Nanomanufacturing in the Defense Industry

Nanomanufacturing Summit 2009

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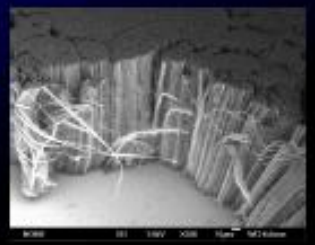
Lockheed Martin Business Areas

Nanotechnology in Lockheed Martin

- Ultra Lightweight Structures
- Smart Structures
- Distributed Sensor Systems
- Modeling and Simulation
- Integrated Platforms

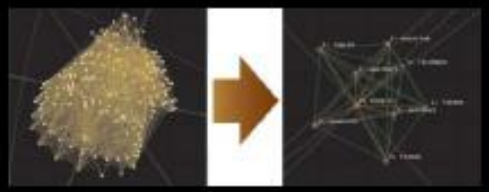
Space Systems

Materials
Sensors
Power



Information Systems and Global Services

Control Algorithms for Missions



Electronic Systems

Materials
Sensors
Platforms

Aeronautics

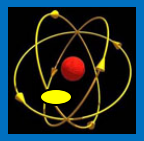
Materials
Sensors

Nano-enabled Technologies for Air Force

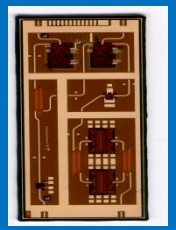
Chart Compliments of Air Force Research Labs

Our Challenge

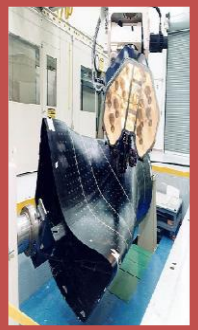
Research → Development → Application → Deployment



Technology



Device



Subsystem

System

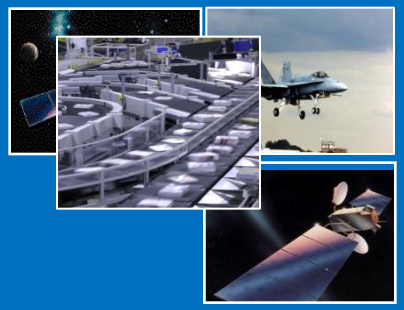
Need to Increase TRL Levels

RESEARCH → ***PROTOTYPE*** → ***PRODUCE*** → ***DEPLOY*** → ***SUSTAIN***

Partners

Internal R&D

Product Development



Programs/Systems

University Labs

Tech Centers

Dev't Centers

TRL 9

TRL 8

TRL 7

TRL 5-6

TRL 2-5

TRL 1-3

Integrate product designs into subsystems

Be the development lead and champion

Identify and Define emerging product opportunities, with LOBs, Tech. Centers & Suppliers.

IRAD | **IRAD** | **IRAD**

Levels, Players and Objectives Are All Important in Bringing Materials and Devices to Operational Status

Nanomanufacturing Challenges

- **Technical**
  - Strong link between nano-structure and macro-properties requires high degree of control and consistency in high-volume production
  - Uneven dispersion and agglomeration, which ruins high-performance properties
  - Contaminants in factory-quantity materials
  - Price premium for incremental improvement in properties and performance
- **Economic**
  - Brutal competition and fast-dropping prices
  - Rising volumes and quality
- **Other**
  - Inconsistent supplies from different manufacturers
  - Poor understanding of EHS aspects and lack of regulations
  - Lack of real-time characterization tools

