

CANEUS - MNT for Aerospace Applications

A Coordinated International Development / Investment Strategy

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4th ESA Round Table on
Micro-Nano Technologies for Space Applications
ESA/ESTEC, Noordwijk, The Netherlands
May 20-22, 2003

1. Objective of this Presentation

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2. Background of CANEUS Organization
3. About CANEUS Organization
4. Aim of CANEUS Organization
5. Activities of CANEUS Organization
 - Working Groups
 - Pilot Program and Projects: Phase I and II
 - Other
6. CANEUS Organizational Structure
 - Proposed LOI / MOU
 - Structure
7. Invitation and thoughts for discussion

CANEUS - MNT for Aerospace Applications, A Coordinated International Development / Investment Strategy
Presentation at the 4th ESA Round Table, May 20-22, 2003

1. Objective of this Presentation

In order to achieve the coordinated strategy for investment and development in MNT for Aerospace applications through partnerships between participating organizations within Europe, North America and Asia

- To outline, on behalf of CANEUS Organization:
 - (a) The Background and Creation of CANEUS by CLS3 of Canada
 - (b) Aim of CANEUS Organization
 - (c) Scope of Activities by CANEUS Organization
 - (d) Proposed Plan of Actions for implementation
- The coordinated investment/development strategy will be facilitated under the auspices of the CANEUS organization.

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2. Background of CANEUS Organization

2.1 Initiated by CLS3 of Montreal, Canada

The Centre for Large Space Structures and Systems (CLS3) of Montreal, Canada was responsible for pioneering the concept of the joint Canada-Europe-USA-Asia (CANEUS) organization for the advancement of Micro-Nano Technologies (MNT) for Aerospace applications.

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2. Background of CANEUS Organization

2.2 CANEUS 2002 Workshop

The CLS3 together with partners from Canada (CSA and NRCC), Europe (ESA and NEXUS), the US (DARPA and NASA) and Japan (ISAS, NASDA) hosted a very successful CANEUS workshop in August 2002, with worldwide participation from MNT and Aerospace organizations.

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2. Background of CANEUS Organization

2.3 Coordinated Development Strategy

- *The CANEUS 2002 workshop reached the following important conclusion:* Given the fact that there is a relatively small worldwide investment into the emerging area of Micro-Nano-Technologies (MNT) for Aerospace applications, the time has come to develop a coordinated, international investment and technology development strategy.
- Such a strategy is urgently needed in order to maximize the return-on-investment, and to minimize duplication of effort and wastage of precious resources. In brief, the strategy calls for coordinated technology development between participating member countries via the creation and nurturing of complementary core competencies.

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2. Background of CANEUS Organization

2.4 Coordinated Development Strategy - Goal

- The ultimate goal is the establishment of a cost-effective means, through joint technology development, for the rapid infusion of new MNT-based devices and instruments for Aerospace applications.

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3. About CANEUS Organization

- CANEUS is a non-profit, hands-on organization based in Montreal, Canada for the development and advancement of Micro - Nano - Technologies (MNT) for Aerospace applications from concept to systems.
- It brings together MNT developers (researchers and scientists) from Canada, Europe, US, Japan and elsewhere with end-users from aerospace and diverse application sectors comprising practitioners, policy-makers and investment community.

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4. Aims of CANEUS Organization

The CANEUS Organization aims at:

1. Providing a platform for coordinated strategy for investment and development of MNT via the creation and nurturing of complementary core competencies between government, private sector and academic organizations from participating countries.

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4. Aims of CANEUS Organization

The CANEUS Organization aims at:

2. Implementing a coordinated investment / development strategy through cost-effective means and mechanisms for the rapid infusion of new MNT-based devices and systems for Aerospace applications.

