BioNet Command, Control, and Communications Infrastructure for NASA's Exploration Mission

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What is BioNet?

- BioNet is a software middleware infrastructure that integrates disparate data from differing devices and sensors into a unified command and control system
- BioNet is an open-architecture and is standards-based. Importantly, BioNet does <u>not</u> dictate the hardware solution
- BioNet was designed for independent multi-developer use

Who will use BioNet:

- Engineers and operations personnel whom wish to communicate, control, command, and/or monitor a facility, crew member, or some physical phenomena
- Safety assurance systems to provide environmental control
- Flight operations to verify systems status
- Ground personnel to analyze engineering and physiological data

Project History

- BioNet technical demonstration for NASA JSC EB/SD in Fall, 2005
- ISS Flight DTO: Phase I contract completed to port the BioNet infrastructure to Win2K for deployment on ISS MEC
- BioNet Phase I STTR (UC-Boulder/Invocon) contract completed.
  - Advance BioNet infrastructure
  - Gain visibility as a potential C3I solution
  - Set requirements for Phase II (proposal in review)
- Involved with the CCSDS since 2004

Why is BioNet useful?

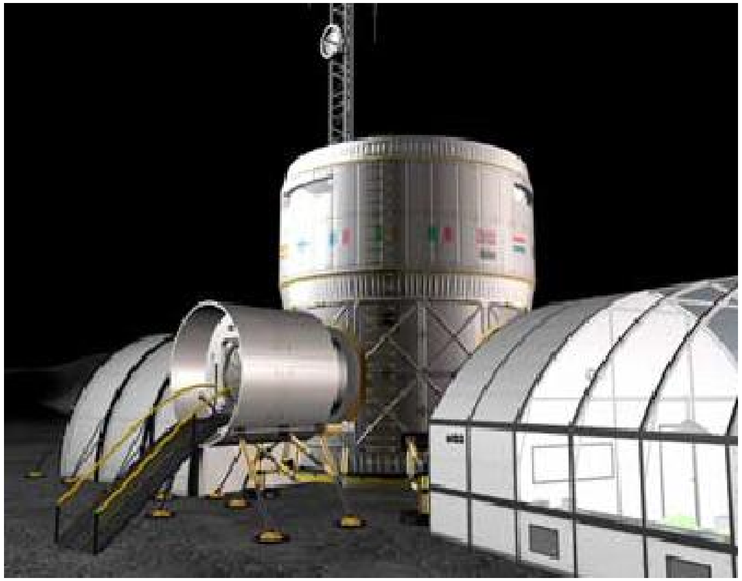
- Environmental monitoring
  - Temp, pressure, humidity, atmospheric contaminants, etc.
- Structural monitoring
  - Leak detection, impact detection, seismic, stress and strain
- Physiological monitoring
  - Health assessment, exercise cardio, BP/ECG
- Voice, Video, and Science Data

A variety of sensors and instrumentation…

A variety of applications…

Why is BioNet useful?

IEEE standard	Data rate	Network topology	Battery (days)	Node #'s	Typical Apps
RFID*	~10s Kbps	Star	1000s	100s	Inventory Tracking
1902.1 RuBee	~10s Kbps	Point-to multipoint	1000s	100s	Inventory Tracking
802.3 Ethernet	10/100 /1000 Mbps	Point-to multipoint	N/A	100 – 1000s	Internet/data Voice/Video
802.11 Wi-Fi	1 – 54 Mbps	Point-to multipoint	0.5 – 5	32	Hi-speed WLANs
802.15.1 Bluetooth	1 Mbps	Point-to multipoint	1 – 7	7	Medical Voice/data
802.15.4 (ZigBee)	40 – 250 kbps	Point-to multipoint	1000+	100s	Low rate Sensornets



A variety of network types…

Why is BioNet useful?

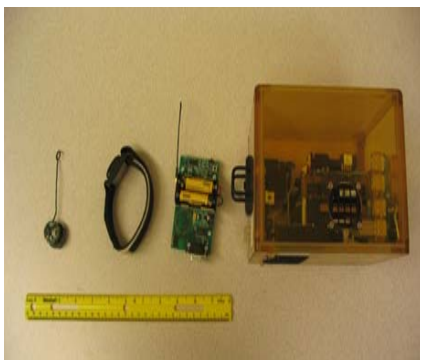
- Design engineers desire to pick and choose between independent solutions to meet design requirements regardless of the hardware vendor