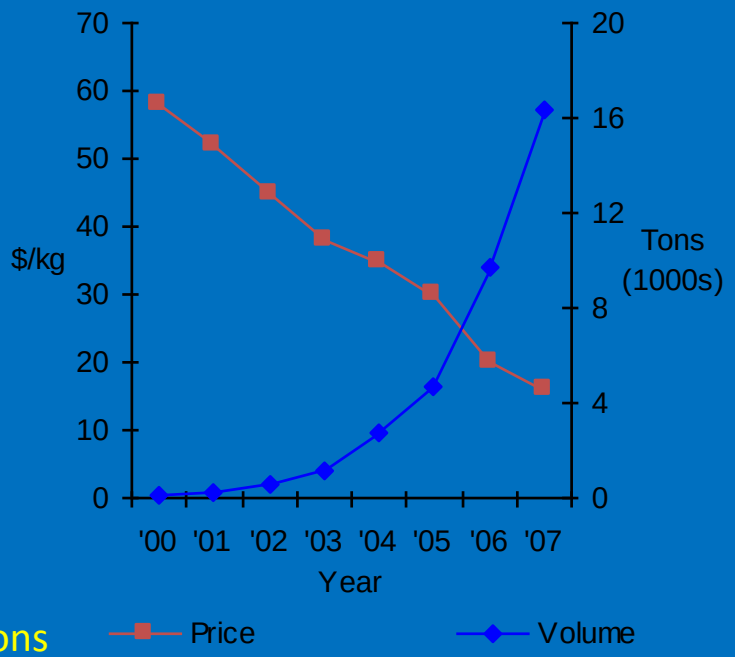
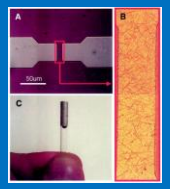


Chart Compliments of Lux Research

Example: Road to Production for Sensors

– A Series of Technical Challenges



Integrated Components

Technology Development → Transition → Product Development

Prototype Development

- New Modeling techniques and Tools
- Design considerations
  - Low noise floors
  - A large dynamic range
  - Realistic excitation requirements
  - Mechanisms to handle fluctuations in power supplies and static electricity
  - determine and create stable calibration curves
  - acceptable output impedance
  - repeatability, accuracy, precision, bandwidth and reliability

Device Characterization and I/F Development

- New metrology tools and processes
  - Identify new parameters and tools to measure them
  - Identify and measure subsurface defects
  - Establish international standards
- Interface to micro, meso, and macro systems

Production

- New metrology tools and processes
- Packaging
- Scale-up considerations
- Manufacturing costs
- Automation, ideally with self calibration and adjustment
- Handling and environmental
- Radiation Effects
- Failure Modes

Nanomanufacturing Process Needs

Fabrication Techniques

- Embedded Sensors
- Remote Manufacturing
- Automation
- Automation with Self-calibration and Adjustment

Modeling and Control

- Modeling and Simulation (M&S) Tools
- Automatic Comparison to M&S Data
- Accurate Modeling at nm scale

Economics

- -Cost
- - EHS
- - High Throughput

Metrology

- International Standards
- Identification of New Measurement Parameters
- Calibration Tools Nano-characterization

Nanostructures into Devices / systems

- Interfaces to Micro and Macro
- Whole System Scale-up
- Rapid Characterization of 3D structures

MEL at a Glance

Mission: MEL promotes **innovation** and the **competitiveness** of U.S. manufacturing through **measurement science**, **measurement services**, and critical **technical contributions to standards**

Divisions

- Precision Engineering (PED)
- Manufacturing Metrology (MMD)
- Intelligent Systems (ISD)
- Manufacturing Systems Integration (MSID)
- Fabrication Technology (FTD)

Funding

$50.4 M annual budget

$37.0 M NIST appropriations

$ 8.7 M Other Agency/External R&D

$ 4.7 M Calibration Service Fees/Reimbursable

Measurement Service Areas

Length, Diameter and Roundness
Complex Dimensional Standards
Optical Reference Plane Standards
Angular Measurements , Surface Texture, Laser Frequency/ Wavelength and Ranging, Mass Standards, Force Vibration, Acoustics

Staffing

174 NIST Staff
98 Guest Researchers
4 NRC Postdoctoral Researchers

Chart Compliments of NIST

Manufacturing Engineering Laboratory (MEL)

- Current Nanotechnology/Nanomanufacturing Programs
  - Precision Engineering Division
    - Nanomanufacturing Metrology Program
    - Next-Generation Nanometrology Program
  - Manufacturing Metrology Division
    - Mechanical Metrology Program
  - Manufacturing Systems Integration Division
    - AFM Probe Modeling
  - Intelligent Systems Division
    - High precision piezo stages
    - MEMS devices

