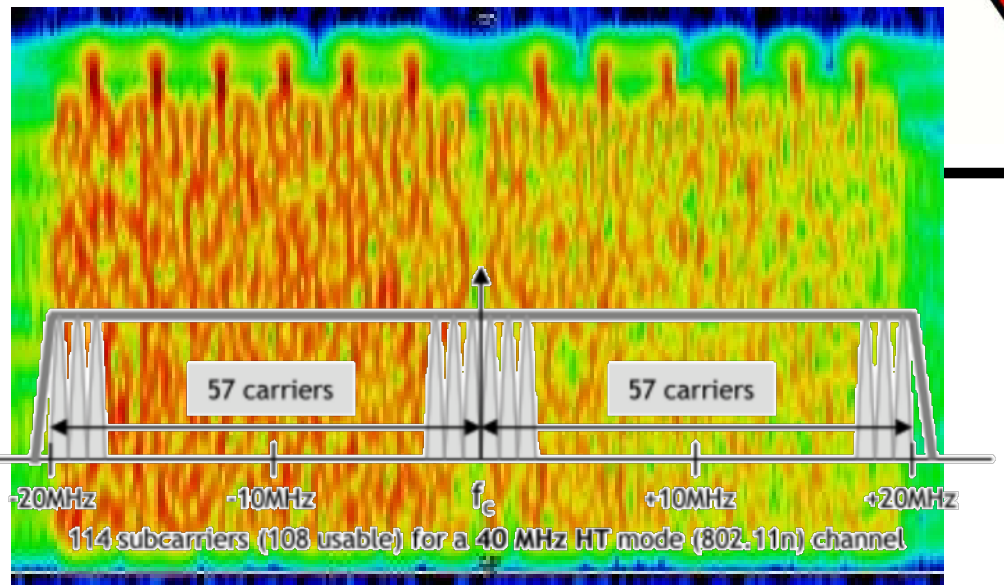
Overview and Experience for External 802.11n on International Space Station (ISS)



Sponsoring Org/Office Code: *EV*
Name of Forum: *CCSDS Spring Meetings*
Presenters : Chatwin Lansdowne
Date: *April 2018*

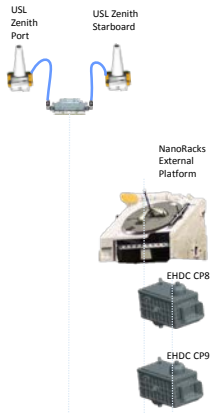
Topics

Status update since May 2017

- ISS External Wireless Communication subsystem overview
  - Evolution
  - Existing
  - Future
- Experience: what was easy, and challenges

