JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: PAS 101

Date: May 6, 2011 **Time:** unknown **Location:** JSC/B5S/R3204

DAA 1676 Form #: 29634

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video \\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY11 Knowledge Capture\20110505 D. Irimies_PAS 101\For 1676 Review & Public Release

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

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* This PDF is also attached to this 1676 and will be used for distribution.

For 1676 review use_Synopsis_Irimies_PAS 101_5-6-2011.pdf

Presenter: David Irimies

Synopsis: EVA systems consist of a spacesuit or garment, a PLSS, a PAS system, and spacesuit interface hardware. The PAS system is responsible for providing power for the suit, communication of several types of data between the suit and other mission assets, avionics hardware to perform numerous data display and processing functions, and information systems that provide crewmembers data to perform their tasks with more autonomy and efficiency. Irimies discussed how technology development efforts have advanced the state-of-the-art in these areas and shared technology development challenges.

Biography: Dr. David Irimies has worked at NASA for 10 years in project management; communications, command, control, and information (C3I) software development; communication systems, including Desert RATS communications infrastructure, ground truthing, and ground station support; and aeronautics software development. His specialty areas have included communication systems engineering, network engineering, and software engineering. He has served as the PAS subsystem lead for EVA Technology Development. He has a bachelor of science in computer engineering from Purdue University and a doctor of jurisprudence from the University of Akron.

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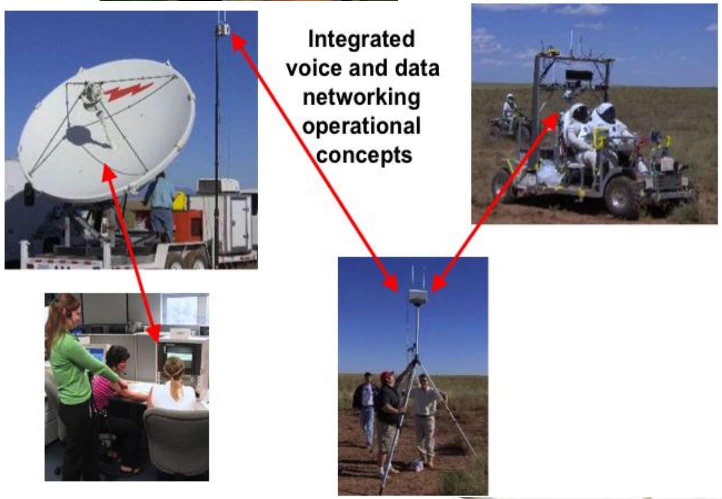
Extravehicular Activity (EVA) Power, Avionics, and Software (PAS) 101

David Irimies
GRC

May 5, 2011

EVA Historical Efforts at GRC

- **2006-Present: ETDP/ETDD**
- **2005-10: CxP EVA Level 3 (SE&I) and 4 (Suit Elt)**
  - Present: LEA
- **2006, 09-Present: Desert RATS EVAIS, ECLDS, other Tech Demos (radio, HMD, etc.)**
- **AEVA, 04-06: Mark-III tests: Integrated Audio precursors, etc.**
- **2003-05: Desert RATS Comm Infrastructure and CAI Pack**



National Aeronautics and
Space Administration

Extravehicular Activity (EVA) Technology Development

Power, Avionics, and Software (PAS) Subsystem

The NASA Glenn Research Center is the lead Center for technology development of the PAS Subsystem for the next generation space suits.

Increase Quality of Data and Communications

- Integrated suit audio
- Miniaturized EVA radios
- Complex electronics




Crew Safety and Comfort

- Caution and warning
- Biomedical advisory software
- Advanced suit batteries and packaging
- Switches and connectors




Multimission Exploration With Increased Crew Autonomy and Productivity, Enabling Faster and Enhanced Returns On Science

- Cameras for science and mission videos and photos
- Information systems
- Helmet-mounted displays
- Cuff-mounted displays
- Speech recognition software
- Surface navigation









enabling future technologies

Power, Avionics, & Software Subsystem I/F

- PLSS
  - Oxygen Subsystem
  - Ventilation Subsystem
  - Thermal Subsystem
- Suit
  - Helmet
  - HUT
  - Gloves
  - LTA* (IMUs)
- Power
  - Battery
  - Power Conversion
  - Power Distribution
- Avionics
  - Radio
  - Caution and Warning
  - GigE Bus
  - Integrated Audio
  - Switches/Ctrls
  - Nav*
- Software
  - Info. Sys
  - Automated C/O

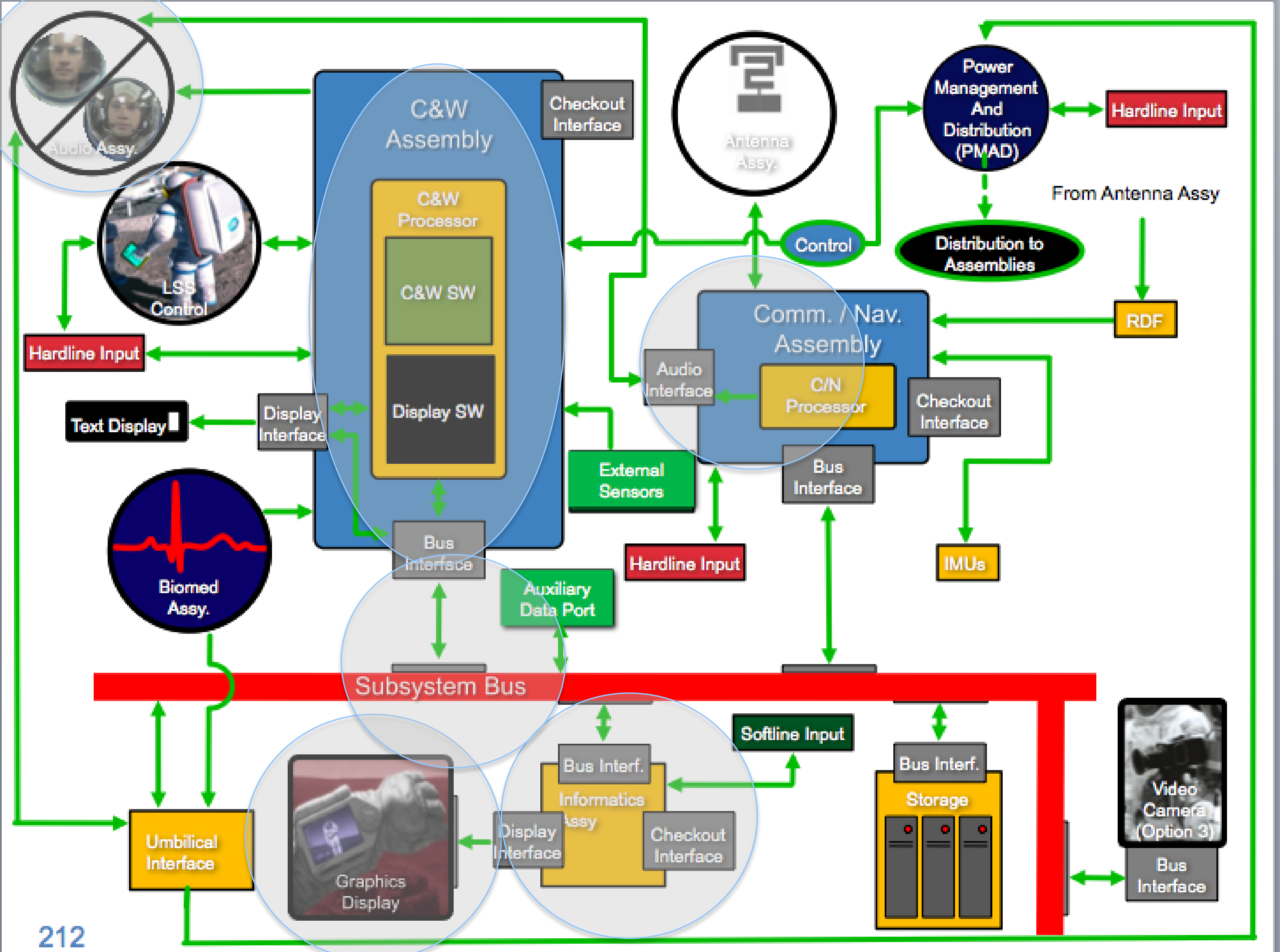
Unfunded Devel.

GRC EVA ETDD

- **The GRC EVA ETDD team develops low Technology Readiness Level PAS technologies to improve efficiency and autonomy of future EVA operations**

- **Technology vs. application**
  - Future EVAs rely on advanced technologies
    - Electronics will get smaller and more power efficient
    - Batteries will get lighter and more efficient
    - Communications will become more capable, while retaining reliability
    - More functions will move to embedded complex electronics tasks (software/firmware)
  - EVA-unique technologies i.e. suit components, information systems tools
  - EVA can also be a platform to evaluate new technologies from other development efforts i.e. ultra-high energy battery, radiation hardened avionics, information systems software

- **Other characteristics that make EVA special**
  - Minimal mass, volume, and power compared to vehicle applications
  - Integration – Due to their general size and extra emphasis on mass and power savings, EVA systems are highly integrated.

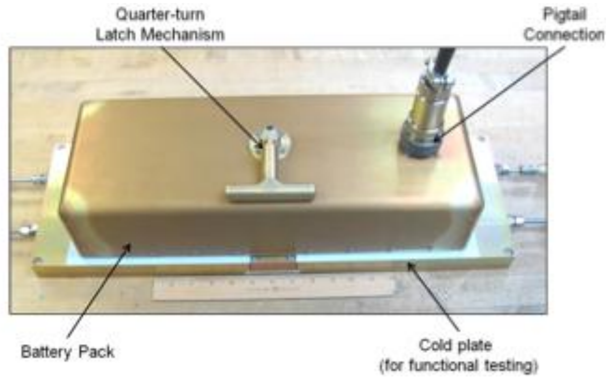

Audio Assy.
C&W Assembly
Checkout Interface
C&W Processor
C&W SW
Display SW
Display Interface
Bus Interface
Antenna Assy.
Power Management And Distribution (PMAD)
Hardline Input
From Antenna Assy
Control
Distribution to Assemblies
LSS Control
Hardline Input
Text Display
Comm. / Nav. Assembly
Audio Interface
C/N Processor
Checkout Interface
RDF
External Sensors
Bus Interface
Hardline Input
IMUs
Biomed Assy.
Auxiliary Data Port
Subsystem Bus
Softline Input
Bus Interf.
Informatics Assy
Display Interface
Checkout Interface
Bus Interf.
Storage
Video Camera (Option 3)
Bus Interface
Umbilical Interface
Graphics Display

Power

- **Objective: Develop a power system to provide the PLSS with energy for up to an 8-hour EVA. Continue working closely with High-Efficiency Space Power Systems (HESPS) ETDD Foundational project (cell provider).**
  - Technology Need: EMU requires 532 Wh (26.6 Ah, 20V) from either Ag-ZN or Li-Ion battery in a mass allocation of 6.4kg. Future PLSS requires 1155 Wh in 5 kg package.

