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Evaluation of the Human Research Facility Ultrasound With the ISS Video System

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August 2003

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Introduction

The majority of the medical equipment on board the International Space Station (ISS) (ISS Integrated Medical System, or IMedS) is manifested as part of the U.S. Crew Health Care System (CHeCS) or the Russian medical hardware system. However, certain medical hardware is also available on ISS as part of the ISS Human Research Facility (HRF). The HRF and the JSC Medical Operations Branch established a Memorandum of Agreement (MOA) for joint use of certain medical hardware[1], including the HRF ultrasound system, the only diagnostic imaging device currently manifested to fly on ISS.

The outcome of a medical contingency may be changed drastically, or an unnecessary evacuation may be prevented, if clinical decisions are supported by timely and objective diagnostic information. In a large number of higher-probability medical scenarios, diagnostic ultrasound is either a first-choice modality, or provides significant additional diagnostic information. Accordingly, the Clinical Care Capability Development Project (CCCDP) is evaluating the HRF ultrasound system for its utility in relevant clinical situations on board ISS. For effective management of these ultrasound-supported ISS medical scenarios, the resulting data should be available for viewing and interpretation on the ground, and bidirectional voice communication should be readily available to allow ground experts (sonographers, physicians) to provide guidance to the Crew Medical Officer (CMO). With the limited CMO, it may also be vitally important to have the capability of real-time guidance via video uplink to the CMO-operator during an exam to facilitate the diagnosis in a timely fashion.

In this document, we strove to:

- Verify that the HRF ultrasound video output is compatible with the ISS video system.
- Identify ISS video system field rates and resolutions that are acceptable for varying clinical scenarios.
- Evaluate the HRF ultrasound video with a commercial, off-the-shelf MPEG-2 video converter, and compare it with the ISS video system.

Effects of Data Transmission on the Overall System Performance

An ultrasound system begins at the transducer and ends with final image interpretation by the radiologist. In the particular case of real-time ultrasound video transmission from ISS to the ground, the affected components of the ISS communication system in essence become part of the ISS ultrasound system. Degradation of the ultrasound video signal acquired aboard ISS must be anticipated upon reception and displayed on the ground. Characteristics of the ISS ultrasound system (including relevant air-to-ground and terrestrial transmission and processing) that affect the diagnostic quality of information on the ground include the following:

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[1] Memorandum of Agreement Among CHeCS Project, Human Research Facility Project, Biological Research Project, and ISS Payloads Office For Sharing Equipment on ISS, current version

Field Rate

The ISS CMO views the real-time image on a high-resolution digital monitor with a high refresh rate. However, the signal that is passed on to the ISS communication system for transmission to the ground is an analog NTSC video signal rendered by the digital scan converter of the ultrasound system. The ISS video system is capable of transmitting at discrete rates from 1.875 up to 60 fields per second[2]. A given field rate may or may not be appropriate for a particular clinical application. Even within the same medical scenario, various modes and characteristics are "sensitive" to the field rate to varying extent. For example, cardiac contractility determination requires a field rate of 30 (marginally acceptable) but should be nominally 60 fields/sec. However, lower rates are acceptable for confirming or excluding accumulation of fluid in the pericardial sac.

Spatial (detail) Resolution

In diagnostic ultrasound, lateral and axial resolution are recognized among the main measures of system performance.

- Lateral resolution is the ability to distinguish adjacent objects in a plane perpendicular to the beam axis. In multi-element transducers, the actual resolution varies somewhat over the field of view, depends on focusing mode and other variables, and may be different for in-plane and out-of-plane objects.
- Axial resolution is the ability to recognize objects closely spaced along the beam axis (also determining the smallest resolvable object along the axis). Axial resolution at a given depth depends on focal zone selection and other settings of the system controls.

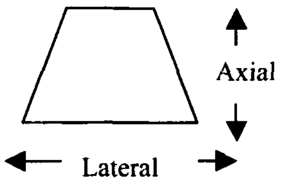

Image quality is very dependent on these parameters. Signal degradation due to excessive compression, improper display device, or noise may dramatically decrease the original resolution of the system, as specified by the manufacturer.

The extent of image degradation may not always be apparent. Objective tools and procedures exist to determine the performance of the ultrasound system. Commercially available test objects and phantoms actually measure the performance parameters, including lateral and axial resolution in millimeters in units of distance.

