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AF CyberWorx hosted 21 government and industry participants in a technical discovery event to explore the viability of HF radio for C2 in permissive and non-permissive environments in current DoD PACE plans. Information included current and possible future capabilities and physical limitations of HF equipment.

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# AIR FORCE CYBERWORX REPORT 19-006
# High Frequency Technical Discovery Event

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**EVENT CONDUCTED**
**29 – 30 NOV 19, AF CyberWorx**

*Produced with input from Headquarters Air Staff A2 and A5, ACC/A6, 1 SOCS, 27 SOCS, 1 CBCS, GCS Program Office, Joint Communication Support Element, 254 CCG, 5 CCG, 10 SFG and our partners in industry.*

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# Executive Summary

04 NOV 2019

**High Frequency Technical Discovery Event**

On 29 & 30 October 2019, twenty-one Air Force, Army, and industry experts formed a team to explore the viability of High Frequency (HF) radio within the current Department of Defense (DoD) Primary, Alternate, Contingency, and Emergency (PACE) plans. The team learned about the current capabilities, the physical limitations, and future growth potential of HF communication through a question and feedback session with subject matter experts. They followed that knowledge discovery with a problem solving session where they developed a way forward with suggested avenues of further research as well as suggestions for earmarks for the FY22 Planning Choices.

**Scenario Focus and Knowledge Discovery**

***How might we better and more quickly employ C2-worthy HF capability to the permissive and non-permissive edge?***

As per the initial problem statement developed by the stakeholders, participants based their discovery on the ability to C2 with HF. A question/feedback session with subject matter experts focused on two categories: What is the resiliency of an HF network considering both environmental and threat factors? What are the capabilities and limitations of HF technology today and in the future?

Key information gained during this session included what environmental and threat factors would affect HF capability, security concerns of HF use in a threat environment, potential bandwidth, physics and technological limitations, and physical support needed for HF integration in operations.

**Problem Solving Session**

After knowledge discovery, the team discussed what the AF needed to make HF more effective and practical for PACE use. Participants determined the best way to integrate effective HF usage would be to "bake it in" to current operations. Through discussions, and based on knowledge gained during the question/feedback session, the team wrote suggestions to integrate HF usage into normal operations. These ideas included incorporating HF usage into exercises and plans; developing a stronger infrastructure that would support HF; procuring modern equipment such as newer composite antennas and encryption technology; and developing a more intuitive user interface for the current radios to mitigate loss of knowledge due to lack of everyday use.

While further exploring the concept of "bake it in," the team separated further research suggestions into three main categories: what was currently available for the AF to gain, what still needed to be developed, and what TTP's needed to be considered. With those categories in mind, the team created suggested guides for the next steps in exploring the efficacy of HF usage.

# High Frequency Technical Discovery Event

On 29 & 30 October 2019, twenty-one Air Force, Army, and industry experts formed a team to explore the viability of High Frequency (HF) radio within the current Department of Defense (DoD) Primary, Alternate, Contingency, and Emergency (PACE) plans. The team learned about the current capabilities, the physical limitations, and future growth potential of HF communications through a question and feedback session with subject matter experts. They followed knowledge discovery with a problem solving session where they developed a way forward with suggested avenues of further research as well as suggestions for earmarks for the FY22 Planning Choices.

## Background

The DoD prioritizes maintaining a competitive superiority no matter the situation or working environment. As such, DoD leadership recognizes the need for command, control, and communications resiliency in permissive, semi-permissive, and non-permissive environments. Other applications of HF identified early on included agile basing. Stakeholders identified the need to explore current HF capabilities and potential future applications and directions of growth, especially in the area of command and control (C2) and on the tactical edge. In this early stage of investigation, participants were more interested in the high-level capabilities and security of HF usage instead of the end user application and usability. Feasibility of front-line use included some of that information.

## Participants

Twenty-one participants came from a wide range of experiences. Seventeen military members came from Headquarters Air Staff organizations A2 and A5, ACC/A6, 1 SOCS, 27 SOCS, 1 CBCS, GCS Program Office, Joint Communication Support Element, 254 CCG, and 5 CCG. The Army also participated with two members from the 10 SFG. Four industry specialists attended from NTIA, Teledyne, Raytheon, and GIRD Systems to provide their expertise on the subject outside of current DoD use.

