate.


The **Verify** operation can be terminated by selection of the **End Verify** button. This command sets the RSUs listed in the **Remote Sensor Units** section back to idle mode. If the RSU list is empty, then an open file dialog will be available to select a **RSU Configuration** file. Again, a **RSU Status** dialog will appear to provide the system operation status being placed into idle mode.

7.2.4 Test Operations

This command programs the RSUs into the schedule mode. The original DIDS units did not support this function. Background noise measurements are required when the environment is quiescent and active (i.e., quiet and noisy). For that purpose, threshold triggering is inadequate. If the environment is quiet, then the RSU units will not trigger because the trigger threshold signal will be too low. If the threshold trigger level is set very low, then when the environment becomes noisy, the RSU units will start to trigger too often, causing an overflow of data.

The **Schedule** mode provides a rudimentary level of control that is sufficiently flexible to capture the background noise levels by targeting ISS operational phases. The system allows up to sixteen data acquisition windows to be set. The data acquisition windows are setup by specifying the start time (date and time) and the window's duration (from 3 to 255 minutes, in one minute units). During a data acquisition window, the frequency of triggering can be set between 15 to 127 seconds per trigger. The fastest rate of 15 seconds/trigger is an approximate limitation of the RSU's ability to record and store data, and then to reset itself for the next event. The concept is to be able to plan data acquisition windows during planned ISS operations. However, the system could be set to record events throughout a day on a nearly continuous basis if desired. The system allows the RSU to be in both a scheduled and a threshold trigger mode simultaneously, in case the operator wants to try to capture loud events while recording on a regular schedule. Testing under the dual trigger mode did indicate data recording errors suggesting triggering collisions between the synchronous and asynchronous triggers. Therefore, dual trigger mode will not be used for this SDTO.

Selecting the **Test** button will open a file dialog box, which will allow selection of a **Test Configuration** file. The **Test Configuration** files will contain the programming information for setting the RSUs for data acquisition. The **Test Configuration** files will be written on the ground and uploaded to the SSC for crew selection. If a **Test Configuration** file is not uploaded in advance of a specific test or the crew cannot start a test by the appropriate time, then a software filter compares programmed data acquisition window times with the SSC clock. The

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 29 of 45	


Test Configuration file will be processed appropriately to avoid missed windows and allow remaining windows to be processed. Once selected, the RSUs will be displayed in the **Remote Sensor Units** section and a **RSU Status** dialog will be shown to provide the operation status during programming. The command includes four operations: Set RTC, Program acquisition setup, Set idle rate, and Set schedule. Once the programming operations are completed, the RSUs should be in the scheduled mode ready to acquire data. At this point, the SSC is not required for the RSUs to function. If the GUI is turned off and restarted, then a **Request Status** command will be necessary to update the **Remote Sensor Units** section to obtain the latest status information.

If the ISS crew should need to terminate a test operation, they can implement the **End Test** command to set all RSUs listed in the **Remote Sensor Units** section to the idle mode. After selecting the **End Test** button, a RSU Status dialog window will appear providing the operation status. The status dialog will automatically close upon completion.

7.2.5 Data Downloading Operations

The original RSUs only provided for downloading raw data. One method of data transfer from the RSUs to a computer is to remove the Micro-SD card and install it into a computer card reader. This can be accomplished if the RSU units are readily accessible. However, if the RSU units are behind ISS equipment racks, then this method of data transfer is impractical. The other process for downloading data requires transfer via RF link, which has the disadvantages of limited transfer rates and battery power usage. With optimal RF communications and sufficient battery power, the transfer time for a file was measured to be approximately 12 seconds. One RSU unit with 1,000 files would require between 3 to 4 hours to transfer files, which would consume a significant amount of battery power. Multiplying that time by six or seven RSUs as proposed in this investigation, means the total data download would take more than a day's time. It is expected that more than 1,000 data files per RSU unit will be acquired in this SDTO, so the time impact would be greater. The download process does not require ISS crew oversight, but it would require a computer to be operational during that time. Furthermore, it is not expected that all of the data acquired will be of immediate interest. Only a fraction of the data will be required to obtain an understanding of the ISS background noise levels. However, it is not known a priori at which instances the important data will occur, so the system will be required to be programmed to record substantial amounts of data to capture the few important times when the noise levels are at their maximum.

To address these data constraints, it was decided to emulate the process used by the SSP Orbiter WLEIDS. The WLEIDS system records data continuously for a number of minutes starting with launch and running until the external tank has been jettisoned. The goal is to detect impact signals that are only a few milliseconds in duration. The system captures several gigabytes of data during launch and ascent, yet the SSP Orbiter's downlink capabilities are limited. Hence, a system was developed to download summary files that are only a few kilobytes of data. Based

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 30 of 45	


on the summary file review, the complete time history data for only a few larger amplitude signals of interest are downloaded and reviewed for possible impact signals.

