Performance Requirements for Emergency Responder Interoperable and Compatible Electronic Safety Equipment

The Fire Protection Research Foundation

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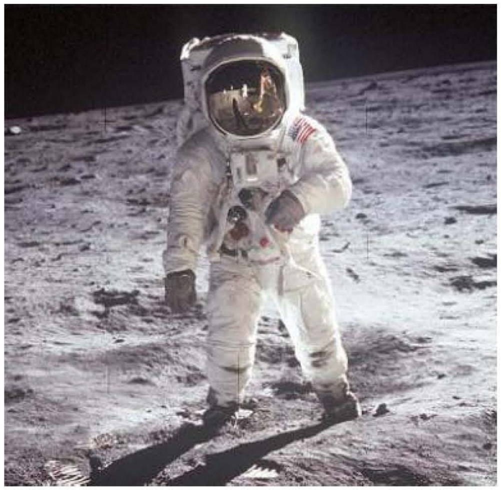
Why was NASA asked to support this activity?

- The Emergency Response environment shares many common features with EVA (Extra Vehicular Activity) operations.
  - Autonomously functioning individuals operating in severe environments.
  - Physically challenging activities with high metabolic loads.
  - Critical need for key physiologic and location data.
  - Real-time communication, and supporting information on surrounding environment.
  - Requirement for high reliability of system hardware and communication.



Common Objective: Insure personal safety and mission success.

NASA-Glenn Research Center also has extensive experience in:

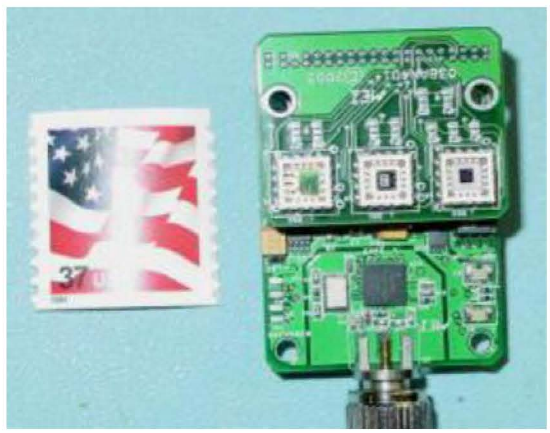
- Spacecraft fire safety, materials evaluation, detection, and suppression.

- Robotics for early emergency response and hazardous environments.

- Sensor development for particulates and gas-phase composition.

Robotic platforms for specialized tasks

Handheld ultrafine particle classifier



Wireless 3-gas sensor package

Systems and Operations: Similarities with Space Environment

- Physiologic, system, and environmental data promotes sensor rich platforms.

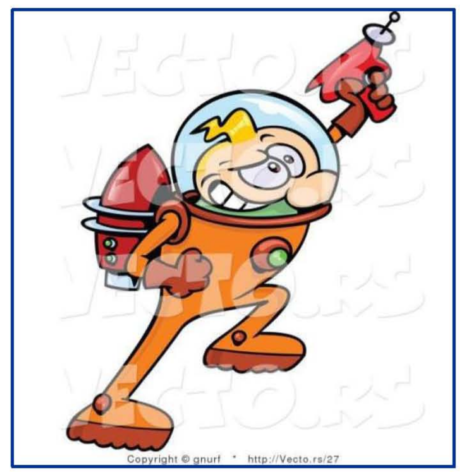
- Variability in types of data products:

  i) Immediate status or alarm needed locally (i.e. responder or astronaut).
  ii) Information needed by field commander or operations center.
  iii) Data for archival logging.

- Presence of physical and/or electromagnetic interferences.

- Emphasis on:
  - Overall system weight
  - Power consumption

    SWaP (Size, Weight, and Power)
  - Simplicity of operation and interpretation
  - Reliability, maintainability, shift duration and cycle time
  - System lifetime cost
  - Agility and flexibility of gear and suit taken as a whole



Systems and Operations: *Differences* from Space Environment

- Sources of interferences and physical barriers not well known ahead of time.
- Broad array and rapidly changing nature of surrounding thermal and chemical species environments.
- Detailed and current physiologic profiles of responders not necessarily on hand.
- Market-driven entrenchment on sensor/communications architectures and interfaces.
- Lack of a singular, pre-specified communication frequency and protocol.
- Leverage issue: Degree of control that mediating organizations (e.g. NFPA) have in mandating architectural and operational requirements.
- Immutability of mission: Emergency responders will be dispatched irrespective of state of hardware readiness.