NTIA, the Institute of Telecommunication Sciences, provided proven skills in the areas of LTE, statistical data analysis, antennas, radio frequency (RF), and network analyzers. The NTIA

representative who attended the event had a strong electrical engineering background to share expertise in the HF field. Teledyne Brown Engineering brought a mixture of military and Missile Defense Agency experience. Teledyne specializes in providing disciplined planning and enterprise integration to overcome complex challenges. Raytheon engineers generalize across many areas the DoD operates in including aerospace, defense, and civil government. GIRD Systems focuses on applying the latest digital signal processing research to DoD and other government agencies in communications and electronic warfare. All four industry specialists brought a broad range of experience and specialized knowledge to the event for technical discovery and to answer technical questions.

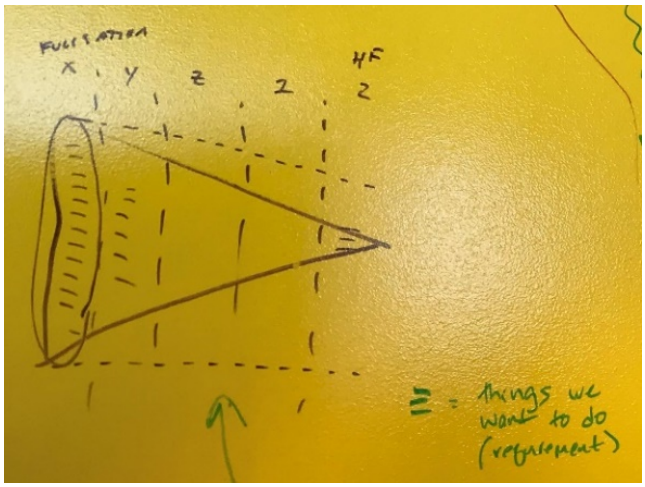
The diversity of the team gave value by breaking down traditional military and organizational barriers, allowing all viewpoints to be shared and heard. Key insights from industry partners helped shape the team's efforts, expanding knowledge beyond current Air Force capabilities.

## Scenario Focus

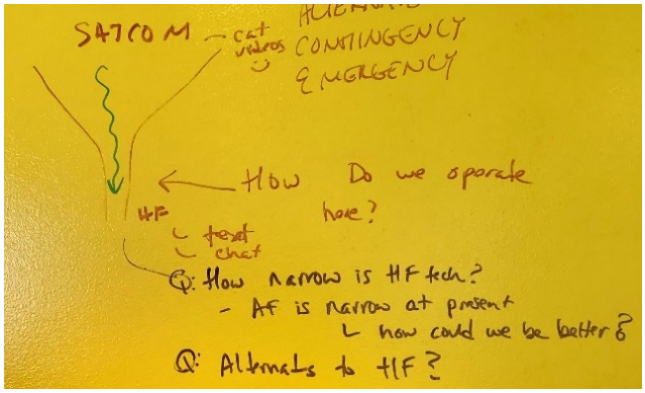
***How might we better and more quickly employ C2-worthy HF capability to the permissive and non-permissive edge?***

Stakeholders identified the initial problem statement stated with the focus on C2 capabilities of HF technology for PACE plans from the Tactical Edge perspective. Per this focus, the team based their discovery on the ability to C2 with HF. The team used diagrams of a pennant and funnel to represent high-level organizational requirements. After questioning whether each organization needed all their desired options to be effective, the team decided to focus on the base needs of C2: communication and situational awareness.

For organizations to be effective at C2, the **preferred** communication method is satellite communications for speed, capability, and bandwidth. **HF is much more limited**…




*The pennant diagram lists the organizational requirements given a specified amount of capability. The left side represents the greatest capability with the right side representing the least.*




*The funnel diagram gives a visual representation of how much data can be transmitted given communications capabilities. Satellite communications provides the greatest capability, HF the least.*

For organizations to be effective at C2, the preferred communication method is satellite communications for speed, capability, and bandwidth. HF is much more limited, but a potential for situations where satellite communications are degraded or unavailable. To further focus the discovery process, the team asked three main questions. **(1) What are the wants versus needs for the warfighter requirements? (2) How can we make more of the requirements available at the narrow end of the pennant now and in the future? (3) What are the high bandwidth capabilities of HF in the future?**