The RSU firmware was modified to write both a data file and a data summary file for each event. A data file is approximately 65 kB, while the summary file is only a few bytes containing header information including the Peak and the RMS values for the four recorded RSU channels. The GUI has a command button to download the summary data. Once activated an open file dialog window will be available to select a **RSU Download Summary List**, which will have been uplinked to the ISS. Once selected, the RSUs will be displayed in the **RSU list** and the **RSU Status** dialog will display the operation status. The command includes three operations: Request Status, Request Configuration, and Download. The system will download a summary file for each file requested in the **Summary Configuration File**. Once downloaded to a SSC, the software will write a single file with tabulated summary data from each RSU. In addition, a Download List Extensible Markup Language (XML) file with all file numbers listed in the Summary Combined file will be generated for each RSU. The Download List XML file can be modified into a Download Data Configuration file specifying the specific data files to be downloaded. This process simplifies the programming of a Download Data Configuration file. Both the Summary Combined file and the Download List XML file will be down linked for evaluation and development of the Download List Configuration file that will need to be uplinked to the ISS.

The Download Data command will download the requested event files. Once the Download Data button is activated, an open file dialog window will be available to select a RSU Download List Configuration file. Once selected, the RSUs will be displayed in the RSU list and the RSU Status dialog window will be shown to provide the operation status. The status dialog window will show how much time has been spent on downloading each RSU. The downloaded files can be converted to engineering units and exported to comma-separated values (CSV) text files. The raw data files will be down linked for processing. During downloading of summary data and event data, the RSU activity and error log files will be down linked for review, if desired.

7.2.6 Memory Management

The original RSUs only allowed for 999 files to be written to the Micro-SD card. The limitation exists due to a file naming limitation of 8 characters per file name. As five of the characters were dedicated to the RSU serial number naming convention, only three characters were available for numbering. This feature was modified to allow for four characters to be used for numbering, allowing 9,999 files to be written. This new feature required that the Micro-SD card to be increased to 1 GB or larger. The firmware had an upper limitation on the addressable memory size of 2 GB. Since memory card sizes have been increasing, it is becoming difficult to find the smaller memory cards, so it was decided to certify the usage of 2 GB cards. The operational impact is that the files now require more time to write than they did for the original 250 MB cards. The original speed for recording a file was approximately 5 seconds to record,


	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 31 of 45	

store, and reset the RSU. Now the approximate recording cycle time is approximately 12 seconds.

It should be emphasized that there is no data backup for the current configuration. Only the data that is down linked will be backed up. Once data is down linked, the files on the SSC will be purged. A second set of Micro-SD cards was included in the SDTO package to provide contingency for extra memory. The plan is to trade the Micro-SD cards with spares in between the transition from setup in the Node 3 to the US Laboratory to help ensure that the data requirements on orbit are not exceeded during the SDTO operations. It is desired to recover these Micro-SD cards, which is difficult in the present space flight system environment (i.e., limited down mass opportunities).

Given the limited memory options, it was decided that the erase files command should be made available to the ISS crew in case it became necessary to clear the memory during this SDTO. This operation allows commanding units that are in the idle mode to: erase all files, format the memory cards, perform a reset, and return their status information. After selecting the **Erase SD Card** button, an open file dialog window will be available to select a **RSU Configuration** file. After a file is selected, the RSUs and a warning dialog will be displayed requesting confirmation that the Erase SD Card action is intended. If the crew decides to proceed, the **RSU Status** dialog will provide the operation status. Set RTC and Set idle rate will be performed immediately after the data is erased and reset performed on the units. When the operation completes, **Idle Rate**, **Memory Free**, **RTC Time**, and **File Number** columns will be updated to match the RSU status. The **File Number** will be zero for units that are in the idle mode.

While these software modifications have greatly increased the RSU capabilities, there are several software and firmware issues that should be highlighted. First, the RSU program memory for the internal operation of the sensor units has reached its limitations. No additional algorithms can be added without deleting or losing other capabilities. Secondly, the system does not fully implement automated command file processing. The utilized operational method simplifies the operations the ISS crew must implement, but the system does not allow fully autonomous operation. Crew action is required to start and stop the software. This capability exists in other Invocon, Inc. systems (e.g., the SSP WLEIDS and the External Wireless Instrumentation System (EWIS)). Fully automated command file processing would enable the ground to perform system operations remotely. Third, the data file lengths are fixed. There may be other applications where having flexibility in the recorded data lengths might be required. The EWIS and Internal Wireless Instrumentation System (IWIS™) that are on ISS have this capability. If the RSU had the ability to continuously write data to non-volatile memory, then it would significantly expand the applications for which a RSU could be used. Presently, each acquisition is 8,192 samples long. In many cases, longer acquisitions are desired or required. Adding this capability would be primarily focused on upgrading the field-programmable gate array code with the result that data could be continuously streamed to the SD card until the available memory is depleted.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 32 of 45	

Finally, with regard to the use of the DIDS for an impact detection system, it should be reiterated from the NESC report [ref. 2] that two features impact the accuracy and ease of use. One issue is the poor internode synchronization between DIDS units. For this investigation, that is not an issue, as the sensors are synchronized before each test, but it does become an issue for long testing or sensing operations (i.e., waiting for days for an impact signal). Once set up, these units are autonomous from each other so that if the timing of one unit drifts with respect to a second unit, data correction cannot occur. Modifying the RSU by refining the internode synchronization would enable multiple sensor units to be synchronized based on when they are triggered via an input waveform. This is useful for integrating and analyzing a signal covered by multiple sensor units. Secondly, for purposes of impact location, it would be helpful if the software could identify the triggering channel. This is not an issue that affects this SDTO effort.


