ATO Communications Programs

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Communications have become the backbone of modern warfare.
"No bombs without comms," was the way Air Force Brigadier General Goodrich put it recently.
Today we often say that information superiority is the key to victory.
But it's communications technology - the connectivity links of the network - that gets the information to the planner, to the commander, to the soldier.

Communications is like the fingers and toes, the hands and feet of the body.
It's what brings power to and from the edge of our networks.

Technological change has accelerated exponentially - maybe especially in militarily critical mobile communications technology.
But our paradigm for thinking about communications remains remarkably static and rooted in the past.

If we're to meet the challenge of fully exploiting our informational advantage in warfare, we'll need to transform - revolutionize - our approach to communications.

Let me put that broad technological challenge in context.

We see five major features of the context in which we traditionally approach mobile, military communications challenges - and we aim to change every one of them.

First is our paradigm.
Traditionally, we've adopted the seven-layer conceptual "stack" of the Open Systems Integration - or OSI - paradigm to define our approach to wireless military communications.
The OSI paradigm served us pretty well in the stable, predictable world of wireline communications -- where the behaviors of all the channels and connections from one layer of the "stack" to another are stable and well-known.
But mobile networks are nothing like that.
The channels we use to propagate signals through air and space - the connections we use to link these signals to terrestrial wireline or fiber-optic communications - are exactly the opposite.
They're unpredictable and highly variable.
If we're going to achieve the always available communications essential to our fighting forces, and the robustness that this implies, we need to reinvent our communications paradigm.
We need to think of the different levels of the stack relating to each other directly and inter-connectedly - like a mesh - instead of from one level up to the next, like a ladder.

Our communications structures will need to operate more like the DNA helix - where different elements can combine and recombine directly, in varying patterns according to the circumstances.

Another feature of our context: we traditionally approach our communications challenges as if all that was required was to be able to pump more and more information to the user.
We've now reached the point where this is becoming counter-productive - where we're in danger of creating so much "information overload" for the commander or the soldier that the information is useless.
At times, the processed information becomes so voluminous that it gets treated like the indigestible mountains of raw data from which it was distilled.
We need to allow information to inform critical thinking - and not to allow the sheer volume of information to replace critical thinking! In the process of moving

all this information around, we're also consuming precious resources - spectrum; communications channels; time; battery power.
We think its time to approach this problem differently - to concentrate on getting the "right" information - actionable information - to the user when it's needed.

This leads to the third feature of our operating context: spectrum crowding.
It's an entailed consequence of our traditional approach of pumping ever more information out to users through our networks, over our communications links.
One of the results, naturally, is interference - customarily a bane for communicators.
That's the phenomenon that keeps the information from getting through, right?
What do we do about this? There are many possibilities - but some that intrigue us most are efforts to develop novel ways to take advantage of interference - to make it our friend - and to hide our communications presence in the crowded spectrum.

Communications research always confronts a trade-off between revolutionary and evolutionary development.
This is another fixture of our operating context.
At any given moment - and now more than ever - we need revolutionary breakthroughs to surmount the unprecedented challenges of mobile military communications.
But we are always faced with a tremendous investment in existing communications infrastructure - an investment that is simply too vast, pervasive, and costly to replace at once.
How do we reconcile this "revolutionary versus evolutionary" trade-off? For this, we'll need breakthroughs that also have "reach-back" - that can be implemented with, or at least operated alongside of, our existing military communications infrastructure.
At the same time, these breakthroughs will also have to support tomorrow's military wireless communications needs.

One last point: mobile military communications differ from wireline communications in another fundamental respect.
There is no "God's eye view" of the operation of these mobile networks.
There is no one place - or even series of places - where issues of routine operation and congestion, of efficiency and resource allocation come together.
The consequence: we'll need technologies that enable us to do, "on the fly" and autonomously, the same resource management and efficiency functions that are built into wireline communications systems.

I just described the context in which we're pursuing our search for breakthrough technologies that will revolutionize our mobile military communications capabilities.
Now I'd like to review with you what we're looking for - at the macro, "big picture" level and at the level of specific technologies - to help us achieve our vision of 21st century military comms.

At the level of our macro vision - the "fantasy", if you would, that we're aiming to translate into reality with your help - we've coined a phrase to capture what we're looking for: R3I.
What's R3I?
It stands for "Robust, Responsive, Reconfigurable, and Invisible."
That what we want - and need - our military communications to be.

Robust.
They've got to be resilient in the face of natural or man-made impediments.
They've got to maintain connectivity, even if somewhat degraded, in the face of attacks on any layer.

Responsive.
Our systems must achieve "anywhere, anytime" availability and mobility.
Link and network capacity, latency and coverage must be instantaneously responsive

to mission needs, globally, locally, or anything in between.

