Habitation 2004

Conference on Space Habitation Research and Technology Development

Wireless Crew Communication System Concept Demonstration

Space Human Factors Engineering
Technical Development Project

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Wireless Crew Communication System Concept Demonstration

Why Wireless Communications?

- Reports from completed ISS missions indicate issues associated with communication impacted crew time and caused inefficiencies in operations.
- Noise interferes with intra-module communication.
- Interruption of tasks to travel/translate to an audio terminal unit (ATU) to communicate with fellow crew in other modules or with ground control requires time and impacts efficiency.
- Emergency situations require use of portable breathing apparatus (PBA) – O2 flow hinders hearing.
- Emergency situations would require proximity to ATU – highly inefficient during the emergency.

Project Goals and Objectives

- Long-range goal is to have unified integrated wireless technology system that supports all wireless activities on ISS and has well-designed and tested human interface options to support the wide range of operations.
- Define **functional, performance, and operational requirements** for wireless communication aboard the ISS.
- Develop **conceptual portable wireless crew communication audio devices** for use on ISS.
    - System conceptual design based upon augmenting existing ISS audio system.
    - Eliminate cabling between crew audio device and ISS audio terminal unit (ATU).
    - Focusing on using commercial industrial RF wireless standards.
- Test a **prototype** for wireless functionality, usability, human interface, and ergonomics.

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Information from reports on completed ISS missions:

- Communication considered by some to one of the critical aspects of long-duration human missions.
- Acoustic environment causes comprehension problems and impacts crew time, requiring crew to repeat messages or translate closer to fellow crewmembers.
- Translating to ATUs during tasks takes time from the task, causing a general increase in required completion time.
- Estimates were developed for crew translation to ATUs:

Communications intra-module with fellow crewmembers	Assume .5 hours per day to translate to ATUs, primarily on work days (5)	2.5 hours per week
Communication with ground control	Assume .5 hours per day to translate to ATUs to address ground calls, primarily on work days (5)	2.5 hours per week
Increase in communications time due to interruptions and acoustic noise interference	6.5 work hours per day, costs .26 hours/per day	1.3 hours per week
PER CREW MEMBER		6.3 hours per week

- Of the 6 hours/week per crewmember, and **estimated 3 hours/week per crewmember could be saved** by reducing translation time to mounted communication hardware or to fellow crewmembers.

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Methods:

- Development of functional, performance, and operational requirements.
  - Investigate and define ISS system level specifications and requirements.
  - Define and perform communication task analysis.
  - Evaluate user interface research and guidelines from industry and academia.
  - Define requirements specific and unique to spaceflight (both functional and operational).
  - Define functional/operational crew-input-driven requirements (based on ISS Expedition debriefs and previous crew comments to WCC proof-of-concept.

- Development and evaluation of conceptual designs.

- Development of wireless technology testbed and fully-functional ground-based prototype.

Communication Task Analysis:

Products

- Scenarios requiring communication with ground and other crew on-orbit.
- Definitions of operational, functional, and performance requirements at both system level and lower levels.
- Forward plan mapping conceptual design and evaluation of crew interface, with development of wireless technology testbed/fully-functional ground-based prototype.

Task Analyses

- Identification of discrete tasks involving significant crew-to-crew and crew-to-ground communication.
- Within these tasks identify and analyze all of the following that were applicable:
  - Information required to initiate the task.
  - Required decisions/actions involved with each subtask.
  - Instances of important inter-crew and crew-ground communication.
  - Instances when required communication necessitates ATU use, but translation to and from ATU not possible or convenient.
  - Subjective level of risk.
  - Likelihood of operator error and potential implications.
  - Other environmental conditions (i.e., low visibility, noise) affecting ground and/or crew communication support.

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Task Analyses

Identification of candidate task classifications

- Medical
  - Advanced Crew Life Support System (ACLS) Algorithm
- Hardware maintenance
  - Multi-Purpose Logistic Module (MPLM) Vestibule-Configure for Ingress
- Payload/science
  - Advanced Diagnostic Ultrasound Operations
  - Space Linear Acceleration Mass Measurement Device (SLAMMD)
  - Life Science Glovebox (LSG) Drosophila Malanogaster Airflow Demonstration, Rodent Dissection Test, Plant Science Test
- Non-medical emergencies
  - Fire
- Public affairs
  - Space-to-ground live interviews
- Robotics
  - Manipulation of the robotic arm – specifically movement and installation of the Port 1 (P1) truss segment