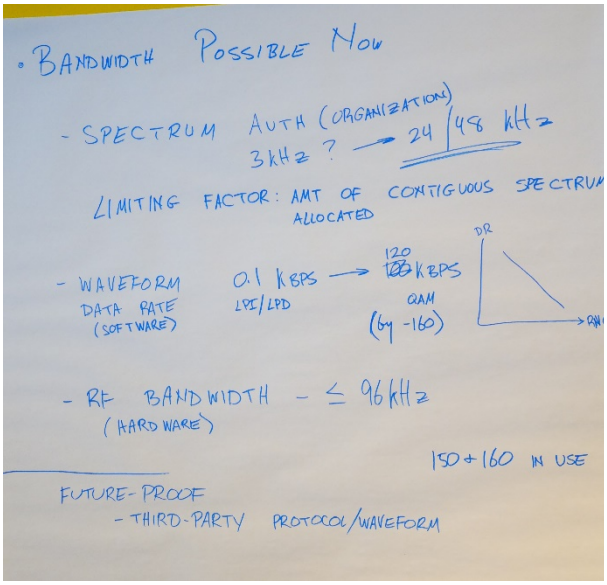
## Knowledge Discovery Session

With the team's focus on communication capabilities, the team expanded the three questions into eleven more specific questions. Subject matter experts – both military and industry specialists – fielded a question/feedback session for each question to investigate in-depth knowledge discovery. This allowed the team to clarify concerns and gain a better understanding of the capabilities of HF.

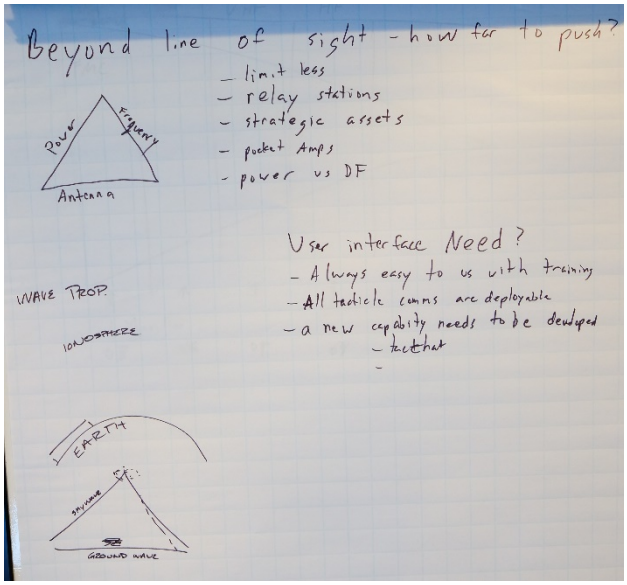
1. How resilient is HF considering environmental and non-permissive conditions?
    - Post-nuclear
    - Jamming
    - Solar activity/weather
    - Space-denied environment
2. How much bandwidth is possible now and in the future with HF?
3. What will radio channels give us? (Point to point? Area broadcast?)
4. How far can we push communication beyond line of sight?
    - How far do we need to push?
    - What would the footprint be for that?
5. What are the user interface needs?
    - Easy to use?
    - Deployable?
    - What platforms are needed/used?
    - What are its power needs?
    - Does it have data entry operability?
6. What base of support is required?
7. What concerns are there about frequency management and interference?
8. Can we live stream with HF? What would be the FPS? COP data?
9. What is the smallest, most powerful form factor?
10. What security concerns are there? Encryption capability?
11. What is the user maintainability? Is Reachback needed?

One of the key concerns which came out of the question/feedback session was the resiliency of an HF network due to both environmental and threat factors.

Identified environmental factors affecting HF effectiveness included atmospheric changes due to solar activity, weather, time of day, seasons, and geographic obstacles. Threat factors included post-nuclear changes to the atmosphere, susceptibility to identification and interception by the enemy, and jamming interference.