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4. Aims of CANEUS Organization

The CANEUS Organization aims at:

3. Fostering the competency of stakeholders and improving the educational base amongst CANEUS participating countries.

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5. Activities of CANEUS Organization

The CANEUS organization will be implementing the objectives in the following way:

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    graph TD
      subgraph WG [Working Groups]
        R[Recommendation]
      end
      subgraph DC [Developing Coordinated Strategy]
        P[Pilot Programs]
        E[Expanded Scope]
      end
      subgraph WCC [Workshops and Conferences]
        WCC
      end
      subgraph PUB [Publications]
        PUB
      end
      subgraph EDU [Educational Programs]
        EDU
      end
      R --> P
      P --> E
      WCC --> P
      WCC --> E
      PUB --> WCC
      EDU --> WCC
  
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5. Activities of CANEUS Organization

The CANEUS organization will be implementing the objectives in the following way:

5.1 Working Groups

The first stage of implementation will be by formation of working groups. Multiple working groups consisting of membership from CANEUS participating MNT organizations will be commissioned to examine current and planned areas of MNT development for Aerospace applications.

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5. Activities of CANEUS Organization

The organization will be implementing the objectives in the following way:

5.1 Working Groups
The end product of the working group's effort will be reports containing the following :

A. Identify partnerships between the MNT organizations from the CANEUS member countries for bringing together complementary technologies for rapid and efficient Aerospace MNT system development

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5. Activities of CANEUS Organization

The organization will be implementing the objectives in the following way:

5.1 Working Groups
The end product of the working group's effort will be reports containing the following :

B. Propose quantifiable metrics for evaluating the return-on-investment and efficient resource utilization for these proposed partnerships

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5. Activities of CANEUS Organization

The organization will be implementing the objectives in the following way:

5.2 Pilot Program and Projects

A step-by-step approach would be followed for the gradual implementation of this program. First, a "pilot program" is proposed for implementing the initial partnerships recommended by the Working Group. Lessons learned during the pilot program will be crucial for future efforts.

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5. Activities of CANEUS Organization

The organization will be implementing the objectives in the following way:

5.2 Pilot Program and Projects

- Lessons learned during the pilot program will be crucial for future efforts, and hence should be well documented, so that similar types of expensive mistakes are avoided.
- Should the results from the pilot programs prove to be positive, as measured by quantitative metrics developed by the Working Group, then and then only, should the scope of the program be expanded further.

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5. Activities of CANEUS Organization

The organization will be implementing the objectives in the following way:

5.2 Pilot Program and Projects

It is hoped that having a well-thought out implementation strategy for MNT investment/development, will ultimately demonstrate significant improvement over the status quo and result in a faster, higher efficiency development of new Aerospace systems based on advanced MNT concepts.

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5. Activities of CANEUS Organization

5.3 Technical and Programmatic Conferences

- The CANEUS organization also has additional important roles to play in fostering the coordinated MNT investment / development strategy.
- CANEUS will sponsor regularly scheduled technical and programmatic conferences to enhance the knowledge base of the stake holders by rapidly highlighting new and exciting technical developments in the field, making participants aware of success stories as well as lessons learned from failures.

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5. Activities of CANEUS Organization

5.4 Identify & Address International Issues

- CANEUS will actively strive to keep the appropriate international governmental agencies engaged in the enterprise.
- These activities are expected to help establish uniformity in R&D and integration of MNT into aerospace applications amongst different regions

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5. Activities of CANEUS Organization

5.5 Furthering MNT Education Worldwide

CANEUS has an important role to play in furthering MNT education worldwide, not only to keep the existing skill set at the cutting edge but also for the development of a well-trained future workforce.

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5. Activities of CANEUS Organization

5.6 Publications

CANEUS publications would include electronic and printed newsletters, scholarly journals, professional text books, educational materials, technical reports as well as Conference / workshop proceedings.

