2009 NASA Goddard Space Flight Center Nanotechnology Safety Training

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Developed by the NASA/GSFC Nanotechnology Safety Council

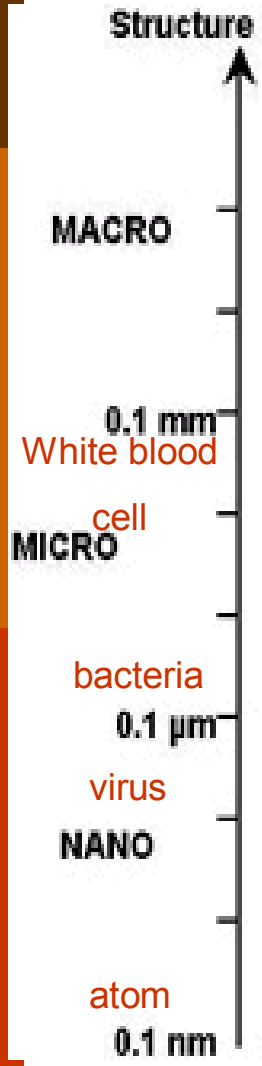
PRESENTATION OUTLINE

- Nanomaterial Overview
- Engineering Requirements & Considerations
- Health/Safety
- Contacts and References

NANOMATERIAL OVERVIEW

- What is Nanotechnology?
- Common forms of Nanomaterials
- GSFC Applications & Plans
- Lifecycle Design Considerations

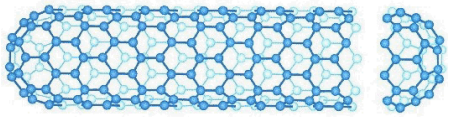
What is Nanotechnology ?



- **Nanomaterials** –
  - Have at least one dimension less than 100 nm and are typically engineered to have unique properties which make them desirable for research or commercial applications.
  - Nanoparticles are similar in size to atoms, viruses, DNA, and proteins.
  - Most biological processes (e.g. cellular interaction with viruses) occur at the nanoscale
  - Combustion processes, welding fumes, wild fires, and diesel exhaust generate nanoscale particles
  - Portions of many conventional industrial chemicals are nanoscale (e.g. paint pigments)
  - Nanomaterials are not new, but the ability to measure, manipulate and process at the nanoscale is new
    - Nanomaterials are engineered from known materials (e.g. carbon, iron, silicon, titanium)
- **Nanotechnology** –
  - The creation of materials, devices and systems through control of matter on the nanometer length scale (1-100 nanometers)
  - Exploitation of novel phenomena and properties (physical, chemical, biological, mechanical, electrical, etc) at that scale

Common forms of Nanomaterials

- **Raw Nanomaterials are available in different forms:**
  - Powder – most hazardous
  - In a composite
  - On a substrate
  - Suspended in liquids



- **Nanomaterials Common at Goddard:**
  - Carbon NanoTubes (CNT) attached to substrates (CNT Magnetometer and other devices)
  - Embedded nanomaterials (nanocomposites)
  - Limited quantities of raw materials

- **Powder nanomaterials are currently not in use at GSFC**
  - Hazards are more likely associated with work involving or generating loose nanoparticles

GSFC Applications & Plans

- **Current research & development applications**
  - Nanomaterial doped epoxies and composites
  - Nanomaterial doped metal matrix composites
  - Sensors & electronic components

- **The present plan calls for nanomaterials to be used in substrate or in liquid suspension form**
  - Should future plans require the use of powder nanomaterials, detailed evaluations will be performed to ensure the safety of all employees

- **GSFC is working closely with the National Institute of Occupational Safety & Health (NIOSH) to ensure that proper precautions are taken**
  - All operations are reviewed by the NSC and S&E prior to operation
  - The NSC is maintaining a user database of current operations on Center
  - Notification will be provided to impacted building occupants prior to the start of nanomaterial work

Lifecycle Design Considerations

- **Implementation of nanomaterials into GSFC hardware**
  - Electronic Sensors and Devices
  - Structural Materials and Components