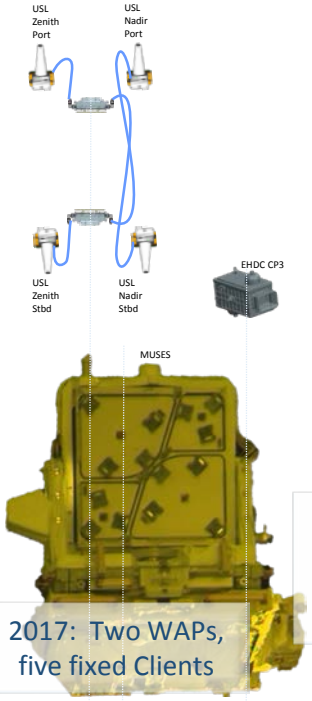
Evolution of EWC

Single-user Fixed Point-to-Point

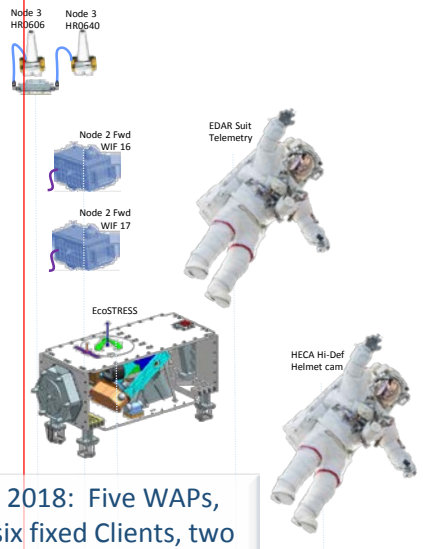


2016: One WAP, three fixed Clients

Multiple User Fixed Star Network



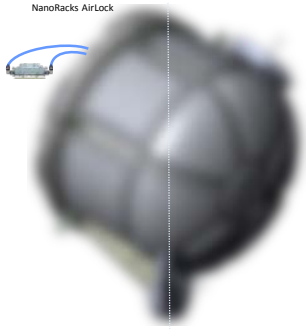
2017: Two WAPs, five fixed Clients



2018: Five WAPs, six fixed Clients, two transient mobile low-rate clients

Multiple User Fixed/Movable and Mobile Wireless Network

2019: More WAPs, fixed clients, three transient mobile high-rate clients



2020: More WAPs, fixed clients, transient mobile high-rate clients

5/16 8/16 9/16 5/17 6/17 10/17 4/18 5/18 6/18

EWC Committed Users

EWC Client	On-orbit Date	Operating Location(s)
NREP	Operational	JEM-EF; utilization will ramp up
EHDC	Operational	Truss CP8, CP9; CP13, CP3 planned; coverage coupled to pan-tilt
MUSES	Operational	ELC-4; utilization will ramp up
EcoSTRESS	6/2018 SpX-15	JEM-EF site 10; HISUI and NRAL disrupt coverage
CR15502 EMU Data Recorder	~6/2018	Suited EVA ops
CR15697 HD EVA Camera Assy	~1/2019	Suited EVA ops
CR15277 NanoRacks AirLock	10/2019 SpX-18	SSRMS port nadir, POA temp stow truss port nadir
DDVS	6/2020	SSRMS nadir inspections

- Other 802.11n, coexisting with EWC:
  - JAXA iSEEP payload
  - RRM-3 payload
  - Boeing CST-100

Coverage Expansion Projects

- Approved