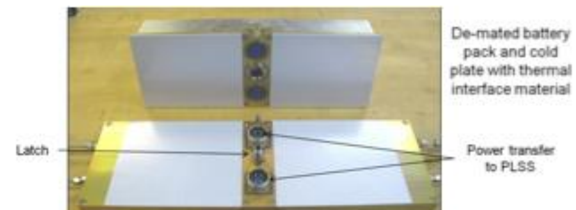
Past Accomplishments

- Completed trade study on power management and distribution architecture, convertor efficiency, and battery voltage range on battery mass
- Refined PLSS power and operational requirements, and established state-of-the-art lithium-ion technology baseline
- Developed swappable battery mockup with ZIN technologies to mitigate Suit Risk #2527 of not achieving sufficient energy density for an 8-hour battery.



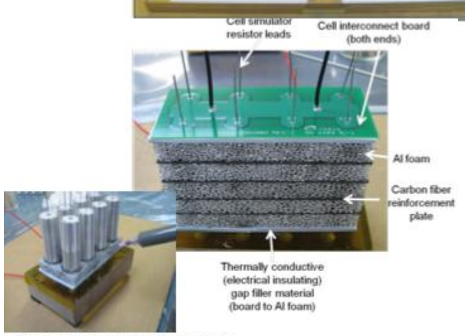
FY'10 Accomplishments – DC-DC Converters

- Market Survey of suitable converters to mitigate power losses
- Completed Design and Build of DC-DC Test Assembly
- Completed Functional Test Report of DC- DC Converters



FY11 and Long-Range Plans

- Revised Powered Equipment List/Battery Sizing
- Develop a 2nd Gen battery design and prototype
  - Analysis of cell packaging materials and designs that account for the required structural and thermal protection of the cells and minimize the volume of the battery assembly
  - Incorporate HESPS High Energy and Ultra High Energy Cells into batteries that can be used for EVA system demonstrations



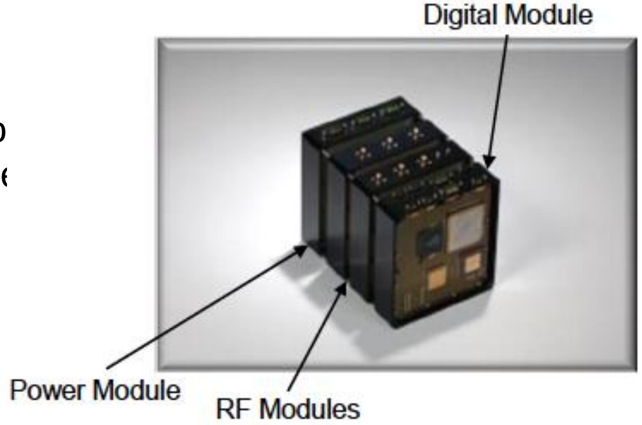
of thermally conductive resin to bond cell case to foam


Vicor Converter Under Test

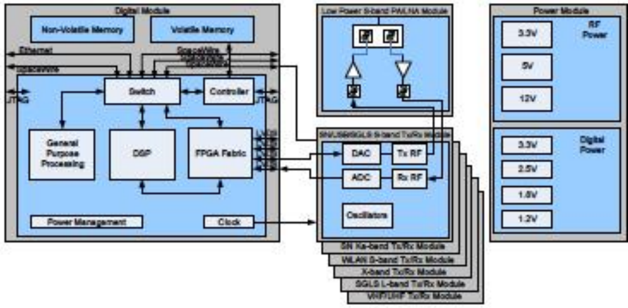

DC-DC Converter Test Assembly

Radio

- **Objective: Develop an EVA radio capable of transferring EVA data flows under various operational scenarios, within the given SWaP allocation.**
  - Technology need: Radios such as SSER do not provide sufficient flexibility to accommodate for changing mission profiles; yet, the size, weight, and power envelope of current software radios exceeds those of EVA.

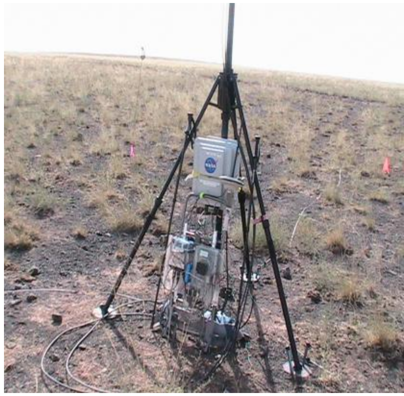


- **Past Accomplishments**
  - Defined a WiMax/802.16e System Profile applicable for destinatio wireless network, specifically for meeting EVA data flow requireme
- **FY'10 Accomplishments**
  - Link Layer Control and medium access control (MAC) Models of System Profile
  - Network Performance/Analysis Report (ongoing)
  - Kickoff Miniaturized Radio Technology Trades (ongoing)
- **FY'11 & Long Range Plans**
  - Continue Miniaturized Radio Technology Trades
  - Define operations concepts and interfaces for ISS Radio
  - Continue development of link layer and MAC algorithms for point-to-point and mesh mode radio.
  - Deliver & Field Test 1st Gen Radio prototype

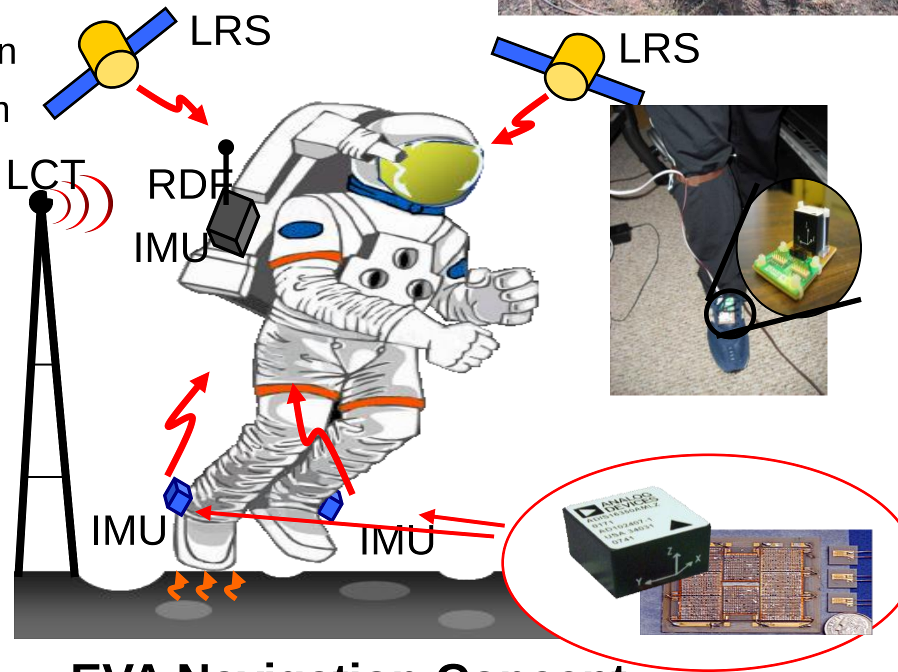


*Navigation

- **Objective: Develop concepts, analyses, and technologies in support of an EVA crewmember location determination system sufficient for walk-back and navigation to EVA sites.**



- **Past Accomplishments**
  - Simulation study examined performance of combined radiometric/inertial system
  - Demonstrated 1st Gen EVA Crew Location Determination System at DRATS '09
- **FY'10 Accomplishments**
  - Report of DRATS Nav Demo Testbed Data Collection
  - Updated Performance Projection of EVA Nav System
  - Report of Navigation Infrastructure Requirements
  - Nav Demo Testbed v1.2 Fielded at DRATS 2010
  - Evaluated effects of different sensor technologies, signaling structure, infrastructure, traverse path and walk-back scenario, filtering technologies on sys. perf.

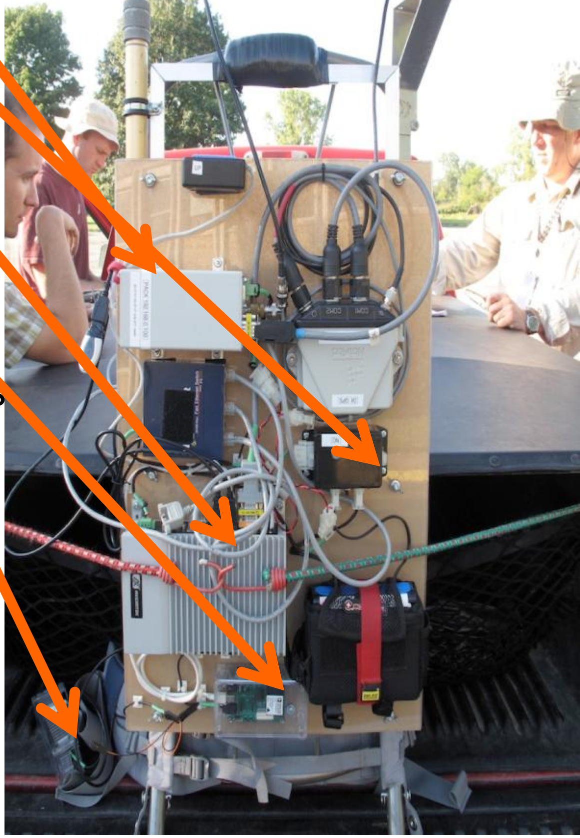


EVA Navigation Concept

ECLDS at DRATS 2010

GRC tested a prototype EVA crewmember navigation system. Test subjects performed 10-km "walk back" exercises, using the navigation system to guide them to back to base.