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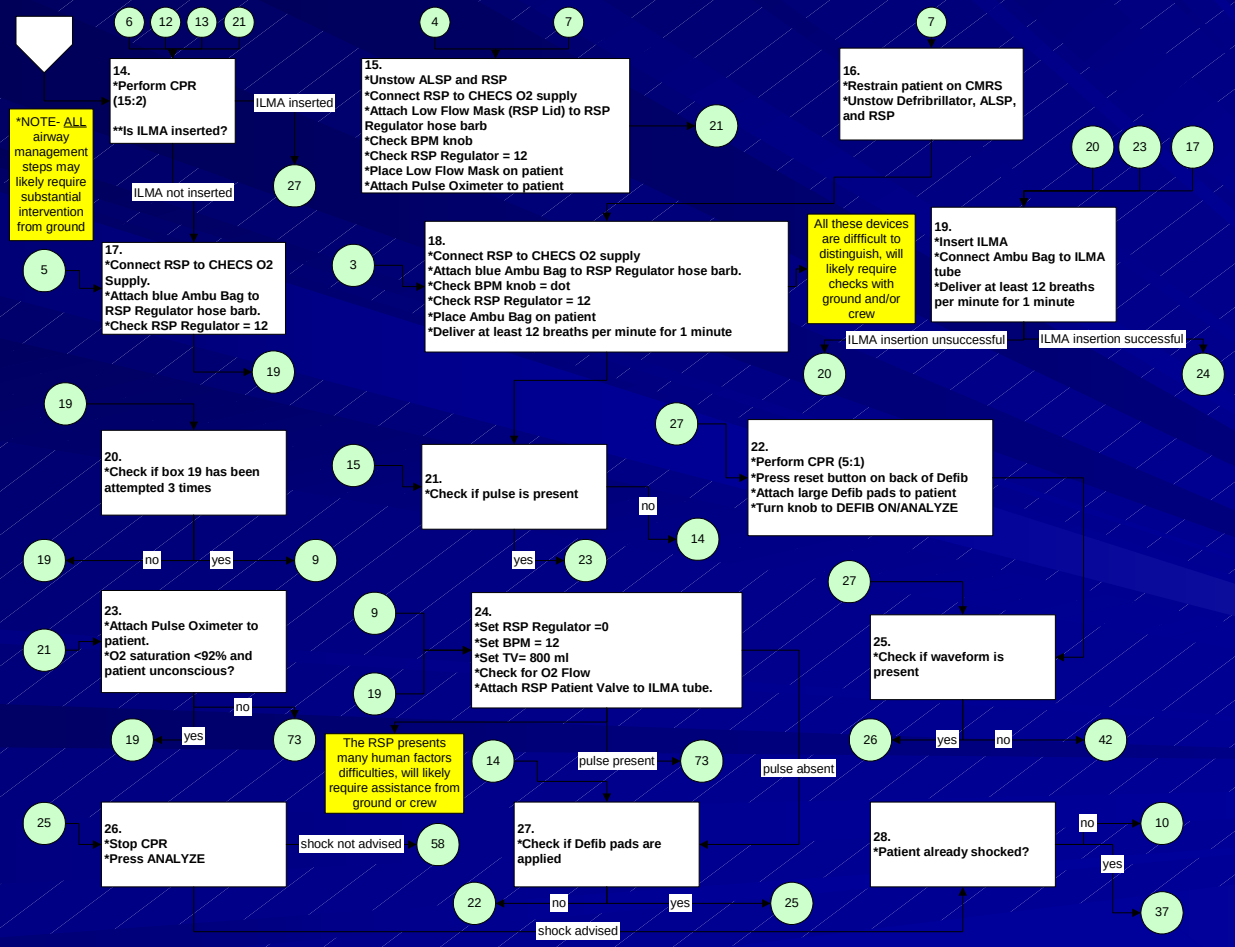
Medical - Advanced Crew Life Support System (ACLS) Algorithm

Steps 14 through 28 of 76 illustrated:



Medical - Advanced Crew Life Support System (ACLS) Algorithm, con't:

Communication is essential to completing the tasks in the algorithm – complexity and criticality may require constant communication.

- A **tracheotomy** is an extremely difficult surgical procedure that involves cutting the throat and inserting a tube into the trachea. Although this procedure is shown in three steps in the ACLS algorithm, it is in reality a 2- 3 page procedure that would require constant communication and guidance from the flight surgeon and/or other medical staff from ground.
- Treatment of a **collapsed lung** is also an extremely complex and stressful procedure that is far more complicated than described in the ACLS algorithm procedures. A flight surgeon would be necessary for diagnosis and guidance via space-to-ground communication.
- All **airway management** steps (e.g., Intubating Laryngeal Mask Airway (ILMA) insertion) will likely require substantial communication with the ground.
- **Administration of drugs via injection** should always be guided by the flight surgeon and/or other crewmembers in contact with the ground.
- When **resuscitation** efforts (e.g., CPR) must continue for up to 45 minutes before termination, the crewmember needs another person, likely from the ground, to guide them through the process and monitor and/or count all steps.
- **Post-resuscitation** steps have limited procedures available and require support from the flight surgeon.