  - Node 2 Forward
    - Two WAPs; 4 months from ATP to Launch!
  - Truss
    - Cable runs supporting up to 10 connections for GbE
    - Up to 6 EHDC camera clients dual-purposed or re-purposed as externally mounted WAPs
  - NanoRacks AirLock at Node 3
- Concept
  - Ram shadow

Achievements

- Although not advertised as reliable, EWC has been providing wireless connectivity for multiple high-rate “uplink” users, with very high availability and no complaints
- EWC provides an inexpensive and popular first-choice option to payloads
- EWC leverages
  - worldwide investment in miniaturized COTS, standards, and open-source
  - block-buy investments and accumulation of knowledge about components
  - industry consortium interoperability testing

Tweaks and Challenges

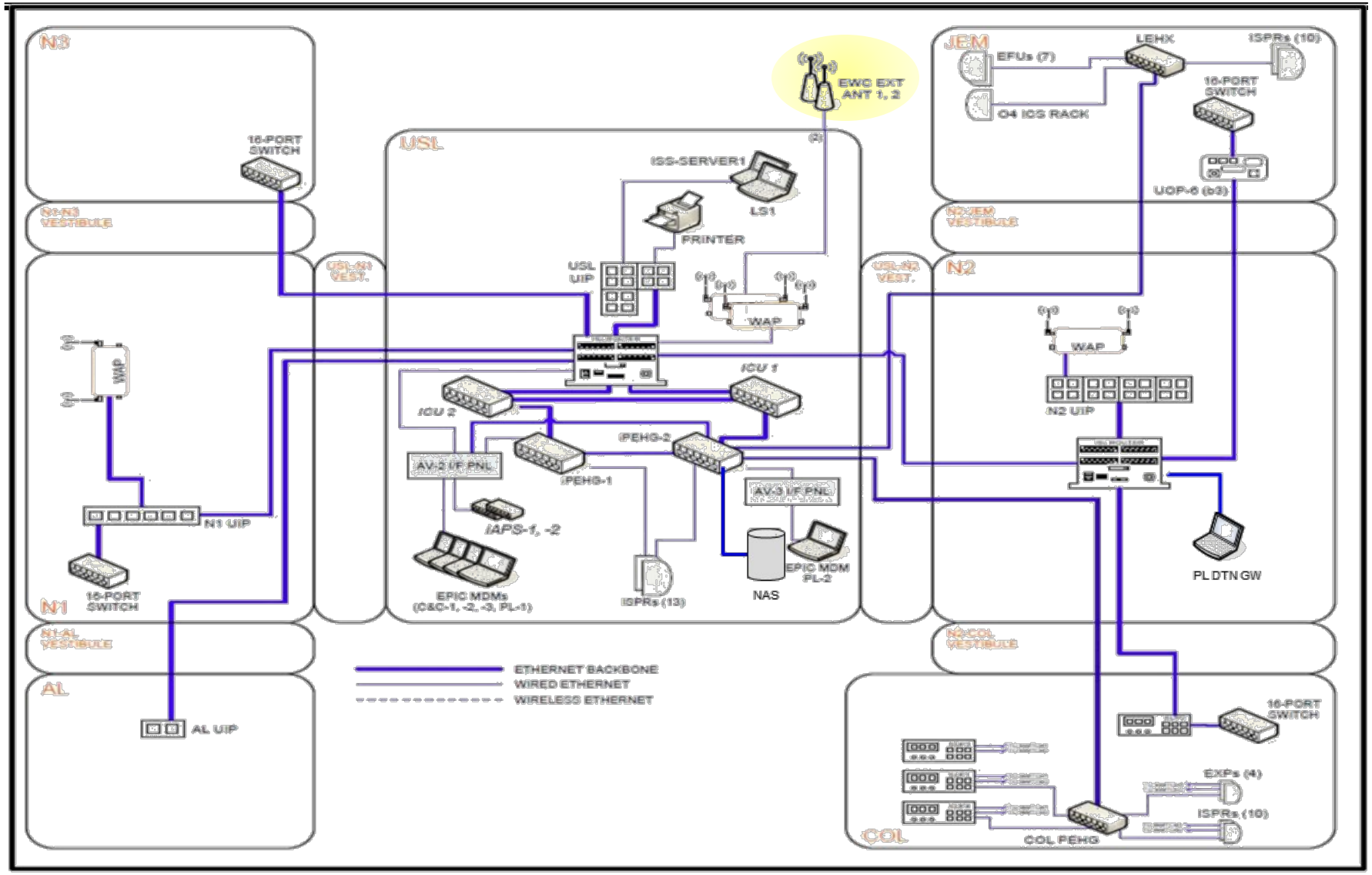
- Wired/wireless cameras and WAP/client-bridge continue symbiosis. However camera viewing angle coupled to antenna pointing angle is not being optimal
- With spacesuits needing to move between IVA and EVA, distinctions between EWC and internal wireless are being erased
- Interoperability: the last 20dB. Behavior depends on specific model of client and specific model of WAP.
- Mobility. Unless clients are aggressive or WAPs are managed, mobile clients do not handoff for best connection

