DARPA Wireless Networking Vision (DWNV)

"Making Network Centric Accessible for the Warfighter"

Wireless Adaptable Network Node (WANN)
BAA 06-26
Proposers' Day Presentation

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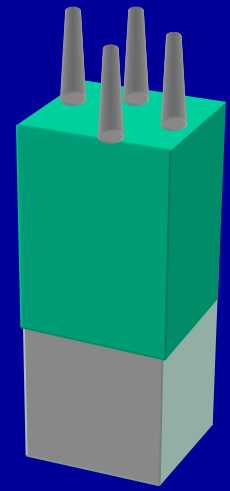
Defense Advanced Research Projects Agency
Advanced Technology Office

Today's Topics

- "DWNV" vs. "WANN"
- The Problem, and the New Technology Philosophy
- The DARPA Technology Approach
- Specific Enabling Technology
- Proposed Program Structure (*NEW*!)



Enabling the Transition from Robust Radios to Robust Networks

DWNV vs. WANN

- **DARPA Wireless Networking Vision (DWNV)**
  - Overall DARPA Program - Concept Remains Unchanged
  - Program has been Divided into Two Components:
    - Radio
    - Network
- **Wireless Adaptable Network Node (WANN)**
  - Radio Component of DWNV
  - Design and Procurement Strategy and Timeline have Changed but the Concept and Objective for the Wireless Node Remain Unchanged

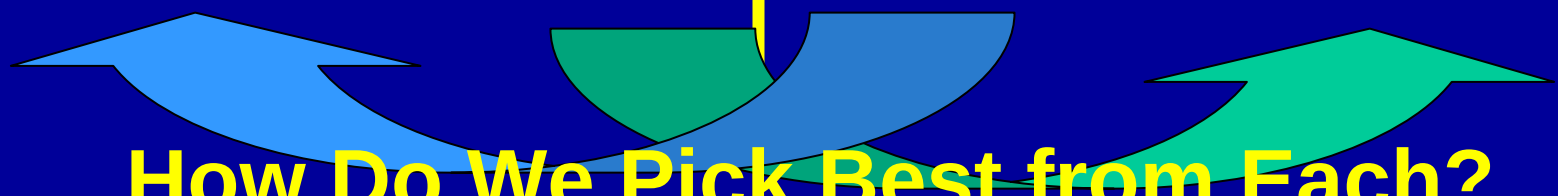
How to Reconcile/Leverage Visions of Wireless Strategies

Commercial World

- Ultra-Low Cost, Disposable
- Multiple Low-Cost ASICs
- Mission Specific Layers
- Multi-Band
- Low Energy Focused (RIM Blackberry Philosophy)
- Infrastructure Focused

Sophisticated SDRs

- Costly, Long Amortization
- Reprogrammable FPGA/GPP
- Core IP Layer for Everything
- Wideband
- High Energy
- Less Infrastructure



How Do We Pick Best from Each?

Analog Impact Technology Impact on the Network Vision

- **Analog Capability Drives Radio Cost**
  - Digital will be Handled by Moore's Law
- **High Cost Leads to Low Density**
  - Low Density Stresses Radio Range, thus Cost
- **Networking Not Viable as Primary Connectivity Without Suitable Density**
  - Forces Higher Costs and Less Density!
- **Current Networking Technology Accentuates Hardware Weaknesses, Not Mitigates Them**

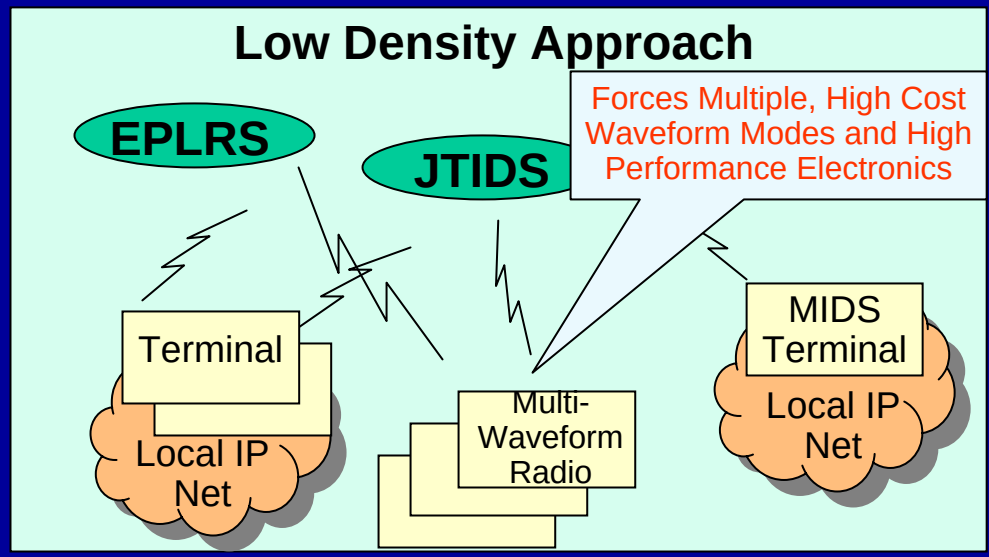
Overall Program Objectives

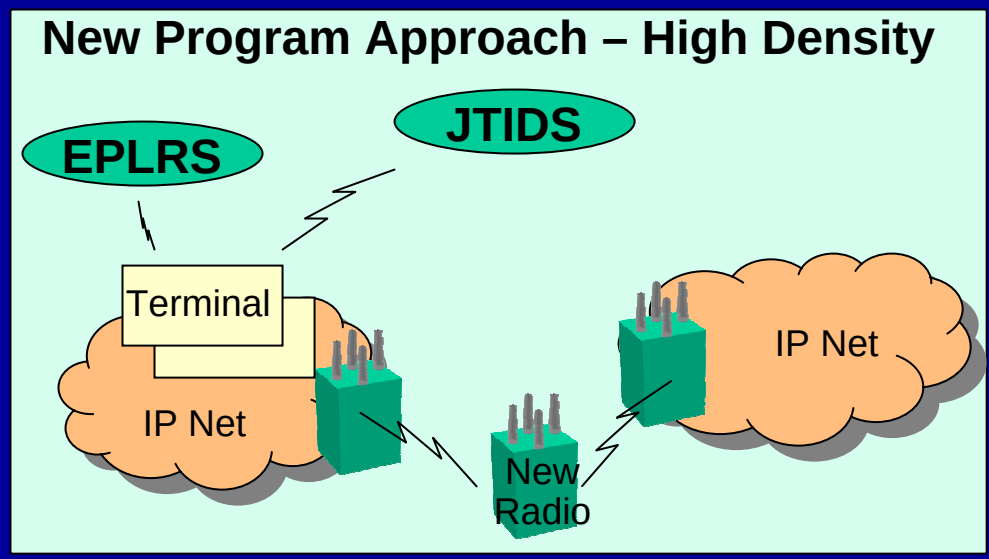
- **Develop a Purpose Built Military Network Radio Based on Commercial Parts, Lines, and Processes**
  - **Working, Form Factor Product in Phase R1 and R2**
- **Network-Focused End-to-End Military Communications Model**
- **Develop Network Capability that Adapts to Mitigate Hardware Shortfalls and Implement Essential Military Functions**
- **Develop Network Capability To Integrate 1,000's to 100,000's of Radios into One Effective and Efficient Network**
- **Adaptation Mechanism to Leverage Successful Elements of DARPA Programs**
  - **MnM, XG, DTN and CBMANET**
- **Brigade-Sized Demonstration**