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[2] Every 2 TV fields make a full TV frame (e.g., 60 fields per second make 30 frames/sec, i.e. standard NTSC frame rate). The exception is the lowest (1.875) rate, where each field makes a frame.

The present test was arranged at a very short notice, therefore test objects were not available at the time of testing. Consequently, spatial resolution was evaluated subjectively, as "sharpness." A blurred image, insufficient line sharpness, and the quality of in-field text areas were used as indicators of image degradation. Digitally acquired images from the same system, as well as images transmitted in different modes, were used for reference and comparison.

Grayscale (contrast) Resolution or Dynamic Range

Ideally, gray-scale and/or color presentation of the information on the ground should reproduce all the detail of the original ultrasound image displayed on the system monitor on board ISS. The communications system should preserve the intensity and color of the original image. However, certain image degradation occurs and its extent determines the resulting diagnostic power of the system. Even in hospital environments, it is not uncommon for lesions observed in real time to be absent on hardcopy films, due to losses in grayscale resolution in the film exposition and development system.

Noise

Sensitivity is a measure of the ability of the system to recognize small, weak reflectors, and therefore directly relates to the signal-to-noise ratio of the system. If generated in significant quantities or high levels compared to a weaker signal, the noise can substantially reduce the overall diagnostic accuracy of the system.

Test Opportunity

The HRF ultrasound is configured to stream video through the station video system, which can operate at various field rates and color/grayscale resolutions. The quality of the video in a clinical scenario can greatly affect the ability to make a diagnosis. Because there is no simulator of the ISS video system, ultrasound video had never been tested end-to-end. Working with contacts in the Avionics Division, CCCDP was given the opportunity to include the HRF ultrasound system in a test of the ISS video system, particularly the video baseband signal processor (VBSP) in the Electronics Systems Test Laboratory (ESTL). The ESTL is a unique NASA facility where multielement crewed spacecraft communications systems are interfaced with relay satellites and ground elements for end-to-end testing in a controlled radio-frequency environment. The video equipment was at JSC for a limited time, until August 4, 2000, therefore we accomplished quick coordination among ESTL, HRF, and Medical Operations personnel to conduct this test. Furthermore, the Avionics Hardware development group offered to provide two Minerva VNP MPEG converters to the ESTL to permit evaluation of the ultrasound video using digital compression techniques and space-to-ground communication via the Orbiter Communication Adapter (OCA) TCP/IP backbone.

With both the ISS Video system and the Minerva system, there will always be some video information loss. The original ultrasound signal is RGB 24 bit (RS 370), which is then converted to an NTSC signal (RS170a). The degradation of the signal associated with this conversion is readily acceptable in the clinical community, as many ultrasound diagnoses are made from data collected on VCRs, which require an RS170A input.

The ISS video system was created to handle video from multiple synchronized cameras and control the position of each of those cameras for robotic arm applications and external views of the station. All other video signals must adjust to this paradigm. The ISS video system samples each video line 200 times per second and the color (8 or 6 bit) 50 times per second. Due to current bandwidth constraints, the highest possible resolution that we could test was 60 fields per second and 6-bit resolution.

The Minerva system uses MPEG compression. There are two major MPEG standards: MPEG-1 and MPEG-2. MPEG-1 provides a video resolution of 352-by-240 at 60 fields per second (fps). MPEG-2 offers resolutions of 720×480 and 1280×720 at 60 fps. This is sufficient for all the major TV standards, including NTSC. MPEG-1 and -2 define techniques for compressing digital video by factors varying from 25:1 to 50:1. The compression is achieved using five different compression techniques:

- The use of a frequency-based transform called Discrete Cosine Transform (DCT).
- Quantization, a technique for losing selective information (sometimes known as *lossy compression*) that can be acceptably removed from visual information.
- Huffman coding, a technique of lossless compression that uses code tables based on statistics about the encoded data.
- Motion compensated predictive coding, in which the differences in what has changed between an image and its preceding image are calculated and only the differences are encoded.
- Bidirectional prediction, in which some images are predicted from the pictures immediately preceding and following the image.

The ISS video system and the Minerva MPEG system handle video in very different ways and on a technical level cannot really be compared, however our goal for this test was to determine if we can get clinically useful video to make a medical diagnosis.