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5. Activities of CANEUS Organization

5.7 Time Frame:

Activities	2003	2004	2005	2006	2007
Working Group	START	FINISH			
Implementation Phase		START			
Pilot Programs		START		FINISH	
Expanded Scope				START	

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5. Activities of CANEUS Organization

5.7 Projected Budget:

Activities	2003	2004	2005	2006	2007
Working Group	300K EURO	300K EURO			
Implementation Phase					
Pilot Programs		15M EURO	15M EURO	15M EURO	
Expanded Scope				200M EURO	400M EURO

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6. CANEUS Organizational Structure

6.1 LOI / MOU - Regions

Regions:

America: Canada, USA, Brazil

Europe: EC / ESA, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, UK

Asia: Japan

International Federations: IAF / IAA, COPUOS (U.N)

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6. CANEUS Organizational Structure

6.2 Proposed Structure

- 1. Board of Directors**
Members acting for effective functioning and growth of the CANEUS organization from Canada, Europe, US, and Japan
- 2. Board of Governors**
Members representing stakeholders and project partners
- 3. Advisory Board**
Members of participating organization representing MNT developers & end-users
- 4. Scientific / Technical Committees**
Working groups for each priority issues

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6. CANEUS Organizational Structure

CANEUS Organization Founders (based in Montreal, Canada)

- 1. Milind Pimprikar**,
Centre for Large Space Structures and Systems (CLS3)
Montreal, Canada
- 2. Thomas George**
NASA - JPL

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7. Invitation and Thoughts

7.1 Invitation

Two Step Process:

- 1. Letter of Intent**
- 2. Memorandum of Understanding -MOU**

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7. Invitation and Thoughts

7.2 Thoughts and Contacts

- 1. Thoughts for Discussion**
Input is welcome

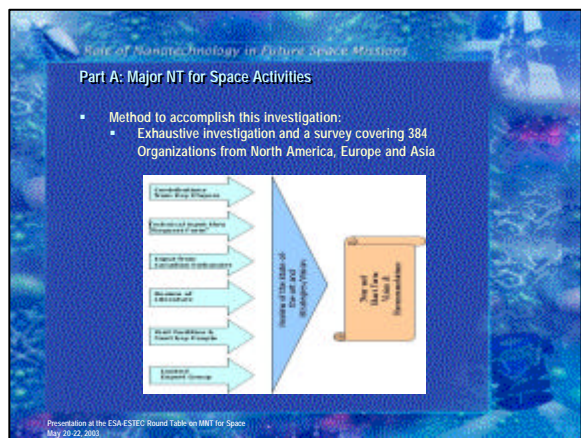
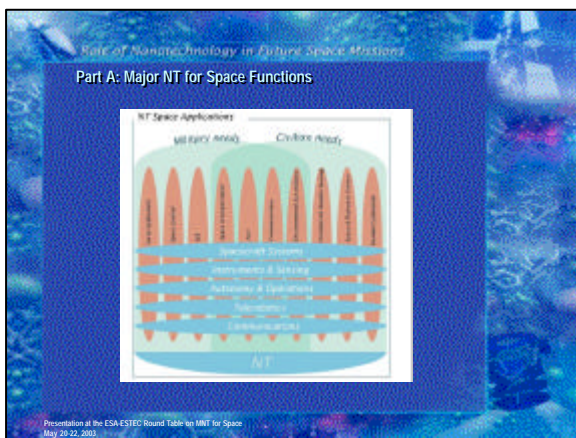
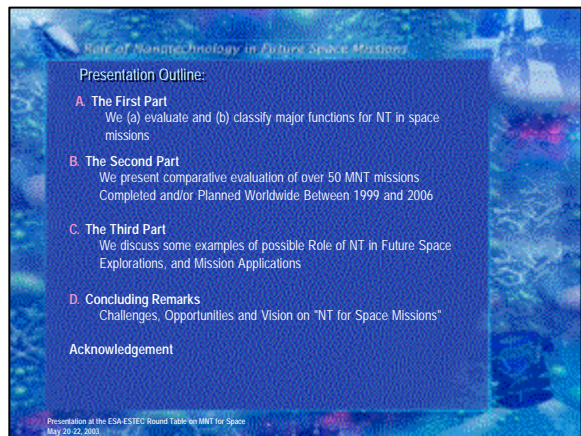
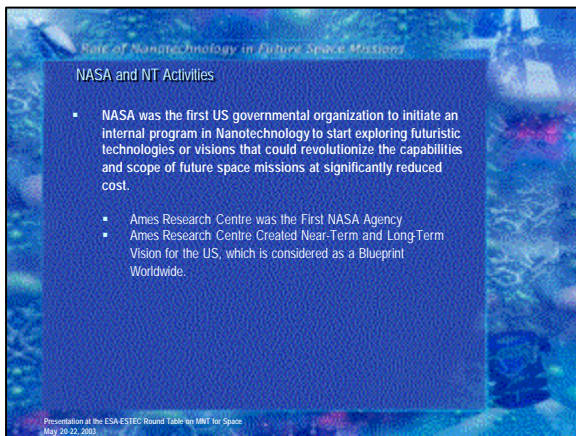
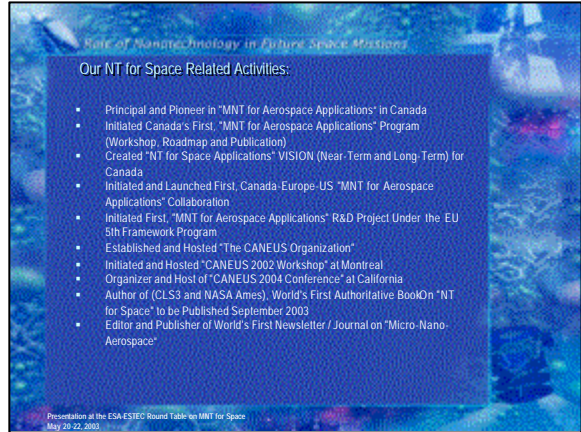
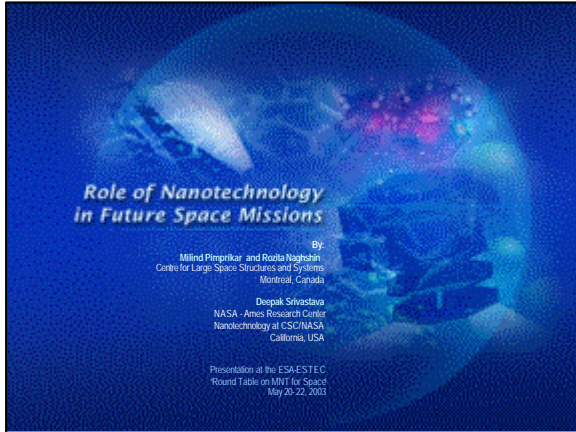
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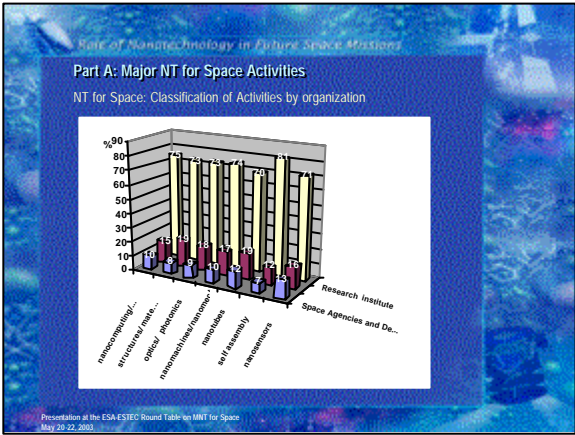
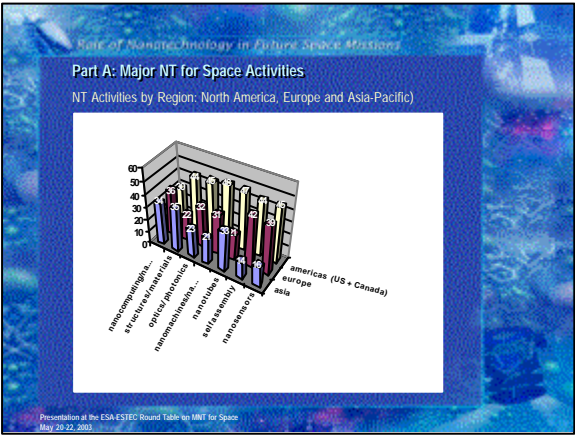
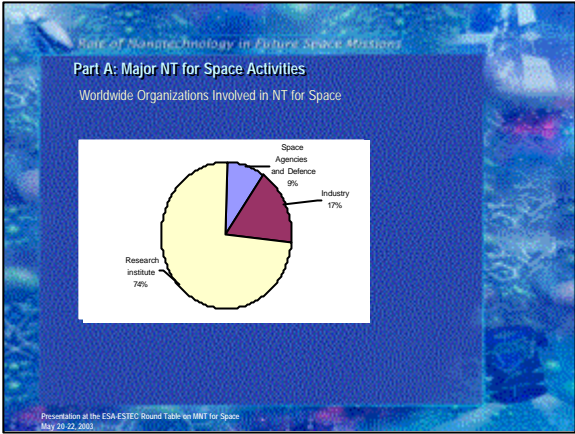
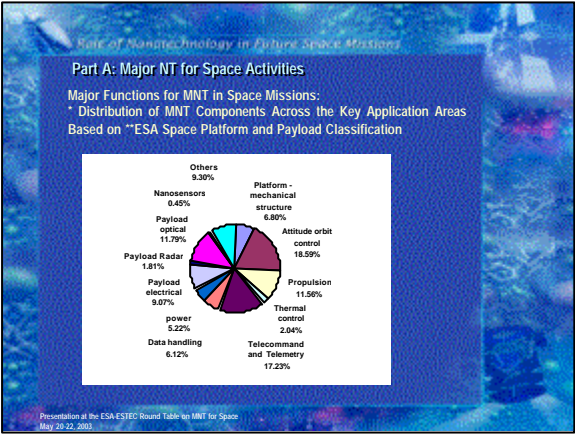
7. Invitation and Thoughts