7.3 UBNT Certification

7.3.1 Requirements

In 2008, the ISSP developed SSP 50835, which outlined the requirements for payload to be launched on any ISS-approved vehicle. It was decided to certify the equipment for this SDTO to these requirements. By increasing launch flexibility, the SDTO's schedule risks were reduced. Another benefit for meeting SSP 50835 requirements is that it would help simplify possible future development and certification of a leak location system that might be based on this type of hardware. Meeting SSP 50835 requirements implies by internal references meeting the necessary ISS certification documents.

The initial target vehicle was the SSP flight STS-134, which was initially scheduled for launch in the second half of February 2011. To launch on that flight, this SDTO package needed to be completed with the required certifications approved and shipped to KSC by December 19, 2010. By October 2010 this SDTO had secured a place on the payload manifest for STS-134, but this activity was not listed as a high priority payload compared to other manifested hardware. An opportunity to be included as a late load on ESA's ATV-2 vehicle was identified as an alternate launch vehicle. The schedule requirement for launch on the ATV-2 flight was to have the hardware and required certifications approved and shipped to KSC by December 10, 2010. The team shipped the SDTO package on November 26, 2010, and obtained the final approval on the certification documents on December 6, 2010. At KSC, a Preship Review was completed and the SDTO package was then delivered to the Arianespace's Spaceport in Kourou, French Guiana on January 6, 2011, for integration onto ATV-2.

An SDTO should represent a minimum level of risk to the ISS and those certifications required for that purpose are mandatory for completion. Beyond these ISS safety certifications, additional certifications became a trade between cost, schedule, and performance risks. To minimize development costs, only the minimum certification tasks were proposed. It was initially decided to focus on the certifications required for ISS safety and to accept the risks of not performing

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 33 of 45	


additional certifications. Formal reviews (e.g., Preliminary Design Review, Critical Design Review and System Test Review) and certifications (e.g., EMI susceptibility and radiation susceptibility, thermal and vibration testing, comprehensive hardware and software verification and integration testing, and EEE parts reviews) are significant cost drivers. During the development of the ISS CR 012334, it was directed by the ISSP that EMI susceptibility and radiation susceptibility testing should be included. The ISSP requested the EMI susceptibility testing to ensure that there were reasonable expectations the wireless systems would function in the ISS environment. The ISSP was concerned about the issue of radiation susceptibility in part because the RSU Micro-SD memory cards had no previous ISS use history. If they were susceptible to radiation effects, this could prevent acquisition of data. The ISSP felt the cost of the SDTO installation and operations was sufficient to justify verifying these two issues in addition to the originally proposed SDTO safety certifications.

7.3.2 Certification Testing

To meet the flight deadline schedule, efforts were made to perform certification testing in parallel with the system modifications being performed. Items, such as the WLEIDS L91 battery packs, which were already available and were certified for the SSP, had their certification documents adapted or converted to ISS certification documents where possible. The L91 battery packs were modified by having an additional Nomex[®] covering, which caused the battery packs to require recertification for off gas products.

Materials such as the RTV142 adhesive started undergoing certification immediately. The Toxicology group at JSC issued a report on the RTV142 offgas products [ref. 5]. Testing showed that 454 mg of RTV142 produced 1.2 mg of methanol or propylene glycol and 9.8 mg of siloxanes during the first 24 hours. After 9 days, additional siloxanes were emitted for a total of 21 mg. The generation of all alcohols is regulated on the ISS because of their deleterious effects on filters in the Water Processing Assembly (WPA). Therefore, a VOC Usage Agreement (VUA) was required [ref. 6]. The agreement required that the SDTO would not release more than 10 mg/day. This equated to the installation of about 14 transducers per day maximum. The toxicology report indicated that the level of siloxanes would not present any problems provided the SDTO did not exceed more than 300 transducer bonds per 6-month increments on the ISS. As this SDTO only planned to make 52 bonds total, this limit will not be violated.

To start the certification process, Invocon, Inc. agreed to deliver two RSUs with the required hardware modifications (but lacking software modifications) as early as possible. Those units were used to begin off gas and EMI testing. The off gas testing was performed at the JSC-White Sands Test Facility (WSTF) at the end of August 2010. The testing involved a RSU, including RSU sensor unit, transceiver, transducers (4), transducer cables (4), antenna extension cable, antenna mount, USB data cable, battery pack, Micro-SD card, and adhesive syringe dispenser. As mentioned previously, at this time a separate offgas test was also performed on the battery


	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 34 of 45	

pack, which addressed the addition of Nomex[®] among other issues. The UBNT kits passed this test. The Toxicology group at JSC issued a toxicology assessment memorandum for the Energizer[®] L91 Li iron disulfide batteries [ref. 7].