ISS Video System

Test Setup

In preparation for this test, the HRF engineers built a video cable to interface with the common video interface unit (CVIU). We transferred an engineering (nonflight) HRF ultrasound with L12-5, C5-2, and P4-2 probes to the ESTL in Building 44, and fed the balanced video output from the ultrasound rack interface connector into the CVIU that was connected to the ESTL flight setup (See Figure 1). Video was collected at the point of acquisition using the Hi-8 mm tape deck built into the HRF ultrasound system. Video was also collected on the receiving end at the simulated ground station at the output of the ESTL, using a Sony DSR-V10 digital video (mini-DV) recorder. Both the "acquisition" and "receive" signals were displayed real time on side-by-side Panasonic video monitors. The ultrasound unit was located in a separate room from the display monitors. The lab intercom system provided communication among test operators. This setup is very similar to how ultrasound would be performed on station.

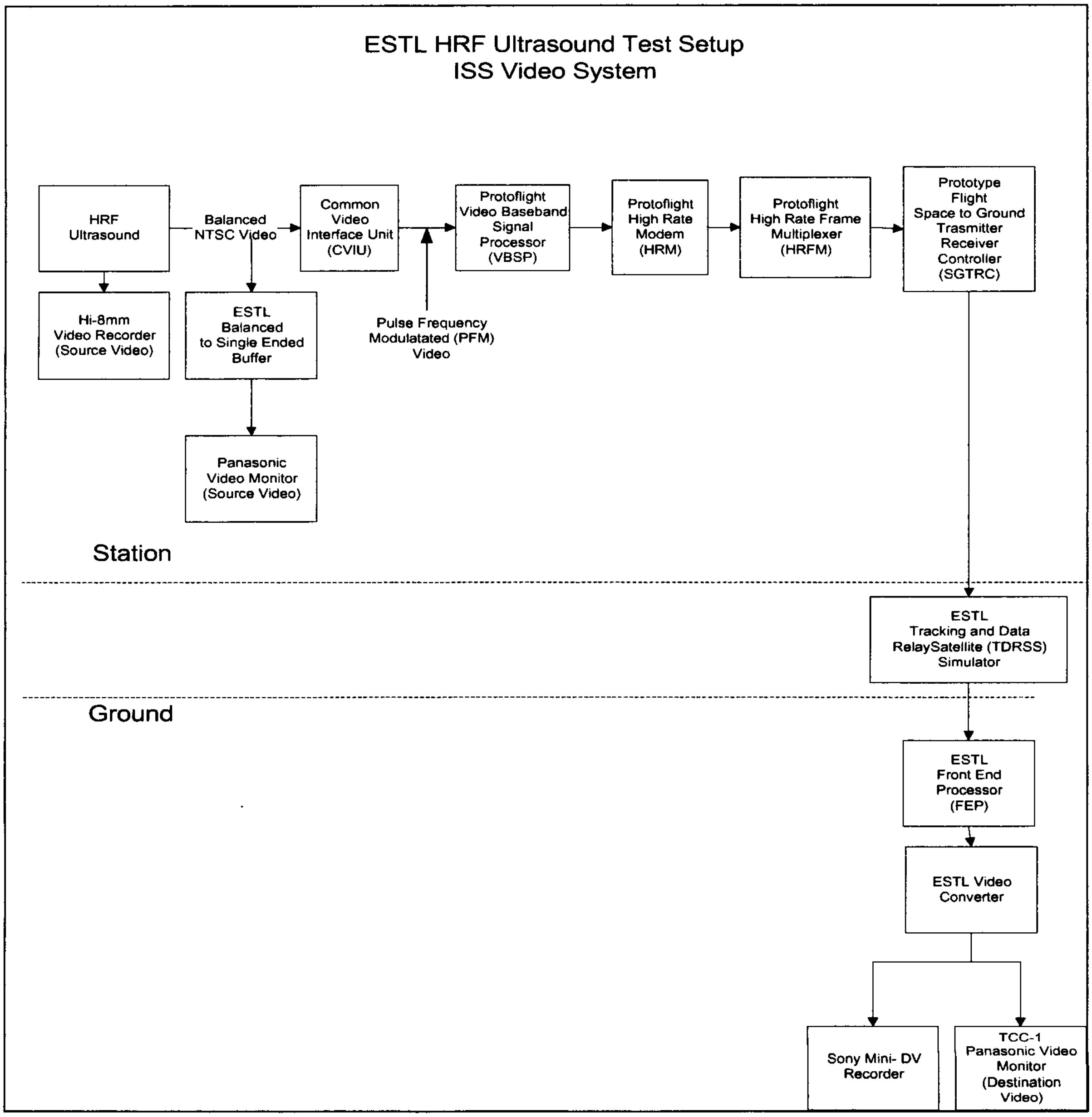

Figure 1: ISS video test setup.