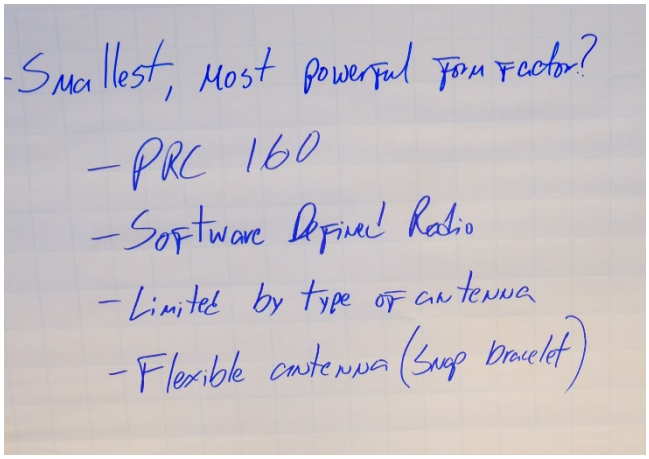



*Subject matter experts gave detailed information about the current and potential future capabilities with knowledge of physics and technological limitations.*




*Subject matter experts also outlined the physical limitations to how far HF could feasibly be pushed and what would be needed to extend beyond those limitations.*

**Another key concern identified during the question/feedback session was what the specific capabilities and limitations of HF technology are today and in the future.** Specifics included potential bandwidth, availability of live feeds and video, speed of communication, and physical support needed for HF use.




*With portability in mind, subject matter experts described the best value on the market that combines compact size and power.*

## Problem Solving Session

After knowledge discovery, the team discussed what was needed to make HF more effective and practical for PACE use. Building off the knowledge gained during the question/feedback session, the team listed potential changes and things to try from previous discussions. (Transcribed list of ideas in the proposed changes/things to try list found in Appendix 1.) Some key ideas included incorporating HF usage into exercises and plans, developing a stronger infrastructure that would support HF, and designing a stronger user interface to mitigate loss of knowledge due to lack of everyday use. These all would ideally lead to HF capability being "baked in" to the system to better integrate current capability and encourage continued technological growth through end user innovation.

To better understand the problem solving direction they needed to take, the team dug deeper into the proposed change of "bake it in." The resulting questions led in to a separation of categories for further research**.** The team separated further research suggestions into three main categories.

- **What's currently available for the AF to gain?**
- **What's missing that we can build or R&D?**
- **What TTPs need to be considered?**

## Recommendations

The list of action items, next steps, and physical equipment ranged from extremely specific to general items of interest. "The Menu" contained specific items dealing with equipment and software development and acquisition. Action Items suggested directions for further research. Categorized research items listed necessary actions and changes to current organizational operations.

## The Menu

*Equipment and software that needs to be acquired or further developed.*

**Modems/Radios**

- German-made Military handsets – Handsets to translate analog to digital not currently made in the USA
- LPI/LPD – Low Probability of Interference/Detection; most expeditionary units do NOT have this capability but are required
- Non-CCI encryption – More for policy. In most cases, radios have NSA-approved software encryption, making hardware encryption unnecessary. Taking out the hardware layer reduces bandwidth overhead.
- Wave Forms
  - Wave forms need to be standardized.
  - Messaging applications between HF GCS and end user radios are currently incompatible but need to work together.
- Predictive capability should be built in to better find the proper frequencies

**Antennas** (available now)

- purpose built/scalability
- material/new models
- passive Sounder Receivers (suggested)