- New and improved test-bed back-pack sports cleaner look! and…
  - » Extensible data link radio antenna (adds safety margin for RF radiation)
  - » New FGR+RE data link radio (enables Ethernet connectivity to nav processor)
  - » New power sub-system (hot swap)
  - » New dual-core processor (better data throughput for GPS, IMU, 5 Hz updates)
  - » New Torso IMU (increased sensitivity, better synch with radiometrics)
  - » Boot IMU with Tremont Electric energy harvester (look Ma! No wires!)
- – Built-up new IMU interfaces—employs pulse-per-second signal from GPS for synchronization.
- Built SW interface to new data link radios (and old ones too)–kinematic filter now uses measured range
- Aural displays —waypoint alarm and turning bells allow for "heads-up" operation



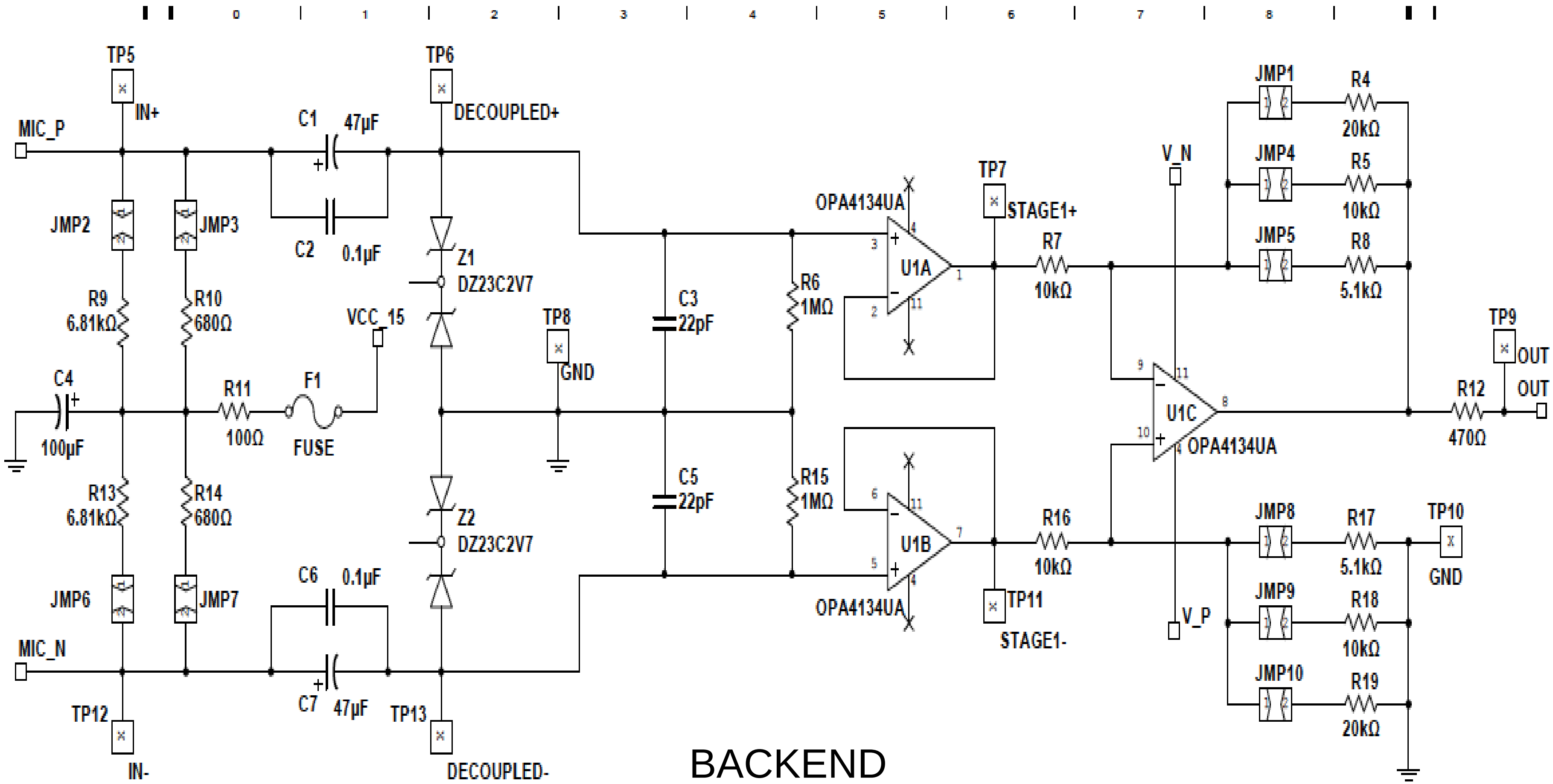
Integrated Audio

- **Objective: Develop IA system (helmet mounted speakers and microphones) to overcome logistical issues that cannot be addressed with incremental improvements to cap-based solutions.**

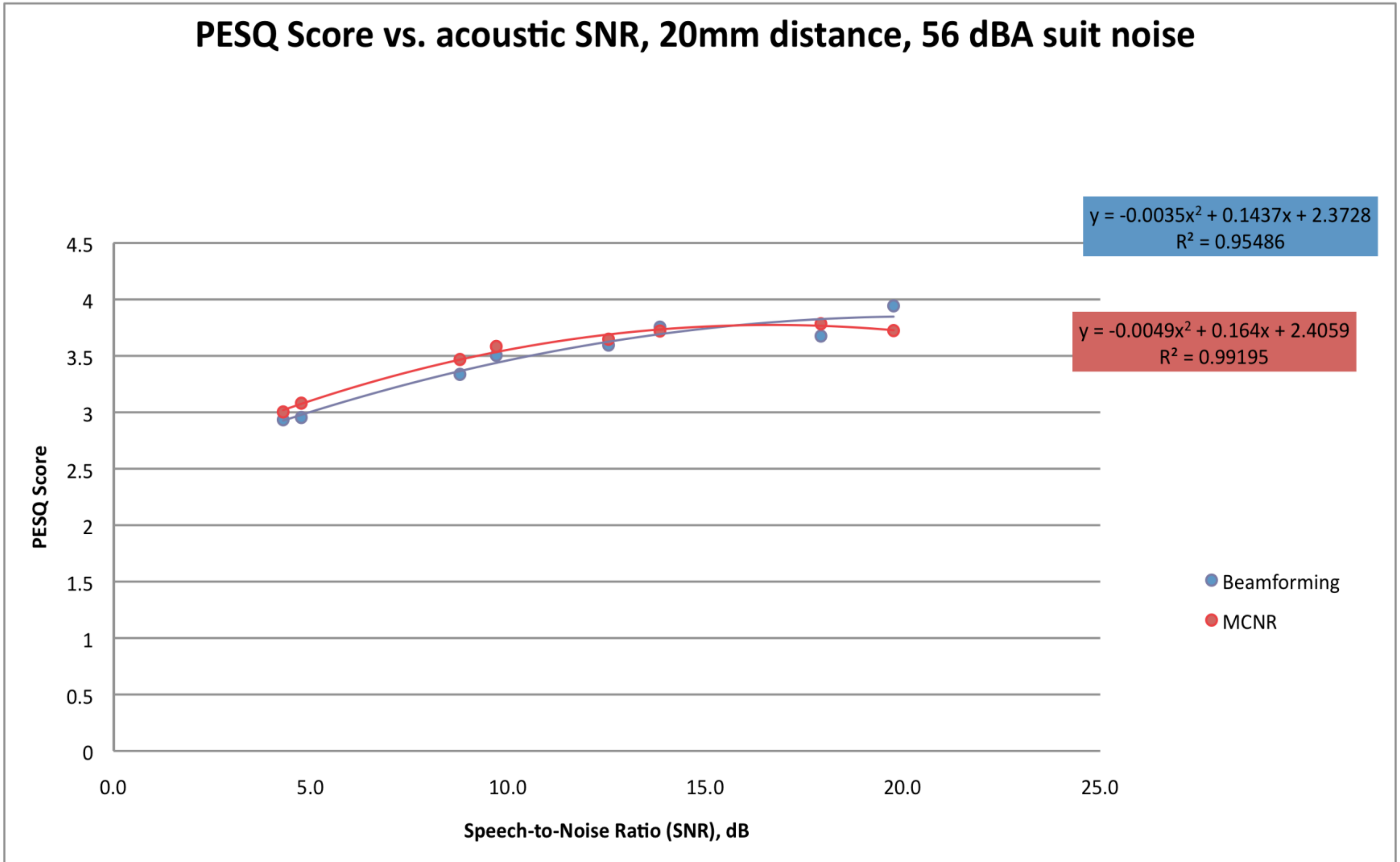
- STS-130 MOD IMMT: sweat/moisture in ear cup electronics shorted out CCA and unexpectedly decreased volume and crew feedback on EMU issues

- **Past Accomplishments**
  - Integrated Audio trade study - subjective assessment recommends "hybrid" system
- **FY'10 Accomplishments**
  - Built full-up IA system with options for:
    - Noise reference suppression of inbound channel in outbound chanr
    - Updated beamforming/multi-channel noise reduction (MCNR) algor
  - Completed Pressure Chamber Tests and Reported on Mean Opinion Score Characterization of MCNR
    - Test speech quality/intelligibility using subjective (people) methods
    - Test board with HATS, characterize MOS, etc. at GRC

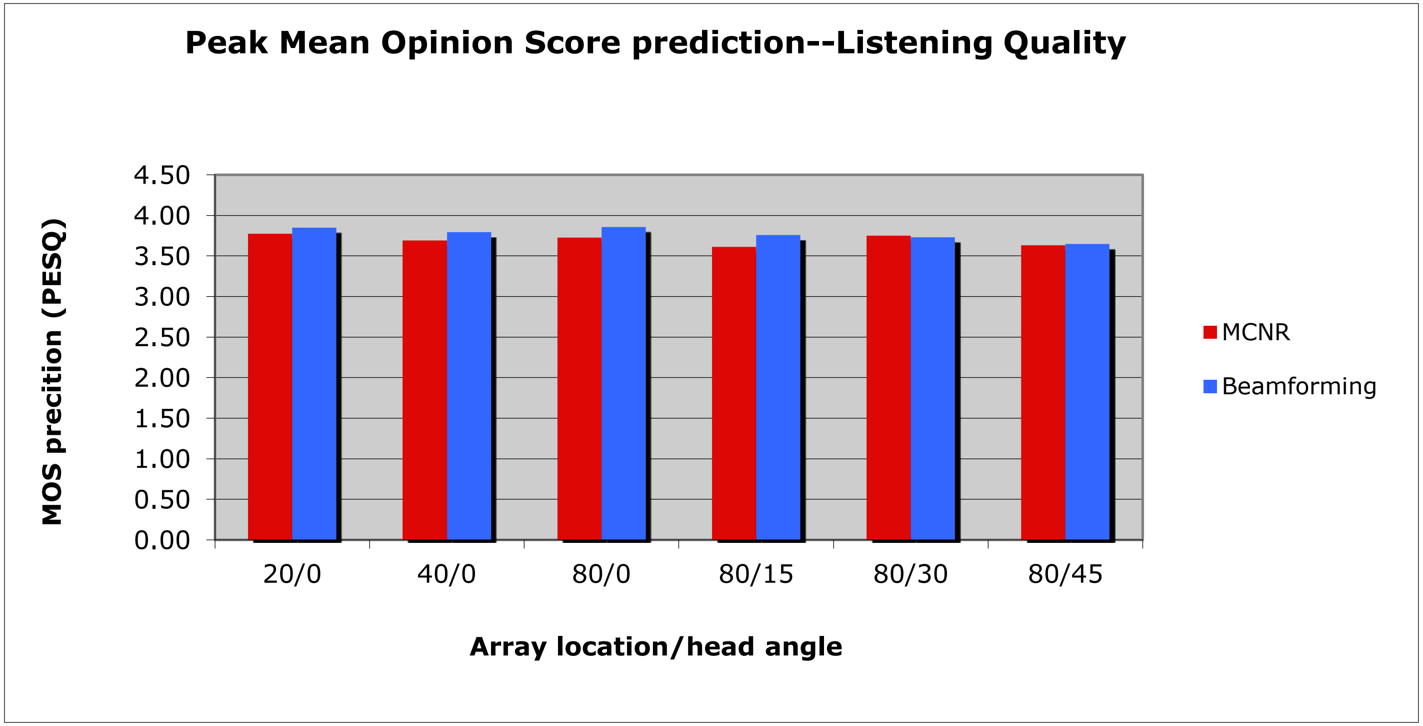
- **FY'11 & Long Range Plans**
  - Develop processing for suppression of interference from structure-borne vib.
  - Develop advanced outbound audio options