- **Initial design considerations**
  - Development of processes to protect people/hardware
  - Determination of necessary training
  - Processing of components
  - Integration, verification, testing and operation of subsystems
    - Handling (e.g. incoming inspection and cleaning)
    - Integrating with hardware (e.g. bonding, grinding, fracture)
    - Environmental exposure
    - Failure assessment
  - Facility accommodations, e.g. Heating Ventilation & Air Conditioning (HVAC)
    - In the event of a release, whether the nanomaterial can be contained and/or will contaminate the system

- **Subsequent design considerations**
  - Delivery of material, i.e. form and packaging
  - Storage of material

ENGINEERING REQUIREMENTS & CONSIDERATIONS

- Safety Documentation
- TSA and Environmental Checklist
- Requirements for Storage, Shipping and Transport
- Overview of Approval Process
- Key Approval Process Steps

Safety Documentation

- **Material Safety Data Sheets (MSDS)**
  - Contain information to assess the safety, health, and storage hazards of materials
  - Use with caution, as information found on MSDS might not be accurate or complete

- **The Task Safety Analysis (TSA) and Environmental Checklist for Research and Development Projects**
  - The TSA (GSFC form 23-60) shall document task sequence, potential personnel & facility hazards, and mitigation techniques
  - The Environmental Checklist (GSFC form 23-75) shall document potential environmental issues
  - Both forms are available on the Goddard Directives Management System (GDMS)

- **Equipment Maintenance Plan**
  - Standard operating procedures may be required
  - Maintenance, modification and/or calibration of equipment shall be conducted by personnel who are aware of the nanomaterial hazards
  - Equipment that has been exposed to nanomaterials shall be labeled to alert personnel of the potential hazard until the cleanliness has been verified by appropriate personnel

- **Prior to the start of work**
  - All applicable lab personnel and management shall review all forms
  - The NSC and S&E shall review and approve all forms on a case-by-case basis

TSA and Environmental Checklist

When completing forms 23-60 and 23-75, consideration should be given to the following topics:

- Use of Personal Protective Equipment (PPE) to minimize contact
- Containment/storage of nanomaterials
- Minimization of possible explosion hazards
- Limiting nanomaterials contamination of facility and surrounding environment
- Hazard precautions during maintenance of instruments and work stations
- Clean-up precautions
- Waste storage/disposal
- Environmental impact of nanomaterial use on
  - Air emissions
  - Wastewater quality
  - Hazardous Waste generation

Requirements for Storage, Shipping and Transport

- Loose Nanoparticles shall be
  - Double bagged with 6mil polyethylene bags to prevent particulate release
  - Stored in sealed containers
- During transport, containers must be placed in a lined container to prevent shifting, damage or spillage
  - Nanomaterial containers may have special requirements, e.g. use of anti-static materials to prevent fire/explosion hazards
- Containers & Packages must be labeled with contents
- MSDS must be available

Key Approval Process Steps

User

- User has nanotechnology concept
  - Receives training
- Completes TSA & Environmental Checklist, develops Equipment Maintenance Plan
- Obtains Lab Manager & NSC approval
- *If process involves loose nanomaterials, obtain medical surveillance*
- Notify neighbors of process & hazard
- Start Process
  - If changes made to process, notify NSC and reevaluate TSA & Environmental Checklist
  - Notify maintenance personnel of hazards

Lab Manager

- Reviews and approves TSA, Environmental Checklist, Equipment Maintenance Plan
- Informs Facilities Operations Manager (FOM) & works with FOM to include process in Emergency Action Plan

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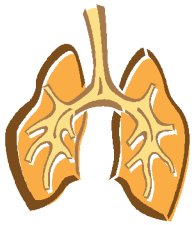
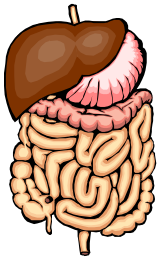
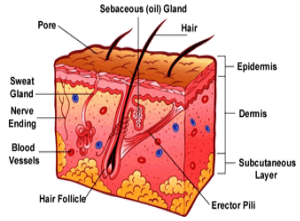
- Reviews and approves TSA, Environmental Checklist, Equipment Maintenance Plan
- Obtains approval from Safety & Environmental
- Add process to user database & maintains record of approved processes
- Performs documentation review/lab inspection every 2 years