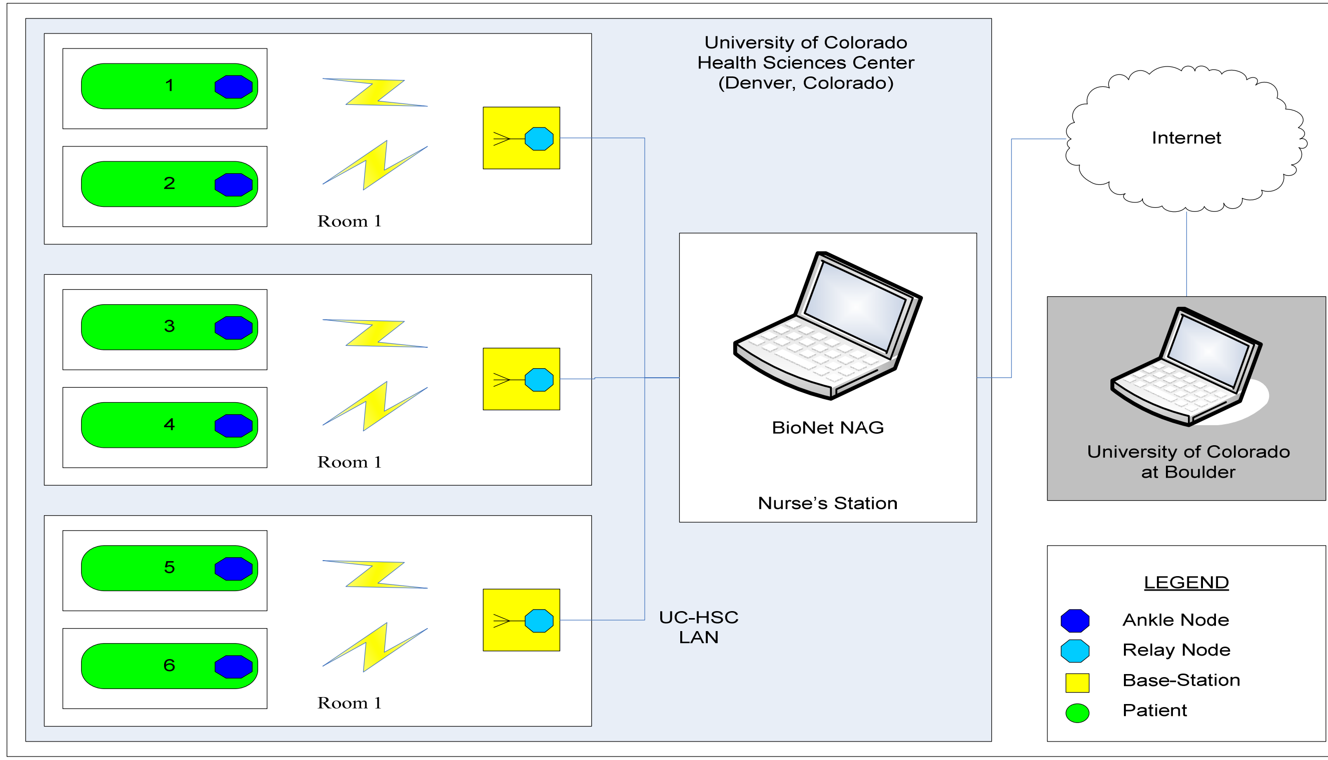
- Provide a network-independent framework:
  - Integrate any hardware device (data generators)
  - Explicitly designed for mobile wireless devices
  - Applications can use any piece of data in the system
  - Is a distributed architecture by design – scales across large distances and multiple communication networks

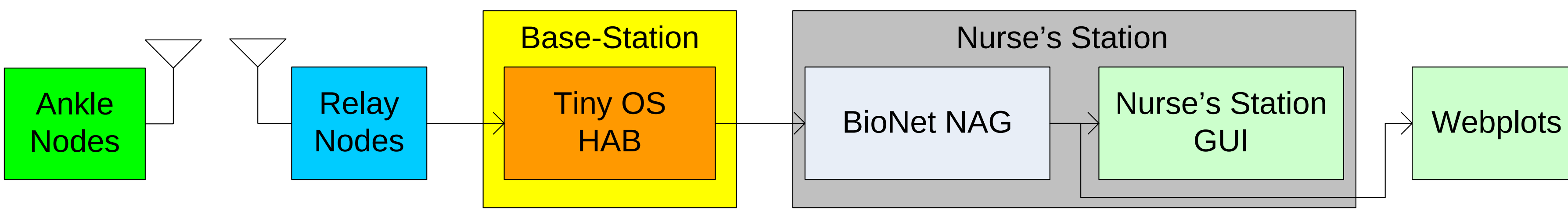
BioNet core software components

- Hardware abstractor (HAB): responsible for communicating directly with hardware
  - Each different device has its own unique HAB
- Network Aggregator (NAG): a network-accesible central data repository
  - HABs send all of their data, in a unified format, to the NAG
  - The NAG “serves” data to client applications
  - Publication/subscription data distribution architecture
- Applications (Apps): client applications that use data for decision making decisions
  - Client apps subscribe to the NAG for data they’re interested in

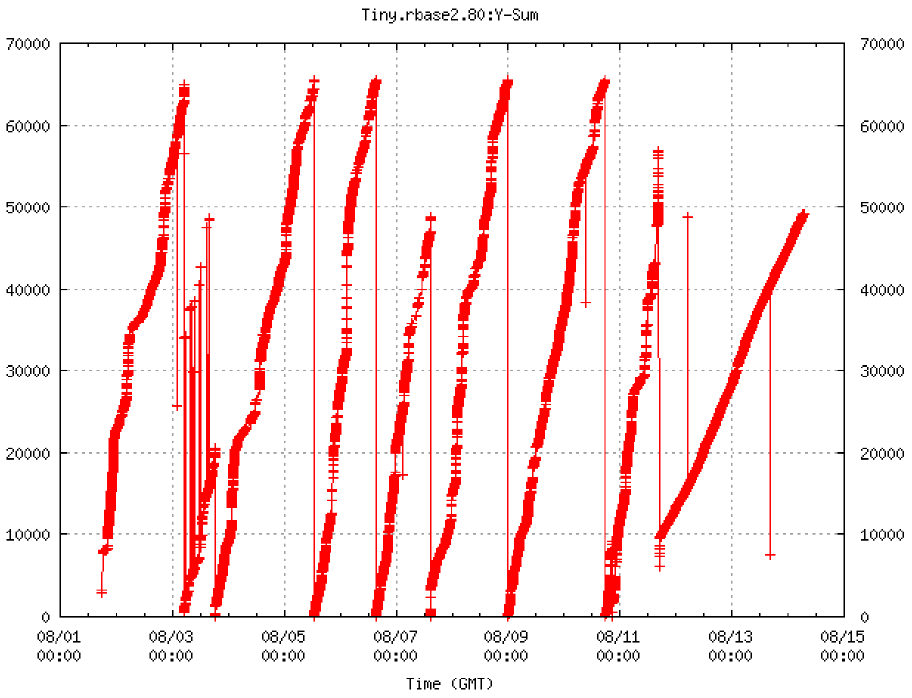
BioNet Command, Control, and Communications Infrastructure