BACKEND
CONVERTER

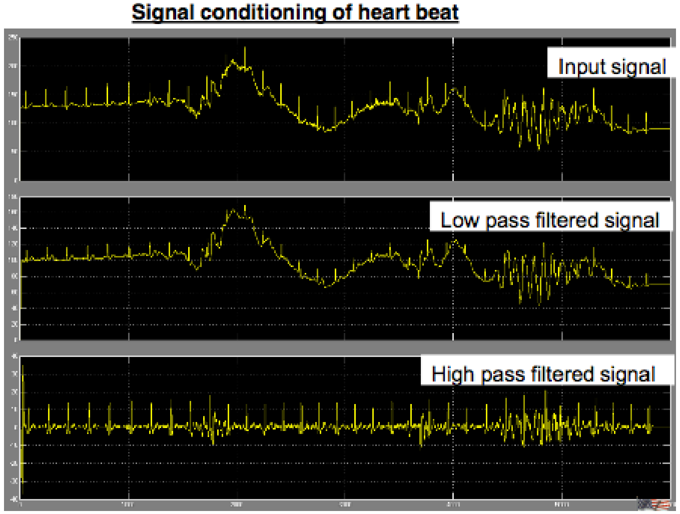


PESQ Score vs. acoustic SNR, 20mm distance, 56 dBA suit noise
y = -0.0035x² + 0.1437x + 2.3728
R² = 0.95486
y = -0.0049x² + 0.164x + 2.4059
R² = 0.99195
PESQ Score
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.0
5.0
10.0
15.0
20.0
25.0
Speech-to-Noise Ratio (SNR), dB
Beamforming
MCNR


Peak Mean Opinion Score prediction--Listening Quality
MOS precition (PESQ)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
20/0
40/0
80/0
80/15
80/30
80/45
Array location/head angle
MCNR
Beamforming

Embedded Hardware

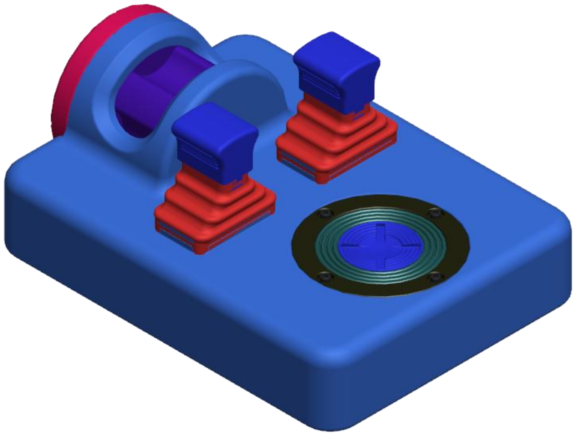
- **Objective: Identify and prototype specific, more SWaP efficient, dedicated hardware solutions - such as FPGAs, ASICs, and System-on-Chips - for processing as compared to a general purpose processor running software.**
- **Tighter development and timing considerations than GPP/SW**
- **Past Accomplishments**
  - Prototyped functions which can be carried out by a uniquely developed integrated circuit hardware element (ASIC, FPGA, SoC, etc) that will more efficiently implement PAS requirements.
    - C3I-baseline G.729 voice codec
    - Voice/Speech Recognition
    - Biomedical application for pulse-rate conditioning (Heart Rate Monitor)



- **Supports the assemblies and serves as knowledge group**
- **FY'11 & Long Range Plans**
  - GigE Bus Interface
  - Voice/Speech Recognition
  - G.729 Encoder
  - Evaluate all prototyping methods' performance (Stacked, FPGA, ASIC, other)

*Dust Tolerant Connectors & Switches

- **Objective: Design and develop connectors and switches that operate reliably in a dusty destination surface environment.**



Past Accomplishments

- Designed a membrane cycle test fixture
- Designed 3 different dust tolerant switch types:
  - Toggle
  - Rotary
  - Castle switch
- Delivered Dust Tolerant Switch Rapid Prototype and Mockup

FY'10 Accomplishments

- Refined Pro-E models of Connectors and Switches

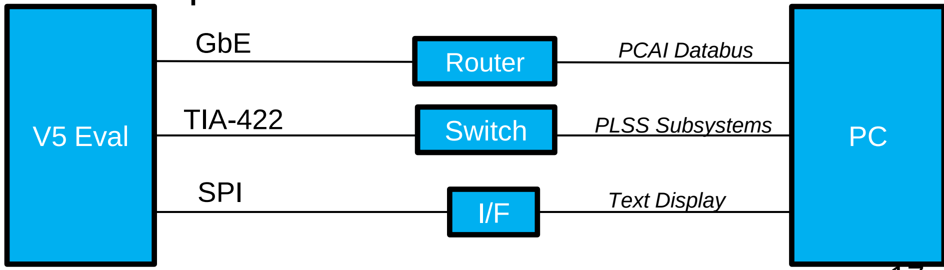
Long Range Plans

- Gen-2 electronically functional prototypes
- Evaluate the performance of the flight like hardware in a dust box

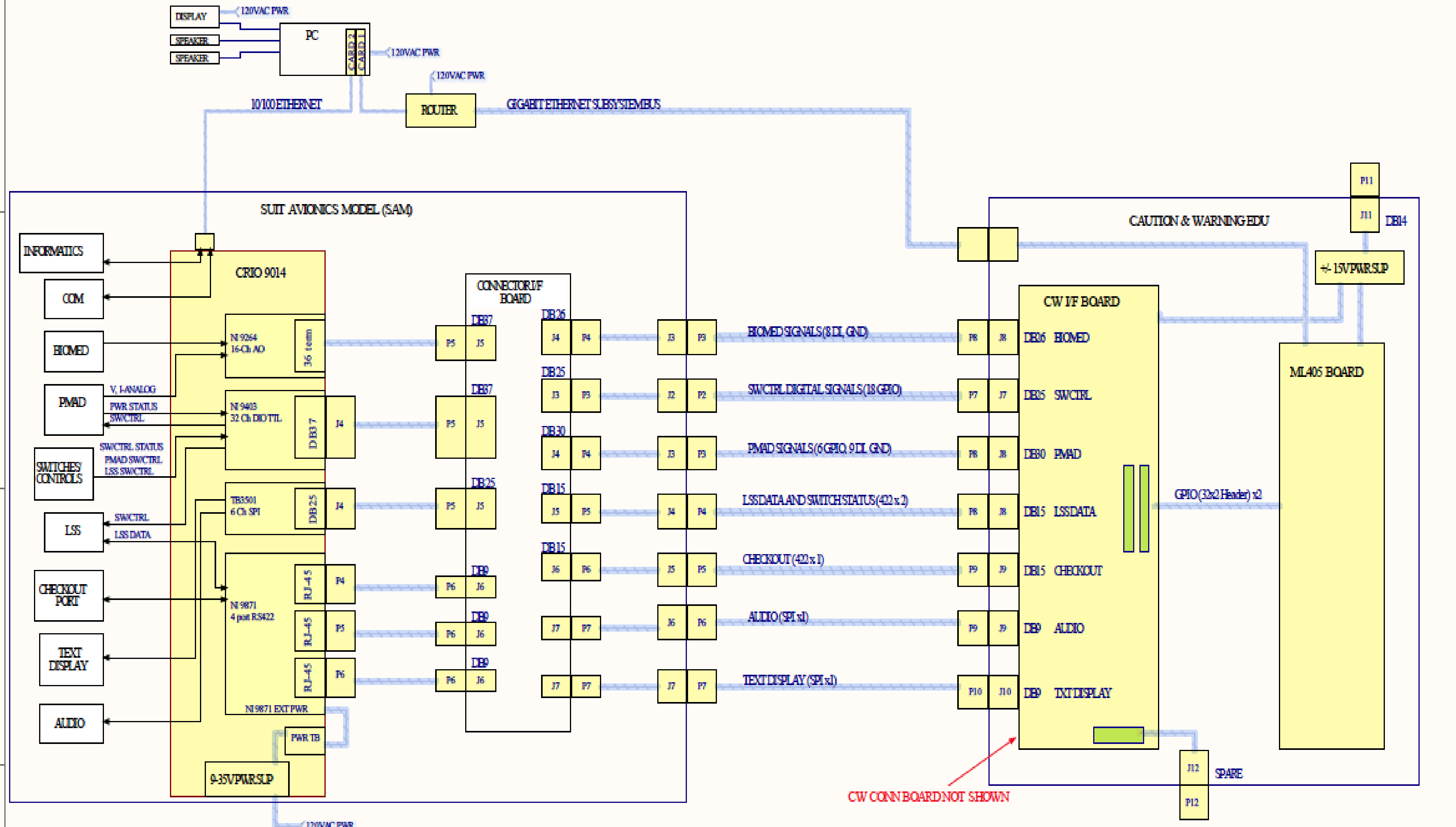
Caution & Warning

- **Objective: Design and develop next generation C&W system.**
  - Technology Need:
    - Stakeholder interviews revealed strong support for the future C&W system to obtain, process, and visually displayed each crewmember's individual C&W -and- other crewmember's C&W.
    - Interfaces more complex than EMU's eCWS, in a tighter SwAP.

- **FY'11 and Long Range Plans**
  - Gen 1:
    - Target the processor platform and incorporate subset of C&W functions (3 PLSS controllers and 'Lite' PLSS component interface development), GigE subsystem bus interface development, and 'Lite' text display interface
  - Gen 2:
    - Implement vast majority of blocks as hardware in Distributed Control Electronics Block Diagram: serial transceiver, watchdog, FPGA, RAM, OSC, Bus Driver, PMAD for sensors. Expect all the functions we need here.
  - Gen 3: Flight qualify and package Gen 2