More Capable, 99% Cost and Weight Reduction…, Every Soldier to Any Place

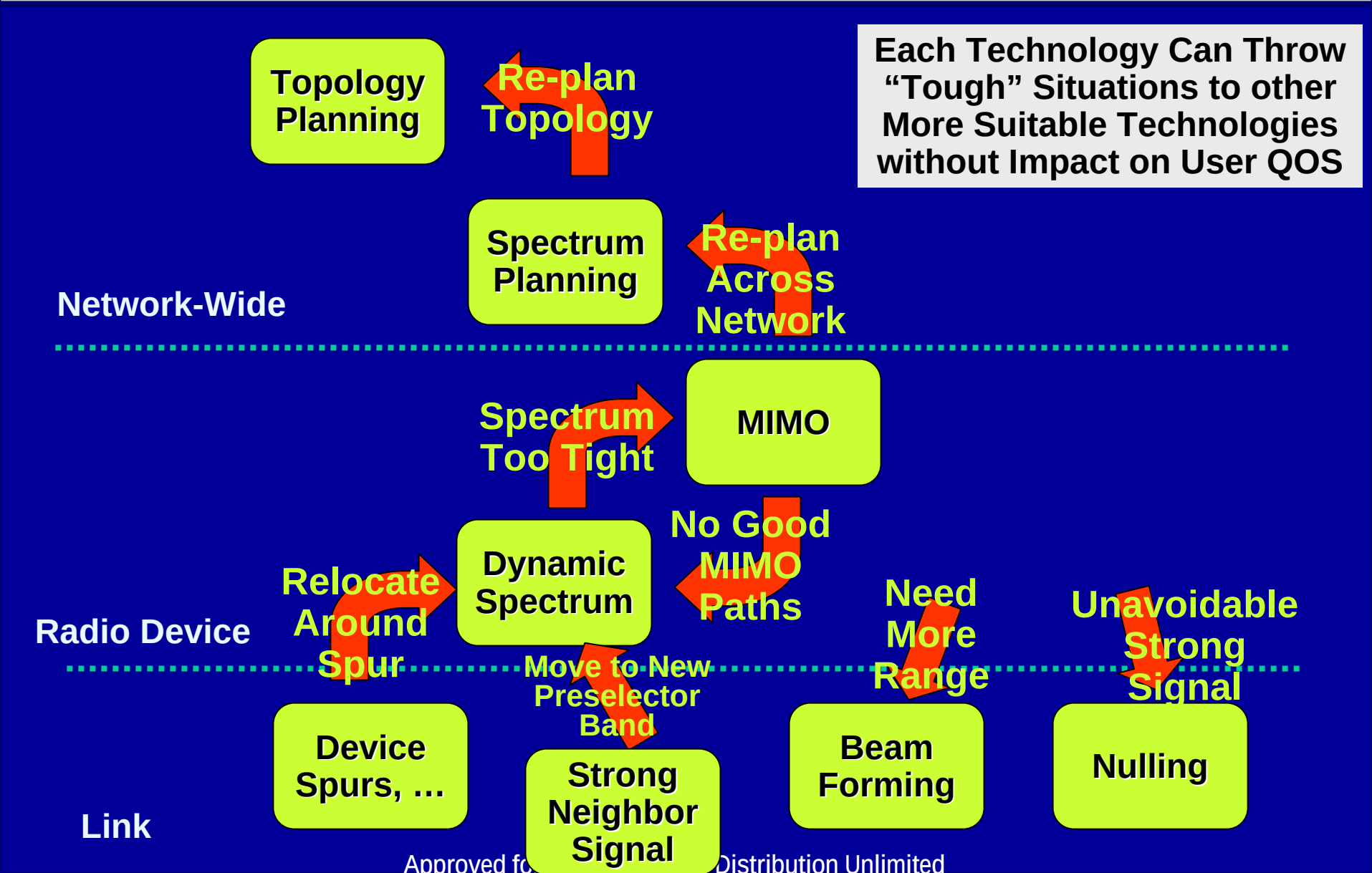
Philosophic Transition to Density Rather than Range

- **Transition from End to End to Meshed Network Connectivity**
  - Network Takes Responsibility for Delivery
- **Use IP Linkage to Avoid Need for All Nodes to Reach All Platforms**
  - Network Provides Range and Reliability
- **Interoperate at Network (At IP, Not Physical) Layer with JTIDS, SINCGARS, EPLRS, …**
- **Use Global Network to Resolve Local Shortcomings**
- **Not Your Grandfather's NxN Gateway – Everyone to IP**