EMI testing began in early August 2010. The test involved a RSU, including RSU sensor unit, transceiver, transducer, transducer cable, antenna extension cable, antenna mount, USB data cable, battery pack, and a 1 GB Micro-SD Card. The emission tests spanned frequencies from 14 kHz through 10 GHz. Results [ref. 4] are presented in graphical form in Figure 7.3-1. The RSU emissions threshold limitations are indicated in the graph showing that the hardware fails the EMI test at about three frequencies near 100 kHz. It was reported that these failures did not cause concern because there were no receivers at these frequencies on ISS [ref. 8]. A Radio Frequency Authorization Report and a Tailoring Interpretation Agreement (TIA) [refs. 9, 10] were generated as required from the Station Electromagnetic Effect Board (SEEB) to approve these exceedances. With respect to susceptibility testing, there were several frequencies where the RSU failed the EMI susceptibility testing [ref. 4]. These frequencies are where known transmitter frequencies exist on ISS and from other space vehicles that might operate nearby, which could be a concern. These issues would be mitigated if the RSUs were to have a metallic enclosure rather than the Delrin[®] case.

At the point of this testing, resources and time were not available to modify the enclosure, so the investigation pursued other means to mitigate those risks. The method to mitigate the risks will be via procedure changes. For example, the RSUs use the same communication frequency as the ISS IWIS[™]. While the communication links are coded, the IWIS[™] is a more powerful transmitter so it could interfere with the RSU. In this case, a procedure was established to ensure the two systems do not operate at the same time, avoiding the potential conflict. A similar process will be applied to other frequency conflicts to limit the risks.

After the EMI testing was completed, it was determined there was a need to change the Micro-SD card capacity from 1 to 2 GB, and to switch manufacturers to obtain better quality cards. For that hardware change, an assessment of similarity certification was performed. The USB cable was verified for continuity, dielectric withstanding voltage, and insulation resistance. A de-rating analysis of the circuit protection devices of the WLEIDS L91 battery pack was performed and the equipment passed that analysis.

	<p align="center">NASA Engineering and Safety Center Technical Assessment Report</p>	<p>Document #: NESC-RP-10-00629</p>	<p>Version: 1.0</p>
<p>Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)</p>			<p>Page #: 35 of 45</p>

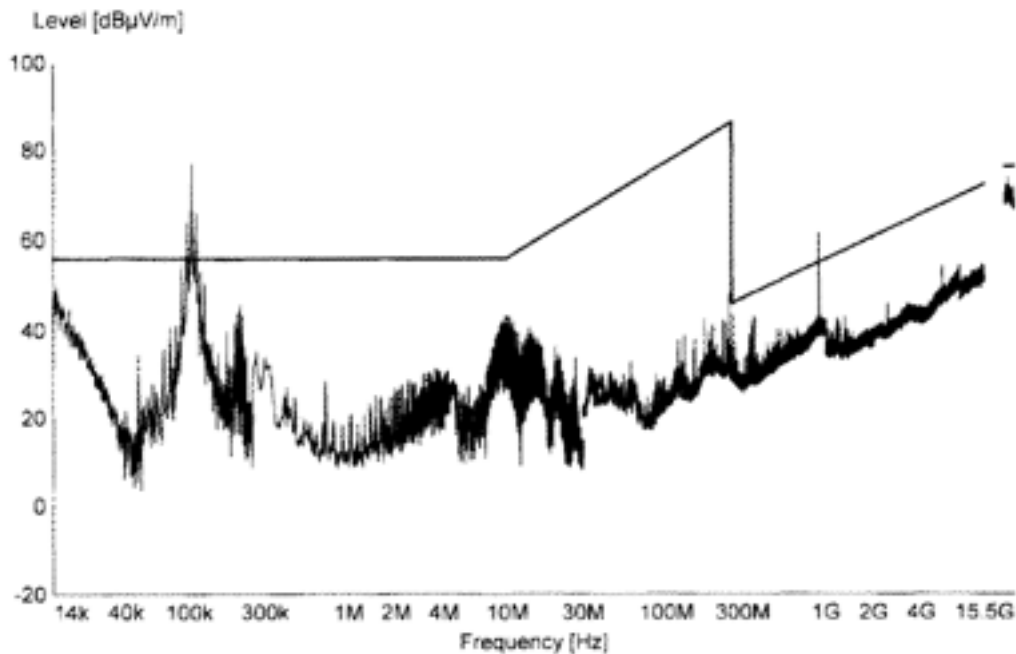



Figure 7.3-1. EMI Test Results

A thermal analysis memorandum was generated for the UBNT [ref. 11]. Each of the UBNT system's components was assessed for strength, fracture, and venting and all parts were classified as non-fracture critical and safe to venting hazards. A Materials and Fracture Control Certificate was issued for the UBNT [ref. 12].