Protocol

The video signal from the HRF ultrasound system contained data acquired by a trained radiologist and ultrasound technician performing standard medical scans on a healthy human subject. This video signal was transmitted in real time through a simulated ISS air-to-ground video downlink configuration. The protocol for this test received expedited approval by the JSC Institutional Review Board on July 28, 2000. Each type of scan (ultrasound application) was performed using several discrete field rates and resolution settings (Table 1).

Data were recorded continuously on both ends of the system.

In each field rate, two color/grayscale resolution modes were available for testing (6 bit and 8 bit), except for 60 fields per second where only 6-bit resolution is available. The first series of tests included both resolution modes at each field rate. Initial review demonstrated that the field rate affected the overall quality of the received diagnostic information much more than the resolution, and therefore the lower resolution setting (6 bit) was used for the remainder of the test at each field rate tested.

Table 1: ISS Video System Test Protocol

Application	**Probe Type**	**60 Fields per second**		**30**		**15**		**7.5**		**1.875**	
	C5.2	**8**	**6**	**8**	**6**	**8**	**6**	**8**	**6**	**8**	**6**
HDI-5000 Startup	N/A	N/A	X								
Abdominal Ultrasound – Initial Evaluation of 6 vs.8 bits	C5-2	N/A	X	X	X	X	X	X	X	X	
Abdominal Ultrasound	C5-2	N/A					X	X	X	X	
Superficial Organs	L12-5	N/A					X	X	X	X	
FAST (abdominal)	C5-2	N/A	X		X		X		X		X
Thorax – Pneumothorax Screening	L12-5	N/A			X		X		X		
Cardiac - 2D	P4-2	N/A	X		X		X		X		X
Cardiac - Color	P4-2	N/A	X		X		X		X		X
Cardiac - Color and Doppler	P4-2	N/A	X		X		X		X		X
Carotid artery (survey, color Doppler, spectral)	L12-5	N/A			X		X		X		X
Ophthalmic	L12-5	N/A					X		X		

MPEG Converter

Test Setup

The Avionics Hardware Development group has been evaluating commercial, off-the-shelf equipment that will work on the orbital communications adapter (OCA) Ku-Band link. The OCA link functions as a TCP/IP network and is used for the ISS Operation Local Area Network. The Minerva Video Network Player (VNP) (Minerva Networks, Inc. Santa Clara, California, http://www.minervasys.com) is a TCP/IP packet-based MPEG video compression system that works with the existing ISS space-to-ground communication bandwidths and can withstand the satellite delays associated with space communications. The Minerva VNP takes analog video signals and converts them to digital packets using MPEG-1 or MPEG-2 compression algorithms. This system is being considered for future use aboard ISS, therefore the HRF ultrasound video was streamed through this system to compare the video quality with the ISS video system and to determine bandwidth thresholds of video quality. Figure 2 shows the configuration of the MPEG test.

Due to time constraints, we evaluated only the most motion-intensive medical scans through this system. Because the Minerva system intrinsically has a higher resolution with Y/C video input over NTSC, we used Y/C video signal for this test.

Protocol

As with the Station video system test, a trained radiologist and ultrasound technician generated the video from the HRF ultrasound system real time by performing standard medical scans on a healthy human subject. They ran each type of scan using MPEG-1 or MPEG-2 compression with multiple bandwidth settings (Table 2). With MPEG conversion, the field buffer is always updated 60 times per second, and the resolution dynamically changes with bandwidth and the content of the video. However, the information in the field buffer may not be updated every time it is sampled.