**Supporting**

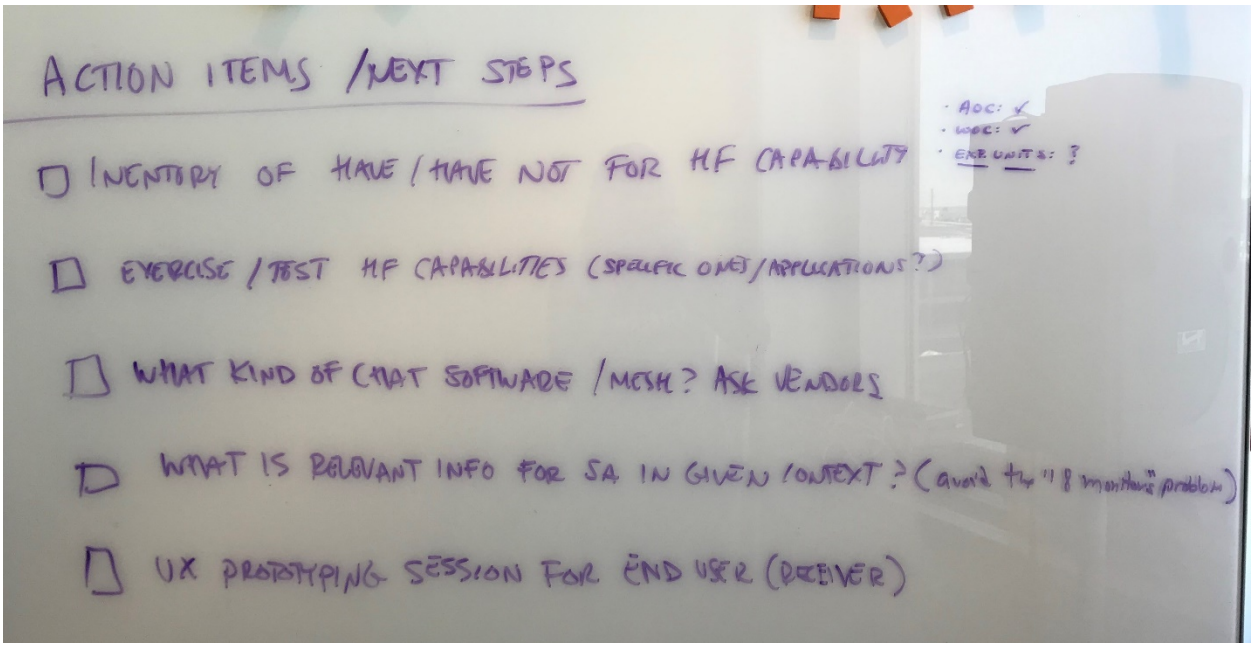
- Output power/Amplifiers (available now)
- Industry can help develop a better User Interface.
- Need better compression software to enable more data to be transmitted (i.e. video) (suggested)-can be developed by Compix (used by UK)
- Sufficient physical space for extended field operations
- Split-site capability with remote antennas to avoid enemy targeting
- Use of HF to C2 and not just test how much power the operator can produce
- Better interoperability between HF GCS and end user
- Identify where ground relay stations are needed and procure/field equipment
- Use of airborne assets for relay to include aerostats, BACN, etc.

**Emerging Technology**

- TAC CHAT software upgrades
- File compression and apps can mitigate HF physical and environmental limitations.

## Action Items/Next Steps

*What needs to be done as soon as possible to further explore HF for modern operations?*




- Inventory HF capability. AOC, WOC, and Expeditionary Units have different HF capabilities. Need to know what's in the inventory and what we are missing, i.e. antennas, LPI/LPD, amps, etc. (POC: ACC)
- Exercise/Test HF capabilities with real world scenarios to develop TTPs vs just doing power checks and pings between radios (POC: MAJCOMs, units)
- What chat software/applications/mesh networks are available? (POC: AF CyberWorx)
- UX prototyping session for end user (receiver) (POC: AF CyberWorx)
- Receive inventory (MTOE) from 10 SFG and 1 SFC (POC: 10 SFG/AF CyberWorx)

## Categorized Research Items

*What's currently available for the Air Force to gain?*

- Modern antennas (POC: 10 SFG)
- LPI/LPD (POC: 10 SFG and 1 SFC)
- Passive sound receivers (POC: AF CyberWorx/Industry partners)
- Split operations capabilities (POC: 10 SFG)
- Relay station capabilities (POC: HF GCS/CCC)
- Amplifiers (POC: 27 SOCS)
- New generator capabilities (POC: AF CyberWorx)

*What's missing that we can build or R&D?*

- Better messaging
- Short burn decoy antennas
- Messaging interoperability (GCS vs Tactical Edge)
- Compression software and transcoding (POC: Compix (Industry partner))
- New apps with UX built-in
- Airborne Relay (e.g. drones)

*What TTPs need to be considered?*

- AES Encryption
- Split operations
- Mesh network
- (Live) EW
- Practice C2 on HF
- Relays

**Conclusion**

The final take-aways from the problem-solving event included key needs to determine the efficacy of HF for C2 and the Tactical Edge in a PACE plan.

1. There needs to be an inventory of what capabilities the AF already has and what it needs.
2. HF capabilities need to be incorporated into exercises to test specific applications, usability, and feasibility.
3. Required/relevant information for operational C2 needs to be identified for the individual warfighter when limited to HF.
4. More discovery with the National Labs needs to be done to determine current HF capabilities.
5. HF infrastructure needs to be incorporated into existing AF infrastructure. Research and development needs to continue to expand HF infrastructure capability.