Hardware Maintenance - Multi-Purpose Logistic Module (MPLM) Vestibule-Configure for Ingress

- The process takes place at the Node 1/MPLM Vestibule berthing region and lasts approximately 3.5 hours.
- There are 11 main elements in the set of procedures.
- A significant amount of reporting, status verification, and subtask clarification takes place from ISS to Mission Control Center (MCC) (at least 19 instances).
- A unique aspect to this procedure is the required communication that takes place between ISS and Shuttle. For example, reporting must take place from Station to Shuttle that MPLM power and data jumper installation is complete and MPLM activation can begin.
- Crew-to-crew communication is highly critical in many steps. In particular, whenever Personal Computing System (PCS) commands are to be entered (at least 3 detailed command sequence entries), inter-crew communication (ICOM) must be used between crewmembers to deliver the appropriate commands.

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Payload/Science

Advanced Diagnostic Ultrasound Operations

- Operation of the ultrasound during experiments will require communication to the ground beyond the current capabilities of the ATU
- The ground 'remotely guides' the ultrasound operator through the process of collecting real-time images, determines acceptability of the images, informs the crew of the location on the subject to which the probe should be moved.
- The crewmembers will need to hear and acknowledge the ground without having to use their hands while executing these procedures
- Communication wires will likely cause interference with the probe wires. Limited (rather than constant) voice activation is a valid recommendation.
- Constant voice activation would not be desired because the operator may need to talk to the subject during the procedures without requiring ground communication. For this reason, voice activation via pre-determined verbal commands may be a viable option.

Space Linear Acceleration Mass Measurement Device (SLAMMD)

- The main steps of the procedure include assembly, calibration, mass measurement, and disassembly.
- Warnings (as defined in "SLAMMD Calibration" procedure, step 2.3) state that no other crewmembers can be in the vicinity of the equipment. For this reason, inter-crew communication will need to take place between modules.
- Crewmember needs to be able to use both hands throughout most of the test and may not be able to press ATU buttons. The tests need to be performed quickly because equipment components will release (equivalent to 'cancel') if one minute elapses without activity.
- Communication cannot involve significant translation of crewmembers to an ATU in support of several other procedures.

Life Science Glovebox (LSG) Drosophila Malanogaster Airflow Demonstration, Rodent Dissection Test, Plant Science Test

- All LSG tasks, some requiring two crewmembers, will involve insertion of both hands into glove holes in the glovebox.
- Ground support, status verification, and other step-by-step crew-to-crew communication throughout each step will be essential to successful task completion.
- The operator would need to remove his or her hands from the glovebox to access the ATU or a 'push-to-talk' (PTT) mechanism. In the example tests, hand removal may cause disturbance among the Malanogasters, unnecessary jostling of the plants, or the need to set down the rodent in the middle of the experiment.
- All of these changes would cause inconsistencies, additional unwanted variables, and noise in each test. Voice-activated wireless communication would eliminate this problem.

Non-Medical Emergencies – Fire

- Crew will need to follow a unique set of guidelines specific to the module in which the fire is located.
- If an automatic smoke or fire signal has not been activated, the crew should immediately manually activate the C&W panels.
- Breathing masks should also be administered and worn by each crewmember, adding the O2 flow noise.
- All crewmembers must be immediately notified that a given module contains a fire, regardless of their locations within the Station.
- Fire will not always occur within a short distance from an ATU. If this is indeed the case, crewmembers will be forced to leave fires unattended in order to contact the ground to verify status and/or receive instructions.
- Wireless connection to the ground and other crewmembers could result in quick receipt of text messages that would be simple and enhance the transfer of information while minimizing risk in such a stressful and dangerous situation.

Public Affairs - Space-to-Ground Live Interviews

- The office determined that a wireless system would be of little value with these interviews because the crew already successfully uses ATUs and normal audio downlinks, synchronized with the video on the ground.

Robotics - Manipulation of the Robotic Arm: Movement/Installation of Port 1 (P1) Truss Segment

- Standard operating procedures for robotics tasks typically involve specification of camera views, arm movement rates, arm positions, joint angles, and precise coordinates of robotic arm components.

- There is little room for error in any of the procedures, as risk is often considerable. For example, the Port 1 (P1) integrated truss assembly install, ungrapple, and handoff procedures involve three EVAs which elevate risk and the need for efficient and accurate crew performance.

- Communication (i.e., status updates, questions, off-nominal communication, etc.) to the ground occurs with relative frequency during robotics tasks such as these.