Table 2: MPEG Converter Test Protocol

Scan Type	Probe Type	Fields per Second	MPEG Compression Used	Bandwidth Used MB/s
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 2	12
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 2	10
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 2	8
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 2	6
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 2	4
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 2	2
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 1	2
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 1	1
Cardiac -2D, Color, Doppler	P3-2	60	MPEG 1	700 Kb/s
Abdominal and Thoracic	C5-2 / L12.5	60	MPEG 1	2
Abdominal and Thoracic	C5-2 / L12.5	60	MPEG 2	2
Abdominal and Thoracic	C5-2 / L12.5	60	MPEG 2	4

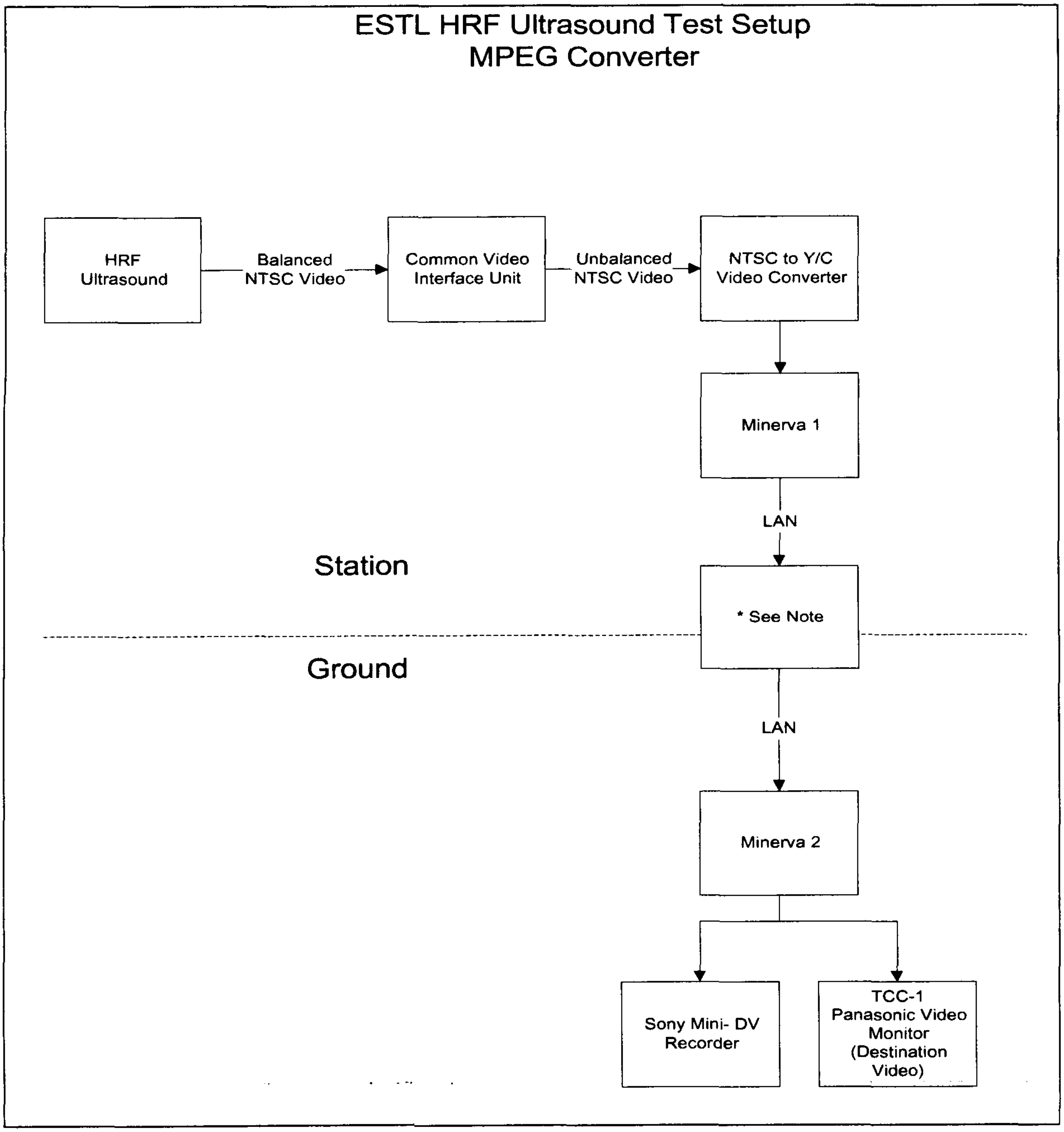

Figure 2: MPEG converter test setup

* The Minerva system has been tested extensively in the ESTL facility with the TDRSS simulator and all the components of the ISS OCA communication system. There has not been an appreciable difference between the Minerva's function when transmitting though the ESTL versus a standard Local Area Network (LAN). Therefore, to simplify the configuration of this test, the ultrasound video was tested with the Minerva system through a LAN connection.