BACKUP

The Current External Wireless System

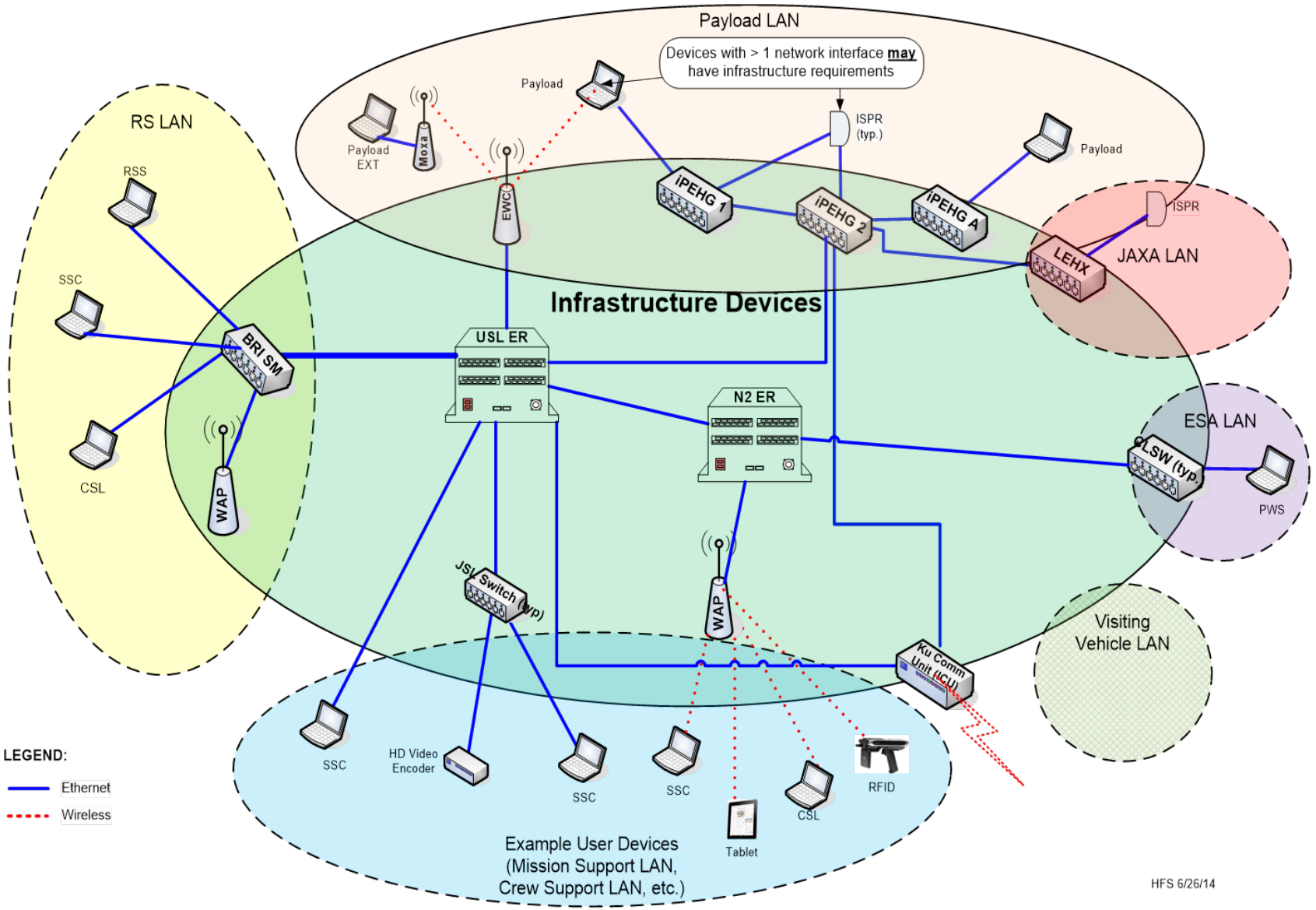
- The Express Logistic Carrier (ELC) Wireless system provides a COTS solution for external high data rate 802.11n wireless capability to payloads on the ELC
- The system consists of two separate segments
  - US Lab
    - COTS Wireless Access Points (WAP) placed inside the lab with external antennas to provide the core wireless capability
  - Payloads/Users
    - Characterization of a wireless solution for the payloads/users to integrate and provide piece parts to the developers

