National Aeronautics and
Space Administration

Potential Aerospace Applications for Cellulosic Nanomaterials

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Cellulosic Nanomaterials – A Path Toward Commercialization
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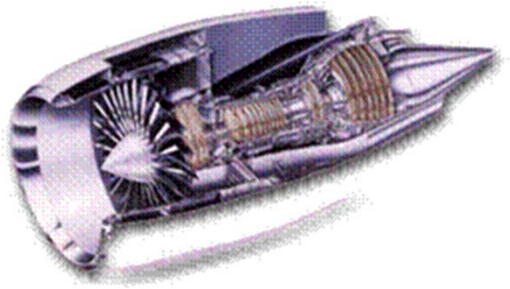
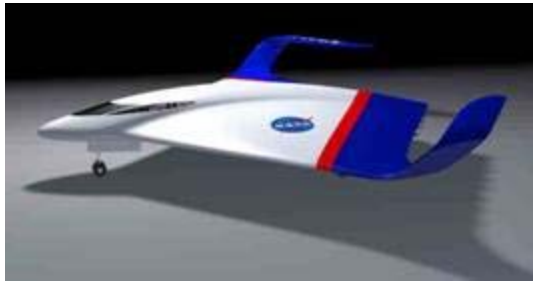
Critical Concerns for Aerospace Systems

Weight
- Reduced fuel consumption & emissions
- Reduced launch costs
- Enabler for many vehicles



Functionality/Performance
- Reduced fuel or power consumption
- Multifunctionality – reduced weight

Durability
- Safety and reliability
- Maintenance down-time and costs



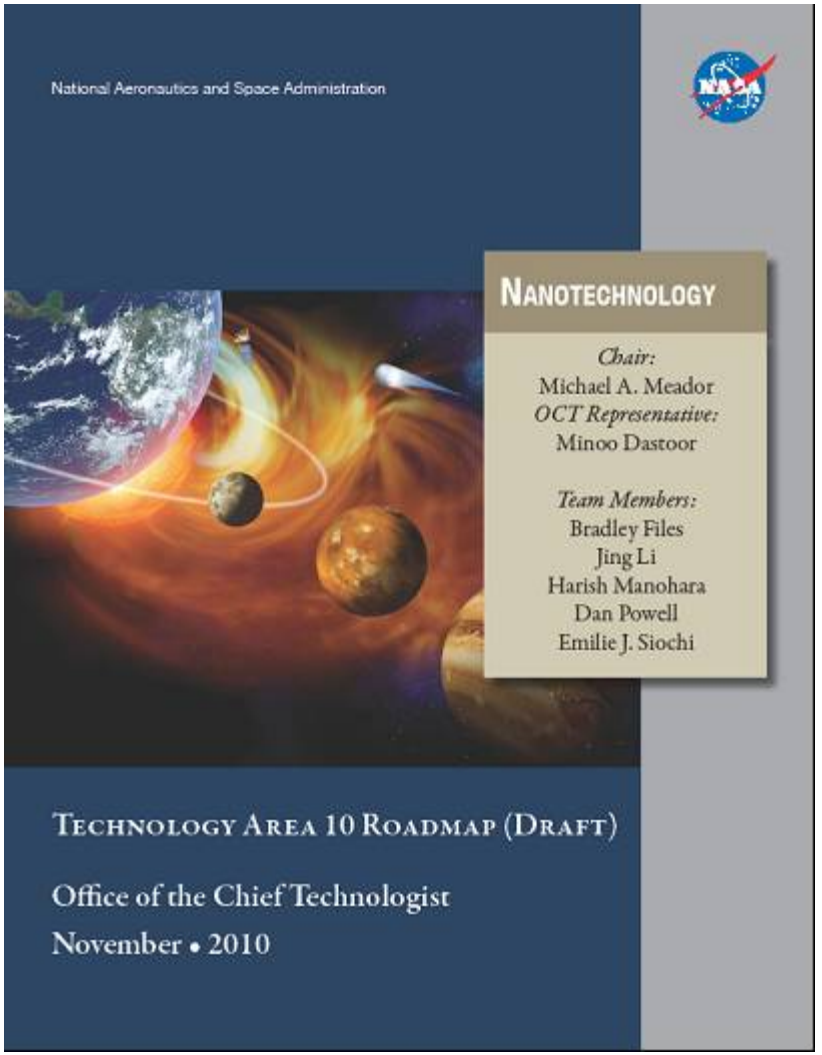
How Nanotechnology Impacts Materials Properties

Nanotechnology enables discrete control of desired materials properties :