Results (by Performance Parameters)

We viewed the output of the system in real time on a 14-inch Sony Trinitron monitor and conducted subsequent reviews of recorded data. We used a Sony DSR-V10 equipped with an editing station for both recording and playback of the resulting video and made the following preliminary observations.

Grayscale Resolution

VBSP: We noted only slight, barely noticeable degradation of contrast/grayscale resolution in normal ultrasound scans upon transition from 8-bit to 6-bit resolution of the ISS video system. This difference did not seem to substantially compromise the diagnostic quality of data in all tested applications. However, this observation has been made in only one subject with normal findings, is subjective, and cannot be adopted as a final conclusion. A detailed side-by-side comparison of the two modes is necessary, as well as use of special test objects (phantoms). However, this observation allowed limiting VBSP-based testing to the lower (6-bit) color/grayscale resolution.

MPEG: Satisfactory grayscale performance of the system was demonstrated upon review of the video on the simulated ground display. However, objective testing with tissue-equivalent phantoms and other test equipment is warranted to obtain unequivocal data.

Spatial (Detail) Resolution

The ISS video system preserved the fine detail of tissue structure substantially better than MPEG-1 conversion at all bandwidth settings tested. Although image blurring was less prominent, it was still noticeable and probably would have resulted in decreased performance in certain pathological conditions if those were present in the test subject. The MPEG-2 conversion outperformed the ISS Video system and MPEG-1 conversion in terms of image sharpness and detail resolution, in all tests. This may in part be due to the fact that a large part of the ultrasound display (in average, 55%) frame is static and the actual ultrasound scanning field occupies less than half of the entire frame area. The required bandwidth is therefore reduced, making ultrasound video an excellent signal for digital compression.

Field Rate

Five discrete field rate settings were available during testing of the ISS video system. Table 3 identifies the cut-off points suggested to determine suitability of a particular mode for clinical ultrasound applications.

Table 3: Suggested Field Rates for Specific Clinical Applications

Ultrasound Application	Cut-off rate Fields/Sec (marginal)	Comments
Duplex Echocardiography, with or without color	60 (30)	Field rates below 30/sec may reduce diagnostic value in certain conditions, especially at higher heart rates.
Abdominal Ultrasound	30 (15)	Slower movements of probe across the area of interest will be necessary.
Superficial & Small Parts	30 (15)	Slower movements of probe across the area of interest will be necessary.
FAST (abdominal)	30 (15)	May be insufficient in a distressed patient, high respiration rate
FAST (thorax)	60 (30)	Rates below 30 may reduce diagnostic value in certain conditions, especially at respiratory distress
Duplex Vascular (carotid), with and without color	60 (30)	Rates below 30 may reduce diagnostic accuracy in certain conditions
Spectral Doppler and M-mode display (only)	30 (15)	Not practical as must be viewed in combination with Duplex Echocardiography

The field rate in all MPEG modes was sufficient for any dynamic application tested, including duplex echocardiography, vascular sonography, and chest sonography for trauma assessment. The temporal performance of the MPEG-based system was excellent in the entire range of available bandwidth settings. As suggested above, this is in part due to the nature of ultrasound display, with the majority of the frame being static in nature, and only 30% – 45% requiring update in most clinical applications.

Results (by Clinical Applications)

Duplex Echocardiography

Standard duplex echocardiography, with color Doppler where appropriate, was performed at all field rate settings (VBSP) and bandwidths (MPEG) available. This ultrasound application is among the most "dynamic," due to the fast motion of the cardiac structures, and is therefore most vulnerable at lower field rates. Even the highest field rate available in the ISS video system (60 fields/sec), although acceptable in almost all cases, is still below the ultrasound field rate generated and displayed during actual scanning.

The grayscale resolution was adequate during subjective assessment of recorded material; spatial resolution was moderately degraded in the case of the ISS video system, regardless of the field rate. MPEG-1 compression at low bandwidths resulted in severe "blurring" of the image. However, MPEG-2 compression at all available bandwidth settings provided satisfactory spatial resolution, as well as acceptable detection of motion of cardiac valves and other intracardiac structures.

Vascular Duplex Sonography With/Without Color Doppler

Vascular sonography is another dynamic ultrasound application. It is believed that 60 fields per second is necessary to perform a fully adequate study of peripheral vasculature. In this application, however, the grayscale resolution is of special importance for detection of intravascular lesions such as acute venous thrombosis or soft arterial plaques. Spatial resolution is also very important, and very little degradation can be tolerated before the diagnostic accuracy of the system becomes inadequate. Quantitative (objective) testing of the system is necessary to determine its suitability for a given clinical situation.