Radiation testing was performed on August 31, 2010, at the Indiana University Cyclotron Facility [ref. 13]. The Micro-SD cards and a RSU with a transducer were tested in both static and dynamic operating modes. The proton radiation levels were in excess of 600 rads. Three Micro-SD cards tested suffered fatal destructive errors during the dynamic testing. The rate of failure indicated that the MTBF ranged from 54.6 to 473 days for that test condition. The RSUs with an attached transducer suffered a single functional interrupt during its testing. Power recycling the RSU allowed the unit to recover normal operations. The estimated MTBF was 1,790 days. Both of these system failures appeared to occur during dynamic operational states. When the unit was in idle mode or when the Micro-SD cards were in a static state, they did not appear to suffer failures. It was only when the components were undergoing dynamic operations that failure occurred. Since the RSUs will generally be quiescent during most of their installation time, it is expected that the effective MTBF will be an order of magnitude greater. Therefore, it is expected the radiation susceptibility risks are low. Finally, a UBNT Safety Data Package was generated and approved and a Flight Safety Certificate was signed [refs. 14, 15].

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 36 of 45	

7.3.3 Functional Testing

With the hardware delivery, functional testing was undertaken to evaluate the hardware and software performance. In total, nine RSUs required testing. Only seven systems were going to be launched. The other two systems were to be used for ISS crew training and ground support testing as required. It was determined that these functional test results would be used to determine which units were to be for ground support.


Prior to delivery, Invocon, Inc. measured the energy used by the nine RSUs. The units were essentially identical in their battery power drain except RSU 1001. This unit was one of the first two units purchased and had an idle current drain that was about twice what the other eight units experienced. As battery maintenance is an operational issue, RSU 1001 was assigned to ground support.

For functional testing, a continuous signal from a signal generator was input into the RSUs. Test Configuration files were written to configure the systems to operate in a programmed schedule mode and in simultaneous programmed, scheduled, and threshold-triggered modes. In all, the systems were configured to record 9,999 event files.

Invocon, Inc. reported that during software functional testing prior to delivery, errors had been observed. With the infrequency of the faults, it was difficult to determine their origin. In all, there appeared to be three distinct types of errors that occurred. One error type was manifested by the RSU unit locking up. The system could download data and be programmed, but when it was set to acquire data, it would drop back into idle mode. The unit would not record additional data until the memory card was erased. A second error type involved one of the RSU channels to become unresponsive, recording zeros instead of signals, while the other three channels functioned properly. This error would persist until the power was cycled. The third error type occurred when an event was triggered, but all the channels read zero. The unit would recover on the next trigger. This error only occurred when the systems were operated simultaneously in the scheduled and triggered modes. This error did not appear when the systems were operated in the scheduled mode only.

It was suggested that the first error type might be related to a Micro-SD card interaction with the RSU unit. This type of error appeared to occur more frequently with the poorer quality Micro-SD cards that were first tried and was part of the justification for switching to the final model of memory card. As part of a method to mitigate this error, all the Micro-SD cards were tested and the RSU unit they were tested with was documented. It was decided that any case of this first type of failure would result in that Micro-SD card being discarded. Furthermore, during the SDTO, the Micro-SD cards are only to be used with the RSU units in which they had been successfully tested. It is hoped that this procedure will eliminate the source of the problem causing the first type of error. If it did not, then at least the data could be downloaded and the memory card could be reset bringing the system back to a functioning state.

If the second type of error occurs during the SDTO, it is not considered to be fatal to the testing.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP-10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 37 of 45	

Typically, each RSU is to have all four channels connected to installed transducers. This would provide some redundancy so that if one of the channels was to fail, there will be three other transducers that could record significant signals.

The third type of error seemed to be associated with a conflict between scheduled and threshold based triggering modes. If that is correct, then it can be avoided by recording in the scheduled mode only. Initially, it was felt that there might be situations where being able to record a random loud signal while recording the regularly scheduled signals might provide the most complete set of information. However, it is anticipated that recording data in the scheduled mode for long enough time periods should provide satisfactory data to bound the noise environment.

During this functional testing, one of the units (RSU 1034) experienced two instances of errors of the first type. The first time, the error occurred after 7,701 events were recorded, and the second time was after 7,837 events were recorded with the same Micro-SD card. It was decided to use this RSU as the second unit for ground support.

7.3.4 Documentation

Figure 7.3-2 shows the UBNT Drawing Tree for the hardware and the corresponding drawings.