Chart Compliments of NIST

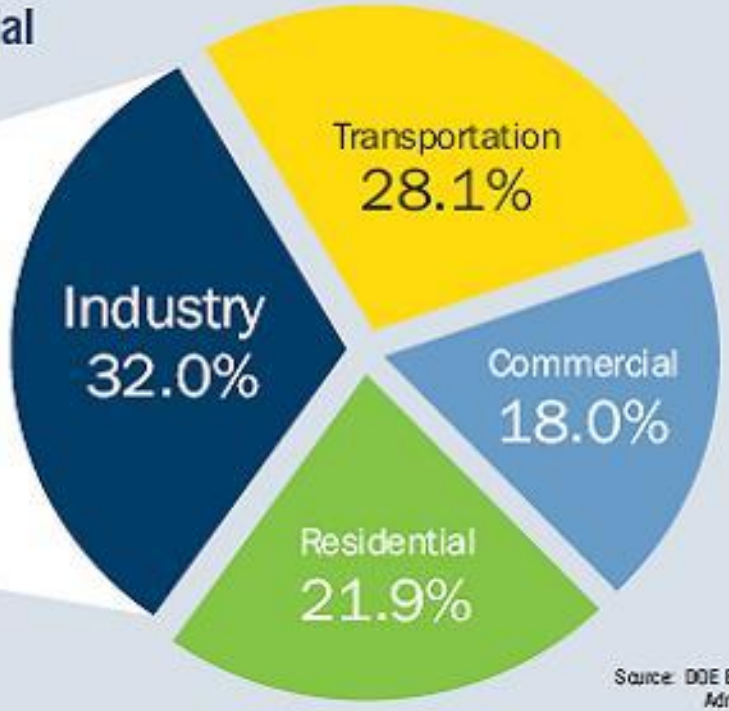
DoE Industrial Technologies Program (ITP): Mission

Improve our nation's energy security, climate, environment, and economic competitiveness by transforming the way U.S. industry uses energy

Reducing U.S. industrial energy intensity is essential to achieving national energy and carbon goals

Petroleum	38.1%
Natural Gas	33.3%
Electricity*	13.5%
Coal and Coke	8.5%
Renewable Energy	6.6%

* Excludes losses



Source: DOE Energy Information Administration, 2006.

Chart Compliments of DoE

ITP Nanomanufacturing Program Focus

Help transform nanoscience into industrial processes and products

Focus:

- **Enabling Processes for Nanomaterials Production:** Improve reliability and scale up nanomaterials production processes
- **Nanomaterials Utilization in Industrial Processes:** Scale up manufacturing processes for utilization of nanomaterials in energy-related products

Top Priorities for Energy Efficiency (based on Lux analysis)

- Batteries and supercapacitors
- Light weight nanocomposites
- Nanocoatings/nanocomposites for thermal management
- Catalysts for chemical, industrial and automotive applications
- Tribological nanocoatings
- Solid state lighting (LED)
- Solar
- Nanomanufacturing research/commercialization center