In certain respects, your job is harder…

Interoperability Issues Critical in NASA EVA Suit Design*

Field-testing of MkIII suit design in Arizona desert

Elements of Design Philosophy:

1. Maximize reliability and ease in maintenance.
2. Minimize SWaP.
3. Retain highest degree of movement and flexibility.
4. Capability for internal monitoring of system status and health.
5. Real-time display of critical data to operator as required.
6. Local processing of information to enable efficient communication and logging.

*EVA Power, Avionics, and Software (PAS) Subsystem Architecture Data Book; TD-EVA-PAS-014, DRAFT, October 7, 2011

Two key elements for achieving these objectives:

- Modularity
  - Facilitates separate testing, verification, and troubleshooting of individual system components.
  - Leads to the more focused development of each individual elements, due to its singular targeted function.
  - Provides system flexibility: ability to upgrade and adapt.
- Centralization of key functions
  - Examples: Power, communication, formatting, display
  - Alternate approach results in redundancies that compromise performance targets (particularly SWaP and communication).

This design approach fundamentally requires element interoperability.

Basic Elements of EVA System Architecture:

1. Power management and distribution
2. Communications: Inter-operator and external links
3. Informatics and storage: Data to/from sensor nodes; internal processing
4. CWC (Caution, Warning, and Control): Displays, remote indicators, and overrides
5. Sensor nodes
6. Control actuators

Baseline listing of required sensor nodes:

From	To	Signal Description	Chan-nels	Quanti-zation bits	Sample Rate (Hz)	Data Rate (bps)
CWC (LSS Device and Sensor Status)	Informatics	**Sensors**				
		Suit Pressure	1	12	1	12
		Primary O_2 Pressure, High	1	12	1	12
		Primary O_2 Pressure, Feedline	1	12	1	12
		Secondary O_2 Pressure, High	1	12	1	12
		Secondary O_2 Pressure, Feedline	1	12	1	12
		Water (H_2O) Pressure	1	12	1	12
		Primary Bladder Pressure	1	12	1	12
		Reserver Bladder Pressure	1	12	1	12
		Helmet Inlet Gas Temperature	1	12	1	12
		LCG H_2O Inlet Temperature	1	12	1	12
		LCG H_2O Outlet Temperature	1	12	1	12
		Ventilation Flow Threshold Sensor	1	12	1	12
		Ventilation Inlet carbon dioxide (CO_2) Concentration (Partial Pressure)	1	12	1	12
		Ventilation Outlet CO_2 Concentration (Partial Pressure)	1	12	1	12
		SWME H_2O Outlet Pressure	1	12	1	12
		Ambient Pressure	1	12	1	12
		LSS Controls and Status				
		Vent Loop Flow Fan Status	1	8	1	8
		Thermal Loop Pump Status	1	8	1	8
		Thermal Loop Pump Temp Control Status	1	8	1	8
		Portable Life Support System (PLSS) H_2O Heater Status	1	8	1	8
		LCG Cooling Mode Valve Status	1	8	1	8
		Glove Heater Status	1	8	1	8
		Total Suit Status Bit Rate			**240**	

The combined list of sensor nodes is comparatively large, but the total bit rate is modest.*

From	To	Signal Description	Channels	Quanti-zation bits	Sample Rate (Hz)	Data Rate (bps)
Biomed Assembly	Umbilical	Radiation Dose Equivalent Sensor	1	12	1	12
		Radiation Absorbed Dose Sensor	1	12	1	12
		Average Absorbed Radiation Dose Rate [1]	1	12	1	12
		Cumulative Absorbed Radiation Dose [1]	1	12	1	12
		Calculated Metabolic Rate [1]	1	12	1	12
		Derived Core Body Temp [1]	1	12	1	12
		Heart Rate	1	8	50	400
		Heart Rhythm Lead #1	1	12	1000 [2]	12000
		Heart Rhythm Lead #2	1	12	1000 [2]	12000
		Biomed Total Bit Rate			**24472**	