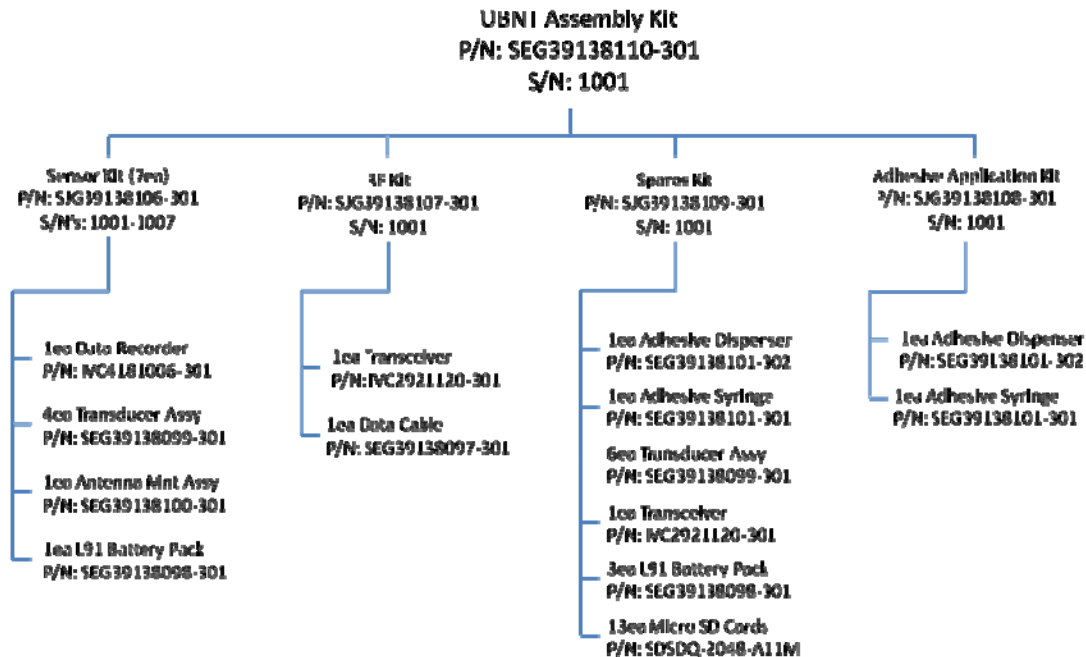




Figure 7.3-2. UBNT Drawing Tree

The following documents are the certification documents referenced for this SDTO:

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 38 of 45	

1. Energizer Lithium L91 Application Manual [ref. 22]
2. L91 Energizer Material Safety Data Sheet (MSDS) Document [ref. 23]
3. RTV 142 Off gas Products Memorandum [ref. 5]
4. RTV142 MSDS Document [ref. 24]
5. Volatile Organic Compound Usage Agreement [ref. 6]
6. Materials Test Data Transmittal Memorandum [ref. 25]
7. Offgas Test Report, WSTF [ref. 17]
8. Toxicology Assessment for Energizer Iron Memorandum [ref. 7]
9. Certification Test Report: Electromagnetic Interference (EMI) for the Ultrasonic Background Noise Test (UBNT) [ref. 8]
10. Certification of Similarity for Use of an Upgraded Micro-SD Memory Card in Hardware Supporting Ultrasonic Background Noise Tests (UBNT) Memorandum [ref. 18]
11. JSC Radio Frequency Authorization [ref. 9]
12. ISS Electromagnetic Effects Panel Tailoring/Interpretation Agreement [ref. 10]
13. Screening Report Electrical Harness Testing [ref. 19]
14. Derating Analysis of Circuit Protection Devices of Ultrasonic Background Noise Test Memorandum [ref. 20]
15. Thermal Analysis of Ultrasonic Background Noise Tests Components Memorandum [ref. 11]
16. Strength, Fracture, and Venting Assessment of Ultrasonic Background Noise Tests (UBNT) Assembly Kit Memorandum [ref. 16]
17. JSC Materials and Fracture Control Certification Memorandum [ref. 12]
18. EP5 Battery Design Evaluation Form [ref. 21]
19. Radiation Test Report Invocon Sensor and Micro-SD Cards [ref. 13]
20. Station Development Test Objective Safety Data package for the Ultrasonic Background Noise Test (UBNT) [ref. 14]
21. Flight Safety Certificate [ref. 15]

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 39 of 45	

8.0 Findings, Observation, and NESC Recommendations

8.1 Findings

The following NESC team findings were identified:

- F-1.** The RSU hardware and software necessary to perform an SDTO to characterize the ultrasonic background noise on the ISS was successfully acquired, modified, tested, and certified for use on the ISS.
- F-2.** There is a lack of instrumentation that can provide a controlled input signal that can perform a quantitative assessment of the transducer and system's response on orbit.
- F-3.** During certification testing, the RSUs did not fully pass the EMI emissions and susceptibility testing but were deemed acceptable as a SDTO.
- F-4.** The 2 GB Micro-SD cards demonstrated radiation susceptibility during dynamic testing that translated into a MTBF of 54.6 to 473 days.
- F-5.** The Micro-SD cards are a pending RSU weak link as the 2 GB storage size will soon become obsolete. In addition, it is noted that the RSU in its current configuration has reached numerous software, firmware, hardware, and operational limitations.

8.2 Observation


The following NESC team observation was identified:

- O-1.** Requests to utilize RSUs to support other NASA testing (e.g., composite overwrap pressure vessels (COPVs) at WSTF and Bigelow's inflatable habitat module) could not be supported.

8.3 NESC Recommendations

The following NESC team recommendations were identified:

- R-1.** The ISSP should complete the SDTO Phase I data acquisition and analysis, and plan for a Phase II effort to the international partner modules. *(F-1)*
- R-2.** The ISSP should assess the results of this SDTO to determine the ability to detect and locate leaks and predict damage locations. *(F-1)*
- R-3.** The ISSP, in preparation for leak location or impact detection operations, should plan to develop a quantitative method and instrumentation to verify system operation while on orbit. *(F-2)*
- R-4.** Future NASA RSU acquisitions that utilize the external antenna should be made with a metal enclosure to provide EMI and radiation shielding. *(F-3 and F-4)*

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 40 of 45	

R-5. The NASA Program offices should continue RSU improvements to address the Micro-SD card obsolescence and operational/functional flexibility to support their program needs. (*F-5*)

9.0 Alternate Viewpoints

There were no alternate viewpoints.