- The current crew has a microphone that can attach to two ATUs in close proximity to the RWS in the Lab. Although this involves three-foot and 15-foot translations to the aft and forward ATUs, respectively, this setup occurs only before each robotics task begins

- For this reason, wireless communication, although a beneficial luxury, is not essential at the present time.

Requirements Assessment

Development of potential operational, functional and performance goals of WCC

- Task analysis, Avionics Division input, market research of existing wireless technologies used
- Results are preliminary requirements, as individual crew preferences and more extensive feasibility studies will be conducted.
- The current functionalities of ATUs onboard Station were investigated as well as identifying possible aspects that should be enhanced via WCC.
- Potential goals sorted into:
  - Controls
  - Compatibility with existing hardware
  - Ergonomics
  - Radio frequency characteristics
  - Power
  - Miscellaneous features

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Controls

Voice Activation - VOX	Push-to-Talk	Dual Mode
Micro-switch mode selection switch	Muting capability during VOX	Micro-switch volume technology
LED indicators for power, link, errors, low battery, etc.	Auditory notification	Prevention from accidental actuation
Blind operation features	Headset control capabilities	Multiple PTT buttons
Speaker	Auditory amplification	Multi-display menus
Multi-crewmember interface	Wireless interface with other ISS equipment	Vibration capabilities
Auditory pager	Voicemail	Voice memo recorder
Preset messages	Text messages	Built-in camera/picture messaging
Signal strength indicator	Timer	Voice-activated mode selection/dialing capabilities

Compatibility with existing hardware

Hardware interface with existing ISS ATUs, ISS headsets, microphones, personal equipment	Hardware interface with STS (Shuttle) communication system	Russian segment interface

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Ergonomics

Overall dimensions/envelope of the WCC controller unit	Overall shape of WCC housing and any additional components	All user interface components/controls

Radio frequency characteristics

Direct links to each crewmember	No interruption link-up from module to module

Power

Rechargeable	Flight certified
Small battery	Strength indicator

Miscellaneous features

Boom microphone attachment for PAO	Velcro or clothing clip for microphone and/or speaker unit
Commercial off-the-shelf (COTS) devices	Chemical resistant covering

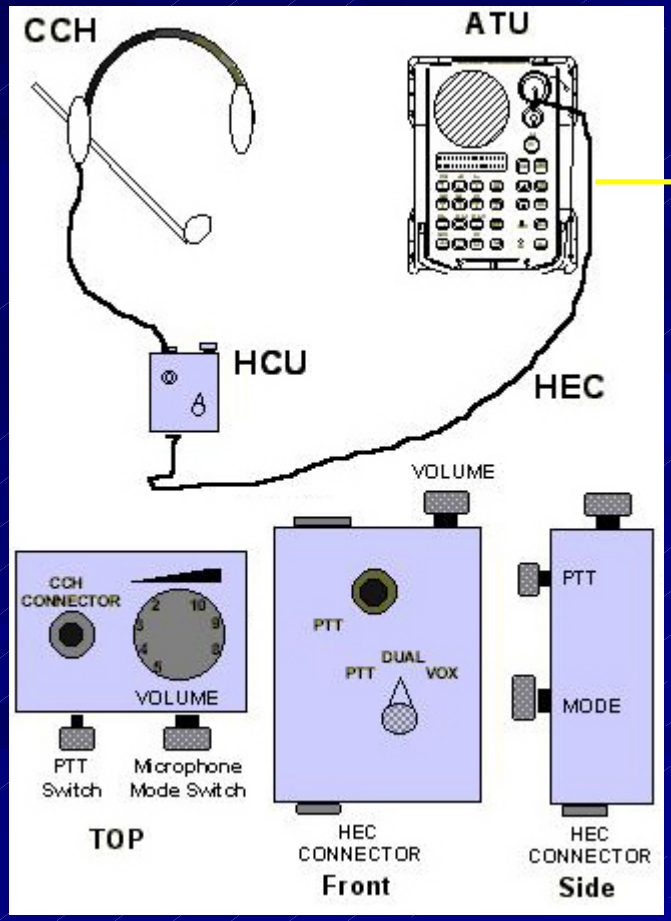
Current ISS Audio Equipment

The International Space Station (ISS) internal audio distribution system crew equipment consists of :