Adaptive Radio Avoids Solving All Problems Itself



Aware and Adaptive Behaviors

Advanced Technology Office

Low Node Density

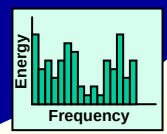
Fixed

Urban Multipath

MIMO

Beam forming

High Node Density



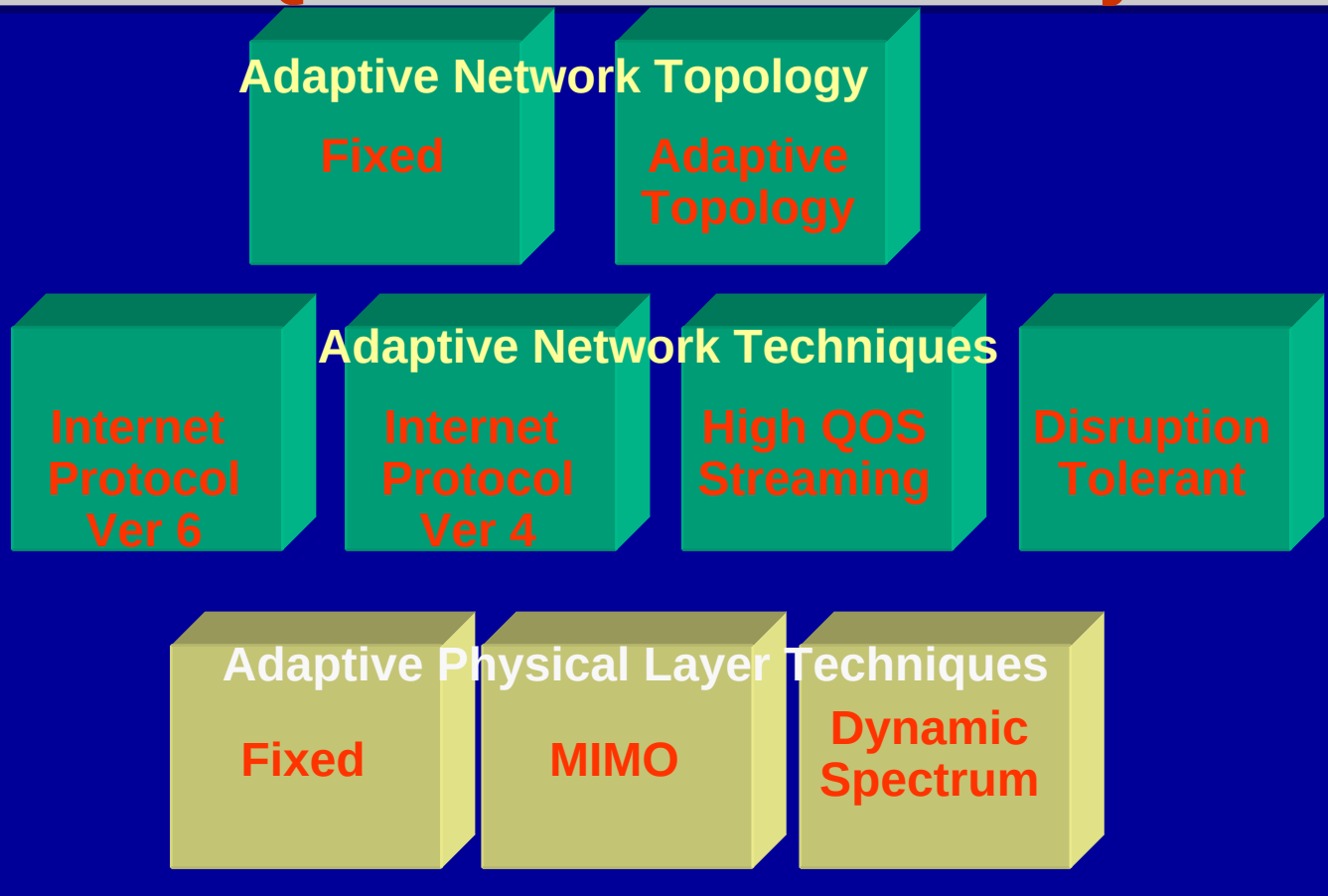
Dynamic Spectrum

High Power Interference

Nulling

Long Comm Range

Key to Low Cost/High QOS is Interactive Layers

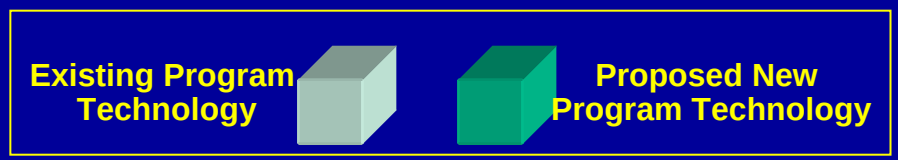


What We Need to Do

- **Develop the Technology to:**
  - Adapt Network in Order to Operate Radios with 20 db Lower SFDR and Linearity at the Same Performance Levels
    - Existing Programs Provide Toolkit for the Physical Layer, but Have no Network to Exploit the Opportunities
  - Scale our Understanding to Ultra-Large Mobile Networks
  - Extend Concept of Packet Networks to Directly Implement Broadcast and Streaming Service that Are the Basis of Tactical Operation
    - Operate Multiple Network Technologies Simultaneously to Meet Each Mission QOS Need
- **Achieve:**
  - 100x Reduction in Network Radio Cost ($500 per 4-Channel Radio)
  - 10x Reduction in Network Area Coverage Cost
  - 100x Increase in Demonstrated and Objective Network Scale (1,000's/100,000's)
  - 6x Higher Goodput/Throughput Ratio Required to Support Broadcast / Netted Voice / Video

The DARPA DWNV Network & Radio

- **Optimizing Layer**
  - "Looks Through" Lower Layers to Make Globally Optimizing Decisions
- **Topology Layer**
  - Makes the Network Topology Achievable by the Radios. Plans Network Around Spectrum, Power, Channel, …
- **Network Layer**
  - Multiple, Unique Networks Optimized for Stream (Voice and Video), Broadcast (GBS-Like) and Packet Services
- **MAC Layer**
  - Adaptive Spectrum, MIMO, and Beamforming Modes
- **PHY Layer**
  - Commercial Component-Based
  - Standard RF Slice Widely Replicated
  - Tunable Filter (Designed with MEMS Technology or Equivalent) and WB Antenna



Control-Based MANET

New WNAN Technology

CBMANET (As Applicable)

New WNAN Technology

CBMANET (As Applicable)

MIMO (MnM)

Dynamic Spectrum (XG)

COTS Chip Set

Tunable Filters and WB Antenna

How Do We Do This?

- **Cost Reduction**
  - Fundamental Change in Approach Requiring Ever Higher Performance
  - We Can Adapt Around Most Analog Weaknesses
- **High Confidence "Dial Tone"**
  - Proliferated, Low Cost, and Expendable
  - Clustered RF Units That Can be Baseline, MIMO, or Beam-formed
- **Enable Network Centric Warfare**
  - Integrate MIMO, XG and LPD modes

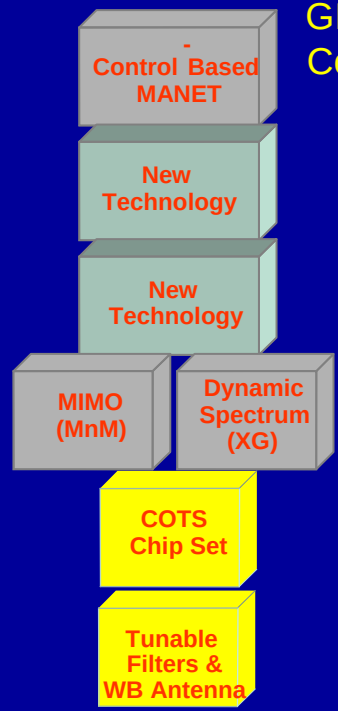
New Technology , Integrated Technology, Plus New Philosophy to Work Around "Defects", Not Spend to Eliminate Them

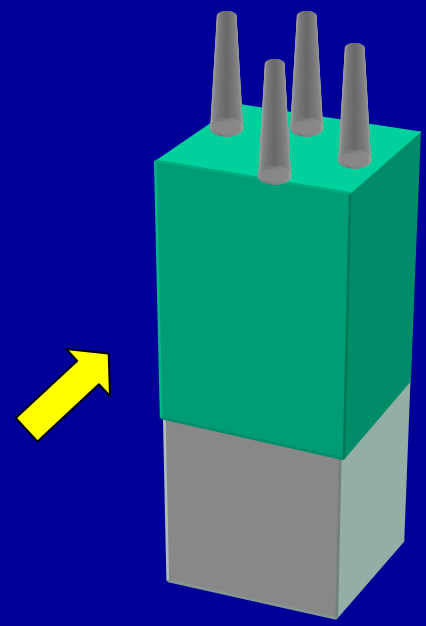
Hardware Platform

- **Single RF Processing Slice Replicated to form 1, 2 and 4 channel MIMO/XG/ Beamforming Capable Radios**
- **Reverse Standard ATO Approach**
  - **Build H/W (WANN) and Incrementally Add Network Capability**
- **Develop Wireless Adaptable Network Node (WANN) Using Commercial Chips**
- **Integrate Tunable Filter and Wideband Antenna Development Efforts into WANN**

Frequency	900 MHz to 6 GHz
Power	36 dBm
SFDR	60 dB
IP3	? dBm
Peak	10 Mbps

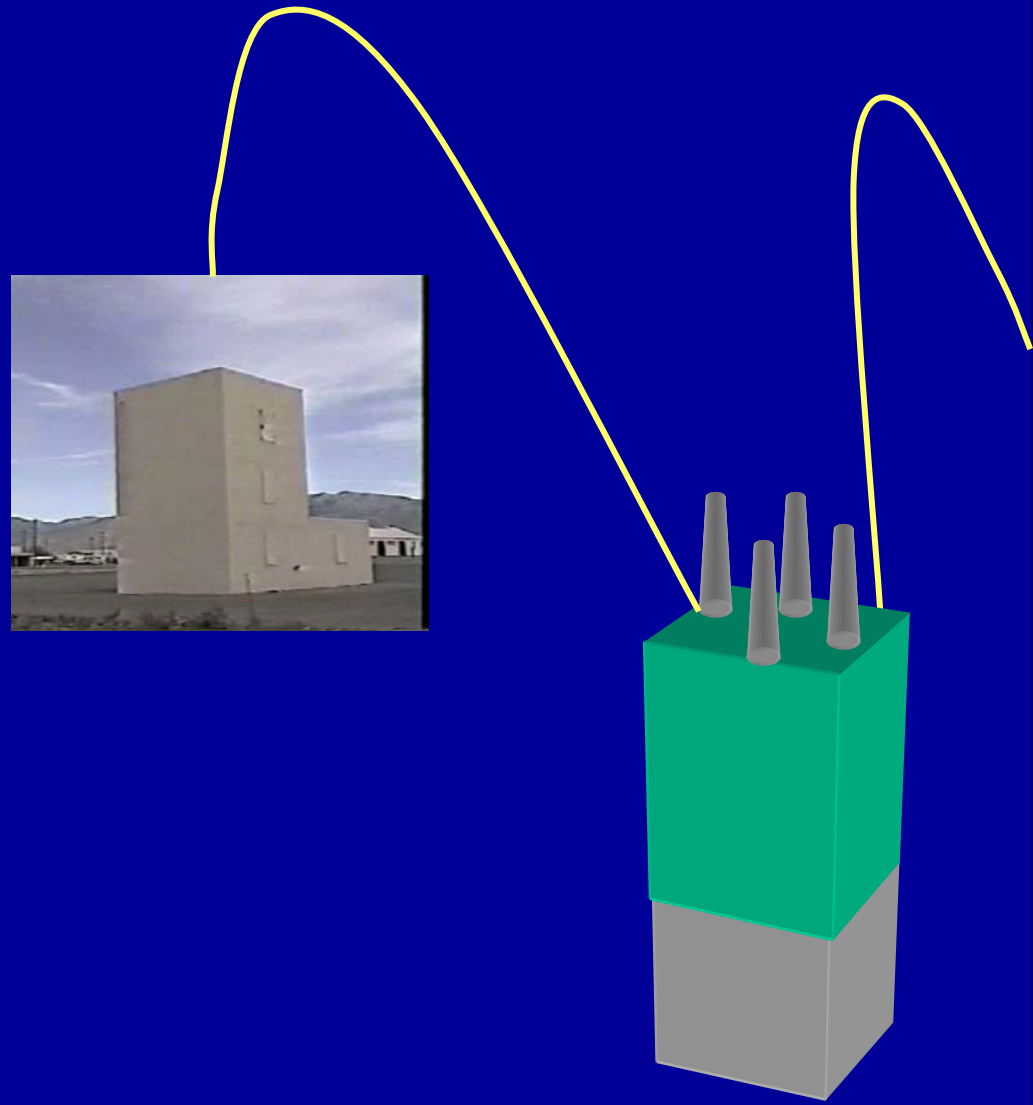
GPS Access Interleaved by Connectionless Networking Digital Post Processing