HEALTH/SAFETY

- Exposure Routes
- Mitigation Techniques
- Engineering & Work Practice Controls for Processes
- Engineering & Work Practice Controls for Clean Up
- Personal Protective Equipment (PPE)
- Air Monitoring
- Medical Surveillance
- Flammability/Explosion Hazards
- Clean-Up/Spills
- Hazardous Waste Management

Exposure Routes

Route of Exposure	Potential Hazard
Inhalation 	-Particle size/distribution, surface area, and reactivity are important factors leading to lung inflammation
Ingestion 	-Swallowed materials can be transferred to other organs -Nanomaterials can cross the placenta barrier in pregnant women
Skin Penetration/Absorption 	-Absorption or penetration via exposure to eyes or skin

In all cases, working with loose materials increases exposure risk

Mitigation Techniques

- Further research is needed in order to realistically assess the health risks from nanoparticle exposure
- There is limited recommended occupational health surveillance guidance
- Exposure to nanomaterials can be controlled with
  - Engineering controls
  - Administrative controls
  - Work practices
  - Personal protective equipment (PPE)
- Engineering and work practice controls are the preferred method for limiting exposure
- PPE are the final measure of protection to the lowest achievable level

Engineering & Work Practice Controls for Processes

- Suspension of nanomaterials in a liquid or bound to a substrate
- Local exhaust ventilation with a low flow rate
- Enclosure of the process in a glove box
- General ventilation (room under negative pressure)
- Limiting area access
  - Administrative controls limiting access to authorized individuals supplement the preferred engineering & work practice controls
- Reduction in periods of exposure
- Prohibit eating and drinking in lab areas

Engineering & Work Practice Controls for Clean Up

- The 'wet method' of clean-up shall be used whenever possible
  - A High Efficiency Particulate Air (HEPA) filtered vacuum shall be used for area cleanup when use of the wet method is not a viable option
    - Identify specific equipment to be used for nanoparticulate cleanup
  - ***Dry sweeping and the use of compressed gas is prohibited***
- Walls and other surfaces shall be cleaned regularly using the 'wet method'
- Thoroughly rinse and wash hands and forearms after removal of gloves
- Contaminated PPE should never be reused
  - Contaminated gloves, garments, and wipes should be stored in a sealed container until proper disposal

Personal Protective Equipment (PPE)

- Respirator with N100 filter
  - Respirator users are required to be in a Respiratory Protection Program, which includes Medical Evaluation, Fit-testing, & training
  - Contact the Health Unit at x6-6666 and Industrial Hygiene Office at x6-6669 to schedule appointments well in advance of intended use
- Nitrile or latex gloves
  - Double glove for prolonged exposure
- Nonporous Tyvek® coveralls and shoe covers
- Lab coat, closed toe shoes, safety glasses or face shield depending on operation
  - Contaminated PPE should never be reused
  - Contaminated PPE and wipes should be stored in a plastic bag and sealed container in hood until proper disposal by Hazardous Waste
- PPE may be downgraded based on the NSC's review of the TSA and associated hazards

Air Monitoring

GSFC Strategies to measure exposure to nanoparticles

- TSI 3007 Particle Counter
  - Measures particulate from 0.01 to 1.0 Micron
  - Verify conditions prior to and during operations

