Electronics in Integrated Microsystems for Battle Space Information Dominance
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Good Morning.
High sensitivity radar .... wireless networks .... satellite reconnaissance .... and GPS guided munitions, ... what do these systems all have in common? Electronics!
None of these capabilities would exist without the advances in electronics pioneered by the Microsystems Technology Office for the US Department of Defense.
By driving electronics technology to address DoD needs that are well beyond commercial requirements, MTO has enabled US warfighters to maintain, and extend, their battle space advantage through information dominance.

There can be no question that electronics have revolutionized our workspace and the battle space, but the question is where are the new frontiers, that when conquered, will lead to the next revolution in how we interact with the environment, with each other, and with machines.
As Zach Lemnios just told you, we see the next frontier as moving beyond electronic alone to Integrated Microsystems.
But those Microsystems will still depend upon, and contain novel electronics, and I want to tell you what we envision for the coming electronics technology that will be encompassed by those Integrated Microsystems.

Let me start by describing an Integrated Microsystem in more detail.
Over the past two decades progress in electronics has been driven by increasing the density of higher performance transistors to realize breakthrough circuit performance, however, the realization of the ultimate functionality requires the optimization and integration of more than the transistors alone.
The progress in photonics and MEMS technology has opened the door to a paradigm shift from the integration of discrete electronics technology to the combination of multiple components from separate technologies onto a single Microsystems platform.
This is what we refer to as an Integrated Microsystem.
When we bring the digital computation power of silicon electronics on chip with high performance photonic analog devices and tunable MEMS components, systems will be able to dynamically optimize their performance in a changing battle space.
Our ultimate vision is to make these components intelligent, able to reason and learn with time! Achieving this vision will lead to the ultimate system capability and extend our information dominance in the battle space of the future.

Over the next few minutes, I want to talk to you about where we are taking electronics for integrated microsystems to further extend US battle space dominance through information superiority.
In MTO, when we think about the future of microsystem technology, we ask the question: How will a new component impact system performance? To do this we consider a generic integrated microsystem architecture that encompasses the functional blocks to: Sense ..... Process ..... Actuate ..... and Power the system.
Electronics plays a central role in all aspects of this architecture.
Let me describe some of our current and future initiatives.

In MTO, we are developing new classes of semiconductor materials and devices to extend our dominance of the electromagnetic spectrum through the Department's radar, electronic warfare, and communication systems.
Under our Antimonide Based Compound Semiconductor program, we are developing narrow bandgap semiconductors with carrier mobilities over 10 times higher than silicon that are able to operate at high speed at less than 1 volt.
This technology will drive down power dissipation on transceivers - impacting both the sensor and the processor-minimizing the power bottleneck for long endurance unattended ground sensors or commercial cell phones and PDA's.
By reducing the required power of low noise receiver amplifiers by 10 times, these devices will enable large active antenna arrays to be fielded in space for persistent target imaging.
You can view the impact of this effort in the trade-off between circuit power efficiency and gate delay, that is how fast is the circuit at a given power.

This program is driving performance to the preferred extreme lower right - faster switching at improved power efficiency - to open new domains of system capability.

MTO is also establishing wide bandgap semiconductors, including gallium nitride and silicon carbide, to extend the analog performance of microwave and mm-wave amplifiers -- the sensors and actuators - for radar and communication systems.
In the commercial market, the advances in power, efficiency, and linearity made possible by this material system will enable cellular base stations to have longer range and can carry more calls.
For the DoD, the extended performance means placing high resolution radar on smaller platforms, realizing higher data rate communications, and producing disposable electronic warfare decoys.
Over the last few years, gallium nitride microwave performance, as demonstrated by the increase in microwave power density, has increased over 20 fold largely as a result of improvements in the material quality.
MTO is now ready to extend our investments in materials to develop revolutionary performance in microwave amplifiers that will lead to new system capability.
For example, by increasing element power and efficiency, future shipboard radar will be able to remain in international waters off an adversary's shore and still detect, track, and discriminate missiles launched 100's of miles in-land.