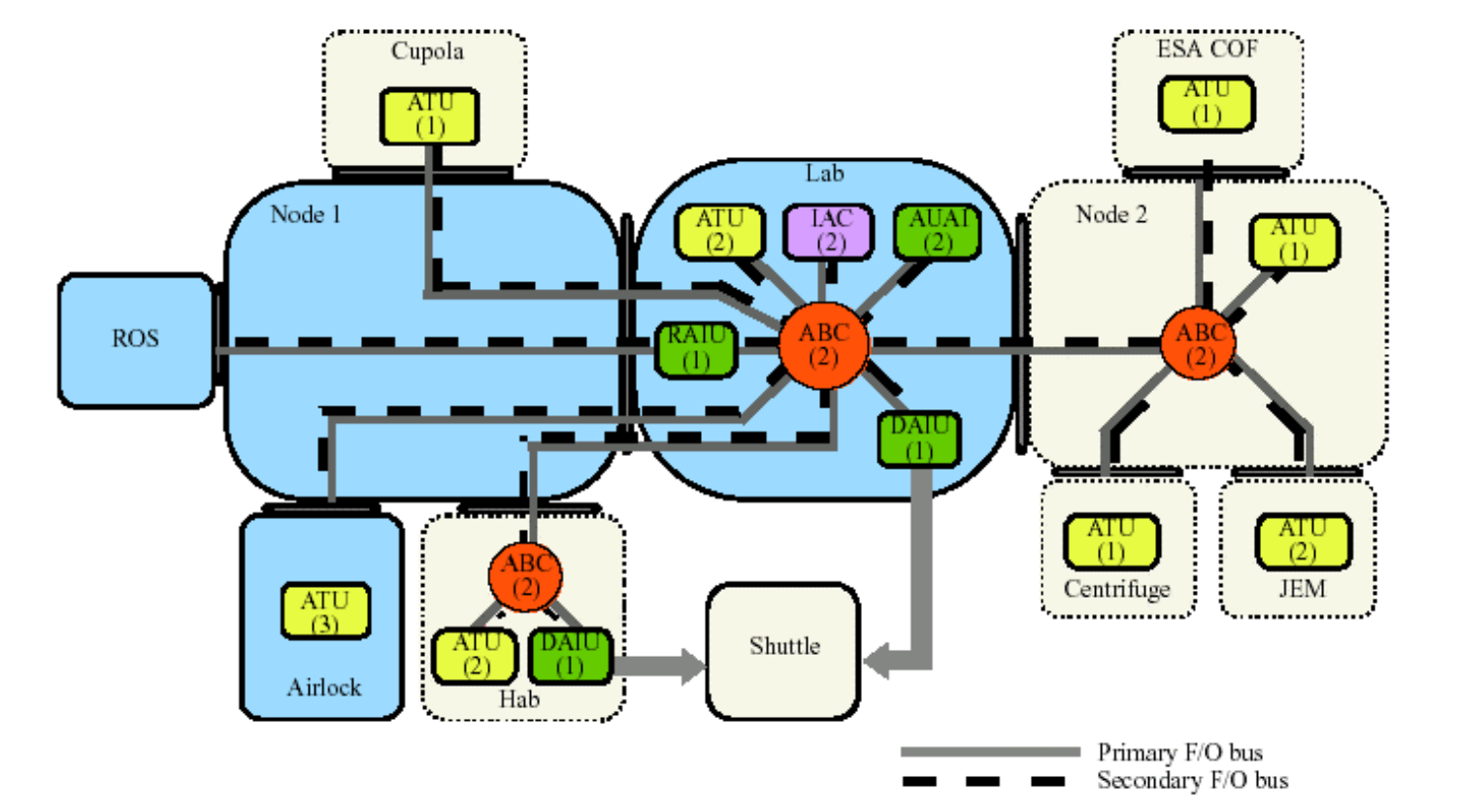
- Audio Terminal Units (ATUs)
  - Located within each ISS module.
  - Provides audio I/O to the Crew members
  - Crew communication headset (CCH) connects to the ATU via headset control unit (HCU) headset extension cable (HEC).
  - ATU has built in speaker
  - ATU can also accommodate connection to a portable microphone (PMIC)

- Headset Control Unit (HCU)
  - Provides the interface between the crew headset and the ATU
  - Provides mode selection (Push-to-Talk (PTT) capability or VOX operation)

Current ISS Audio Equipment Illustrated:



ISS Audio Distribution



(IAC – Internal Audio Controller; ABC – Audio Bus Coupler; AUAI – Assembly-contingency /UHF Audio Interface; DAIU – Docked Audio Interface Unit; RAIU – Russian Audio Interface Unit)

Wireless Crew Communication System Concept Demonstration

Development and Evaluation of Conceptual Designs – Goals Accomplished

- Demonstrated prototype hardware for crewmember to interface wirelessly to ISS ATU's
- Developed prototype wireless headset control unit (WHCU) using the commercial Bluetooth IEEE 802.15 wireless standard ("Bluetooth" is a Wireless Personal Area Network (WPAN) technology)
  - Assisted in defining and baselining functional and operational requirements, Station requirements versus enhanced wireless goals