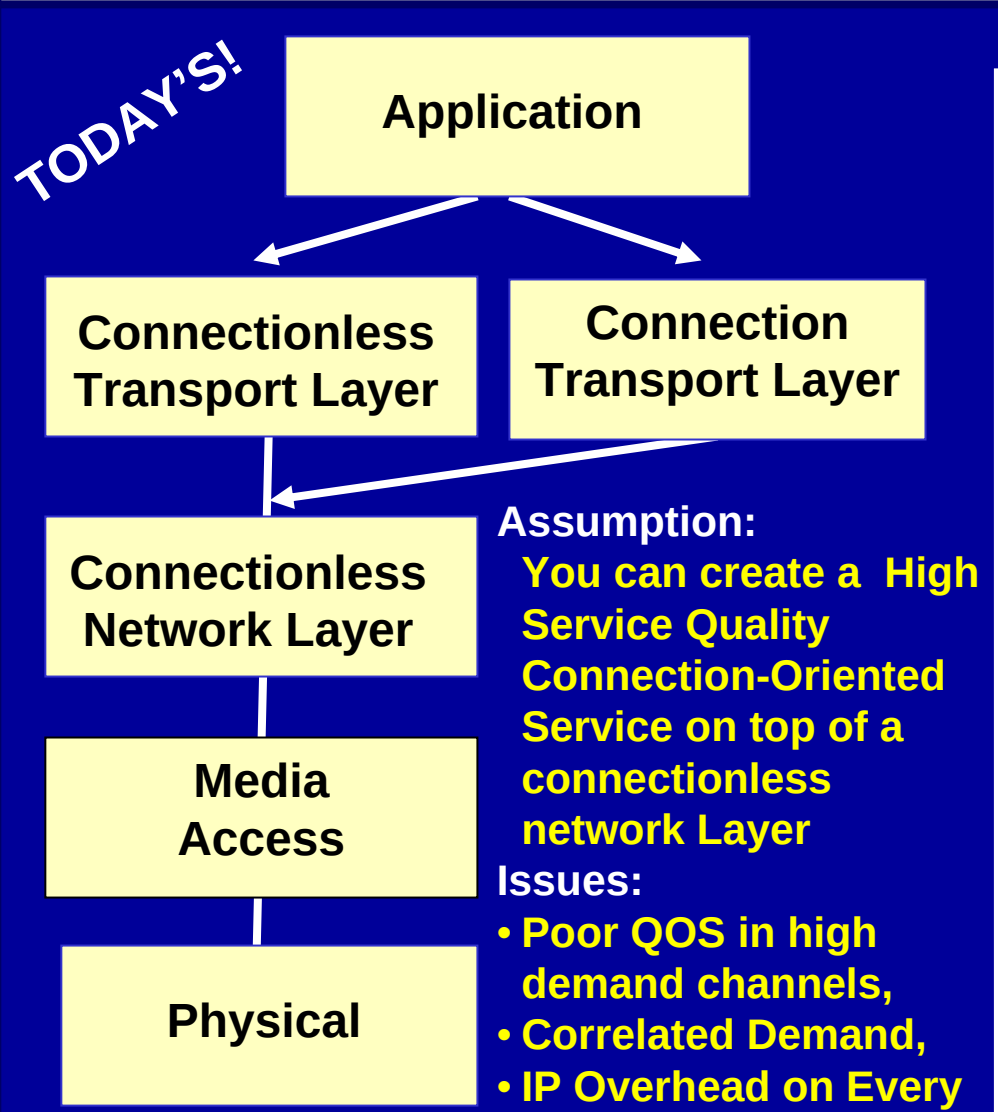


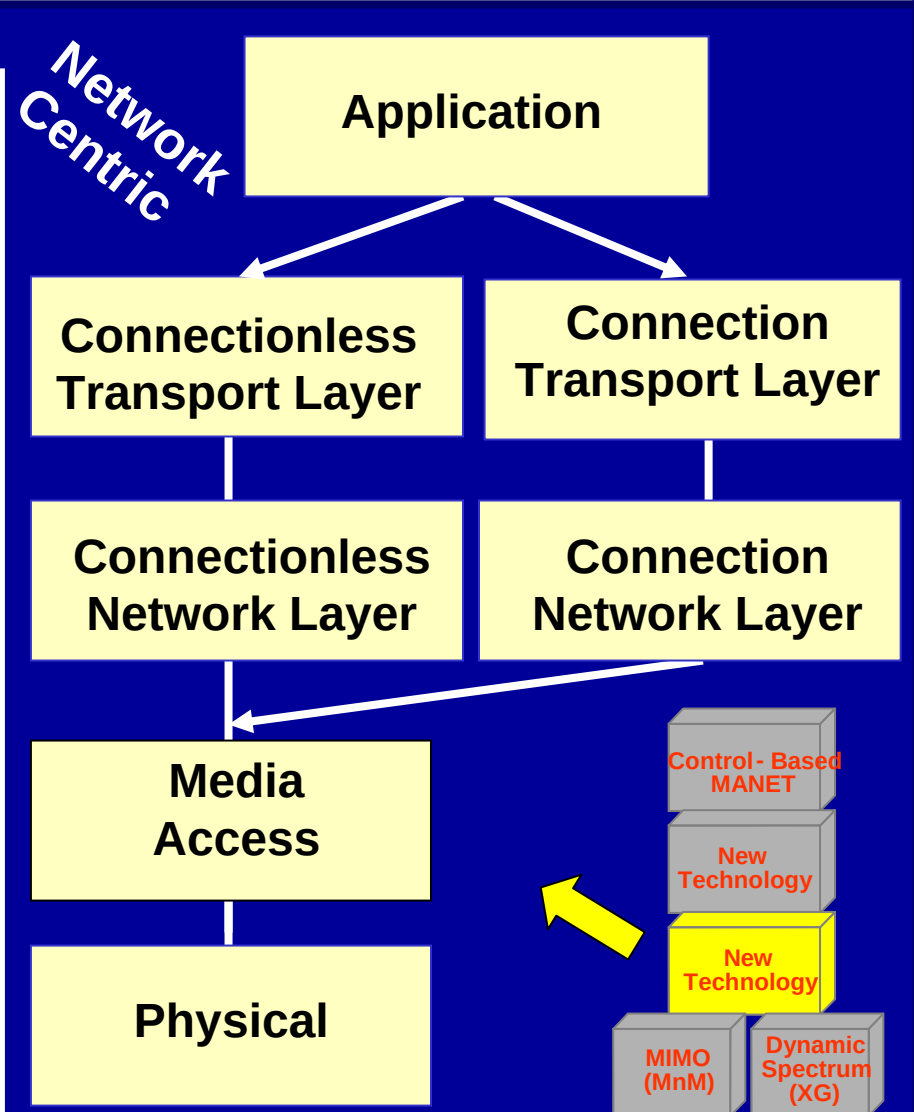
Every Tree a Cell Tower

- Use Expendable WANN as Temporary “Cell Towers”
- Small Propellant to “Launch” into Trees, Buildings, Balconies,…
- Objective:
  - 8 Hours Operations
  - 10 Mbps Data Rate
  - Equiv. to 10 Cell Channels
- Cost Less Than Buying Cell “minutes” in the US
- Pure Router, so Needs no Message Decryption
- Or, Inductively Couple to Power Line (with Battery for Outage) For Temporary Infrastructure