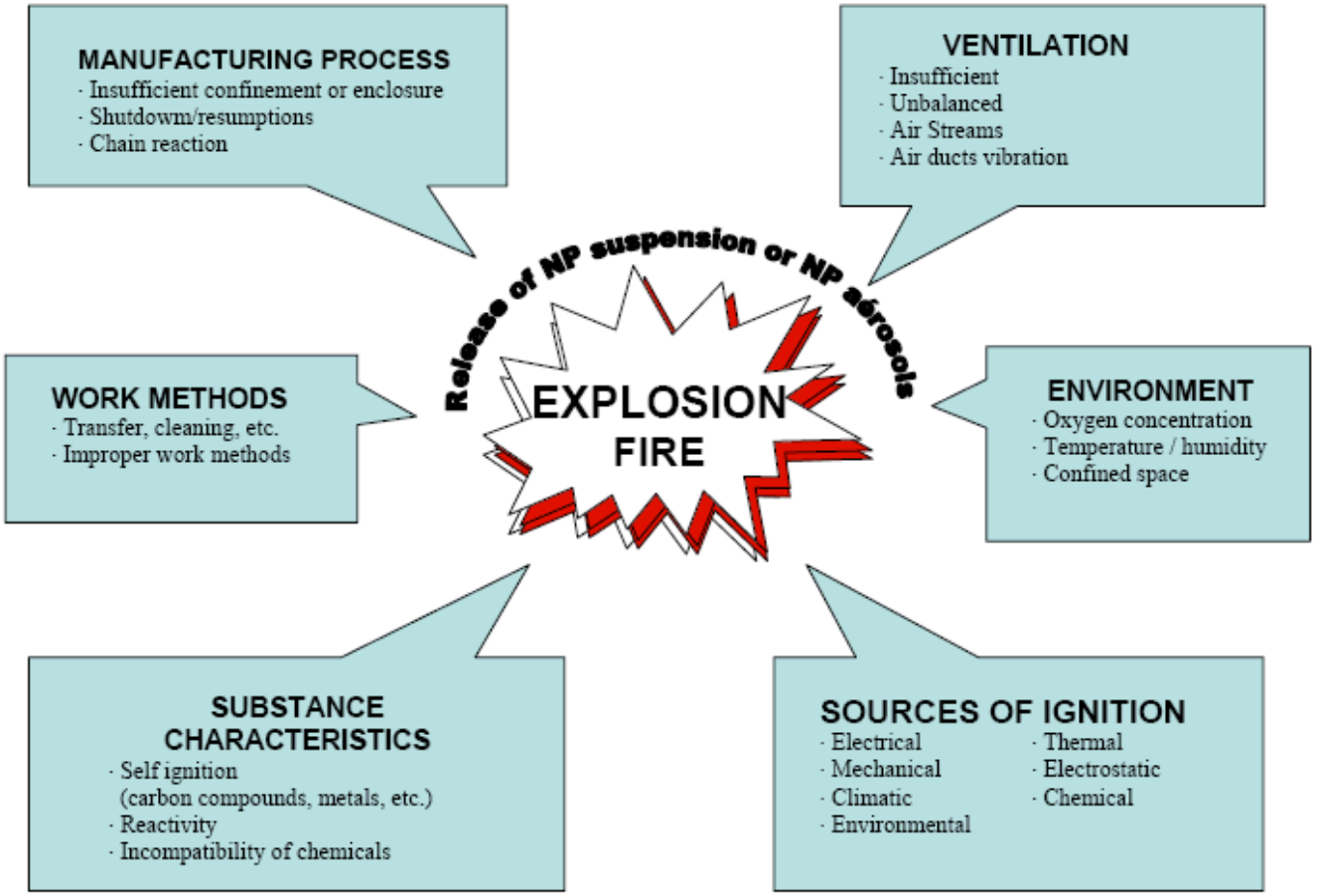
- Aerotrak 8220 Optical Particle Counter
  - Measures particulate from 0.3 to 10 Microns
  - Verify conditions prior to and during operations

- Active Sampling
  - Collection of sample on filters and analysis using Transmission Electron Microscopy (TEM)

Medical Surveillance

- Medical surveillance is in accordance with the NIOSH guidelines and is intended for individuals working with loose nanomaterials
  - Medical monitoring may consist of urinalysis, blood chemistry, and pulmonary function
  - Contractors will be required to follow GSFC practices/protocol
- Medical Surveillance is required prior to beginning work with nanomaterials to establish a baseline
- Contact the Health Unit at (301)286-6666 to schedule an appointment
  - Contractors shall contact their safety office

Flammability/Explosion Hazards



Flammability/Explosion Hazards

- Micron-scale powders can become unstable causing explosions
  - Normally non-combustible materials may burn if the particle size is small enough and there is sufficient concentration
  - Explosion hazard can be more pronounced in nano-scale powders based on the particle size
    - An example: a solid block of aluminum is **not** easily ignitable, but aluminum dust may be easily ignitable

- Storage containers must be tight to avoid leaks and site contamination
  - Different granulometric characteristics
  - Reactivity of certain products
  - Possible resuspension
  - Long sedimentation times