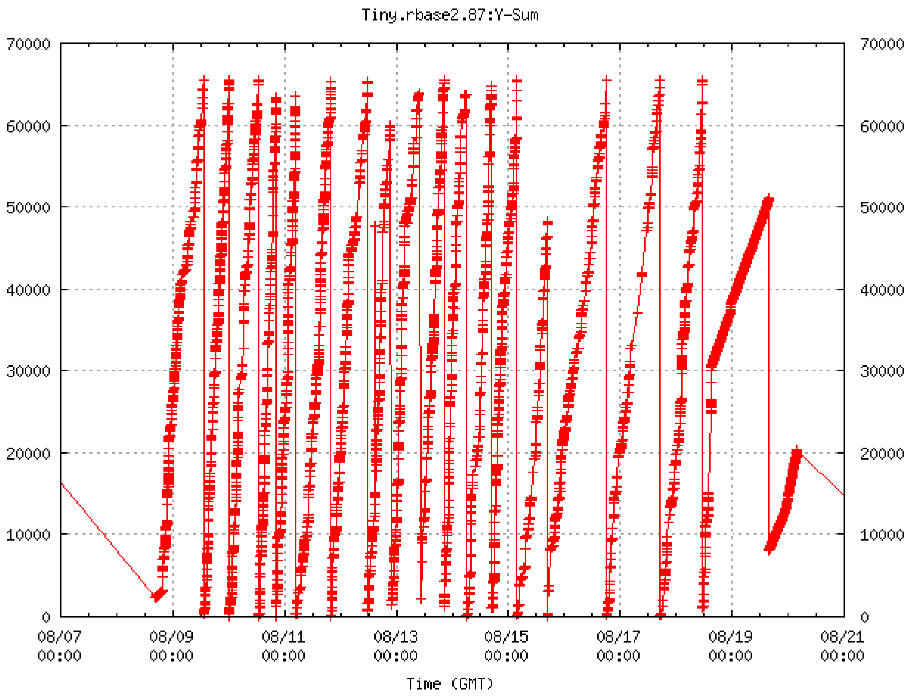




Human-rated Deployment: BioNet-Bedrest results

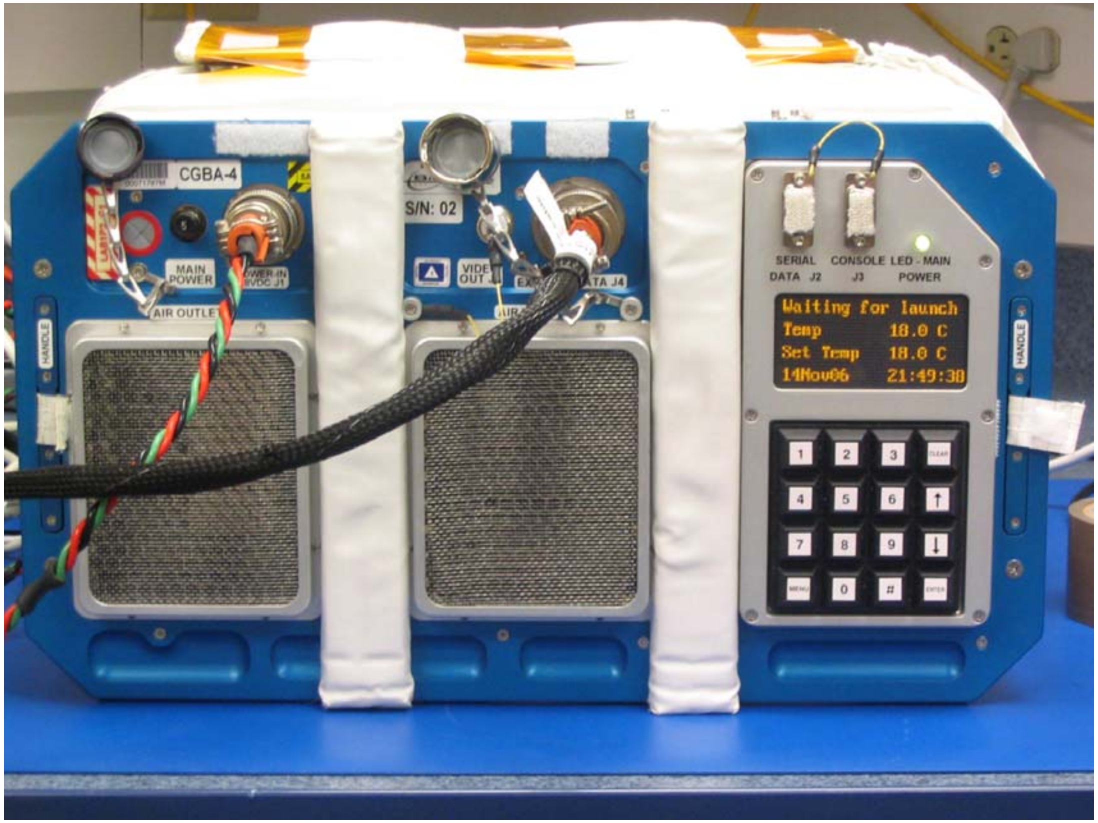


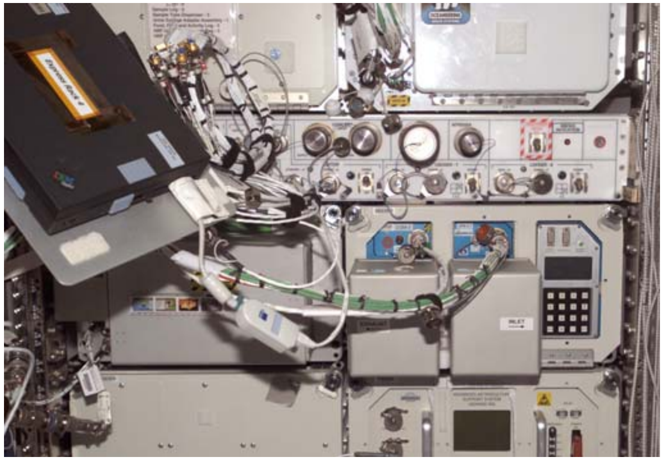
Patient #1



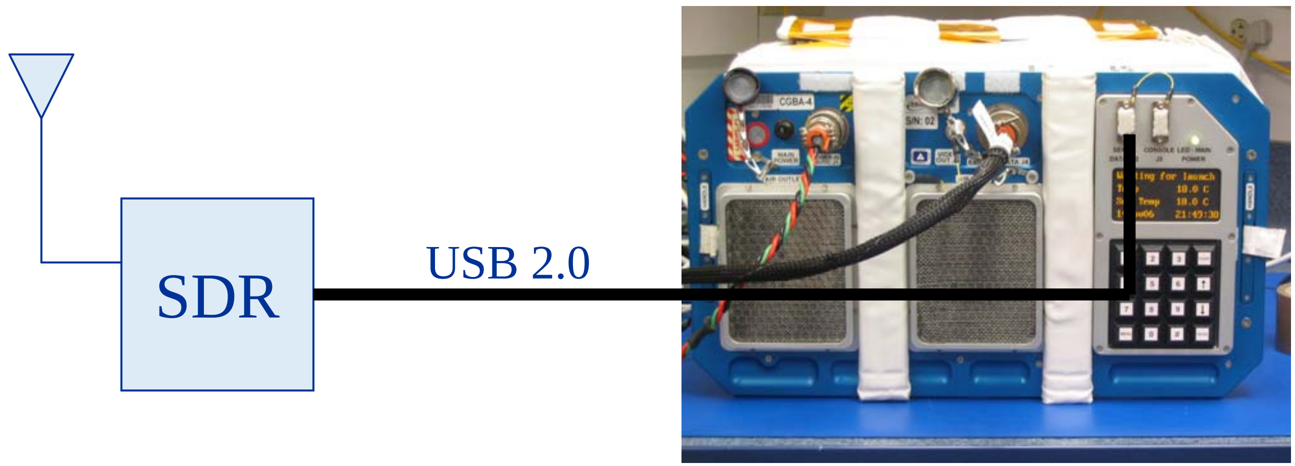
Patient #2