Utilize More Network Models



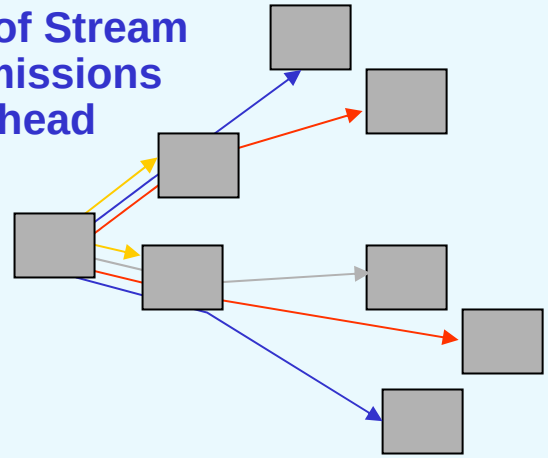


Stream Network Service

- **Network centric Warfare will Transfer Traditional Analog Services to Networks**
  - Voice, Combat Nets, Video, …
- **Internet Packet Model Poor in Delivery Efficiency of these Services**
  - No Intelligent Multicast
  - Header Overhead on Each Packet
  - Random Effects on Delivery (Jitter, loss, …)
- **Bandwidth Savings:**
  - 3 Times Peak Usage reduction
  - 2 Times Usage reduction
  - 1.8 times "Overprovision" reduction
  - 4 Times in 5 hop, video distribution to 250 Subscribers (wired or wireless)

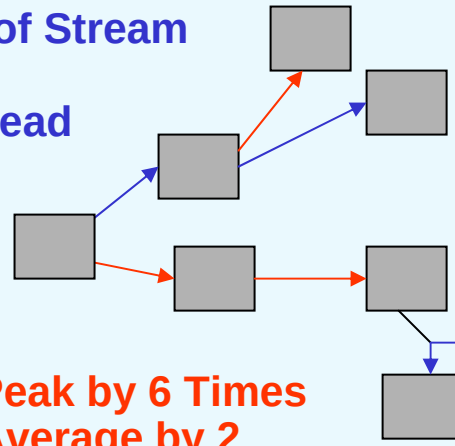
Internet VOIP Model

- 7 Copies of Stream
- 12 Transmissions
- 25% Overhead



DARPA Model

- 2 Copies of Stream
- 6 "Hops"
- 3% Overhead

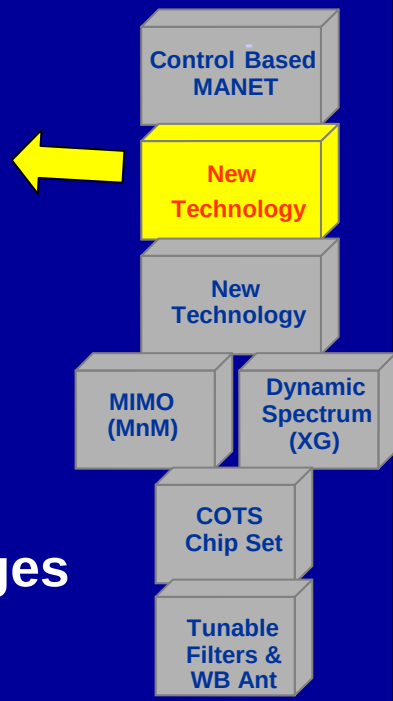


Both Radios Receive the Same Transmissions

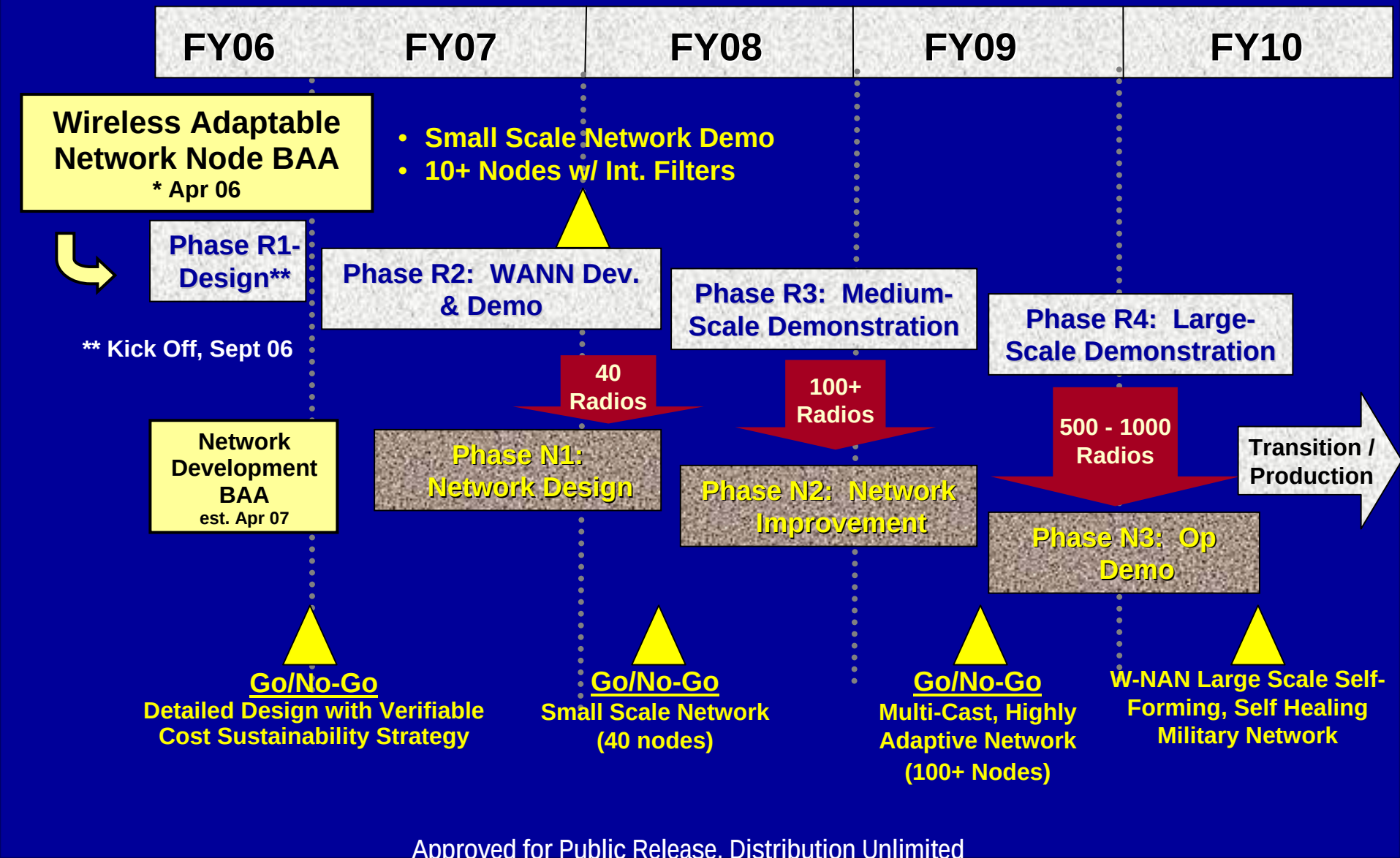
- Reduces Peak by 6 Times
- Reduces Average by 2