Focused Assessment by Sonography in Trauma (FAST)

FAST examination is an emergency screening technique consisting of sonographic survey in four abdominal areas and the anterior mediastinum to detect free fluid in the peritoneal cavity and pericardium. Studies aboard the KC-135 aircraft have demonstrated its validity for blunt abdominal and thoracic trauma in microgravity. The FAST exam has been accepted as a valuable procedure in the emergency room setting, and is widely performed in North American medical centers.

FAST examination was conducted on a test subject repeatedly using all field rate settings of the ISS VBSP. Satisfactory image quality was recorded at both 8- and 6-bit resolution. Field rates of 60-, 30-, and 15-per second provided acceptable conditions for real-time FAST evaluation. At lower field rates, the scanning procedure requires the operator's awareness to deliberately slow down the transducer manipulations; otherwise, the diagnostic information is of limited value and cannot be confidently interpreted.

Detail resolution was acceptable for this application, as tissue characterization is not part of the FAST exam, which is intended to detect presence of free blood or leaking intestinal contents.

Real-time audio communication between the ground and the ISS will be key for achieving good results from the FAST exam. On-board computer based training tools should be available as a quick refresher for the technique and for reviewing baseline image sets of the subject being tested. Should FAST be necessary during an LOS period, availability of such a tool may give a major advantage in terms of time and the quality of recorded video and still images.

Abdomen

Abdominal ultrasound was performed using the standard American Institute of Ultrasound in Medicine (AIUM) protocol, and included longitudinal, transverse, coronal, and oblique scanning of the major retroperitoneal vessels, liver, gallbladder, bile ducts, pancreas, spleen, kidneys, and male pelvic organs, as appropriate. The same protocol was repeated at multiple data transmission conditions.

For this application, field rates as low as 15 fields per second were found acceptable. In certain conditions, even lower rates may yield in useful diagnostic information. At low field rates, the scanning procedure requires awareness of the operator, who must manipulate the transducer slowly; otherwise, the diagnostic information may not be sufficient for correct diagnosis.

Upon subjective evaluation of data, we found the detail resolution marginally acceptable, noting certain blurring and distortion of fine tissue patterns. Objective testing of the system should be performed using tissue-mimicking phantoms and test objects to determine actual resolution values in different scanning modes.

Thorax

The emerging concept of thoracic FAST technique was tested. It is believed (and demonstrated during the recent CCCDP KC-135 experiments) that ultrasound, if used appropriately, provides reliable information regarding the presence or absence of pneumothorax and, to some degree, even its magnitude. This application is expected to gain wide acceptance in terrestrial medicine in the near future, and its utility in space medicine continues to be evaluated.

In nine thoracic (intercostal) windows, superficial scanning was performed with an L12-5 transducer to image the mutual sliding of the visceral and parietal pleura, and other ultrasonic phenomena associated with the mechanics of breathing.

The 9-window protocol was repeated at various transmission modes. It was demonstrated that field rates of 15 and lower are not suitable for this application, and the rate of 30 fields per second is marginally acceptable. Grayscale and spatial resolution of the tested system was found quite acceptable for this purpose. However, in foreseeable situations of thoracic trauma, the thoracic FAST will probably be indicated along with other ultrasound applications, which may be more “sensitive” to image degradation.

Musculoskeletal Ultrasound

Upper extremity muscles and other soft tissues were scanned in multiple modes for further image analysis. Thyroid gland and submandibular salivary gland, as well as the eye and orbital structures were scanned in various modes for further analysis. Spatial resolution is the main concern and should be evaluated using objective means. Generally, conclusions are similar to those for the abdominal ultrasound.

Discussion

The HRF Ultrasound is a powerful tool that may be very useful in a medical contingency situation, but having an agreement to use it is not enough. It will be important to address many logistical issues before an emergency. Issues that require attention may include:

- How to configure the HRF video to the Biomedical Multipurpose Support Room (MPSR) in minimal timeframe.
- How to protect the signal so that only the Flight Surgeon sees the video?
- Determine minimal field rate and resolution requirements for specific scans.
- What level of training is appropriate for the CMO and how can this best be supported from the ground?