10.0 Other Deliverables


There were no other deliverables.

11.0 Lessons Learned

There were no lessons learned.

12.0 Definition of Terms

Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.
Finding	A conclusion based on facts established by the investigating authority.
Lessons Learned	Knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in that it has real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or limits the potential for failures and mishaps, or reinforces a positive result.
Observation	A factor, event, or circumstance identified during the assessment that did not contribute to the problem, but if left uncorrected has the potential to cause a mishap, injury, or increase the severity should a mishap occur. Alternatively, an observation could be a positive acknowledgement of a Center/Program/Project/Organization's operational structure, tools, and/or support provided.
Problem	The subject of the independent technical assessment/inspection.
Proximate Cause	The event(s) that occurred, including any condition(s) that existed

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 41 of 45	

immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome.

Recommendation An action identified by the assessment team to correct a root cause or deficiency identified during the investigation. The recommendations may be used by the responsible Center/Program/Project/Organization in the preparation of a corrective action plan.

Root Cause One of multiple factors (events, conditions, or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Typically, multiple root causes contribute to an undesired outcome.

13.0 Acronyms List

ATK	Alliant Techsystems, Inc.
ATV-2	Automated Transfer Vehicle-2
CIRD	Common Interface Requirements Document
COPV	Composite Overwrapped Pressure Vessel
CR	Change Request
CSV	Comma Separated Values
dB	Decibel
DIDS	Distributed Impact Detection System
EEE	Electrical, Electronic and Electromechanical
EMI	Electromagnetic Interference
ESA	European Space Agency
ESMD	Exploration Systems Mission Directorate
EWIS	External Wireless Instrumentation System
FSSB	Flight Software Systems Branch
GB	Gigabytes
GFE	Government Furnished Equipment
GHz	Gigahertz
GUI	Graphical User Interface
Hz	Hertz
IRMA	ISS Risk Management Application
ISS	International Space Station
ISSP	International Space Station Program
IVHM	Integrated Vehicle Health Monitoring
IWIS™	ISS Wireless Instrumentation System



NASA Engineering and Safety Center Technical Assessment Report

Document #:
**NESC-RP-
10-00629**


Version:
1.0

Title:

Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)

Page #:
42 of 45


JSC	Johnson Space Center
kB	Kilobyte
kHz	Kilohertz
KSC	Kennedy Space Center
LaRC	Langley Research Center
Li	Lithium
MB	Megabytes
mg	Milligrams
MHz	Megahertz
milli-g	1/1000 of the Gravitational Acceleration on Earth
MSDS	Material Safety Data Sheet
MTBF	Mean Time Between Failures
NASA	National Aeronautics and Space Administration
NDE	Nondestructive Evaluation
NESB	Nondestructive Evaluation Science Branch
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
OB	Need acronym (from Team List)
OCE	Office of the Chief Engineer
RF	Radio Frequency
RSU	Remote Sensor Unit
RTC	Real Time Clock
RTV	Room Temperature Vulcanizing
SBIR	Small Business Innovations
S/N	Serial Number
SD	Secure Data
SDTO	Station Development Test Objective
SSC	Station Support Computer
SSP	Space Shuttle Program
SSPCB	Space Station Program Control Board
STS	Space Transportation System
TIA	Tailoring Interpretation Agreement
UBNT	Ultrasonic Background Noise Test
US	United States
USB	Universal Serial Bus
V	Volt
VCB	Vehicle Control Board
VOC	Volatile Organic Compounds
VUA	VOC Usage Agreement
WPA	Water Processing Assembly

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 43 of 45	

WLEIDS Wing Leading Edge Impact Detection System
 WSTF White Sands Test Facility
 XML Extensible Markup Language