Develop wireless test bed

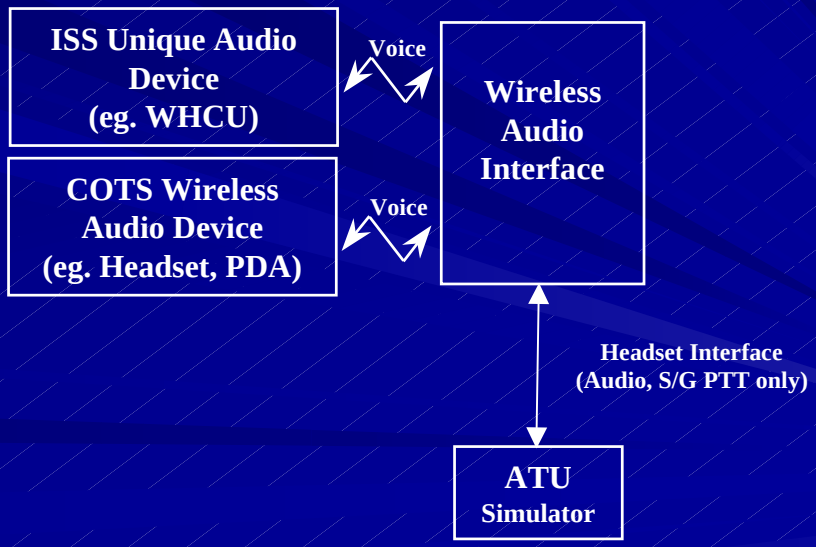
Design ATU Bluetooth interface that is compatible with COTS Bluetooth-enabled audio devices

Design custom Bluetooth radio modules for incorporation into ISS-unique crew audio devices

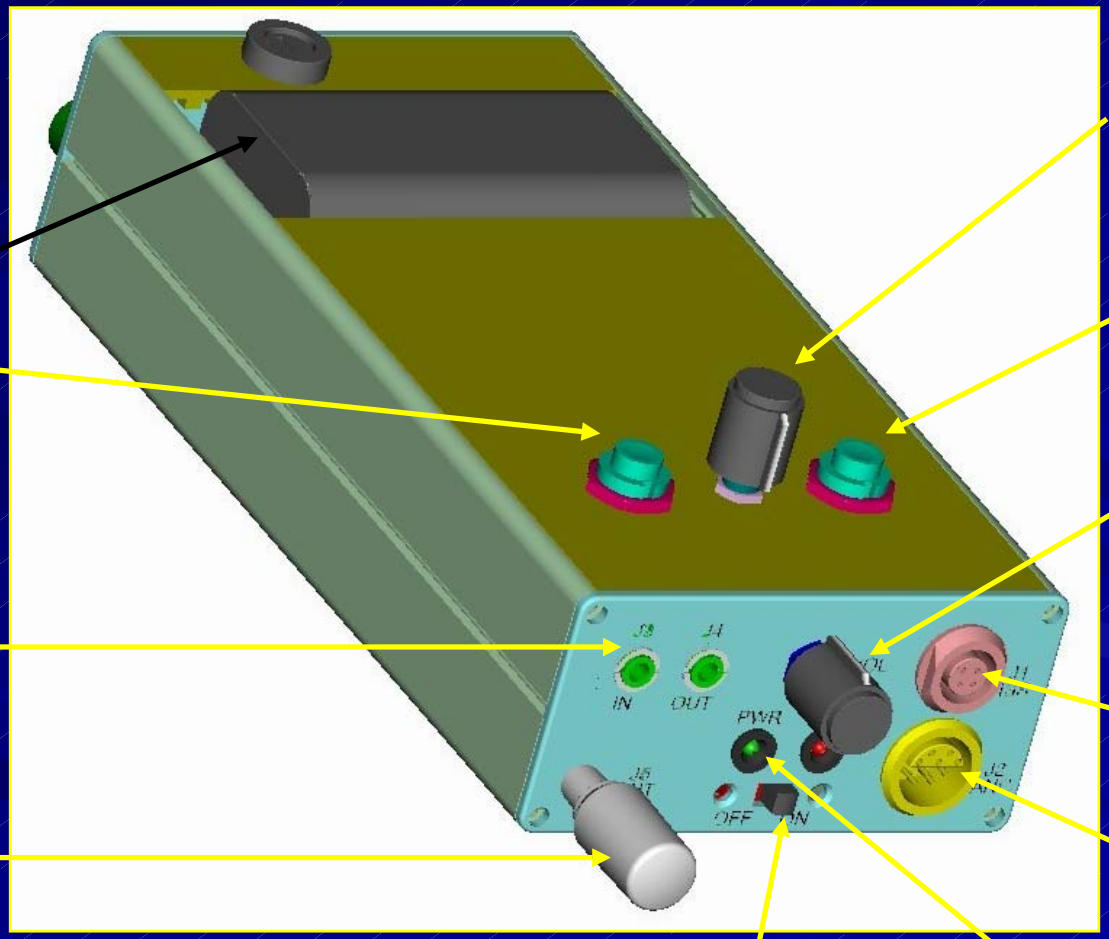
Ergonomic features of crew audio devices