Topology

- **Develop a New Network Function –Deciding the Network Topology**
  - Today – Network Topology is Whatever Links Say it Is
  - Routers Use What they Get, Not What they Need!
- **Objective**
  - Have Network Use Topology to Allocate Resources that Interact Between Radios
    - Spectrum, Interference, Routing Responsibility, Battery Power, MIMO vs. Single Channel…
  - Locally Solves Interactions
- **Typical Actions:**
  - Reduces Certain Radios Bandwidth
  - Forces Frequency Moves
  - Directs Use of MIMO to Resolve Spectrum Shortages
  - Changes Routing to Reduce Load on Low Energy Devices, …



Revised DWNV Structure



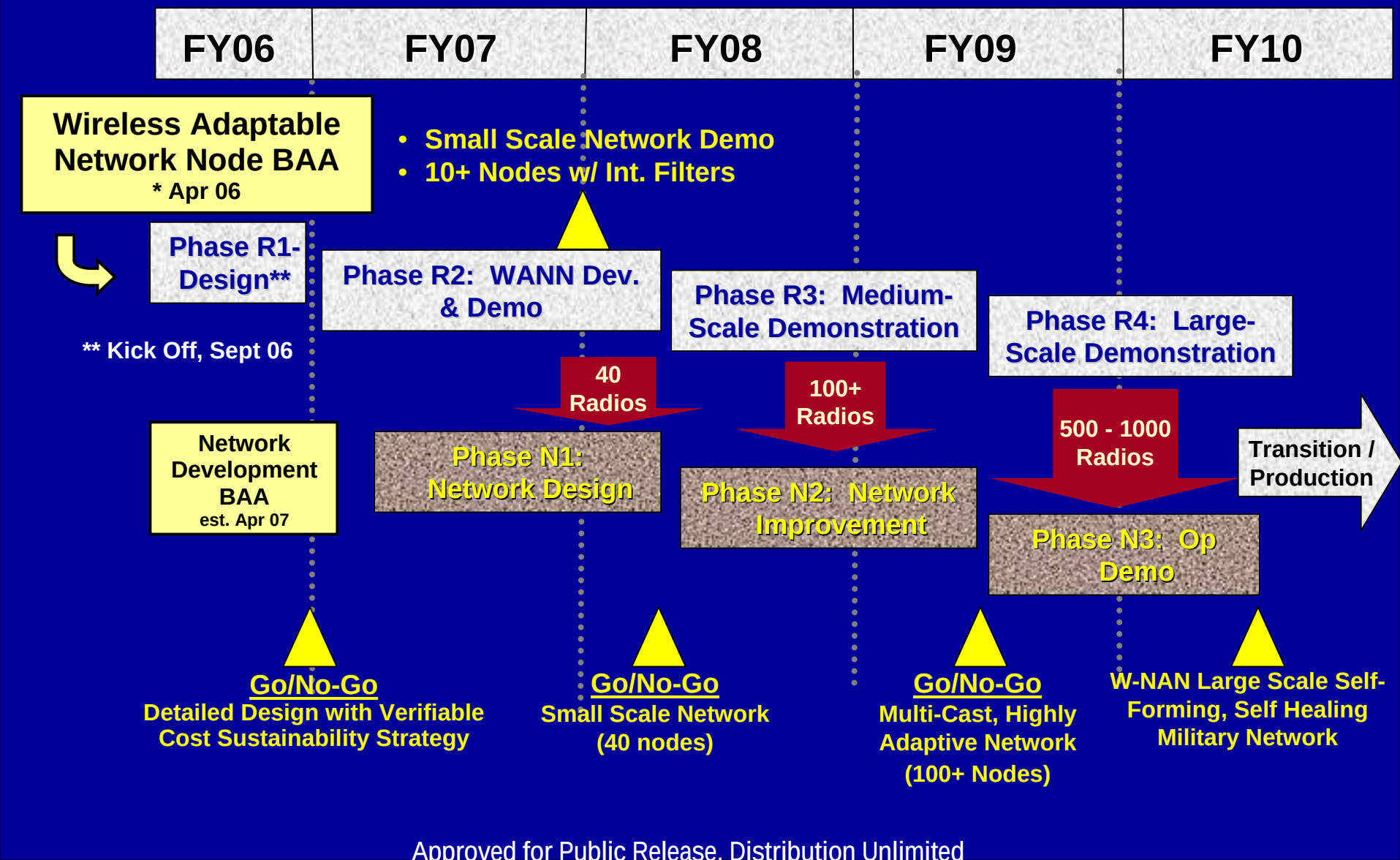
End of Program Overview

BAA Walkthrough: Program Requirements

Caveats!

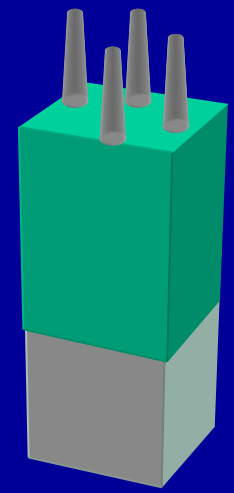
- I have no authority to bind the Government.
- In the event of a discrepancy between the material shown here and the WANN BAA, the WANN BAA takes precedence.
- In the event of a discrepancy between the material shown here and the www.fbo.gov material, the www.fbo.gov material takes precedence.

Revised DWNV Structure



Philosophy & Goals: Revisited

- Low Cost Radios enable dense deployment
- Dense deployment creates rich connectivity
- Rich connectivity enables an intelligent network to work around radio limitations



<u>Design for node density, not for node range</u>

- How do we get there?
  - inexpensive RF circuitry
  - shorter life cycles
  - redesigning the network

Enabling the Transition from Robust Radios to Robust Networks

DWNV Program Overview

- **DWNV program consists of**
  - **Wireless Adaptable Network Node (WANN) - this BAA**
  - **Network Development effort - future BAA**
- **The conjoined programs above will develop and demonstrate Mobile Ad-hoc NETwork (MANET) architecture and technologies**
  - **Low cost multi-channel spectrum-agility MIMO-capable**
  - **A mesh network with densely deployed low-cost wireless nodes and an adaptive network layer that mitigates the shortcomings of those nodes**
- **The result: A novel MANET that is inexpensive and high performance**

WANN Effort Overview

- **Develop WANN nodes based on**
  - **Inexpensive RF circuitry**
  - **Tunable bandpass filters which cover RF spectrum from 900 MHz to 6 GHz**
  - **4 independent radio channels (MIMO-capable), can be synchronized**
  - **Wideband antenna**
- **The goal is the formation of MANETs of thousands to millions of WANN nodes**
- **Those WANN nodes will interoperate with each other at link layer and interoperate with legacy systems at network layer**

Relevant DARPA Technology Programs

- Analog Signal Processors
- Ultra Low Power -- Opportunity for WANN
- Mobile Network MIMO
- neXt Generation Communications
- Connectionless Networking
- Disruption Tolerant Networking

Note: Control-Based Mobile Adhoc Networks will be posted on DARPA WANN Web Site

Programmatics

- **This BAA requests proposals for the first two Phases R1 and R2, design and development, of Wireless Adaptable Network Node (WANN). Proposals for the final two Phases R3 and R4, development and demonstration, will be solicited at later date**
  - **The cost proposals submitted in response to this BAA should only address Phases R1 and R2**
  - **For planning purposes, the government requests that the cost proposals for Phases R3 and R4 will be submitted in rough order magnitude (ROM) costs**
- **Phase R1 is a 6-month design effort leading to CDR at the end of month 5 – develop architecture, functional, and electrical designs that will be the basis for the hardware development in Phase R2**

Programmatics

- **Phase R2 is a 15-month hardware development effort, performers will build 10 WANN nodes at month 12 and demonstrate them in a Small-Scale network with DHCP with VoIP and a wired gateway back to network infrastructure, build and deliver additional 30 WANN nodes at month 15 for Network Development effort.**

- **Note that Phase R2 will be included as an option that can be executed at the end of Phase R1.**