14.0 References


1. Madaras, Eric I, and Prosser, William, "Distributed Impact Detector System (DIDS) Health Monitoring System Evaluation", NESC Technical Report No. 07-035-I, January 14, 2010.
2. SBIR Phase II contract no. NNL06AA13C, "Distributed Impact Detection System (DIDS)", Contracting Officer Sharon Harper, 2006.
3. Wilson, William C., Coffey, Neil C., and Madaras, Eric I, "Leak Detection and Location Technology Assessment for Aerospace Applications," TM-2008-215347, September 2008.
4. SAMS II accelerometer data,
<http://pims.grc.nasa.gov/plots/batch/year2010/month03/day22>.
5. Garcia, Hector, "RTV 142 Offgas Products Memorandum", Memorandum Number TOX-HG-2010-15, July 27, 2010.
6. Young, Kevin, "Volatile Organic Compound Usage Agreement", No. 008, December 3, 2010.
7. Ramanathan, R., Ph.D., "Toxicology Assessment for Energizer Iron Memorandum", Memorandum No. JSCTox-RR-04-611.5.
8. Tran, Dan, "Certification Test Report: Electromagnetic Interference (EMI) for the Ultrasonic Background Noise Test (UBNT)," JSC Report no EV5-10-EMC-018R, September 15, 2010.
9. Nguyen, James, "JSC Radio Frequency Authorization", JSC2010-24, RFA No. 1412, July 20, 2010.
10. Koch, Jody, "ISS Electromagnetic Effects Panel Tailoring/Interpretation Agreement", Agreement No. 1160, October 13, 2010.
11. Barnes, B. G., "Thermal Analysis of Ultrasonic Background Noise Tests Components Memorandum", No. ESCG-4470-10-TEAN-DOC-0177, October 7, 2010.
12. "JSC Materials and Fracture Control Certification," Doc. No. MATL-11-008, December 2, 2010.
13. Allums, Kimberly K., "Radiation Test Report Invocon Sensor and Micro-SD Cards", Doc. No. ESCG-4430-10-EES-DOC-0023, October 15, 2010.
14. Jaramillo, Nelson H., "Station Development Test Objective Safety Data package for the Ultrasonic Background Noise Test (UBNT)", ESCG-6110-10-SS-DOC-0789, JSC No. 65907, December 2, 2010.
15. "Flight Safety Certificate", ATV2/NASA/1/081, October 10, 2010.
16. Nop, J., "Strength, Fracture, and Venting Assessment of Ultrasonic Background Noise Tests (UBNT) Assembly Kit Memorandum", ESCG-4450-10-STAN-DOC-0116, October 7, 2010.

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 44 of 45	

17. “Offgas Test Report Request”, WSTF Test Facility No. 10-44571, JSC Request No. 13341, August 23, 2010.
18. Scully, Robert, “Certification of Similarity for Use of an Upgraded Micro-SD Memory Card in Hardware Supporting Ultrasonic background Noise Tests (UBNT) Memorandum”, October 8, 2010.
19. Drennan, Jill, “RITF Screening Test Report,” Report no. 100982, TPS No. KY1020007, September 8, 2010.
20. “Derating Analysis of Circuit Protection Devices of Ultrasonic Background Noise Test Memorandum”, ESCG Memo No. ESCG-4430-10-EES-MEMO-0026, December 3, 2010.
21. Jeevarajan, Judith, “EP5 Battery Design Evaluation Form”, EP Tracking No. EP-10-13, October 8, 2010.
22. Energizer Lithium L91 Application, <http://data.energizer.com/SearchResult.aspx>, Manual, [Lithium Cylindrical Application Manual](#)
23. L91 Energizer MSDS Document, <http://data.energizer.com/SearchResult.aspx>, [Lithium Iron Disulfide Product Safety Datasheet \(PSDS\)](#)
24. RTV142 MSDS Document, <http://www.momentive.com/MSDS/showOptions.jsp?Product=RTV142>
25. Harper, Susana, “Materials test Data Transmittal”

Volume II. Appendices

Appendix A. SDTO Flight Software Manual

	NASA Engineering and Safety Center Technical Assessment Report	Document #: NESC-RP- 10-00629	Version: 1.0
Title: Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)		Page #: 45 of 45	

Appendix A. SDTO Flight Software Manual

This information was not publicly available at time of publication.

REPORT DOCUMENTATION PAGE

*Form Approved
OMB No. 0704-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 01-06-2011			2. REPORT TYPE Technical Memorandum		3. DATES COVERED (From - To) March 2010 - April 2011	
4. TITLE AND SUBTITLE Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS)					5a. CONTRACT NUMBER	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Prosser, William H.; Madaras, Eric I.					5d. PROJECT NUMBER	
					5e. TASK NUMBER	
					5f. WORK UNIT NUMBER 869021.05.07.03.13	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA Langley Research Center Hampton, VA 23681-2199					8. PERFORMING ORGANIZATION REPORT NUMBER L-20032 NESC-RP-10-00629	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001					10. SPONSOR/MONITOR'S ACRONYM(S) NASA	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S) NASA/TM-2011-217151	
12. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category 16 - Space Transportation and Safety Availability: NASA CASI (443) 757-5802						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT As a next step in the development and implementation of an on-board leak detection and localization system on the International Space Station (ISS), there is a documented need to obtain measurements of the ultrasonic background noise levels that exist within the ISS. This need is documented in the ISS Integrated Risk Management System (IRMA), Watch Item #4669. To address this, scientists and engineers from the Langley Research Center (LaRC) and the Johnson Space Center (JSC), proposed to the NASA Engineering and Safety Center (NESC) and the ISS Vehicle Office a joint assessment to develop a flight package as a Station Development Test Objective (SDTO) that would perform ultrasonic background noise measurements within the United States (US) controlled ISS structure. This document contains the results of the assessment.						
15. SUBJECT TERMS International Space Station; on-board leak detection; NASA Engineering and Safety Center; Station Development Test Objective; Wing Leading Edge Impact Detection System; Remote Sensor Unit						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)	
U	U	U	UU	50	19b. TELEPHONE NUMBER (Include area code) (443) 757-5802	