COTS audio devices

ISS unique crew audio devices



Wireless Headset Control Unit Prototype Demonstration Unit



Mode Switch

PTT A/G

PTT ICOM

Volume

CD Player Interface

ISS Headset
(or PBA Mask)

Antenna

ANC Headset

Power Switch

Power / RF Link LEDS

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- Wireless headset control unit prototype demonstration unit tested in the ISS System Integration Lab (ISIL) with Station audio system.

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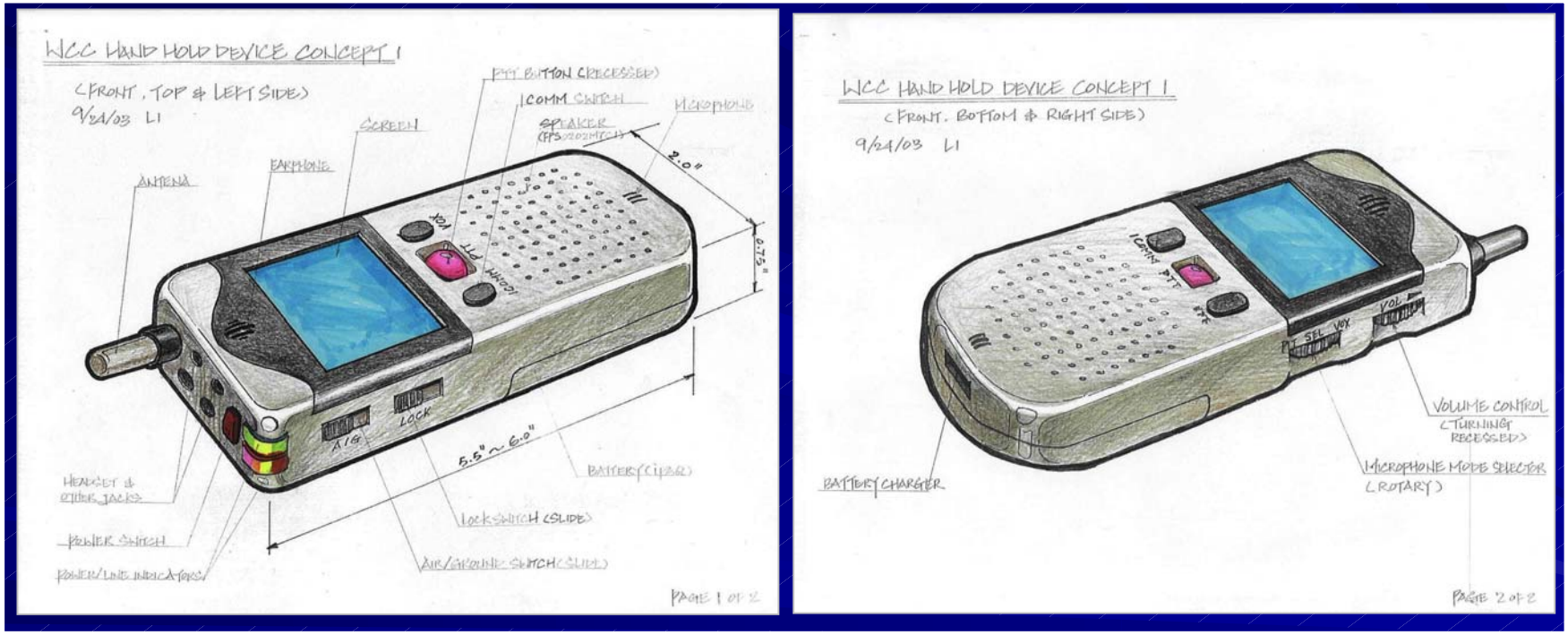
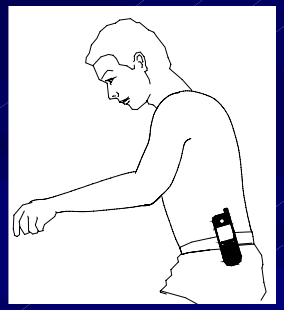
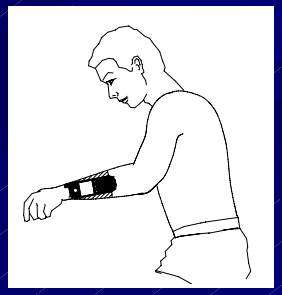
Conceptual Design Development
Preliminary Concept of WCC Hand-held Unit



