Lockheed Martin has a proven pathway to large-scale production, commercialization and rapid time-to-market of nanobased electronics through its relationship with its foundry partners. A fully integrated, embedded sensor technology—a combination of CNT fabric based sensors built on today’s CMOS circuits—is unique among nanomaterials for being qualified and approved for use in semiconductor foundries.

Nanotechnology is the future of electronics, the key to creating the ever more powerful and reliable devices required for the most demanding defense, aerospace, automotive, and other commercial applications. Lockheed Martin engineers and scientists are creating that future today, incorporating a wide range of advanced nanomaterials into next-generation memory and logic circuits, chemical sensors, batteries, and electronic interconnects, among other applications.

NRAM® and CNT Field Effect Transistors (FET)
Lower power use. Inherent radiation hardness. Non-volatile. Readily manufactured. These are some of the key performance characteristics of the nanotube random access memory (NRAM®) chips now being delivered to customers for testing and evaluation. Based on Lockheed Martin’s patented carbon nanotube (CNT) fabric technology, NRAM memory arrays are viable replacements today for flash memory and will soon be ready to replace standard dynamic random-access memory chips, particularly for radiation-hardened aerospace and defense applications and power-hungry servers.

First-generation 16 kilobit NRAM chips proved themselves in 2009 when they completed successful testing during a Space Shuttle mission. Today, a 4 Mbit second generation chip has been incorporated into a standard 64 Mb array that equals or exceeds all standard metrics for memory devices. NRAM modules are manufactured using existing infrastructure and a single-layer fabrication process compatible with radiation-hardened CMOS production methods.

Critical benefits of replacing standard memory with NRAM memory:
- Requires zero standby current and no transistor charging, cutting power use by 50 percent compared to competitive memory technologies
- Instant-on capabilities for time-sensitive applications
- Inherent radiation hardness exceeding 1 Mrad for use in extreme environments
- Data retention at 100 degrees C exceeds 25 years, allowing data storage for long periods of time

Lockheed Martin engineers are using this same CNT fabric technology to develop a new generation of memory and logic devices, including:
- 1 Gigabyte NRAM devices
- CNT FETs that are radiation hardened and both chemically and thermally stable
- Stacked and integrated NRAM and CNT FET devices that permit 65 nanometer densities using 90 nm production technologies and enables instant-on sleep capabilities in servers and laptops
- Wafer-scale integration of NRAM and CNT FET to enable supercomputer-scale capabilities on a single wafer

Advanced CNT Chemical Sensors
Lockheed Martin’s patented CNT fabrics are also at the heart of a new chemical sensor platform technology.

These easily manufactured, reusable sensors can be designed to detect a wide range of gases and volatile organic compounds in a highly multiplexed, battery-powered handheld device with superior performance metrics:
- High sensitivity at ~50 parts-per-billion
- Fast response initial times at ~1 second
- Low power usage within the µWatt to mWatt range
- Custom-designed chemical selectivity through multiple approaches

By taking advantage of the small size and lower power requirements for advanced CNT chemical sensors, Lockheed Martin engineers are creating single-chip arrays capable of detecting multiple analytes for applications that include life support monitoring systems for human spaceflight, industrial chemical detection, and medical diagnostics. Applications under development include:
- Propellant burn back
- Foreign object debris detection
- Chemical sensing to detect the onset of polymer degradation
- Confined area chemical sensing

Advanced CNT gas and vapor sensor chips are designed to be produced at scale in existing microelectronics foundries using traditional photolithographic methods. The devices can be integrated easily into distributed sensor networks or communicate with mobile platforms such as a smartphone, where custom-designed applications can provide real-time analytical results.

QuantumFuse® Technology: High-Performance Lead-Free Solder
Worldwide efforts to rid electronics of hazardous materials have created a growing demand for lead-free solder. Replacements for tin-lead solder are available, but all suffer from costly reliability issues and make them unsuitable for many defense, aerospace, and automotive applications.

Lockheed Martin’s scientists determined that copper nanoparticles smaller than 10 nanometers can serve as highly reliable low-temperature solder and turned this idea into its QuantumFuse™ Technology. The first product from that technology is a nanocopper solder, a printable nanocopper paste that when heated to 200 degrees C forms a durable copper connection with comparable strength and superior electrical and thermal conductivity.

Advantages of nanocopper include:
- Elimination of tin whisker growth, eliminating the unpredictable failures associated with other lead-free solders
- Reduced solder creep under continued stress compared to conventional tin-based solder, providing long-term reliability under elevated temperature conditions
- Manufacturing costs of soldered components reduced by over 50 percent, with significant reductions in size and weight
- Rapid scalability to industrial scale for mass production

Nanocopper is suitable for non-structural components and Lockheed Martin engineers are developing additional formulations suitable for structural and thermal management applications.