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# Glossary

| | |
|---|---|
| ACC | Air Combat Command |
| AES | Advanced Encryption Standard |
| AF | Air Force |
| AFSOC | Air Force Special Operations Command |
| AOC | Army Operations Center |
| AOR | Area of Responsibility |
| ASOC | Air Support Operations Center |
| AWACS | Airborne Warning and Control System |
| BACN | Battlefield Airborne Communications Node |
| BOG | boots on ground |
| C2 | Command and Control |
| CCG | Combat Communications Group |
| CCI | Co-Channel Interference |
| CCS | Combat Communications Squadron |
| COP | Common Operational Picture |
| DASC | Direct Air Support Center |
| DoD | Department of Defense |
| EW | Electronic Warfare |
| FOB | Forward Operating Base |
| FPS | Frames per second |
| FY22 | fiscal year ‘22 |
| GCS | Global Communications System |
| HF | High Frequency |
| HFGCS | High Frequency Global Communications System |
| H.O.T. | Human/Organization/Technical needs triad |
| Hz | Hertz |
| JOC | Joint Operations Center |
| JSTAR | Joint Surveillance Target Attack Radar System |
| Kbps | Kilobits per second |
| LEO | low earth orbit |

| | |
|---|---|
| LINK-16 | ECM resistant tactical data exchange link |
| LMR | Land Mobile Radio |
| LPD/LPE/LPI | Low Probability of Detection/Exploitation/Intercept |
| LTE | Long Term Evolution |
| MAJCOM | Major Command |
| MANET | Mobil Ad Hoc Network |
| MARS | Military Auxiliary Radio System |
| MISCAP | Mission Capability statement |
| MTO | Mission Tasking Order |
| MTOE | Modification Table of Organization and Equipment |
| NGB | National Guard Bureau |
| NSA | National Security Agency |
| NTIA | National Telecommunications and Information Administration |
| O3B | a satellite network |
| OPLAN | Operations Plan |
| PACE | Primary, Alternate, Contingency, Emergency |
| POC | Point of Contact |
| PRC | Portable Radio Communications |
| RF | Radio Frequency |
| SA | situational awareness |
| SADL | situational awareness data link |
| SATCOM | satellite communications |
| SFC | Special Forces Command |
| SFG | Special Forces Group |
| SOCS | Special Operations Communications Squadron |
| TAC CHAT | Tactical Chat |
| TOC | Tactical Operations Center |
| TROPO | Tropospheric scatter transmission |
| TTP | Tactics, Techniques, and Procedures |
| UAV | Unmanned Aerial Vehicle |
| UHF | Ultra-High Frequency |

| | |
|---|---|
| UK | United Kingdom |
| UX | User Experience |
| WOC | Wing Operations Center |

## Appendix 1: Proposed Changes/Things to Try

- Sounding capability
  - turning every node into HF base station (relays, decoys, ionosphere conditions)
  - employ HF radios in TOC/JOC/ASOC/DASC
- Bake it in
  - Exercises
  - OPLANs
  - MISCAPs
  - Customer expectation
  - Expand supporting assets
- MTO ops/"last known order" with disconnected ops utilizing HF
  - Issue movement commands, etc.
- Airborne platforms
  - conventional
  - Drone radio relay
  - Dirigible
  - Drone HF antenna
  - Carrier pigeons
- Commercial LEO
- Mesh Networks
  - oneweb
  - O3B
  - Starlink
- Combined training effort for advanced HF training on current suite of equipment
- MANET
  - Provides C2 in a mesh network in a small 20-30 mile AOR
- Sharks with laser beams attached to their foreheads!
- Scalable messages
  - Notepad (outstation) -> Java (FOB) -> Sharepoint
- TROPO-Army tested! Army approved!
- SADL-LINK16
- Use/Practice AWACS/JSTAR as HF/L16 "portals" for BOG and Airborne assets
- Practice degraded environment in Saber Strike/Defender
- Compression software to streamline data packages
- Wave and Riverbed
- Actually C2ing cape across HF vs just ping
- HF Node on everything
- Actually practice Mesh networks