JSL Architecture – Payload Segment

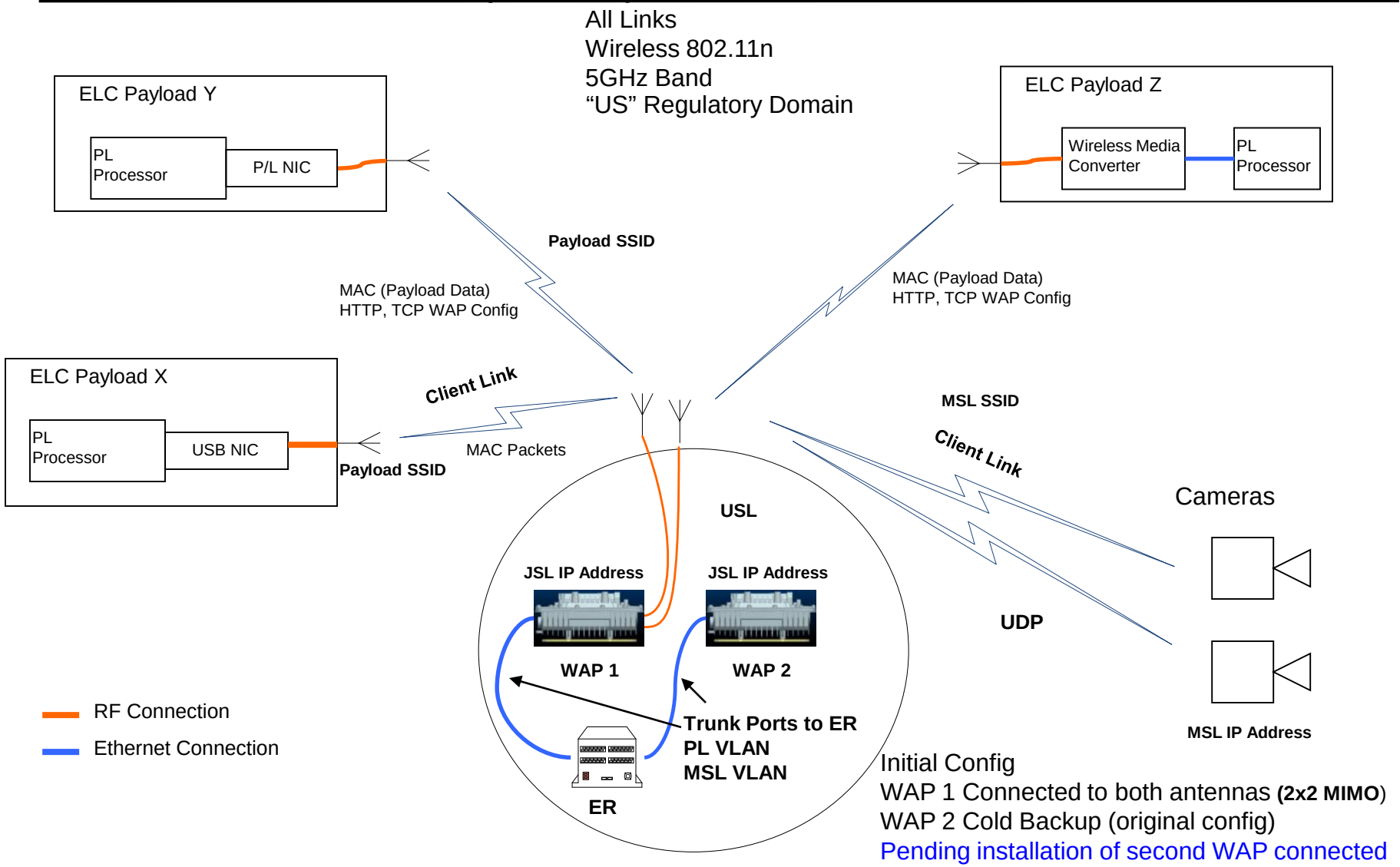


JSL Logical LAN Overview

Ref: SSP 50892 – Ethernet Requirements for Interoperability with the Joint Station LAN (JSL)