Programmatics

- **Phase R3 is a 12-month development effort**
  - Continue to mature the manufacturing and cost plan
  - Produce 100 WANN nodes using production line processes
  - Support Network Development effort (integrating network technologies onto the WANN nodes)
    - Include other DARPA technologies (XG, MNM, DTN, CN, etc.)
  - Support Network Development Medium-Scale demonstration (100 WANN nodes)

Programmatics

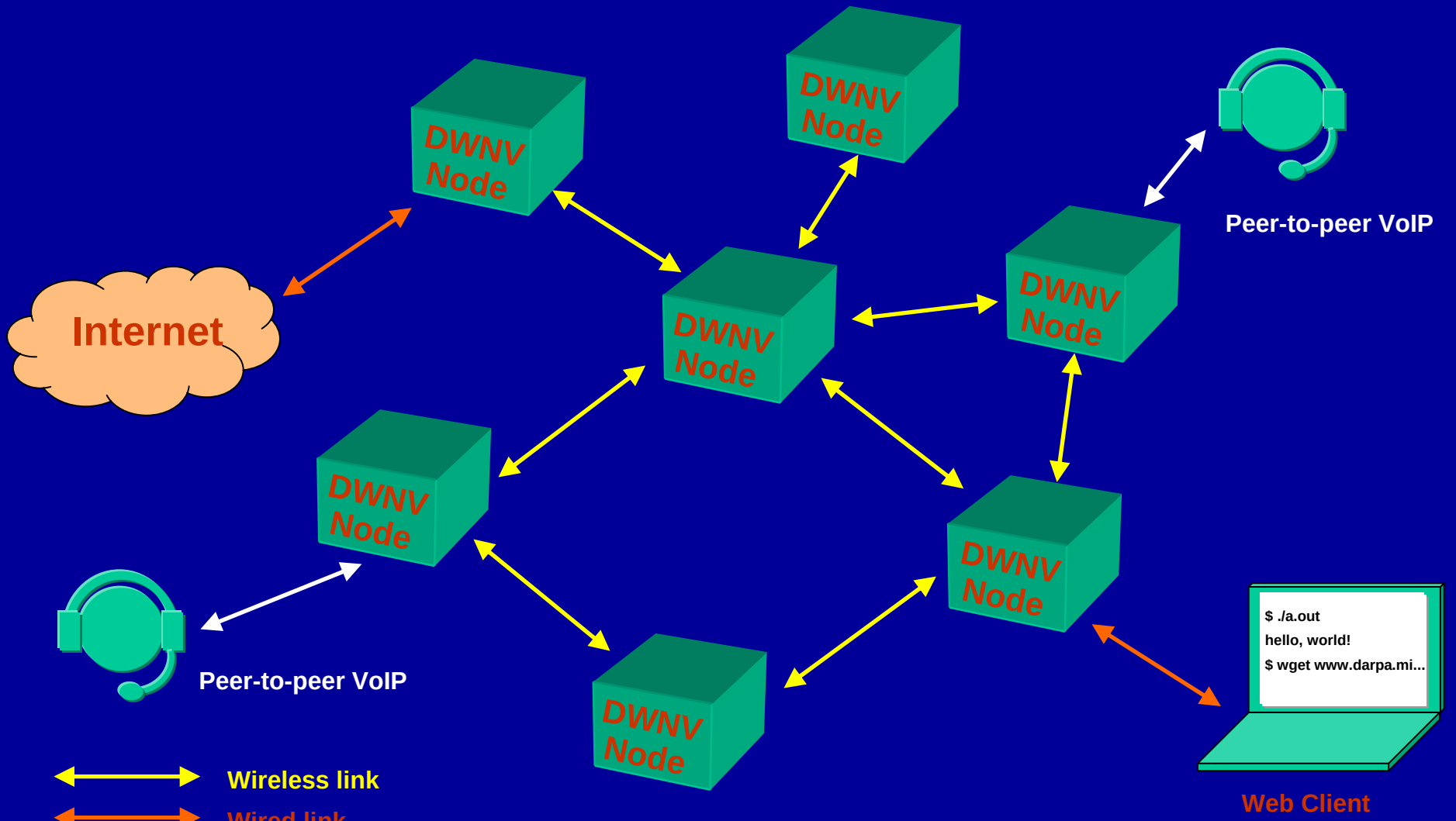
- **Phase R4 is a 12-month development effort**
  - **Will scale up WANN node integrations to a total of 500 to 1,000 units**
  - **Support Large-Scale demonstration (500 - 1,000 WANN nodes)**
  - **Integrate, test and document P^3I functionality**
  - **WANN nodes must be built using production line processes**
  - **Prepare for transition of the program to the Services**

Programmatics

5 of 5

- **Earliest anticipated awards ~ September 2006**
  - **Government may fund full proposals or portions of a proposal at any time. Government may incrementally fund awards.**
- **Government will accept multiple proposals from any proposer.**

The Vision



Technology Development

Hardware (architectural, functional and electrical):

- **Architecture developed in Phase 1 is expected to remain unchanged throughout all Phases**
- **Inexpensive RF core, replicated 4x to form a multi-channel WANN node**
- **Ethernet connector for wired interface**
- **Tunable bandpass filter design / development**
- **Wideband antenna design / development**
- **Capable of subsequent integration with DARPA technologies, especially: should be compatible with spectrum agility and with the processing required to support beam-forming**
- **Proposer-specified waveform**
  - **waveform will likely change in later phases**

Technology Development

Software:

- **Control and Interface Software**
- **Network interface (Application Program Interface documentation)**
- **Network stack – TCP, IP, MAC, and physical layer software**
- **MANET routing layer**
- **Support for network adaptation**
- **peer-to-peer VoIP application**
- **DHCP client software**

Performers should plan to demonstrate networks of 10 WANN nodes at month 12 of Phase R2

Technology Development

Guidelines, *not requirements:*

- **Operating range: 900 MHz to 6 GHz with tunable bandpass filter and wideband antenna, and capable of spectrum agility**
- **Handheld form factor**
- **Flexible data rate, should support up to 10Mbps per physical channel**
- **Adaptable RF bandwidth with a minimum occupied bandwidth of 1 MHz (100 KHz objective)**
- **Center frequency tuning in steps of 10% of occupied bandwidth**
- **Minimum of 4 independent orthogonal RF channels per node. The architecture should permit RF channels to be synchronized**
- **36 dBm total transmit power (aggregate over 4 channels)**

Technology Development

Battery performance:

- **8 hours operation on a single charge**
- **Transmit duty cycle of 2% per node at max power**
- **100% receive duty cycle all channels**
- **Battery cost will not be charged against $100 parts cost**

Design Guidance

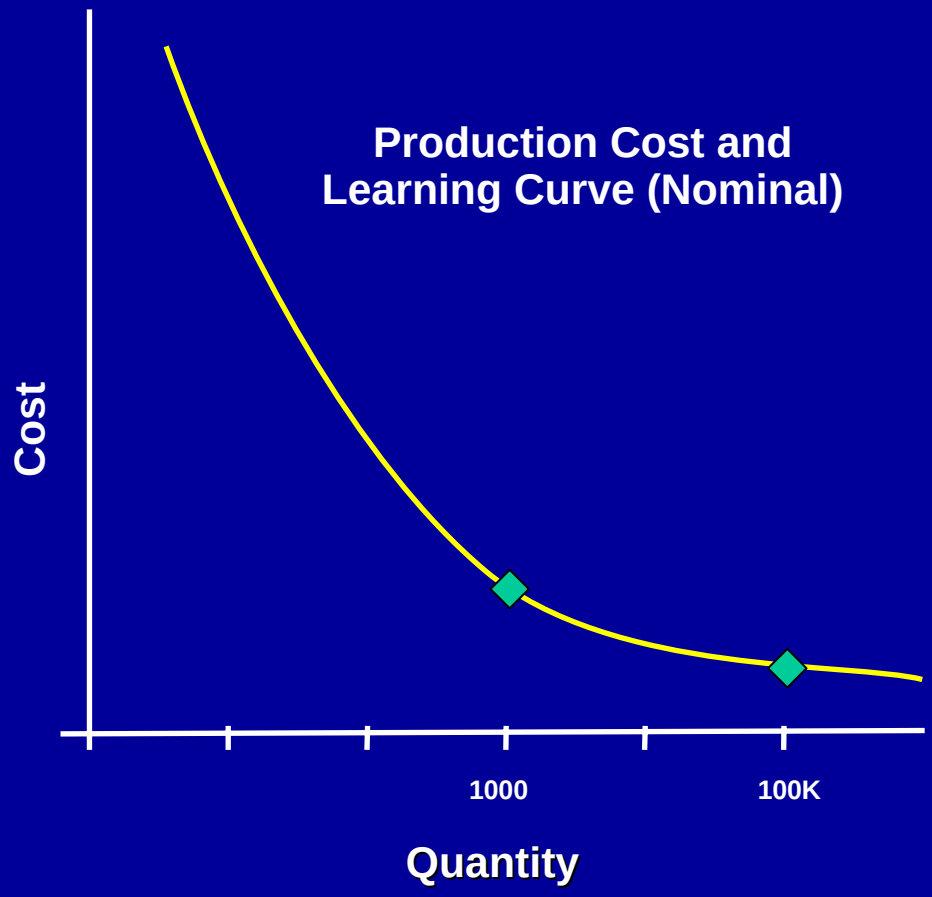
Proposer designs should be conceived with the goals of the program in mind: *the network layer will adapt to mitigate the shortcomings of the WANN nodes. The Government will assess designs accordingly.*