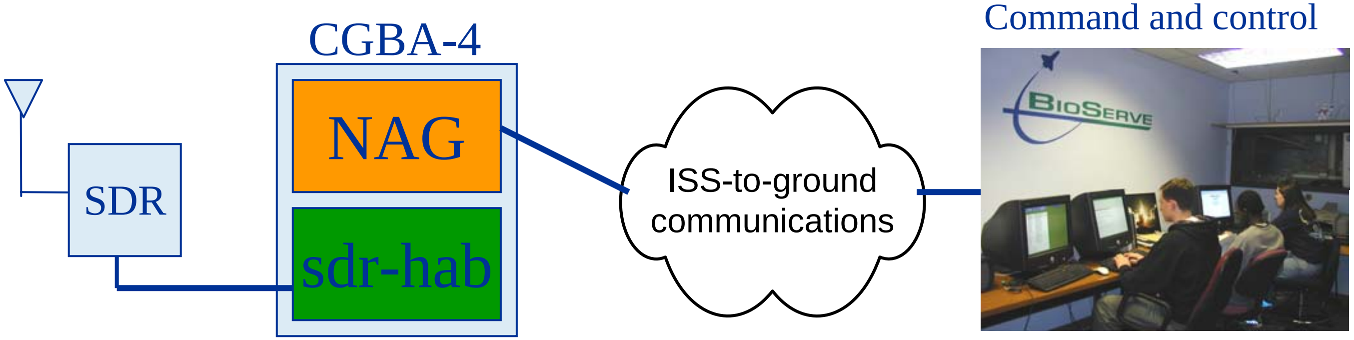
CGBA-4 Payload on orbit

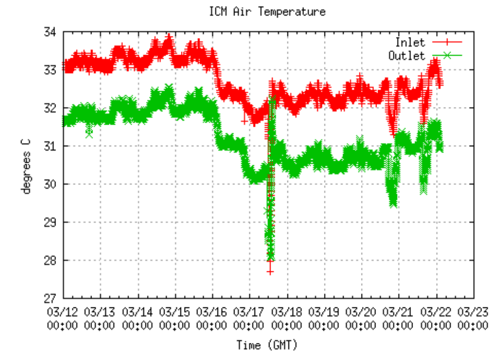


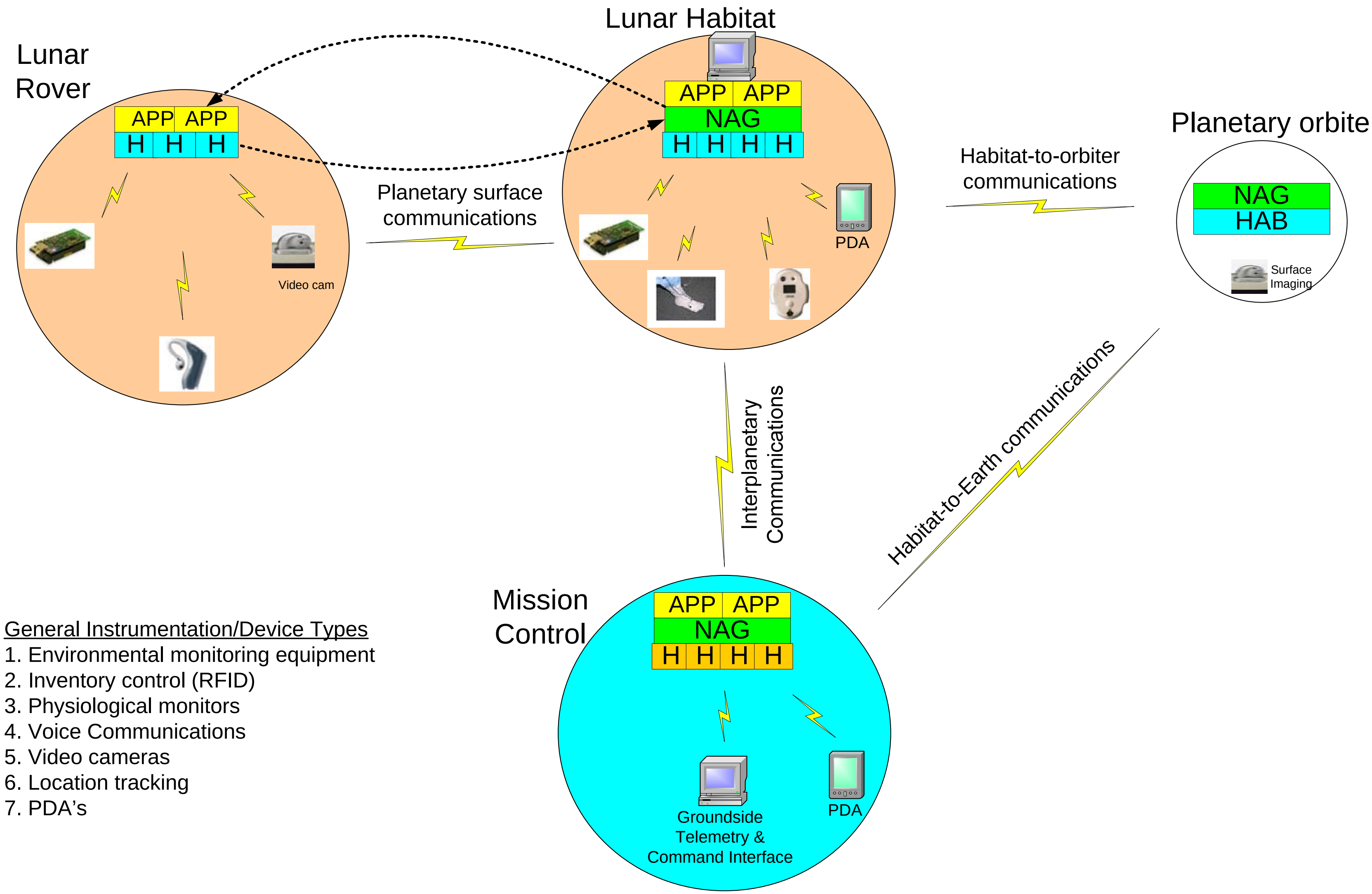


CGBA-4 Payload on orbit





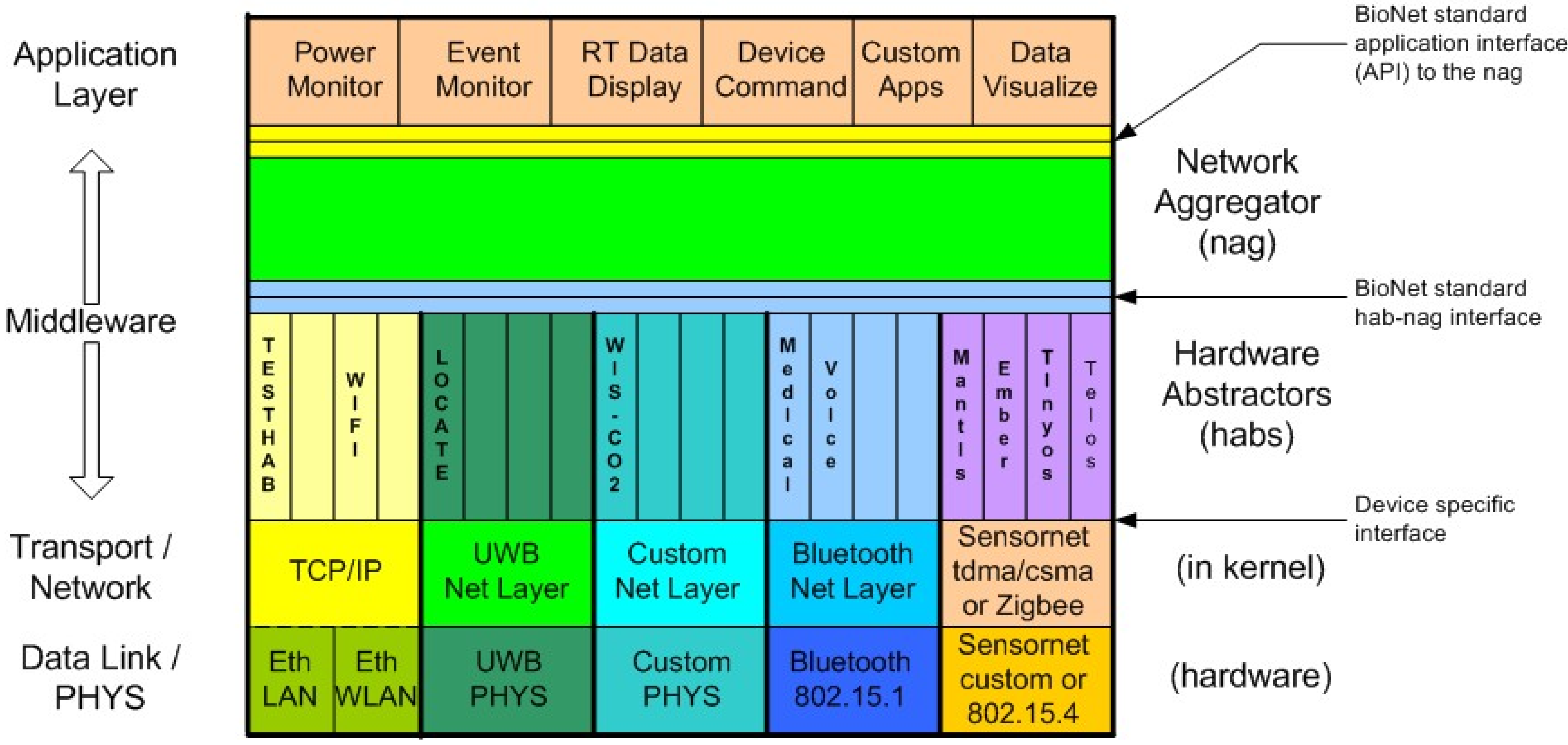




<u>General Instrumentation/Device Types</u>