* 1. Derived quantities
2. NASA unique requirement
3. Does not include audio, navigation, terrain, or ancillary scientific data.
4. Bi-directional audio ≈ 32KB/s

Common Data Bus:

- Every system element (e.g. sensor node, warning indicator, control actuator) possesses a common data bus interface.
- Establishes common protocol for data transfer, and provides the ability to send or receive commands between assemblies.
- Each element represents a network node, and is assigned a static IP address.
- Allows establishment of hierarchy, and affords ability to establish priority interrupts.
- Centralized processor establishes CWC ordering, and packetizes for transmission and logging.
- Nodal architecture provides efficient calibration, and status/health check routines.
- Conducted market survey of currently available bus technologies.* Recommended Gigabit Ethernet bus (GigE), transmitting Ethernet frames as per IEEE802.3-2008. Interconnects via 1000 Base-CX (two twisted shielded pairs)

* *PCAI Subsystem Data Bus Technologies Market Survey and Recommendations Report*, ETDP-EVA-PCAI-0037

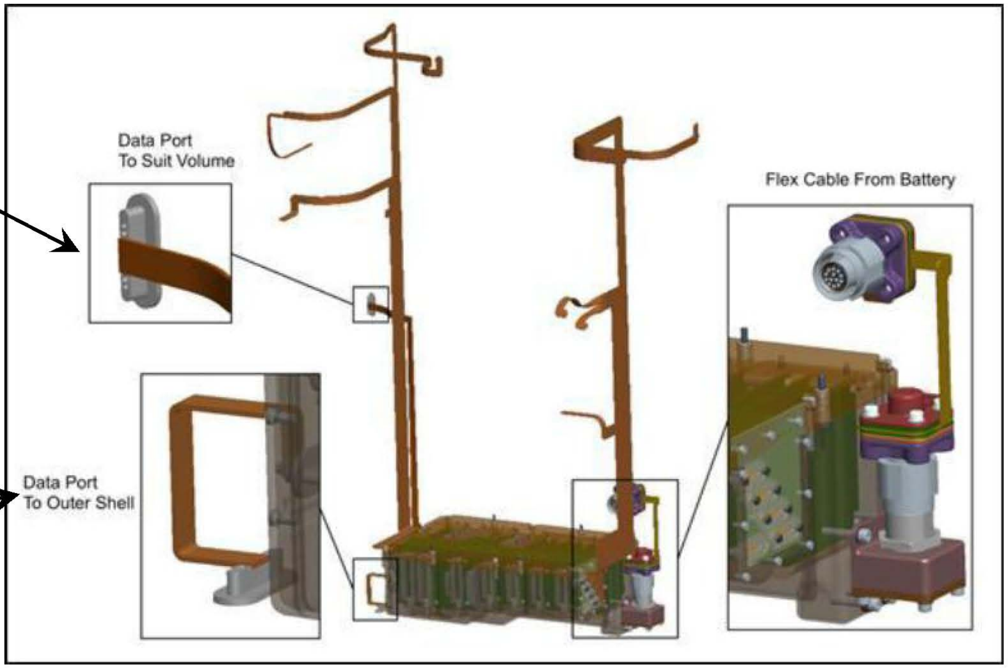
Power Management and Distribution (PMAD):

- Centralized battery reduces size, weight, and cost.
- Facilities ease in stocking/field supply, maintenance, and troubleshooting.
- Location can be optimized for balance and heat distribution.
- Provisions available for POF voltage up/down conversion, but…

*Conversion consumes power…**

Input from internal suit sensors

Output for CWC, comm. and diagnostic maintenance



Sample harness for combined PMAD and data

*In the present EVA architecture study, ≈ 30% of the total power is consumed in conversion.