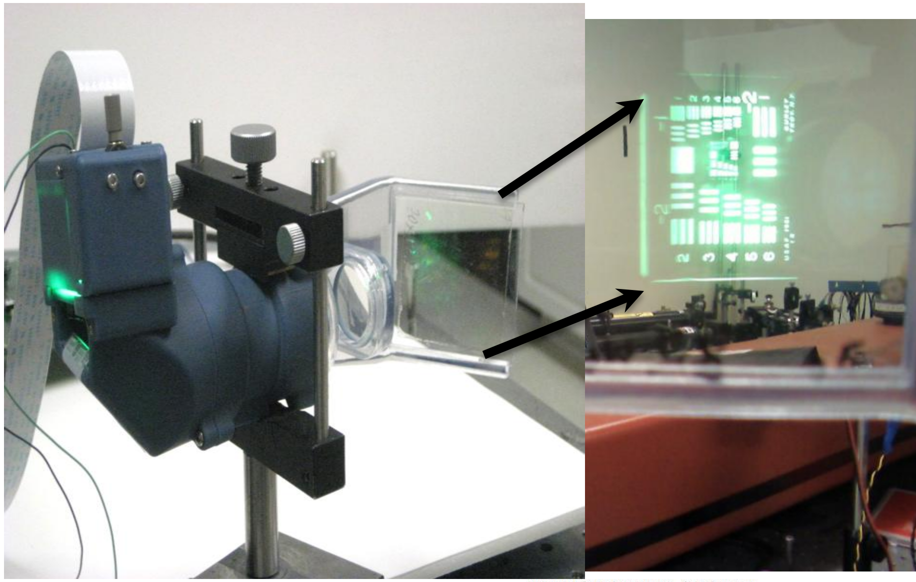
PAS C&W SYSTEM AND EMULATOR SYSTEM



Displays

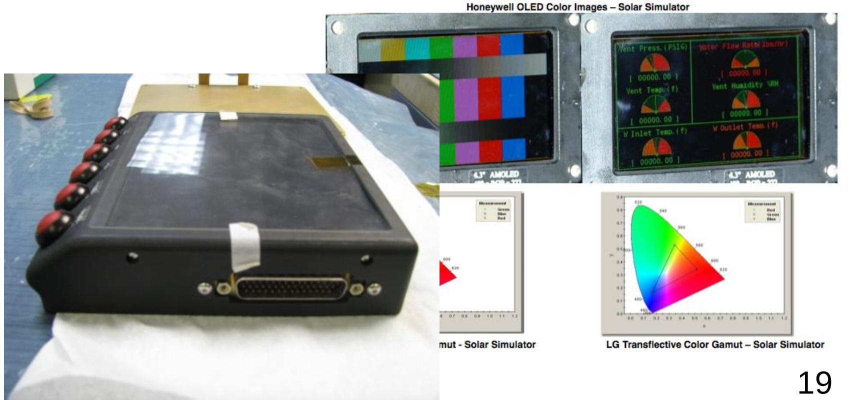
- **Objective: Develop a user-friendly and minimally invasive crewmember information display device that provides significant task efficiency improvement for a broad range of EVA tasks.**
  - As a risk mitigation effort and off-ramp technology for HMD work, investigate flat panel displays.

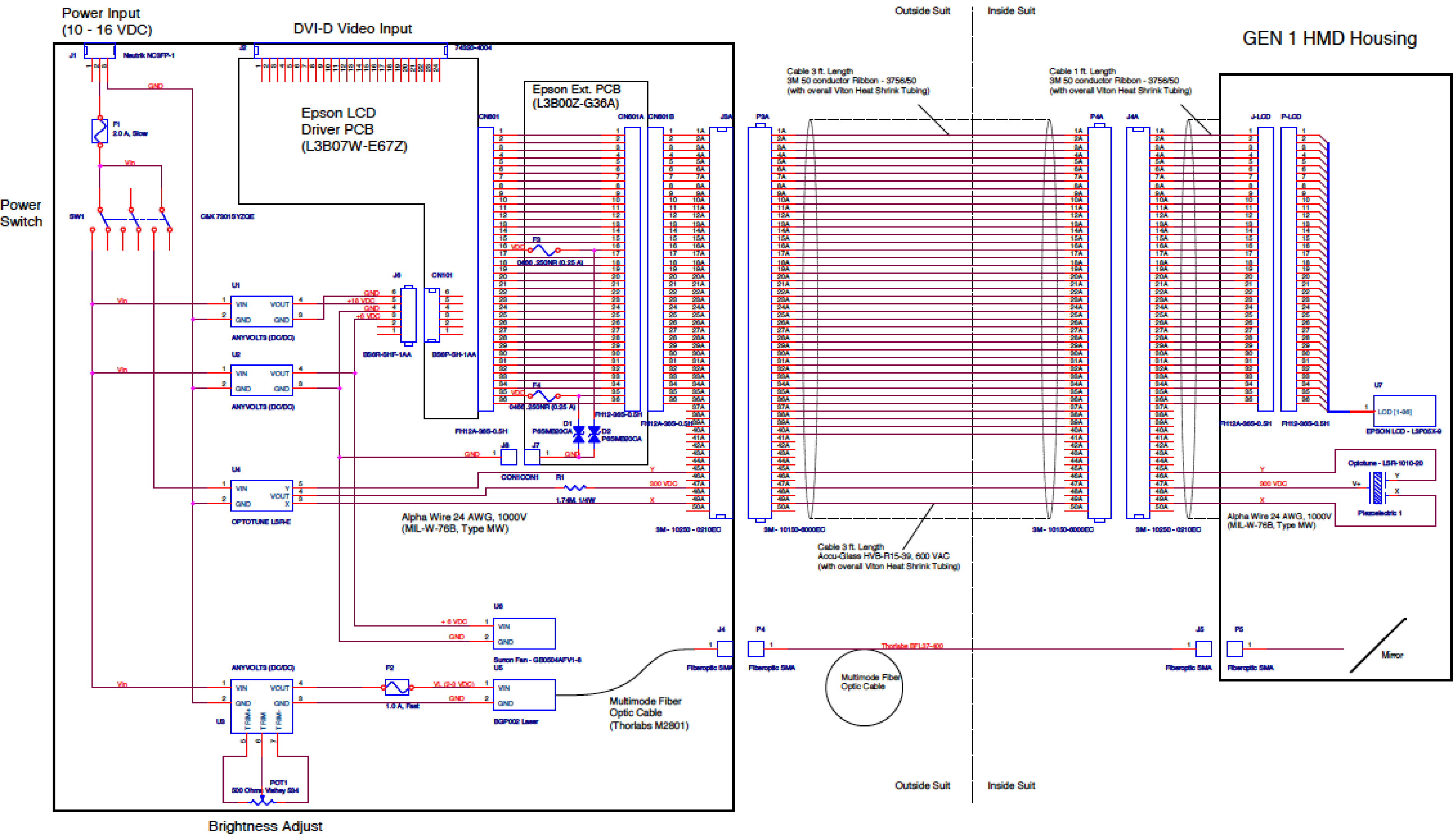
- **Past Accomplishments**
  - Prototype Contract for HMD – Gen. 1 HMD
    - Contract Awarded – Luminit Corp.
    - Conventional reflective single hologram display
  - Held successful Concept Design Review and PDR
  - Delivered demo unit flat panel (below) and DRATS FP



- **FY'10 Accomplishments**
  - Completed Fabrication and Luminit Test of Gen 1 HMD
  - GRC Evaluation and Characterization
  - Qual/Quan. Eval of Honeywell OLED vs. transflective

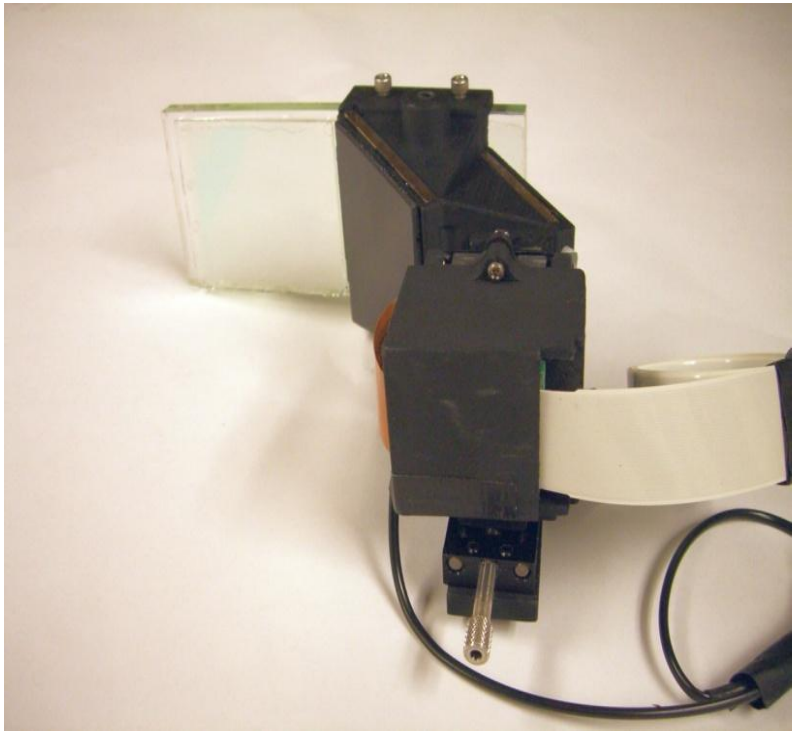
- **FY'11 & Long Range Plans**
  - Gen 1 HMD Mark III Integration Evaluation Test Report
  - Gen 2 HMD (Color, Substrate-Guided optical) Eval.
  - Develop Gen 3 HMD specifications
  - Procurement of Gen 3 HMD
    - Higher fidelity system (TRL 5-6) with flight packaging
    - Oxygen compatible materials.

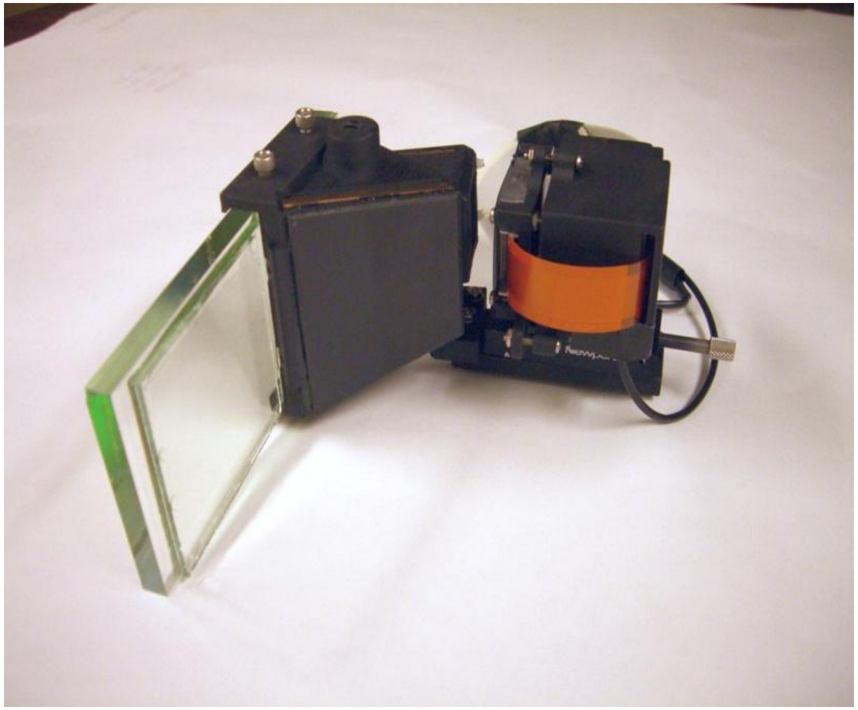




Power Input
(10 - 16 VDC)
DVI-D Video Input
Outside Suit
Inside Suit
GEN 1 HMD Housing
Cable 3 ft. Length
3M 50 conductor Ribbon - 3756/50
(with overall Viton Heat Shrink Tubing)
Cable 1 ft. Length
3M 50 conductor Ribbon - 3756/50
(with overall Viton Heat Shrink Tubing)
Epson Ext. PCB
(L3B00Z-G36A)
Epson LCD
Driver PCB
(L3B07W-E67Z)
Power
Switch
Neutrik NC3FP-1
2.0 A, Slow
ANYVOLT3 (DC/DC)
OPTOTUNE LSR-E
Alpha Wire 24 AWG, 1000V
(MIL-W-76B, Type MW)
Cable 3 ft. Length
Accu-Glass HVB-R15-39, 600 VAC
(with overall Viton Heat Shrink Tubing)
Alpha Wire 24 AWG, 1000V
(MIL-W-76B, Type MW)
EPSON LCD - L3P05X-9
Optotune - LSR-1010-20
Piezoelectric 1
Sunon Fan - GB0504AFV1-8
Multimode Fiber
Optic Cable
(Thorlabs M2801)
Multimode Fiber
Optic Cable
Fiberoptic SMA
Mirror
1.0 A, Fast
Brightness Adjust
Outside Suit
Inside Suit