- **Mechanical**
  - Dictated by particle size (Griffith criteria), morphology and strength of interfaces (chemistry and roughness)
  - High aspect ratios and surface areas radically changes nanocomposite properties relative to host material
  - Molecularly perfect, highly ordered, defect free structures, e.g. carbon nanotubes, leads to maximized properties (not just mechanical)
- **Thermal**
  - Emissivity influenced by particle size and enhanced surface area/roughness
  - Thermal conductivity controlled by particle size (phonon coupling and quantum effects) and nanoscale voids
- **Electrical**
  - Nano structure and defects influence conductivity and bandgap energy (conductivity, current density, thermoelectric effects)
  - High aspect ratios enhance field emission and percolation threshold
  - Nanoscale dimensions lead to inherent radiation resistance
- **Optical**
  - Transparency and color dominated by size effects
  - Photonic bandgap controlled by size (λ/10) and nanostructure

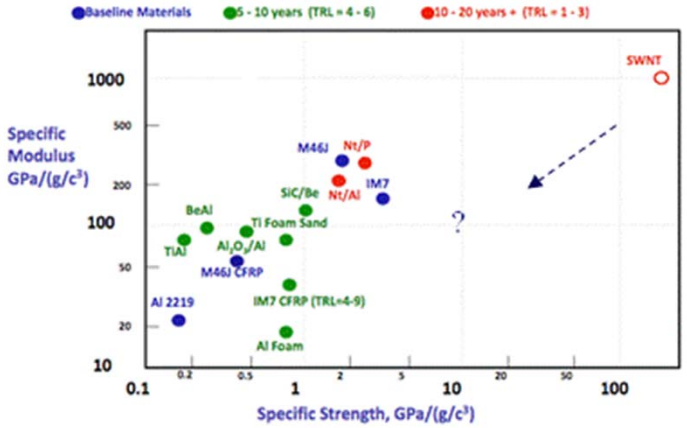
NASA Nanotechnology Roadmap

- Drafted 20+ year technology roadmap for development of nanotechnology (TRL 6) and its insertion into NASA missions
  - Includes both mission “pull” and technology "push”
  - Covers four theme areas
    - Engineered Materials and Structures
    - Energy Generation, Storage and Distribution
    - Propulsion
    - Sensors, Electronics and Devices
  - Used to guide future funding decisions
- Identified 18 Key Capabilities enabled by nanotechnology that could impact current and future NASA missions
- Identified 5 Grand Challenges with potential for broad Agency impact
- Reviewed by NRC – report published in 2012
- Plans to update the roadmaps in FY14



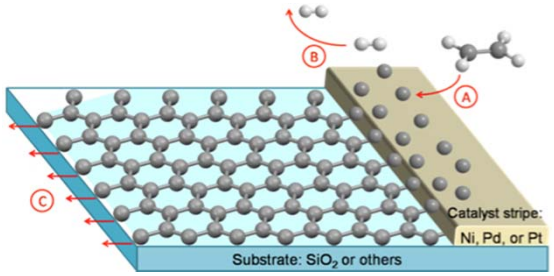
Grand Challenges

Nanopropellants



Ultralightweight Materials

Structurally Integrated Energy Generation and Storage



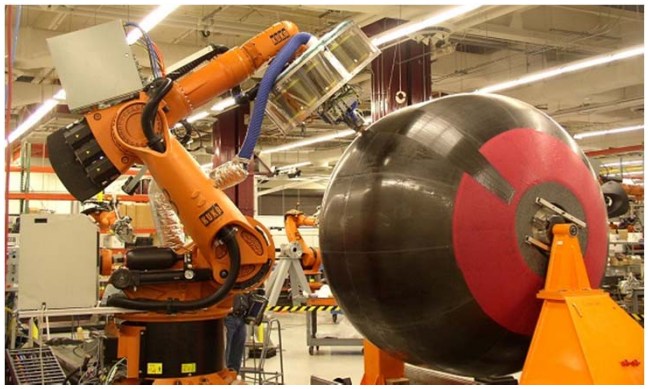
Graphene Electronics

- **High priority items identified by the Nanotechnology Roadmap Team for NASA investment and/or collaboration with other agencies**
- **Working these technologies as budget and overall NASA priorities allow**

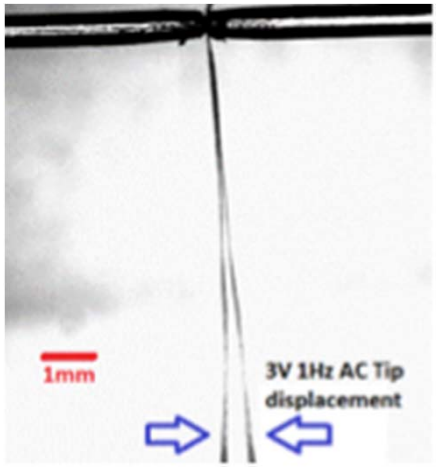
Hierarchical Integration

Potential Applications for Cellulosic Nanomaterials

In situ Resource Utilization – NC Composites from Recycled Materials



Lightweight, Low Permeability Liners for Cryotanks



Stimuli Responsive Polymers

Substrates for Flexible Photovoltaics