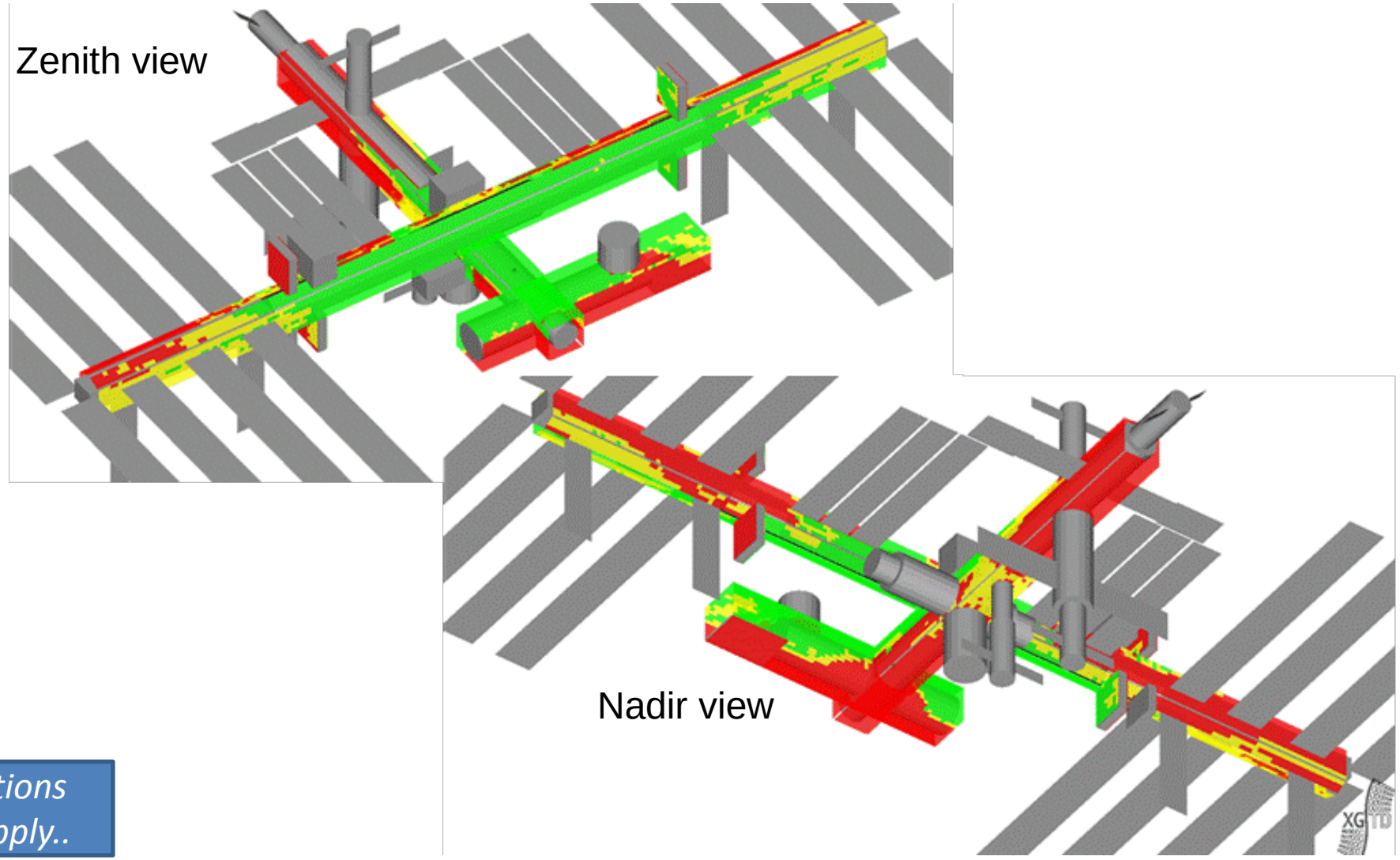


Current External Wireless Communications (EWC) Architecture



Initial Config
WAP 1 Connected to both antennas **(2x2 MIMO)**
WAP 2 Cold Backup (original config)
Pending installation of second WAP connected to the other antenna, so both will be operational

EWC Antenna Coverage Zones



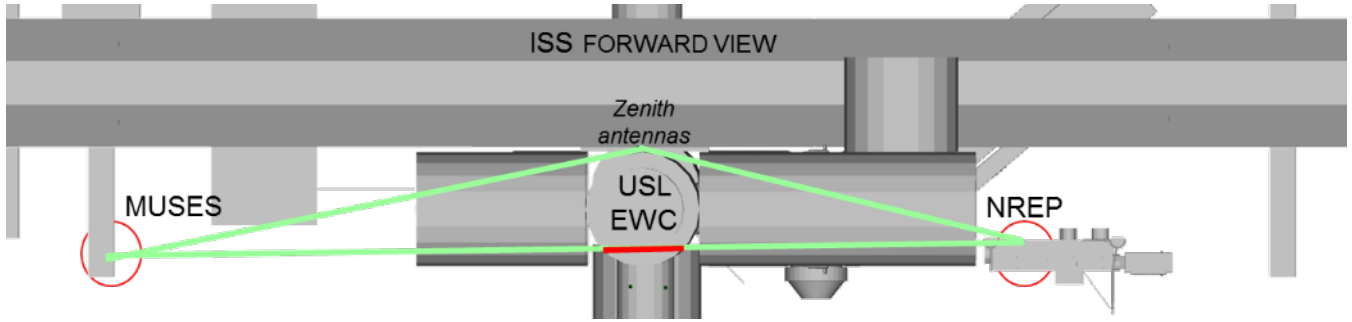
Some Assumptions and Caveats apply..

Achievements

- Communication can inexpensively be provided to payloads and infrastructure by leveraging
  - worldwide investment in miniaturized COTS, standards, and open-source
  - block-buy investments and accumulation of knowledge about components
  - consortium interoperability testing