Flammability Hazard Prevention

- Precautions
  - Vapor proof electrical equipment
  - Use explosion rated equipment
  - Reduce operation temperatures
  - Control air production within operational area
- In the Event of a Fire
  - Leave area immediately
  - Call GSFC 911 (301-286-9111 from non-GSFC phones)
    - Inform operator of the location and situation
- Extinguishment of Fire
  - Dry chemical multipurpose or carbon dioxide fire extinguisher should be available in the work area

Explosion Hazard Factors and Prevention

Potential Factors	Prevention
Vigorous mechanical agitation	Do not agitate in a small area where heat can be confined
Static discharge can cause sparks resulting in ignition	Use anti-static container and ground equipment, if necessary
Nano-powder concentration – the total exposed surface area of a batch is a potential factor for explosion below certain concentration levels	Reduce the amount of well-dispersed material used
Nano-powders are frequently used as catalysts and may cause uncontrolled chemical reaction depending on the environmental configurations	Avoid the possibility of a chemical reaction and understand the material's characteristics
Moisture content *increases* the explosion threshold and *reduces* the explosion violence	Do not use in dry conditions and add humidity if necessary
Nano-scale metal oxides can react to give a higher oxidative state thus becoming explosive	Do not use in an area with potential for oxidation

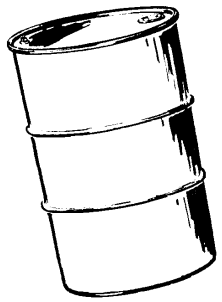
Clean-Up/ Spills

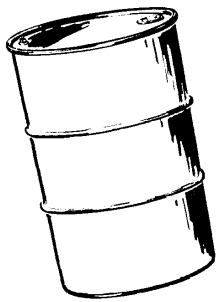
- A spill is any unpermitted release to the environment
  - On the floor/ground
  - To the air
  - Down a drain

- In the event of a spill
  - Protect yourself and those in the vicinity from the release
  - Call the Security Operations Center by dialing 911 from GSFC phones (call (301)286-9111 from non-GSFC phones)

Hazardous Waste Management

- Manage waste nanomaterials according to Waste Management Goddard Procedural Requirements (GPR) 8500.3
  - Handle as waste chemicals – Contact S&E prior to hazardous waste generation by calling (301)286-4613
  - Unused, expired or excess materials that may be considered chemicals, hazardous materials, or in any way dangerous shall be considered hazardous waste until evaluated by S&E
  - Disposal of all hazardous waste shall be coordinated by S&E
- Attend Hazardous Waste Generators Training annually





CONTACTS AND REFERENCES

- Nanotechnology Safety Council Contacts
- General Contacts
- References

Nanotechnology Safety Council Contacts

- Marjorie Sovinski, Chair (Code 541) - 6-1371
- Jeff Dalhoff, Industrial Hygiene (Code 250) – 6-2498
- Kathy Moxley, Environmental (Code 250) – 6-0717
- Brian Montgomery, Safety (Code 250) – 6-6759
- Min Namkung, Materials (Code 691) – 6-6007
- Lixa Rodriguez-Ramon, Environmental (Code 250) – 6-4613
- Russell Rowles, Fabrication (Code 547) – 6-9660
- Ken Segal, Engineering (Code 543) – 6-2895
- Melonie Scofield, Safety (Code 500) – 6-1035

General Contacts

- Safety & Environmental (S&E) Division: (301)286-6296
  - Industrial Hygiene: (301)286-2498
  - Hazardous Waste: (301)286-4613
  - Respirator Protection Program: (301)286-6669
  - Environmental Impacts: Greenbelt (301)286-0469
    Wallops (757)824-2319
- Security Operations Center: 911 from GSFC phones, (301)286-9111 from non-GSFC phones
- Health Unit: (301)286-6666

References

- AETD Safety Manual, Section 3.12 “Nanotechnology”
- GPR 8500.1 Environmental Planning and Impact Assessment
- NIOSH Publication No. 2007-123: Progress Toward Safe Nanotechnology in the Workplace, June 2007
- Texas Engineering Experiment Station:

  http://tees.tamu.edu/index.jsp?page=trc_nanotechnology