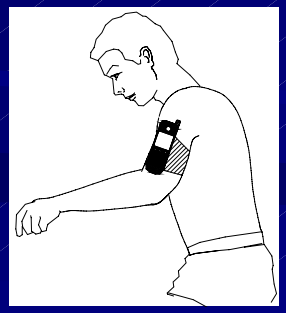
Conceptual Design Development



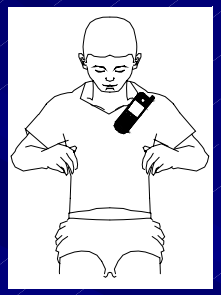
- Attach device on waist
- Use 1 hand to hold device when in use, or attach to surface nearby if speaker built-in
- No headset



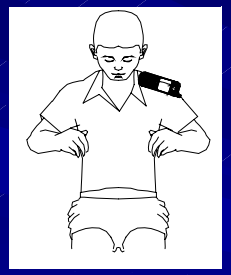
- Attach device on wrist.
- Move the hand close to the mouth when in use, or attach it to surface nearby if speaker built in
- No headset



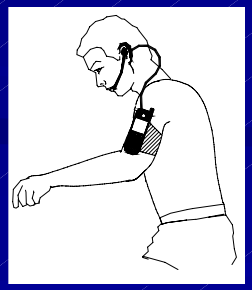
- Attach the device on upper arm
- Turn the head toward the device when use, or take it out hold by hand, or attach it to the surface nearby if speaker built in



- Attach the device on chest
- Turn the head toward the device when talking, or attach it to the surface nearby if speaker is built in
- No headset

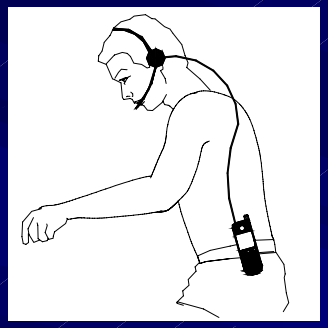
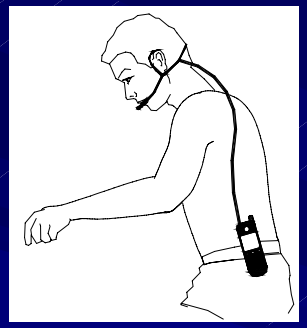
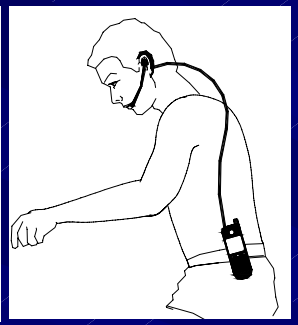


- Attach device on the shoulder
- Turn the head toward the device when in use, or attach it to surface nearby if speaker is built in
- No headset

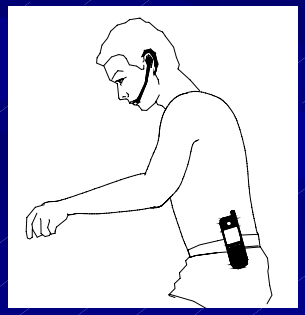


- Attach the device on upper arm
- Turn the head toward the device when use, or take it out hold by hand, or attach it to the surface nearby if speaker is built in
- Attach device on upper arm

Conceptual Design Development

- Attach the device on waist; headset is optional to get hands free.
- Headset connect to the device by cable
- The handhold device can be used independently.
- The cable could be retractable to reduce the volume
- No headset



- Attach the device on waist
- Headset is used to have hands free
- Connecting the headset and the device by “blue tooth” technology.

Wireless Crew Communication System Concept Demonstration

Conceptual Design Development

Conceptual Operational Utilization

Forward Work

- Refinement of requirements
- Conduct an initial focus group, using proven discussion/consensus techniques, in which the user (the crewmembers), and direct support personnel can brainstorm and provide input regarding the most critical features of a wireless communication system.
- Focus group will include crewmembers and ISS Program Office personnel, specialists in crew systems operations, habitability and crew systems engineering, human factors, habitability design, and communication systems.
- Compile a formalized requirements document and use to guide the design process.
- Continuation of conceptual design development.
- Heuristic evaluations and usability tests to be employed to assess each successive design concept.
- Post-iteration of the design and evaluation, a ground-based, fully-operational wireless system prototype will be developed for use in evaluating crew efficiency gains.
- A prototype integrating the results of the wireless technology development testbed and the conceptual design of the user interface will then be developed for formal usability testing.