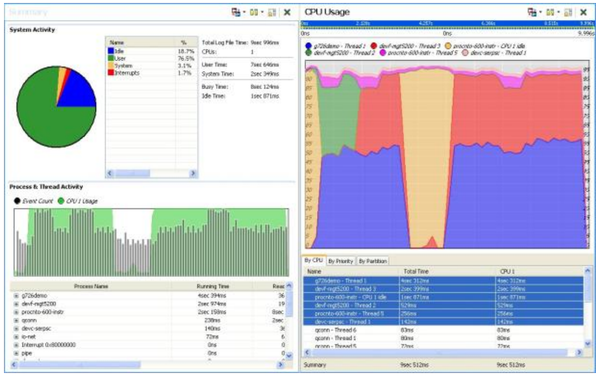
Gen 2 HMD – Substrate-Guided





*C3I Software Development

- **Objective: Develop a Communication, Command, Control and Information (C3I) Interoperability breadboard that implements the EVA-allocated C3I requirements. Coordinate with CxP Level 3 as to feasibility of implementing these requirements.**



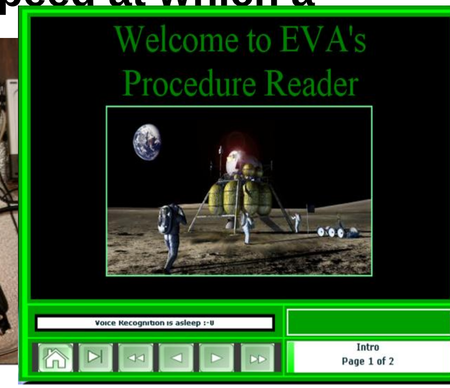
System Utilization Data

- **Accomplishments**
  - Completed design documentation and prototyping of majority of EVA-allocated C3I requirements:
    - Voice Exchange
    - Networking
    - Data Exchange Message and protocols
    - Security
  - C3I-only requirements that resulted in CPU utilization necessitating dedicated embedded hardware/complex electronics
    - motion imagery baseline codec requirements for H.264 and motion JPEG 2000 (Part 3)
    - encoding and decoding with the G.726 codec (43% and 50%, respectively) and encoding and decoding with the C3I-baselined G.729 codec (90% and 90%, respectively)

  - GRC Software Releases / Invention/Contrib. Board Software Initial Awards
    - Voice Exchange, Networking, Delay/Disruption Tolerant Networking

EVA Efficiency & Autonomy

- **Objective: Develop ways to use suit information system to increase crewmember autonomy (i.e. minimize support from secondary crew members or ground personnel) and/or improve task efficiency index (i.e. improve the speed at which a human could perform a task).**



- **Past Accomplishments**
  - Completed report summarizing human factors tests using speech recognition
    - Result: Time to complete tasks approximately the same when using the speech recognition driven procedure software as when prompted through the procedure by a person
    - Result: eliminated need for non-EVA person (IVA, MOD) to walk crewmember thru procedure
    - Most (17/21) test subjects preferred using information system
  - Voice Recording Engineering Memo: determined computing resources and data storage characteristics required for on-suit recording of audio voice notes

EVAIS DDI: Basic layout

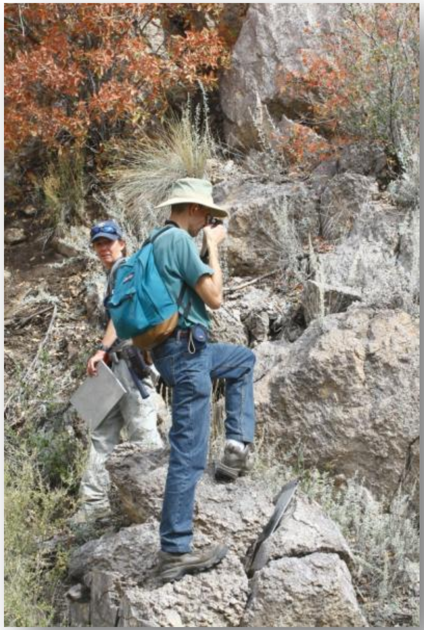
- *Cuff mounted*
- *Screen Resolution – 480 x 272 pixels*
- *Sun Light readable*
- *2 dedicated Edge Keys*
  - One Emergency Procedures
  - One for Voice Note Operation
- *6 Programmable Edge Keys*

- **FY'10 Accomplishments**
  - Metabolic Rate Activity
    - Evaluated and derived requirements for Metabolic Rate algorithms
    - Developed desktop simulation to evaluate metabolic advisor algorithms
- **FY'11 & Long Range Plans**
  - ISS Information System Concept Definition Report
  - DRATS: Camera/Drawing/Schematic Viewers, etc.

What is the EVA Information System?

- **As part of NASA's space suit engineering team, GRC's role is to develop a suite of electronic tools and applications that will help future spacewalking crewmembers work efficiently and autonomously.**
- **The EVA Information System (EVAIS)**
  - Stores and displays timelines, procedures, and graphical information, so that the EVA crew can manage their activities autonomously
  - Records and stores video, still-imagery, and audio data to support science operations

How do we do this?



…while wearing this.

EVAIS In Action

GRC's **EVA Information System (EVAIS)**, consisting of a HD camera, head-set, cuff display unit, and processors in the backpack, withstood the rigorous desert environment and recorded valuable geological data for the science team.

Geologists Dr. Jacob Bleacher (left) and Dr. Jim Rice (Right) take a closer look before collecting samples.

Astronaut Stan Love holds up a sample rock, while recording a Crew Field Note during an EVA.

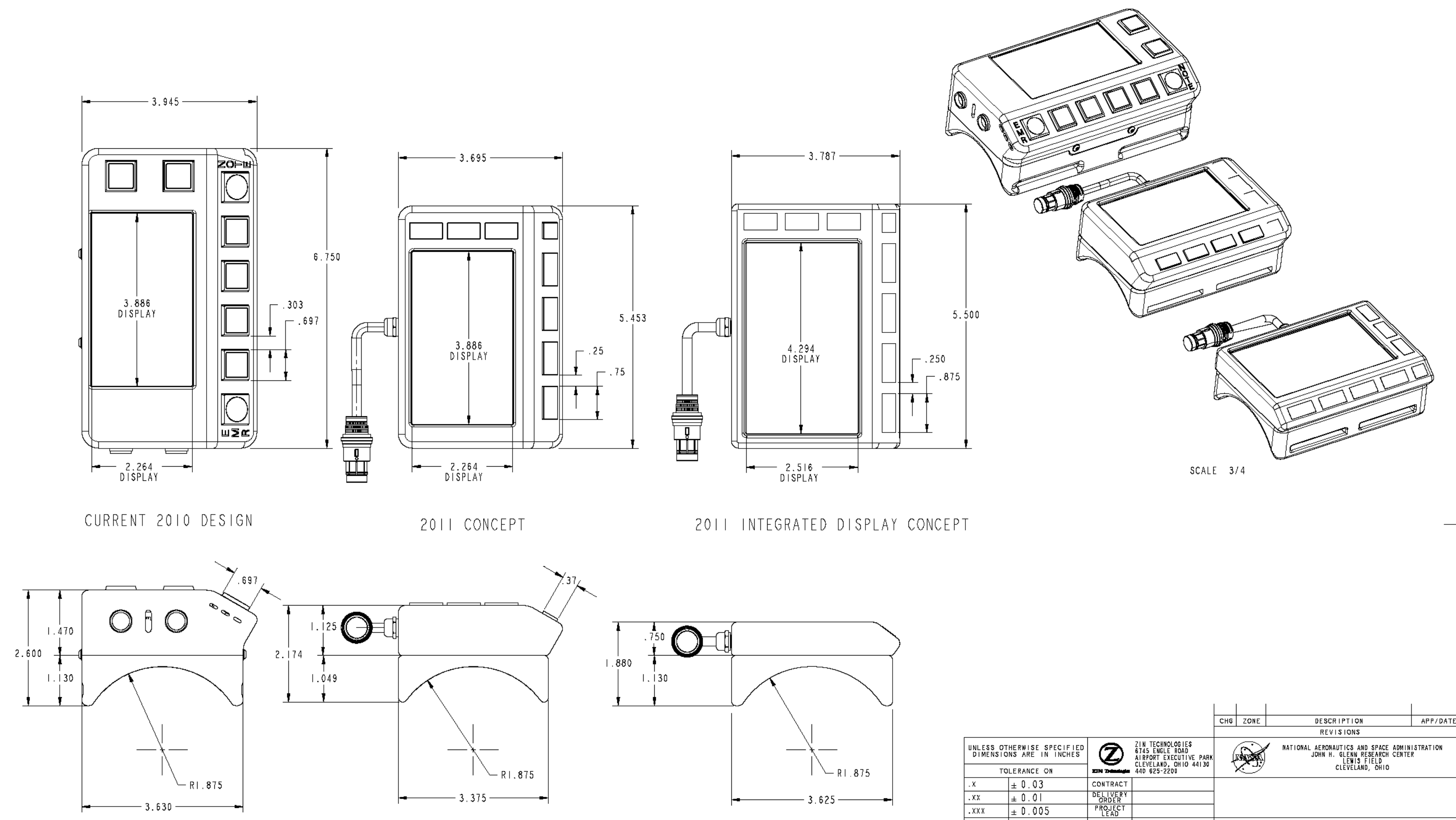
EVAIS In Action

The **EVA Information System (EVAIS)** records HD still images (left) and video/audio called Crew Field Notes.

This is an example snap-shot image recorded by the EVAIS. Space Exploration Vehicle Rover B can be seen in the background. All images are location mapped and time tagged for analysis.

[.\E20904090506.flv]

This is an example Crew Field Note recorded at the beginning of an EVA at the rim of Colton Crater.