RF design engineering tradeoffs should be made with network capabilities in mind.

Operating characteristics of proposed designs should be traceable to production cost.

DWNV Program Metrics

- **WANN Design Traceable to $500 Unit Cost in Quantities of 100K, Excluding NRE**
  - **Detailed Production Cost & Learning Curve Estimates**
- **Demonstration of WANN and Integrated Network Technology in Medium (100+) and Large (500 – 1000) Scale Demonstrations**



<u>WANN</u> Development Effort Must Support Overall <u>DWNV</u> Program Metrics

Proposal Evaluation

Section 5.1 (Technical Approach) Overview

- Program Scope and Robustness
- Wireless Node Performance and Flexibility
- Support for Network Adaptation
- Practicality of Commercial Manufacturing and Sustainability of Wireless Node Production Cost
- Program Flexibility and Risk Mitigation

Proposal Evaluation
Section 5.1.1

Program Scope and Robustness

- *"Demonstrates that the proposed WANN meets the vision and program objectives…"*
- *"Demonstrates an understanding of the Government's desire to manufacture WANN nodes using production line processes as early as possible…"*
- *"Demonstrates an ability to offer WANN nodes at the completion of this effort, and throughout the system life-cycle support WANN node development and evolution, and provide logistical support for fielded units."*

Proposal Evaluation
Section 5.1.2 (details)

Wireless Node Performance and Flexibility:

"Evaluation of the performance characteristics of the proposed wireless node as outlined …"

- **At least 4 independent orthogonal RF channels per node. The architecture should permit the RF channels to be synchronized**
- **Operating range from 900MHz to 6GHz with narrowband tuning over wideband range filter and wideband antenna implementations. Designs should be spectrum agile.**
- **RF Tuning Resolution – center frequency tuning in step of 10% of occupied bandwidth**
- **RF Bandwidth - Adaptable, minimum occupied bandwidth of 1MHz (100 KHz objective)**
- **Tx/Rx duty cycle, 2% Tx duty cycle at max power, 100% Rx duty cycle**

Proposal Evaluation

Section 5.1.2 (details) - continued

Wireless Node Performance and Flexibility:

"Evaluation of the performance characteristics of the proposed wireless node as outlined …"

- **Push-to-talk peer-to-peer VoIP application w/RJ45/Ethernet & DHCP**
- **Network interface – API documentation and support for network adaptation**
- **Handheld form factor**
- **Data rates – minimum of 10Mbps per physical channel**
- **Minimum of 8 hours operation on a single charge at stated duty cycle**
- **36dBm total radiated power (aggregate over 4 channels)**

Note: *These technical objectives are not priority-ordered*

Proposal Evaluation

Section 5.1.3

Support for Network Adaptation:

"Technical features of the proposed WANN design which support the range of adaptive networking technologies envisioned in this program … the quality of the engineering tradeoffs between PHY performance and adaptive network mitigation … the support the design provides for the integration of evolving technologies."

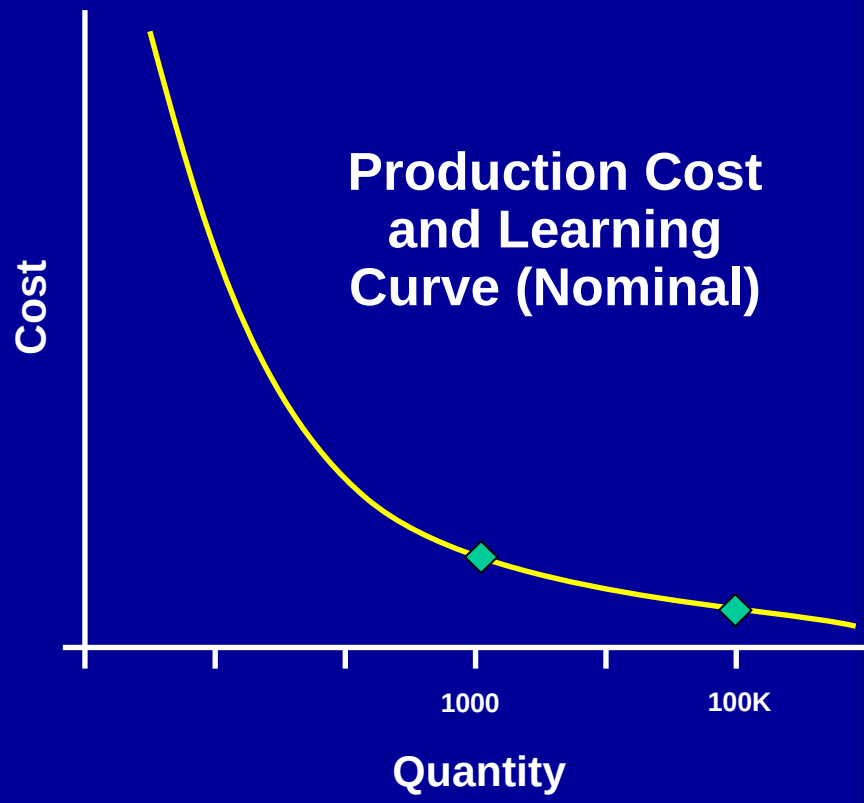
Proposal Evaluation

(Section 5.1.4)

Practicality of Commercial Manufacturing and Sustainability of Wireless Node Production Cost

- ***"[P]roduction costing, credibility of the costing, and sustainability of the costing throughout system life cycle. Practicality of commercial manufacturing …"***

- **The Government will contract for independent cost review and analysis of proposer's cost basis.**



Proposal Evaluation

(Section 5.1.5)

Program Flexibility and Risk Mitigation

- Complexity and scheduling risks
- Technical maturity and feasibility of proposed wireless design
- Confidence-building throughout program
- Minimization of external programs, efforts, and operational factors
- Ability to evolve demonstrations with new opportunities and needs

Proposal Evaluation

(Section 5.2, 5.3, 5.4)

5.2 MANAGEMENT APPROACH

The proposer should describe how the program is to be managed, including a plan for working with the network technology developer(s).

5.3 POTENTIAL CONTRIBUTION AND RELEVANCE TO THE DARPA/ATO MISSION

The potential contributions of the proposed effort with relevance to the ongoing and future DoD and national technology research will be evaluated.

5.4 COST REALISM

The objective of this criterion is to establish that the proposed costs are reasonable and realistic for the technical and management approach offered, as well as to determine the proposer's practical understanding of the effort.

DARPA Wireless Networking Vision (DWNV)

"Making Network Centric Accessible for the Warfighter"

Wireless Adaptable Network Node (WANN)

BAA 06-26

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