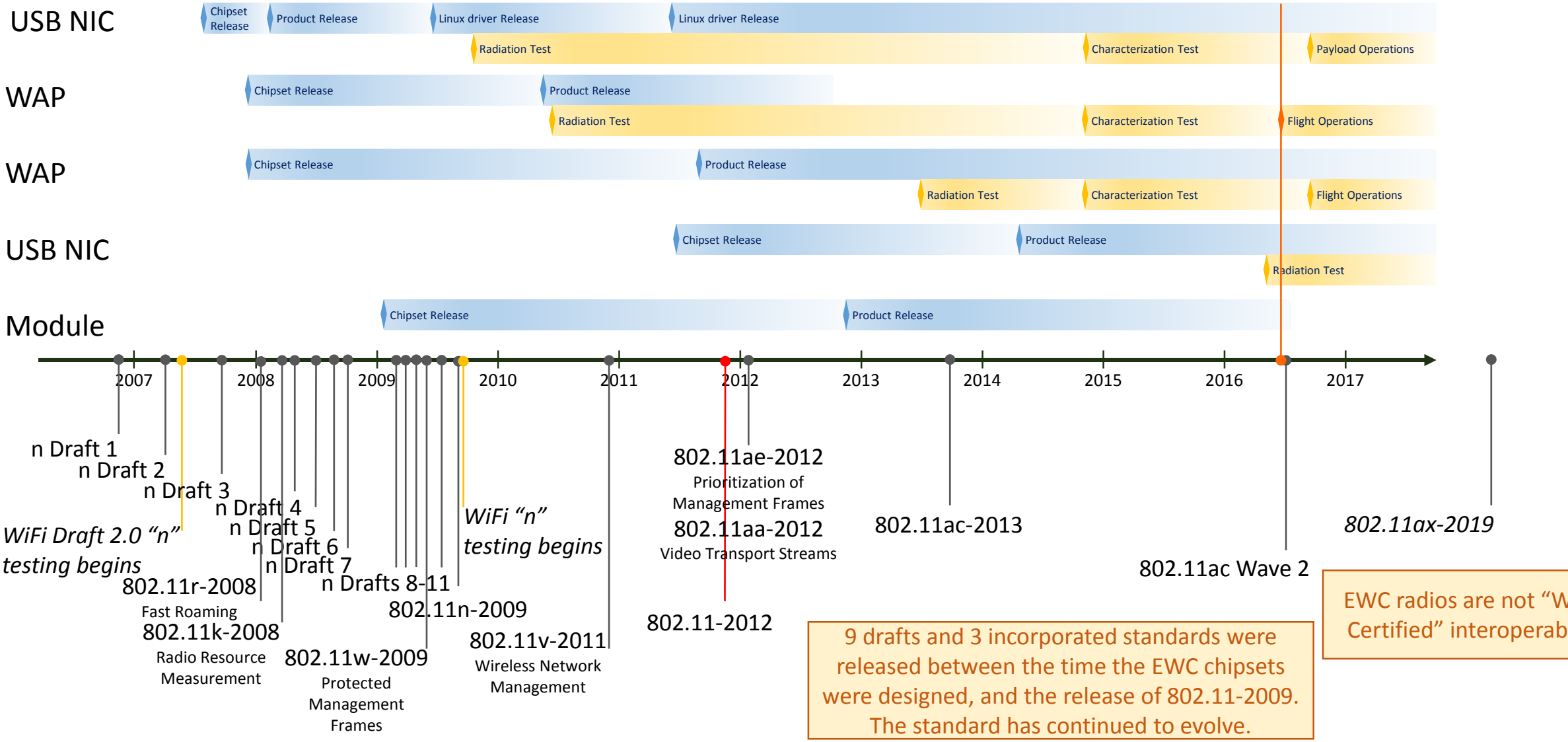
Challenges: Network and Protocol

- User Interaction
  - A high-rate UDP streamer (e.g. video) can deny service to all users of an access point (inclusive of self), when channel is weak and connection speed drops below stream rate. This is a challenge for moveable or mobile video applications.
- Hidden Node– will happen between port and starboard payloads



- Exposed Node– could happen due to channel reuse

Chronology of 802.11n/ac 5GHz MAC and PHY

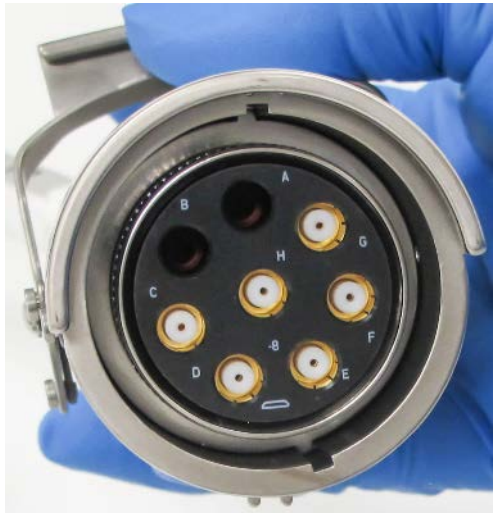


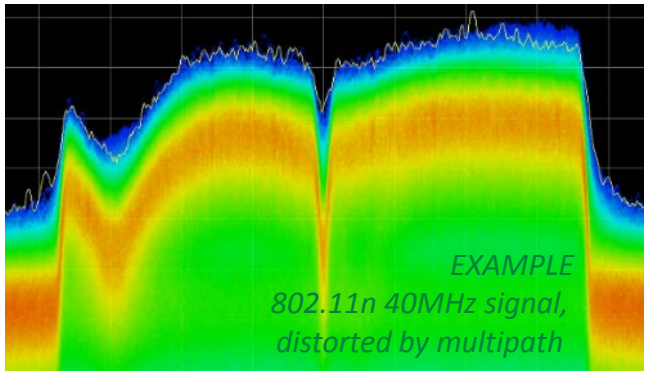
9 drafts and 3 incorporated standards were released between the time the EWC chipsets were designed, and the release of 802.11-2009. The standard has continued to evolve.