Chart Compliments of DoE

Department of Energy's Industrial Technologies Program

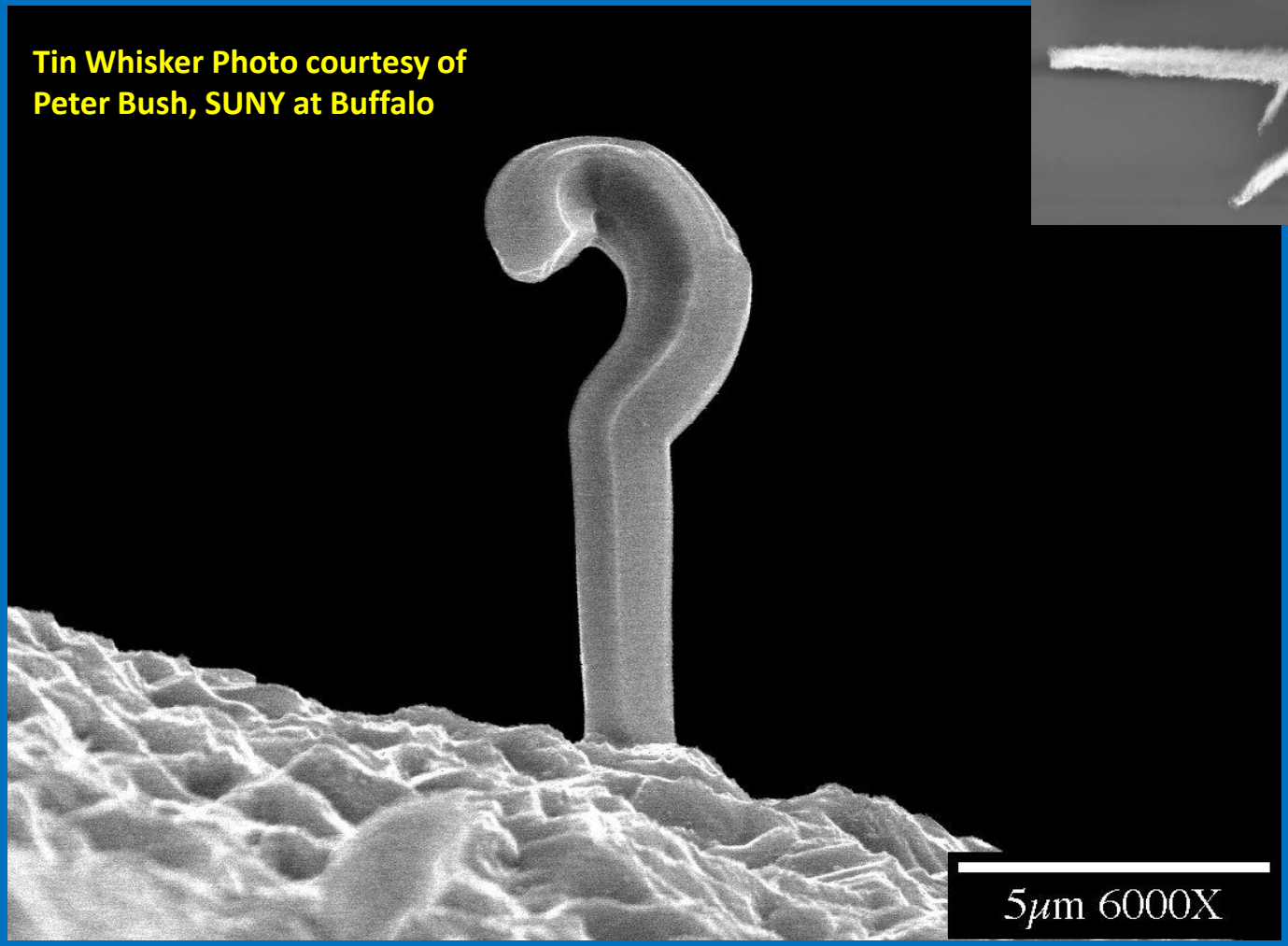
- **Critical challenges for nanomanufacturing include the following**:
  - **Dispersion:** Nanoparticles must be thoroughly and evenly dispersed within a matrix (e.g., film, coating, or resin), as clumping may make them lose their unique properties
  - **Contamination:** Stray molecules of other materials must be prevented from adversely affecting nanomaterial properties, which are highly sensitive to atomic and molecular interactions
  - **Consistency:** The desired properties of nanomaterials must be consistently achieved in mass production.
  - **Environmental, Health, and Safety protocols:** The risk profiles of nanotechnology require further study and clarification

ITP's Nanomanufacturing Program activities focus on the following objectives:

- Develop low-cost manufacturing processes to expand near-term commercial use of innovative nanomaterials in
  - Industrial processing
  - Energy-saving and energy-producing products
- Develop technologies to enable expanded use of nanomaterials
  - Directly as a material to enhance material performance
  - Indirectly as an intermediate device (e.g., nanosensors for thermal management)

Chart Compliments of DoE

Questions



"Think Big, Start Small, Scale Rapidly"