CHG	ZONE	DESCRIPTION	APP/DATE
REVISIONS			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

ZIN TECHNOLOGIES
6745 ENGLE ROAD
AIRPORT EXECUTIVE PARK
CLEVELAND, OHIO 44130
440 625-2200

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHN H. GLENN RESEARCH CENTER
LEWIS FIELD
CLEVELAND, OHIO

TOLERANCE ON			
.X	± 0.03	CONTRACT	
.XX	± 0.01	DELIVERY ORDER	
.XXX	± 0.005	PROJECT LEAD	
FRACTION	± -	ENGINEER	
ANGULAR	± 0.50°	DESIGNER	
BREAK EDGES		DRAFTER	

COMPARISON

DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994

PROJECT FOLDER: U:\WRDOC\xxx
MODEL NAME: COMPARE_1

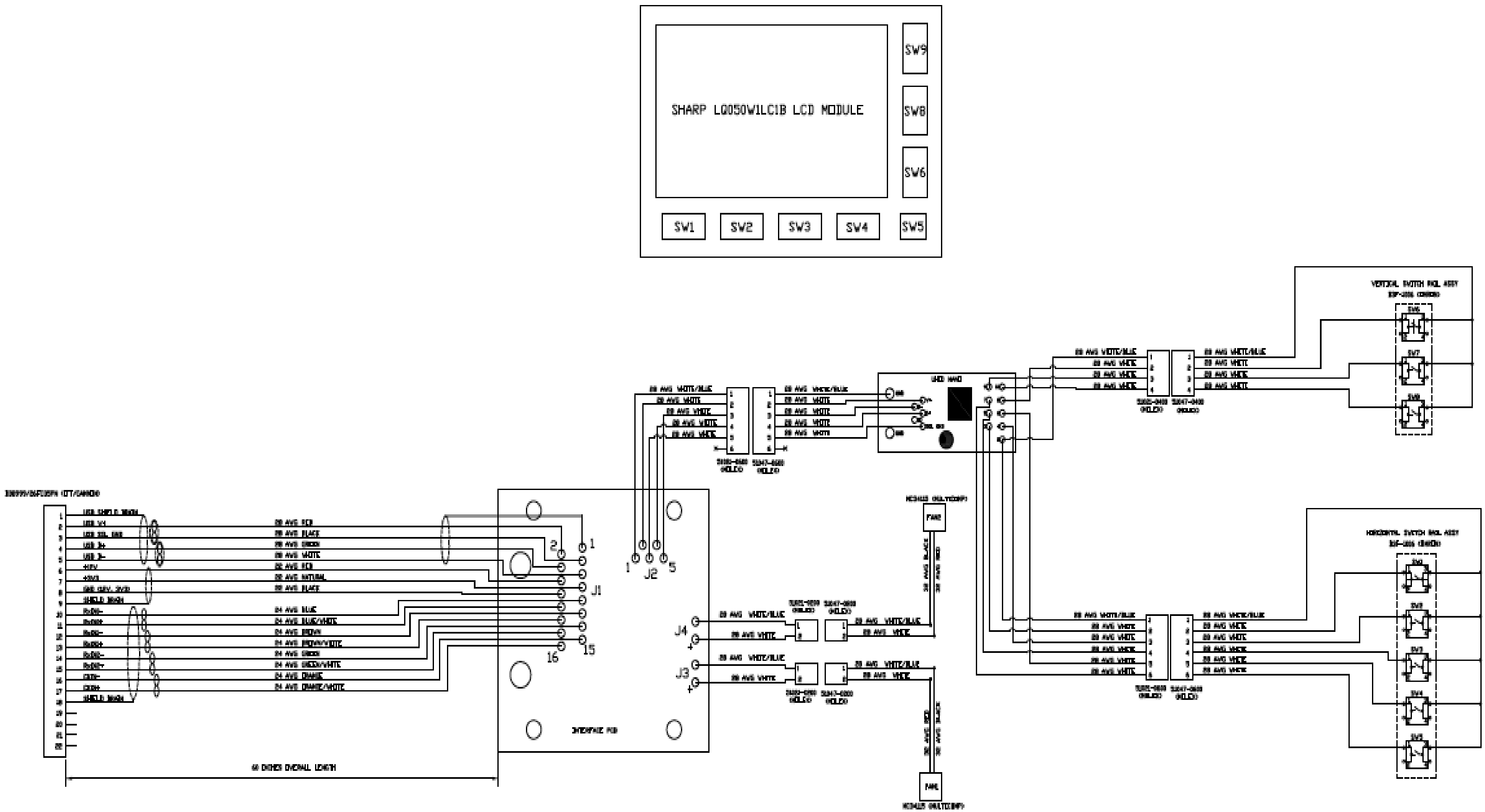
PRIOR TO USE CHECK FOR ANY OUTSTANDING ECO'S WITH CONFIGURATION MANAGEMENT OFFICE

SIZE	DRAWING NUMBER	REV	BLDG	AREA
D		-	XXX	XXX
			UNITS: INCH	

SCALE:	INITIAL REL DATE	SHEET	DISCIPLINE
1/1		1 OF 1	MECHANICAL

PRO/E VERSION: Wildfire 2.0

DRATS DISPLAY ASSY (S1251MBA1000) INTERCONNECT WIRING SCHEMATIC



Message from Stakeholders

- **Nov 08 – Stakeholder interview sessions were conducted with Astronaut Office, MOD (EVA, Science Ops, Flight Activities), LSS, Space Medicine, Safety, Photo/TV, Ground Ops, and EVA Engineering. Scott Bleisath led this activity.**

Top message from the stakeholders:

- **For lunar exploration, we will experience significant time periods where communication with Earth is unavailable. EVA crewmembers must have the proper tools (i.e., avionics capabilities) for them to work without reliance on ground support.**
  - Ground reliance should be workable for the early lunar missions (operate like Shuttle and ISS).
  - For longer missions, EVA crews must have the tools to make mission decisions when comm is unavailable with MCC. Operations will be limited if crew is unable to work with some autonomy.

EVA Power Avionics and Software Scope Configuration 2 – Lunar Surface

- **Power**
  - Energy storage/power source and power management and distribution
  - Power to suit will be provided by batteries
  - Power for Portable Life Support System (PLSS), communications, avionics, and informatics, tools and other suit and EVA loads
  - Technology needs include batteries with low mass and volume, long calendar life, improved safety, wide operating temperature range, and fast recharge capability
- **Avionics**
  - Displays to support text, graphics, and video
  - On suit Information System processor
  - Integrated voice, video, and crew/suit health data
  - Biomed system and sensors to monitor crew health
  - PLSS sensor systems to monitor suit health and met-rate
  - RF communications and navigation
  - Interoperable data networking and interface with surface assets/relays
  - Electronics and control systems to interface with various subsystems
- **Software**
  - Crew interface (user interface displays, voice activated control)
  - Crew and suit health data monitoring
  - Caution & warning system
  - Software systems to increase productivity and enhance autonomous operations (e.g. voice recognition, procedure check off, suit checkout, navigation, diagnostics, etc.)

EVA PAS Capabilities by Design Reference Mission | Core EVA PAS Capabilities | Non-Core (DRM-Specific) EVA PAS Capabilities

LEO/ISS	GEO	NEA & Martian Moons	Lunar Surface	Martian Surface
Software Defined Radio Multiple comm loops Point-to-point EVA comm	**Software Defined Radio** Multiple comm loops Point-to-point EVA comm Receive C&W messages from vehicle & other EVA crew	**Software Defined Radio** Multiple comm loops Point-to-point EVA comm Receive C&W messages from vehicle & other EVA crew Receive, store, & display voice/text messaging to handle comm delay	**Software Defined Radio** Multiple comm loops Point-to-point EVA comm Receive C&W messages from vehicle & other EVA crew	**Software Defined Radio** Multiple comm loops Point-to-point EVA comm Receive C&W messages from vehicle & other EVA crew Receive, store, & display voice/text messaging to handle comm delay
Caution & Warning Consumable monitoring Suit status Life support fault detection Visual & audible warning Automated suit checkout	**Caution & Warning** Consumable monitoring Suit status Life support fault detection Visual & audible warning Automated suit checkout Active radiation detection	**Caution & Warning** Consumable monitoring Suit status Life support fault detection Visual & audible warning Automated suit checkout Active radiation detection	**Caution & Warning** Consumable monitoring Suit status Life support fault detection Visual & audible warning Automated suit checkout Active radiation detection	**Caution & Warning** Consumable monitoring Suit status Life support fault detection Visual & audible warning Automated suit checkout Active radiation detection
Basic Text Data Display Simple alphanumeric display Display of suit status & fault messages	**Basic Text Data Display** Simple alphanumeric display Display of suit status & fault messages	**Basic Text Data Display** Simple alphanumeric display Display of suit status & fault messages	**Basic Text Data Display** Simple alphanumeric display Display of suit status & fault messages	**Basic Text Data Display** Simple alphanumeric display Display of suit status & fault messages
Graphical Display Display text, photos, & graphics Display suit camera field of view	**Graphical Display** Display text, photos, & graphics Display suit camera field of view	**Graphical Display** Display text, photos, & graphics Display suit camera field of view Display maps	**Graphical Display** Display text, photos, & graphics Display suit camera field of view Display maps	**Graphical Display** Display text, photos, & graphics Display suit camera field of view Display maps
Information System Display procedures, timelines, & photos Store suit data & transfer files between suit & vehicle	**Information System** Display procedures, timelines, & photos Store suit data & transfer files between suit & vehicle	**Information System** Display procedures, timelines, & photos Store suit data & transfer files between suit & vehicle Recording of Crew Field Notes (CFNs) Biomed/consumables advisory	**Information System** Display procedures, timelines, & photos Store suit data & transfer files between suit & vehicle Recording of Crew Field Notes (CFNs) Biomed/consumables advisory	**Information System** Display procedures, timelines, & photos Store suit data & transfer files between suit & vehicle Recording of Crew Field Notes (CFNs) Biomed/consumables advisory
Telemetry Suit & biomed data downlink to MCC No data encryption on suit. Encryption on other asset prior to downlink	**Telemetry** Suit & biomed data downlink to MCC No data encryption on suit. Encryption on other asset prior to downlink	**Telemetry** Suit & biomed data downlink to MCC No data encryption on suit. Encryption on other asset prior to downlink	**Telemetry** Suit & biomed data downlink to MCC No data encryption on suit. Encryption on other asset prior to downlink	**Telemetry** Suit & biomed data downlink to MCC No data encryption on suit. Encryption on other asset prior to downlink
Suit TV Camera Standard definition format for situational awareness High definition format for recorded video	**Suit TV Camera** Standard definition format for situational awareness High definition format for recorded video	**Suit TV Camera** Standard definition format for situational awareness High definition format for recorded video & CFNs	**Suit TV Camera** Standard definition format for situational awareness High definition format for recorded video & CFNs	**Suit TV Camera** Standard definition format for situational awareness High definition format for recorded video & CFNs
GRC/S. Bleisath 216-433-8952 1/18/11		**Navigation** Crew location relative to vehicle for CFNs & maps Relies on connectivity with vehicle(s)	**Navigation** Crew location for CFNs & maps Provide distance/heading to way points & for walk back Utilizes Lunar comm network	**Navigation** Crew location for CFNs & maps Provide distance/heading to way points & for walk back Utilizes Martian comm network

Guiding Requirements/Design Tenants

- **Many new and varying desires and visions - however - new functionality must be balanced against cost, schedule, and system complexity**

- **To be affordable - future NASA technology development needs to flow from solid mission requirements**
- **Concept evaluations will help rank and determine future investment areas**
- **Limit Scope and bound problem - keep it simple**
- **Where practical, avoid software intensive systems for Crit1/2 functions**

- **George M. Low, Apollo Spacecraft Program Manger**

  "Major factors contribution to spacecraft reliability are simplicity and redundancy in design; major emphasis on tests; a disciplined system of change control; and close out of all discrepancies. In the Apollo design, the elimination of complex interfaces between major hardware elements was also an important consideration."