Let me now turn to digital electronics, the core of the system's processor performance.
You have all heard of Moore's law as it applies to the continuous progress in silicon digital electronics.
In the past, MTO has accelerated Moore's law by making key investments for military critical technology.
You may have also heard of the brick wall that is looming on the progression of Moore's law where fundamental physical limits are reached and further progress in digital electronics comes to an abrupt stop.
To surmount this barrier, today MTO is moving off the two dimensional Moore's law, no longer focusing on only driving silicon transistor scaling and levels of integration, but rather exploiting new circuit architectures by developing three dimensional integrated circuits.
Under our 3D Electronics program, we are exploiting the third dimension so that chip architects can bring memory on chip and establish reconfigurable signal paths to dynamically optimize circuit performance.
This new class of digital circuits will enable automatic target recognition, speech synthesis, and other complex signal processing to occur in real time.

But what about the progression in device scaling and the brick wall now projected below 20 nm? MTO is pioneering an effort in Molecular Electronics to smash through the brick wall by moving to a new class of materials and devices based on molecular level phenomena to drive circuit complexity to trillions of devices per square centimeter.

So far I have discussed analog electronics for microwave and mm-wave systems and digital electronics for computation.
But how do we move signals between the analog world in which we live and the digital domain where we can apply our computational engines to analyze and synthesize signals?

This brings me to the critical DoD need for high performance mixed signal, combined analog and digital, circuits that lie at the interface between the sensor and the processor.
Extending battle space dominance of our electromagnetic systems is often paced by the progress in mixed signal electronics to support operation at higher frequency, higher bandwidth, and higher precision.
MTO established gallium arsenide HBT technology, meaning heterojunction bipolar transistor technology, explicitly to extend analog to digital performance in the 90's.
We continue to mine ideas for extending mixed signal circuit performance for DoD critical applications.

For example, we are extending high speed SiGe technology, coupled with high levels of CMOS integration, to exploit highly parallel circuit topologies to advance mixed signal circuit performance.
Beyond this, we are developing a new class of super-scaled Indium Phosphide HBT technology to produce 500 GHz transistors, and 150 GHz circuits, that will allow increases in circuit complexity and enable a three fold increase in mixed signal circuit clock speed.

With the continued progression in transistor technology, and rf MEMS performance, the next frontier is in exploiting new circuit architectures that uniquely leverage the transistor and MEMS performance to enable new capabilities by focusing on the device/circuit interface.
One example in this area is in exploiting the blazing speed of scaled silicon CMOS and SiGe devices to produce wafer scale integrated systems.
For instance, we can think for the first time about realizing completely integrated, wafer scale phased array apertures all on a silicon wafer - a complete radar array on a single wafer.
Dan Radack will be pursuing this theme over the coming year.

MTO will continue to drive core mixed signal circuit performance, but our real vision moves beyond the serial analog-to-digital-to- analog data flow.
For example, Denis Healy has a vision for going directly from Analog-to-Information, or A-to-I.
No longer will we need to process all the data collected by a sensor to pick out the small piece that relates to a target of interest, but by exploiting advanced algorithms, along with adaptable hardware, future systems will only analyze the part of the data associated with the signal of interest.
If you want to learn more about direct A-to-I and where MTO is driving this in the next year, talk to Denis Healy.

The pace of electronic technology continues to accelerate and MTO is feeding the innovation engine.
In the next talks you will hear more details about the technologies that are being envisioned in future Integrated Microsystems, but to make our vision a reality for the Department of Defense, we need your ideas.
Come and talk to us, or better still, come and join us to make your vision a part of the future MTO reality.

Thank you.

Now let me introduce Lt Col John Carrano who will described his vision of the role of photonics in the future of Integrated Microsystems.