1. Environmental monitoring equipment
2. Inventory control (RFID)
3. Physiological monitors
4. Voice Communications
5. Video cameras
6. Location tracking
7. PDA's

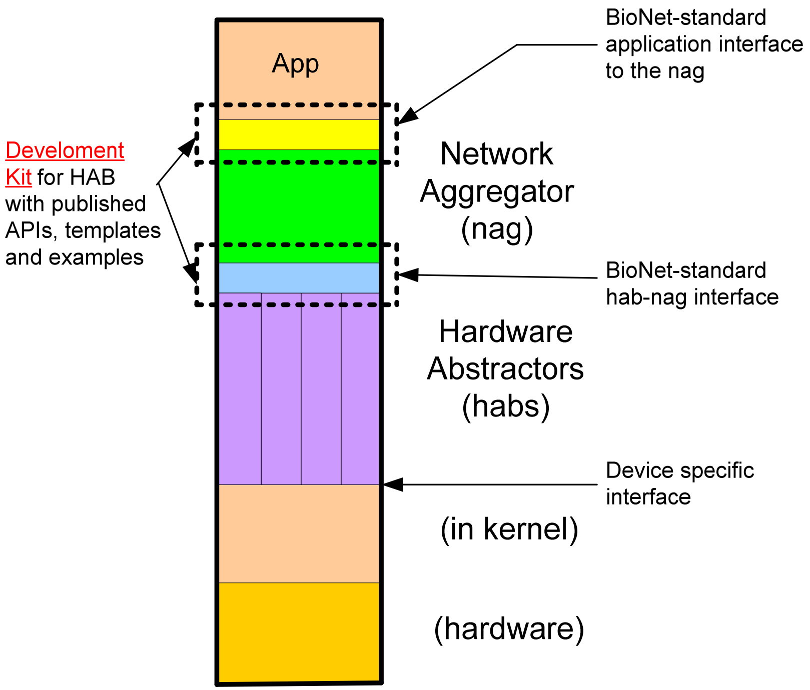
Flight Software Certification



- Minimize (for spaceflight) software certification costs, which is a major expense

The BioNet Development Kit (DevKit)

- Provides template code and libraries for independent developers to integrate their devices into the BioNet system
- Establishes an open-architecture for multi-developer use