Reconfigurable.
We need radio technology that enables the RF "front ends" of our radios to be as flexible, agile, and adaptable as the software definable signal processing "back ends" are.
We need transmitters, amplifiers, analog-to-digital converters - ADCs - and other components that operate over enormously expanded frequency range, nimbly, quickly, and with stability.
We need true cross-layer flexibility to maximize the agility of our radio resource management.

Invisible.
We need to move beyond "low probability of detection"/"low probability of intercept" - to find ways to blend into the ambient electronic environment.
We need to be able to "make interference our friend" - to develop an a priori understanding of its structure so we can hide within it, or find a way to communicate in a universally orthogonal way so that, as far as the enemy knows, we're not even there.

In the broadest terms, that's what we're looking for: real R3I capability for 21st century military communications.
But we're not just "wishing on a star" that someone will come along with magic formulas to give our comms R3I.
We've got some specific ideas about where to look for the breakthroughs we need.
I'd like to share them with you.

First.
We must explore radical new comcepts in radio resource management.
Concepts that will enable us to optimally use resources under natural and man made stresses.

Second - and an area of high priority for us - we need breakthroughs in reconfigurable transceivers.
To achieve the "front end" agility that matches our "back end", software definable flexibility that I mentioned, we're looking for truly channel and mission adaptive systems.
Systems that adjust the communications channel as rapidly as necessary to support the mission.
Systems that minimize the power transmitted while maximizing the probability of correct reception.
Systems that are at once revolutionary and "backwards compatible" with all that existing infrastructure we've mentioned.
We must explore new waveforms, but we also must explore new infrastructures.

Third, we need to explore other frequency bands - beyond the VHF, UHF, microwave, millimeter wave, and near-IR bands we currently use.
We need to investigate their advantages for covertness and building penetration, among other things.

Fourth, we must achieve seamless space, air, ground, and undersea communications.
This, we think, will require a new system of architectures - ones that ensure persistent coverage by incorporating geo-positioning information and that maintain connectivity by predicting the impending movements of mobile units and/or autonomously inserting extra relay nodes.

Fifth, we need to reexamine the recently neglected field of underwater communications - particularly focusing on littoral waters and distributed teams of unattended underwater vehicles - UUVs.
We need to do more than just deliver more bandwidth.
We need end-to-end solutions that overcome the extreme channel variability underwater that comes from layer effects, turbulence, and obscuration.
We need to examine compression technologies, bandwidth-efficient modulation, and

channel adaptation.

We also need to develop links and networks that permit cooperative and non-cooperative "resource scavenging."
Can we build a system that takes better advantage of the overprovisioning invariably designed into our communications nodes so that unused resources - delay, capacity, and energy - at one node could be made usable to reduce demand on other nodes? Could we do this autonomously, operating in a context where there's no "God's eye view" of the network?

To achieve the "I" - invisibility - of our R3I vision, we need to breakthrough work on interference and orthogonal signaling.
Instead of always trying to filter out interference, can we find other techniques - beyond multi-user detection - to improve system performance and enable us to "hide among the clutter"?
Can we construct a system that treats the ambient electromagnetic environment as one set of axes in a multidimensional signal space - a construct that permits us to define another orthogonal axis that will permit non-interfering, non-detectable communications for our forces?
Finding breakthrough answers to these questions will require enormous creativity.
This is definitely "thinking outside the box" territory.

As I mentioned at the outset, we believe that re-examining - reinventing, really - the traditional OSI network "stack" could pay dividends for the "three Rs" of our R3I fantasy.
What advantages would accrue to mobile, wireless communications by supplanting the static OSI "stack" with a more "mesh-like" model of networks?
What might such a model look like?
What would be its components? How would they interact?
These are some of the questions we're eager to explore.

Reinventing the network "stack" and incorporating locational awareness to seamlessly integrate space, air, ground, and undersea communications suggests an intriguing possibility.
Can we build a totally integrated navigation/ communications system - a system in which navigation is as intrinsically part of the architecture as the MAC layer is in traditional wireless communications systems? We're very interested in this question.

Finally, we need to compensate for the lack of a "God's eye view" for controlling and managing our mobile communications.
Can we design a system that requires no centralized control and is capable of distributed self-monitoring and reconfigurable.
For example, how can we achieve relay nodes that autonomously reposition themselves in the battlespace according to the state of the network, the mission requirements, and the communications priorities?
Such technologies would make a big contribution to achieving our R3I vision.

Robust, responsive, reconfigurable, invisible mobile military communications systems.
That's the vision - the gap - that ATO aims to bridge for tomorrow's war-fighters.
We know what our troops will require; we see it in our latest combat experiences.
We can extrapolate from the technology trends we observe - and that we're helping to create.
We have ideas - ideas we've shared with you - about some of the most promising areas for investigation and development to achieve R3I for military comms.
We're confident that, with the involvement and creativity of many of you in this room in our future projects, we'll be able to turn our vision into reality.