We only evaluated the video signal from the HRF ultrasound system during this test, however, there is an audio component to ultrasound when using the Doppler function. It is not known if the audio from the ultrasound system is configured to be downlinked through the Station audio system. If that is the case, Medical Operations does not have confidence in the quality of this audio for clinical use, and it is not clear whether the audio will reliably match with the video signal. These functions need to be tested.

The MPEG conversion box has several advantages over the existing video system that would be beneficial to Medical Operations. Comparable video quality with maximum field rate can be achieved using 1/15th of the bandwidth of the station system. Because the Minerva system sends the video as TCP/IP packets, it is possible to secure the data for medical privacy using commercial, off-the-shelf technology such as Virtual Private Networks, or Public Key encryption. The most important advantage to the Minerva system is that multiple sources of high-quality video can be uplinked to the station through this system. With minimally trained CMOs, the ability to uplink video to enhance real-time mentoring may be crucial to making a diagnosis.

Recommendations

- The overall spatial resolution of the HRF ultrasound system with VBSP may need improvement before it can be accepted as a standard medium to be used for medical operations support.
- Medical Operations should have immediate access to approved ultrasound test objects and phantoms for use during tests such as described in this report.
- Grayscale resolution of the system or its relevant parts should be tested using similar simulations, through use of standard ultrasound test objects.
- Certain ultrasound applications can tolerate degradation in field rate, grayscale resolution, or spatial resolution. However, if multiple applications are indicated at the same time (e.g., in case of abdominal/thoracic blunt trauma), the settings should be available to support the more demanding application.
- It is highly desirable that real-time video downlink and bidirectional voice be available to support ultrasound scanning aboard spacecraft. This capability greatly increases diagnostic value of data, reduces the time spent scanning, and improves the chances for relatively early and definitive diagnosis.
- Computer-based ultrasound training tools should be available on board for predictable operational scenarios where ultrasound is indicated. Those include blunt abdominal and chest trauma, urolithiasis, pneumothorax, eye injury, dental infection, acute deep venous thrombosis of lower extremities, and others.
- Procedures should be available for emergency reconfiguration of the system for operational use, according to requirements posed by Medical Operations in coordination with the HRF.
- If the HRF ultrasound is to be used for operational diagnosis, the ISS CMO must have some clinical training with the ultrasound.

Follow-On Activities

- Medical Operations/CCCDP will work with the HRF and the payload community to determine the details of configuration and technical compatibility of the ultrasound system's video, audio, and digital outputs, and determine the ways of secure and adequate routing of the information to the Crew Surgeon/Biomedical Support area of the Mission Control Center.
- Medical Operations/CCCDP will look for additional test opportunities, including partial tests and simulations if end-to-end testing is not possible.
- Medical Operations/CCCDP will study the possibilities of manifesting an array of ultrasound transducers that would cover the most critical imaging applications. Information is available that the HRF ultrasound system in its near-term flight configuration will be fitted with only one (L12-5) transducer.

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13. ABSTRACT *(Maximum 200 words)*

Most medical equipment on the International Space Station (ISS) is manifested as part of the U.S. or the Russian medical hardware systems. However, certain medical hardware is also available as part of the Human Research Facility. The HRF and the JSC Medical Operations Branch established a Memorandum of Agreement for joint use of certain medical hardware, including the HRF ultrasound system, the only diagnostic imaging device currently manifested to fly on ISS. The outcome of a medical contingency may be changed drastically, or an unnecessary evacuation may be prevented, if clinical decisions are supported by timely and objective diagnostic information. In many higher-probability medical scenarios, diagnostic ultrasound is a first-choice modality or provides significant diagnostic information. Accordingly, the Clinical Care Capability Development Project is evaluating the HRF ultrasound system for its utility in relevant clinical situations on board ISS. For effective management of these ultrasound-supported ISS medical scenarios, the resulting data should be available for viewing and interpretation on the ground, and bidirectional voice communication should be readily available to allow ground experts (sonographers, physicians) to provide guidance to the Crew Medical Officer. It may also be vitally important to have the capability of real-time guidance via video uplink to the CMO-operator during an exam to facilitate the diagnosis in a timely fashion. In this document, we strove to verify that the HRF ultrasound video output is compatible with the ISS video system, identify ISS video system field rates and resolutions that are acceptable for varying clinical scenarios, and evaluate the HRF ultrasound video with a commercial, off-the-shelf video converter, and compare it with the

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