Significance of the BioNet architecture

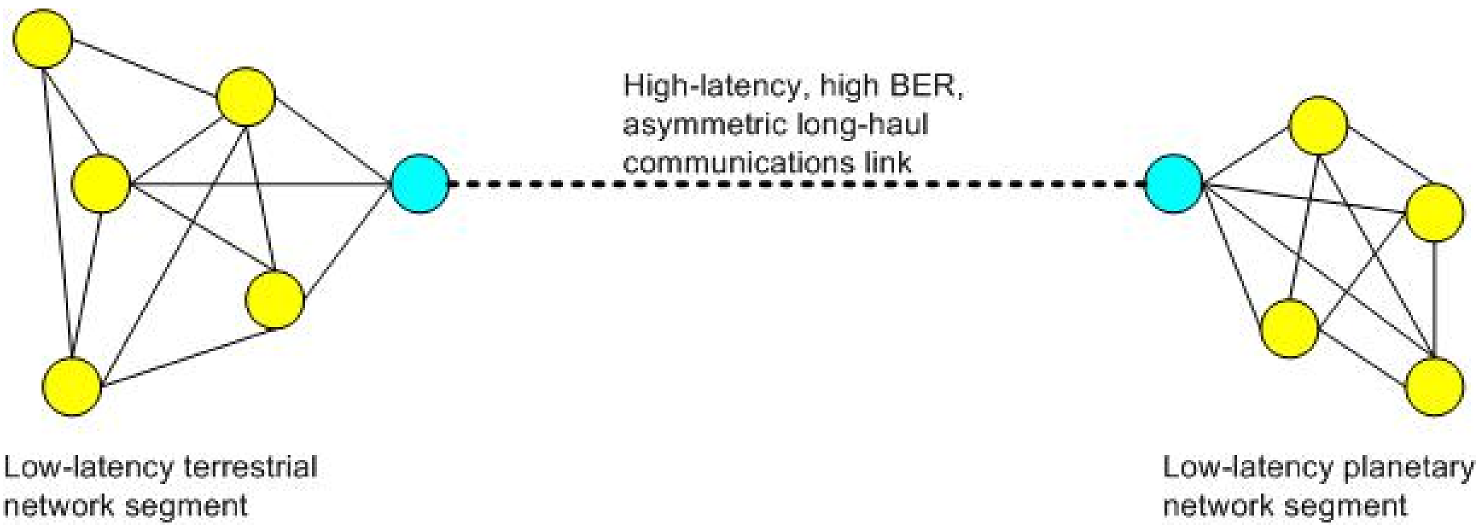
Issue	Desired Solution
Data interoperability	Data from disparate data-producing sensors, controllers, voice, and video can be stored, transported, and display by a single system
Multi-vendor solution set	Multi-vendor hardware (instrumentation, controllers, radios, etc.) can be considered for the engineering solution. Non-proprietary (open) as well as proprietary solutions can both be considered.
Independent development	Provide framework for independent development of (1) software to interface with hardware devices and (2) client applications that can make use of any piece of system data for decision-making.
Mobility	Provide for untethered mobility of sensors, instrumentation equipment, communications devices, and personnel for maximum productivity.
Heterogeneous data networks	Allow for interoperable use of differing radio technologies [RFID, IEEE 1902.1 (Rubee), 802.11 (Wi-Fi), 802.15.1 (Bluetooth), 802.15.4 (ZigBee), 802.16 (Wi-Max), 802.22 (WRAN)] for maximum flexibility.
Scalability	System architecture should be distributed and modular. Prevents single-point failures, facilitates upgrades, decomposes complex systems into manageable components with defined responsibilities.
Endpoint re-programmability	Allow for endpoint devices (sensors, radios, etc.) to be selectively chosen and dynamically reprogrammed to upgrade functionality while maintaining nominal operation of the control system.
Add-on or retro-fit activities	Facilitate the late or retro-fit addition of additional sensors, controllers, and communications equipment to add additional required functionality as test and verification activities impose new requirements.

ROI Implications

- BioNet provides the capability to integrate legacy and today's cutting-edge hardware into a unifying data management system, protecting assets and investments, while enabling a clear path to integrate future devices that take advantage of advances in fast-moving electronics and communications technologies.
  - Obsolescence mitigation, protection of potentially significant capital equipment investment

BioNet Phase II Planned/Proposed Capabilities

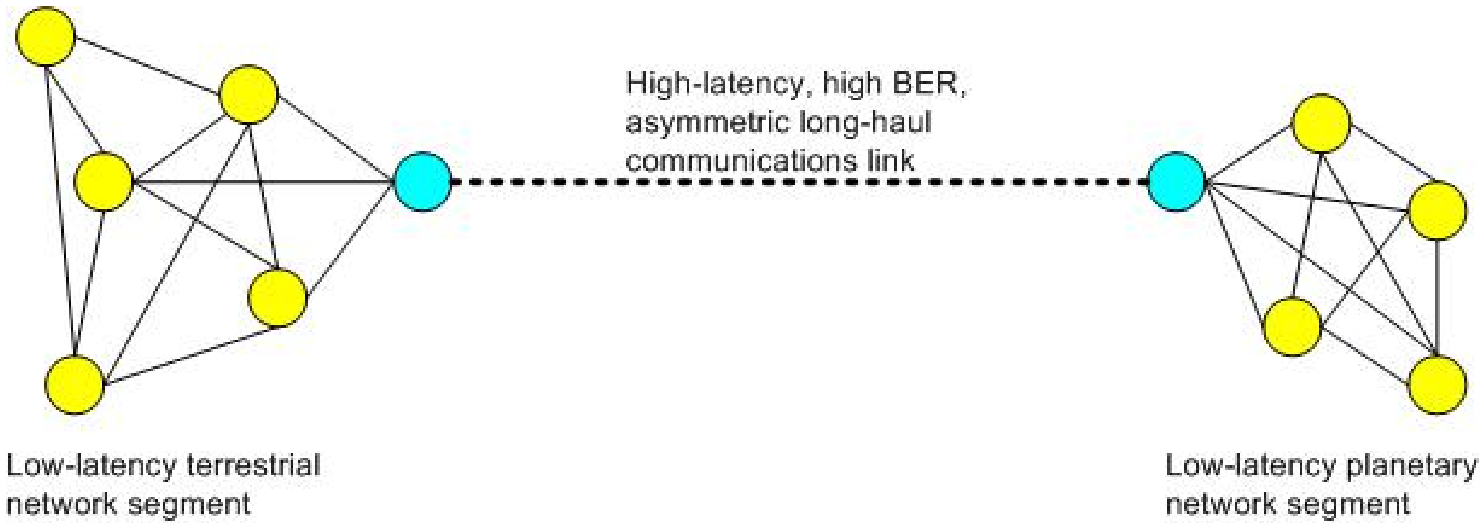
- Integrated security architecture
  - Provide authentication, authorization, data privacy and integrity
- Integrated QoS
  - We “own” the network
  - Data rate control via IntServ, DiffServ, Time Limited Leases, Supervisory process monitor
- Distributed NAG functionality
  - Peer-to-peer network
  - Provides “tear-away” capability
- Interplanetary Networking
  - Delay tolerant communications



- Low-latency short-haul network components include
  - mission control centers, ground stations, and orbiting communications relay satellites in a terrestrial regional network;
  - habitats and associated short-haul communications infrastructure such as surface-based relays and orbiting communication satellites on remote planetary surfaces.