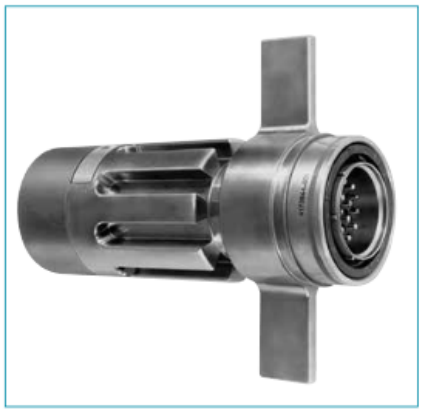
EWC radios are not "WiFi Certified" interoperable.

Penetrations

- Performance of ISS certified NATC / NZGL coaxial bulkheads and connectors is unspecified above 2.5GHz
- Mating performance suffers, as well as crimp performance
- A suitable replacement would enable internal radios with external antennas using carrier frequencies above 2.5GHz

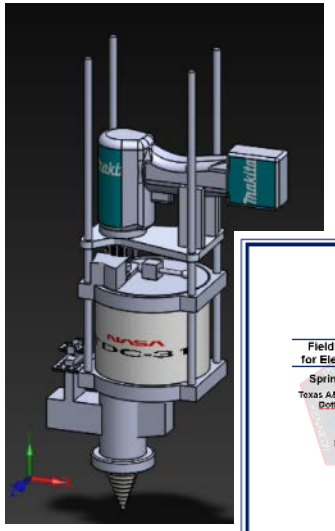


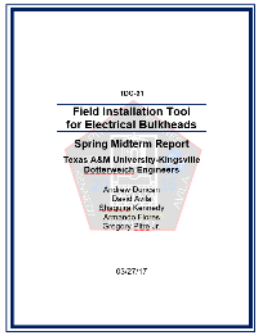




Special configuration Fail-Safe used on space telescope application. Lanyard is replaced by a swivel ring for remote disconnect and "wing arms" have been added for manual actuation accessibility by gloved astronauts.

Available and Future technologies?





Challenges: COTS

- Life of components is generally not specifiable or well-characterized
- NIC and WAP vendors go out of business
- Payloads prefer ISS program provides antennas and NIC

Challenges: Network

- Tendency of payloads to view connection speed not as shared
- Some clients do not support all channels in the country of sale. Clients must support a common channel set for manageability.

Challenges: Radiation

- Roughly 75% of products radiation tested were unsuitable
- 802.11ac adapters are significantly harder than processors. 802.11ac WAPs have had especially soft processors
- Self-corrected failures observed
- Manually recoverable failures observed (soft restart, or hard restart)
- Unrecoverable: a WAP reset configuration to factory default– including the default IP address
- Other failures damaged hardware, even started a fire

Challenges: WAPs and NICs

- Most “802.11n” devices are not “WiFi Certified”
- Some “802.11n” devices on the market today are really “Draft-n”
- Not uncommon for output power or receiver sensitivity of an antenna connection to be 10dB to 30dB degraded after storage on ground
- 802.11ac WAPS generally cannot be configured as clients

Challenges: Antennas

- Rigid antenna mounts: difficult to meet “kick loads” requirements; flexible antenna mounts can be a safety hazard
- Temptation to use dual antennas to increase spherical coverage at expense of network shared capacity and reliability of connection
- Polarization diversity: infrastructure began as vertical and clients had to match. Will become mixed: diverse linear, RHCP
- Temptation to use high-gain antennas and less infrastructure. High-gain antennas become a constraint on infrastructure, and are defeated by maximum EIRP requirement
- Temptation to build antennas in, but then coverage drives box design

COTS, Standards, Open Architecture

- Different standards solve different problems
- Each standard in the infrastructure represents a pool of COTS, tools, software opened to developers

Standard	Power	Distance	Data Rate	Protection
RFID	passive	3m	up to ~3kbps	unlicensed
BLE	harvester, battery	20m	up to ~3kbps	unlicensed
LoRaWAN	harvester, battery	1km	up to ~3kbps	unlicensed
ISA-100a	battery	30m	up to ~200kbps	unlicensed
WiFi	battery, wired	100m	up to ~1Gbps	unlicensed
LTE	battery, wired	100km	up to ~100Mbps	licensed
WiGig	wired	50m	up to ~7Gbps	unlicensed

EWC is a best-effort interface. Any interface based on a standard using unlicensed frequencies, is not usable for critical applications.