- **Interviews with the Apollo Lunar Surface Astronauts in Support of Planning for EVA Systems Design, NASA TM 108846**

  "Design strategy should be marked by simplicity and also reliability. The design should address only reasonably anticipated task requirements and should try to neither include capabilities that are not needed nor events that are unlikely to occur"

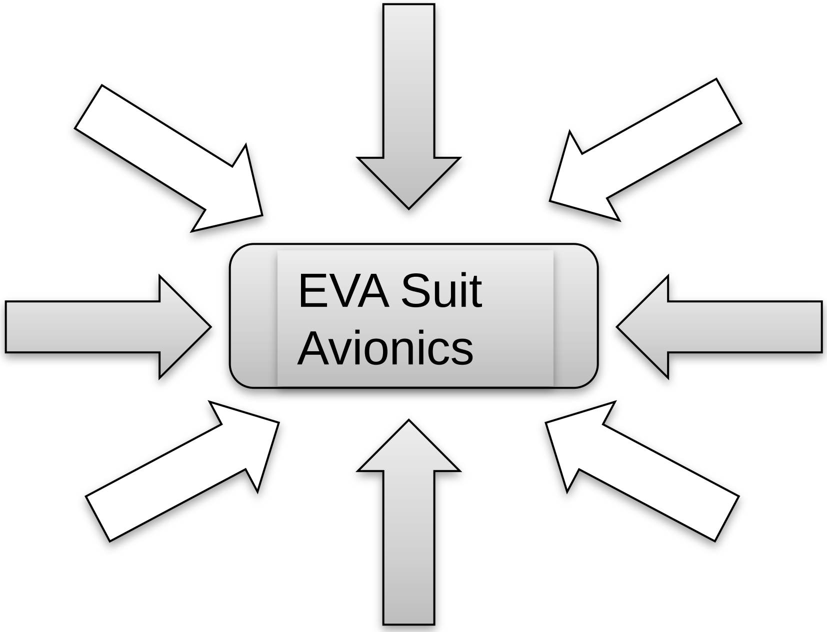
EVA Pwr/Avionics/Software Challenges

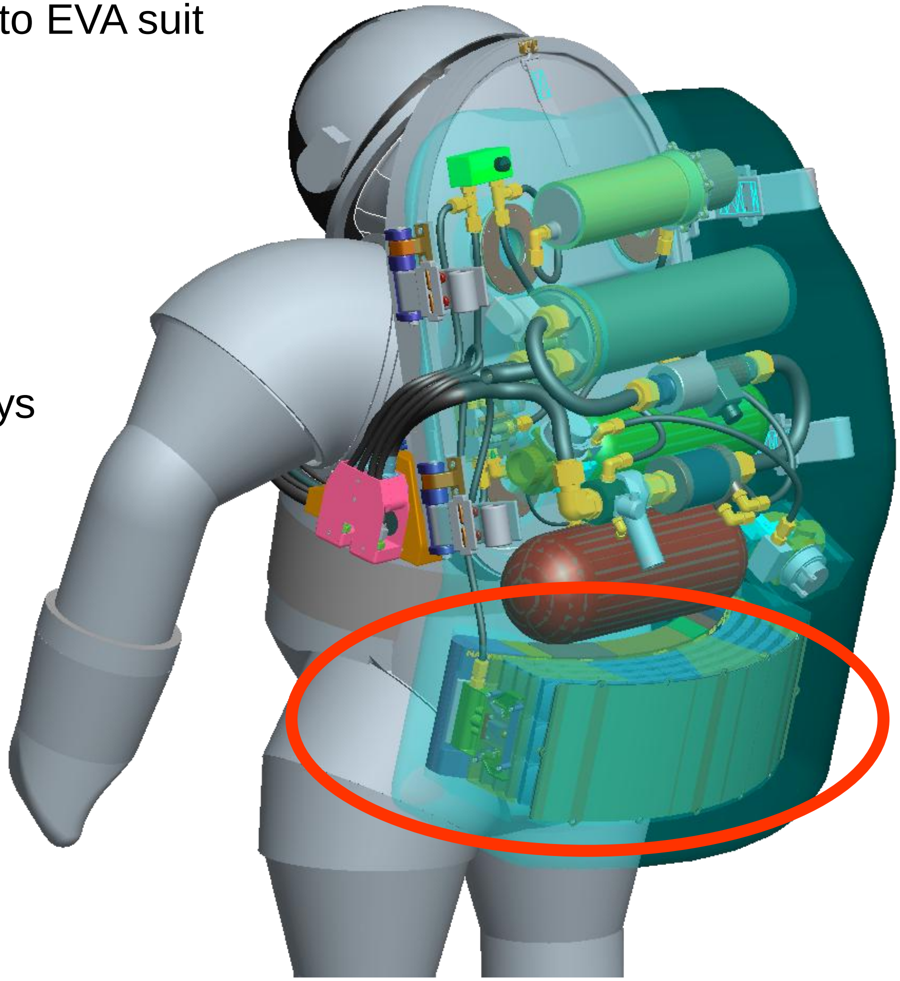
- **PAS is lower TRL than other EVA subsystems**
  - Never been done before
  - So many ways: selection of targets, how to acquire/massage/transit data
  - Need to balance forethought/trades with hardware build cycles and budget

- **Need to balance functionality with reliability/safety**
- **“Free” or “easy” SW is not:**
  - Heavy L2 assumptions of COTS lifecycle cost savings not validated
  - Quantity of requirements and applicable documents
  - Re-verify everything, not breaking other assemblies
  - Can’t realistically test entry and exit points of every decision/condition nor test every possible outcome of every decision/condition
    - should do so, however, on new code

EVA Pwr/Avionics/Software Challenges

- General Challenges /constraints being applied to EVA suit avionics
  - "On-back" mass/volume
  - Suit battery – power budget
  - Radio bandwidth
  - Limitations of "rad-hardened" processors
  - Minimal suit real estate for controls/displays
  - Safe & reliable crew life-support!





EVA Pwr/Avionics/Software Top 10 Challenges

- **Low mass high life battery systems. Need realistic PEL.**
- **Space grade, miniaturized, rad-hardened communications system that supports integrated voice video and data streams that can operate within the limitations of power, frequency, bandwidth, and radiation patterns**
- **Low power/mass radiation tolerant computing for enhanced informatics capabilities (e.g. voice recognition, navigation aids, procedure readers)**
- **Computationally efficient voice recognition software system**
- **Comfort base audio systems that work over a range of operating environments**
- **Display technology**
  - Internal helmet display that meets flammability requirements for 4.3 psia O_2 suit
  - External display that can survive thermal environment
- **Low power, high reliability miniaturized sensor systems**
  - Accurate metabolic rate sensor system
  - High reliability CO_2 sensor
- **High speed avionics data bus to allow data aggregation (voice, video, data)**
- **…**

Backup

Assigning Criticality Categories

- Using the same approach as demonstrated for EMU, the following is the assigning of criticality categories to our CSSS Config 2 PCAI functions…

Crit	Criticality Definition
1	Single failure that could result in loss of life or vehicle.
2	Single failure that could result in a loss of mission.
1R#	Redundant hardware item which, if all failed, could cause loss of life or vehicle…
2R	Redundant hardware item which, if all failed, could cause a loss of mission.
3	All other failures.

Function	Crit	Comments
Minimum RF comm	**2**	**No-go for EVA, terminate, LOM.**
Battery power	**1R2**	**No-go for EVA, terminate, LOM. Possible LOC if redundancy lost (purge valve, SOP).**
Critical Instrumentation		
Measure & display suit P to EVA crew	**2R**	**Redundant gauge prevents LOM. No-go for EVA, terminate, LOM if redundancy lost.**
<u>Measure</u> (data generation) of "suit status" to EVA crew or MCC (IV crew)	**1R2**	**No-go for EVA, terminate, LOM, if status generation unavailable. Possible LOC if subsequent failure is undetected in critical item.**
<u>Display</u> of "suit status" to EVA crew or MCC (IV crew)	**1R2**	**No-go for EVA, terminate, LOM, if EVA crew is unable to monitor status. Possible LOC if subsequent failure is undetected in critical item.**
Detect & provide warnings to EVA crew	**1R2**	**No-go for EVA, terminate, LOM, if EVA crew is unable to receive mal warnings. Possible LOC if subsequent failure is undetected in critical item.**

Assigning Criticality Categories

- Continued…

Crit	Criticality Definition
1	Single failure that could result in loss of life or vehicle.
2	Single failure that could result in a loss of mission.
1R#	Redundant hardware item which, if all failed, could cause loss of life or vehicle…
2R	Redundant hardware item which, if all failed, could cause a loss of mission.
3	All other failures.

Function	Crit	Comments
Single component instrumentation	3	Loss of any one sensor will have no mission impact.
Umbilical power	3	No mission impact as long as battery changeout is available (since more battery power used during umbilical ops).
ECG telemetry	3	Deconditioning or health issues with crew may cause this to be Crit 2. Does this affect design?

Assigning Criticality Categories

- The items below are new functions (not provided by EMU)…

Crit	Criticality Definition
1	Single failure that could result in loss of life or vehicle.
2	Single failure that could result in a loss of mission.
1R#	Redundant hardware item which, if all failed, could cause loss of life or vehicle…
2R	Redundant hardware item which, if all failed, could cause a loss of mission.
3	All other failures.

Function	Crit	Comments
Display suit malfunction & other contingency procedures to EVA crew	2R	No-go for EVA, terminate, LOM. EVA crew would be unable to correct possible LOC contingencies. This is 2R, rather than 2, if we consider redundancy (e.g., small paper cuff checklist, comm with other EVA crewmember).
Display nominal procedures & productivity information to EVA crew	2R	Redundancy (e.g., comm with other EVA crewmember) prevents LOM. No-go for EVA, terminate, LOM if redundancy lost.
Provide EVA crewmember location & navigation for nominal conditions (e.g., worksite to worksite)	2R	No-go for EVA, terminate, LOM. Paper maps & other non-electronic methods will be provided for redundancy, so that this is not Crit 2.
Provide EVA crewmember location & navigation for off-nominal conditions (e.g., contingency walk back)	1R2	Possible LOC if crew is unable to return to spacecraft and consumables expired. Paper maps & other non-electronic methods will be provided for redundancy.