Assembly	Phase 3 to 5 Power
Storage	8.72
Informatics	8.97
CWC	7.49
Comm/Nav	9.91
Audio	5.59
PMAD	17.63
Total	**58.31**

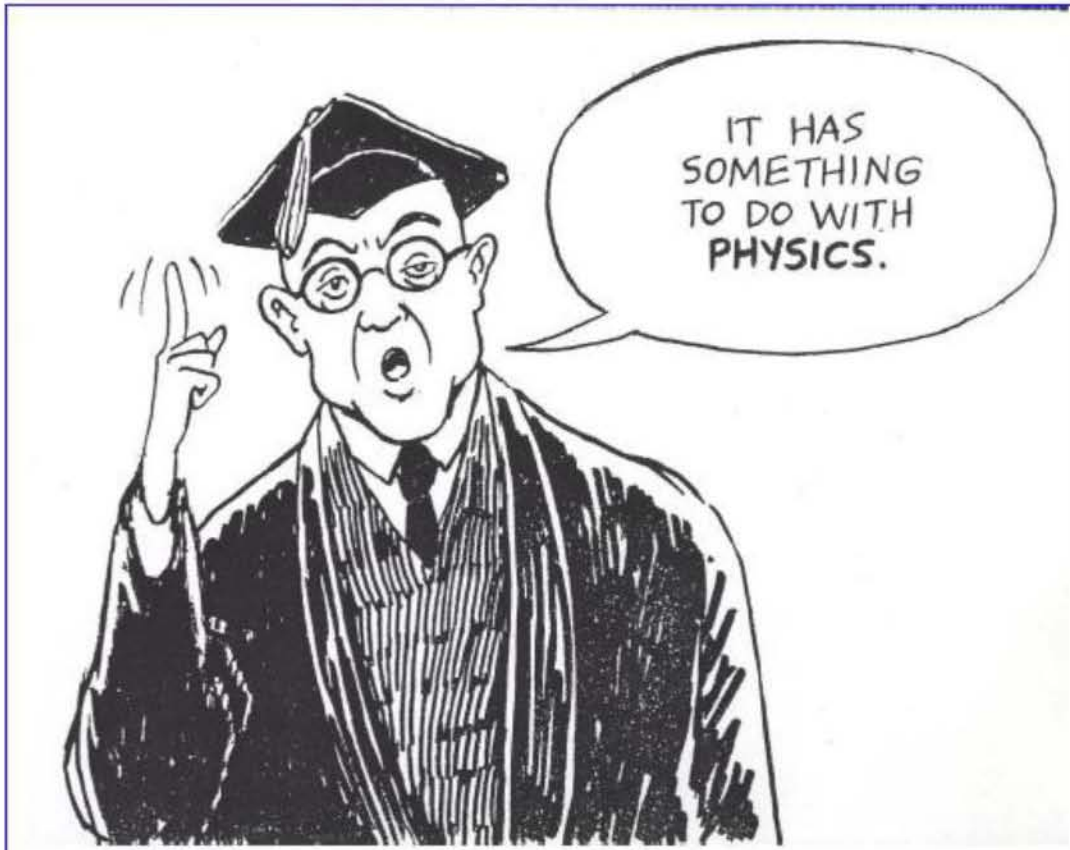
≈10 hrs continuous operation using 2.24 kg UHE cell

CWC: Command, Warning, and Control

- Detects presence of out-of-range or anomalous readings.
- Accorded highest criticality rating of all suit functions (1S: Potential loss of life)
- Establishes and manages hierarchy of local vs. field warnings, and potential overrides.
- Implements sequential protocol for catastrophic or unresolved indicators.
- Provides “time left” calculations for each consumable based on quantity remaining and average use rates.
- Performs periodic or as-needed checks to insure nominal system performance.
- Exceptionally difficult to implement in a decentralized architecture.

Summary Remarks:

- Emergency Response (ER) and EVA share many similar challenges.
- Increasing sophistication of technologies applicable to ER are affording enormous improvements in health and safety.
- The ability to integrate technologies into practical, efficient, and cost effective systems requires a high degree of interoperability.
- Effectively achieving interoperability starts at the system level, and necessitates standards for power, communication, and data protocols.
- ER stakeholders must continue their efforts to advocate for and establish functional standards to realize the benefits that advancing technologies will continue to provide.



The universal answer to all questions.

Questions?