- The defining attributes of these network segments are low-latency and low bit-error rate (BER) communication links. TCP/IP depends upon these link characteristics for proper operation.

Delay Tolerant Networking (DTN)



- Long-haul space-based communications links are subject to large transmission latencies, potentially high bit-error rates, and asymmetric (different uplink and downlink) data rates on the communication channels (e.g., Earth-to-Moon, Earth-to-Mars links)

- To reliably transit data messages across interplanetary communication links, delay (or disruptive) tolerant networking (DTN) is employed.

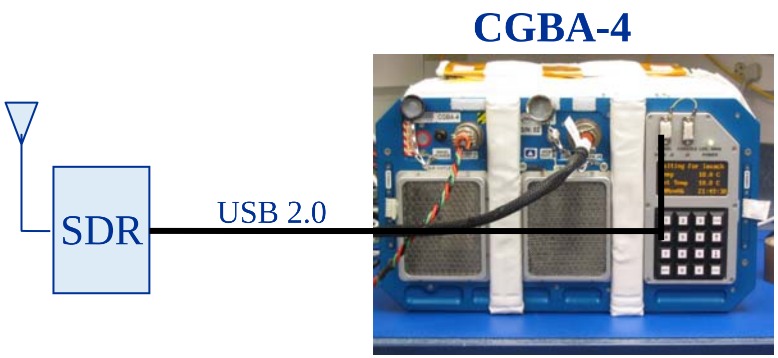
Delay Tolerant Networking

- A “text message” is a form of delay tolerant messaging
- DTN and BioNet together provide the capability to uplink any binary image to remote locations
  - allows uplink of updated configuration files with automated application restart, uplink of updated application programs, and installation of updated or additional device drivers for new device data integration
  - all without affecting the executing BioNet middleware, the DTN communications software, or operation of loaded applications
- This capability provides for partial or full system upgrades and leverages the remote reprogrammability of advanced systems, a fundamental concept of advanced space communication architectures.
- The BioNet/DTN architecture provides for standard communications services to remote spacecraft and structures, and importantly, enables a common tool set for shared Mission Operations usage across the NASA agency and with international partners.

BioNet+Software Radio Experiment Concept

Objectives:

- Utilize the BioNet architecture and existing ISS processing resources to command/control/monitor a SDR platform onboard ISS.
- Implement subset of STRS APIs necessary to enable on-orbit reconfiguration and monitoring on an existing COTS SDR development platform.
    - i.e. GNURadio, TI SDR development platform
- Perform on-orbit reconfiguration.
- Advance the state of the STRS standard.
    - Use existing open source software, COTS hardware, and standards where applicable.
- Low cost, high payoff experiment.



Contacts:

Kevin Gifford, UC/BioServe, Larry Foore, NASA

Technical Elements:

- CBGA payload utilizing BioNet architecture.
- COTS SDR platform
- STRS standard
- Waveforms
    - FFT (power spectrum sampling)
    - WLAN Rx waveform

Impact:

- Simulates command/control operations via IP network communications utilizing advanced middleware concepts (BioNet).
- Perform on-orbit reconfiguration (Rx waveform only).
- Advance the state and understanding of STRS architecture and standard interfaces.

Relative Schedule:

- Q1-Q2
    - BioNet HAB development for radio platform.
    - Hardware structure, electrical, and communication interface development for integration into CBGA \ payload.
    - FFT power spectrum sampling Rx waveform.
- Q3-Q6
    - WLAN Rx waveform development
    - MAC processing necessary to decipher WLAN frames.
    - On-orbit waveform upload and reconfiguration.
    - Packet capture and statistics delivery to ground ops (UC Boulder).

BioNet Product Development Roadmap

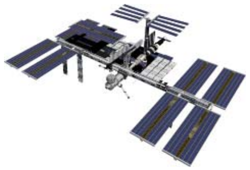
CGBA-4 Flt 12A.1 / CGBA-4 Flt 13A.1

Integration for flight

- Initial flight
- BCS integration
- TRL advancement

2nd ISS flight

- Continue TRL advancement
- Integrate DTN-on-ISS
- Integrate SDR-on-ISS
- Payload computer upgrade?



Win2K Phase I / Win2K Phase II

Release 0.5.0

- Initial Windows port
- Multi-platform support
- Single code base

Advanced Win2K

- Data privacy
- Uplink software mods
- Real-time streaming with no operator
- Port and integrate BCS

JSC Demo

STTR Phase I / STTR Phase II

NAG, DevKit Release 0.40

- Binary protocol
- Win2K port effort
- Market assessment
- Middleware survey
- Packet visualization
- Bedrest application
- Initial test framework
- Webplots infrastructure

UDM, AMS/DTN

- Unified Data Manager, historical data
- ERIS interface to ISS
- P2P, tear-away nodes
- Automated data replication
- DTN for intermittently connected links
- Security {encryption, integrity, authentication & authorization}

- Miniaturized space-rated H/W platform [Invocon MDACS]
- Embedded linux distribution
- Formal testing structure; design-for-test
- Improve fault tolerance
- Redundancy engineering
- UC-Boulder DTP Testbed

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