7.2 Thoughts and Contacts

- 2. Contact:**
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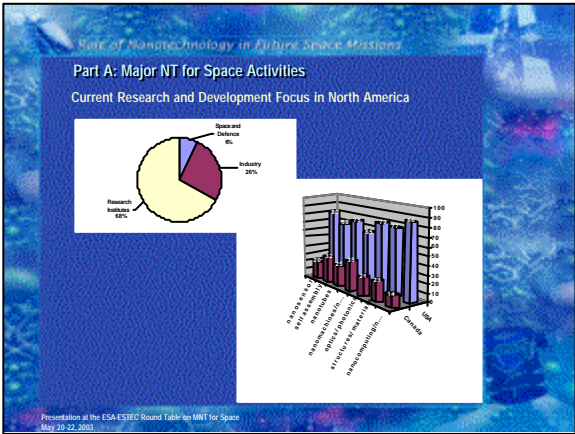


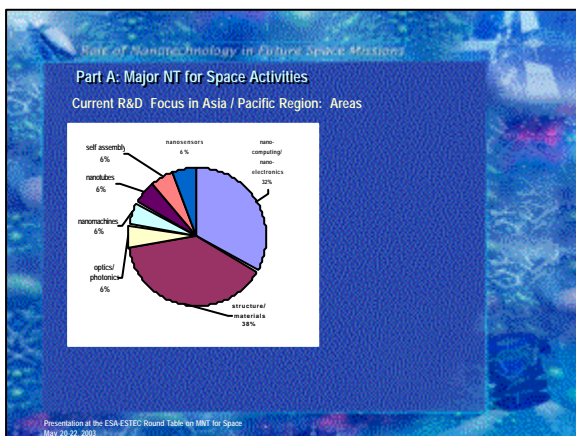
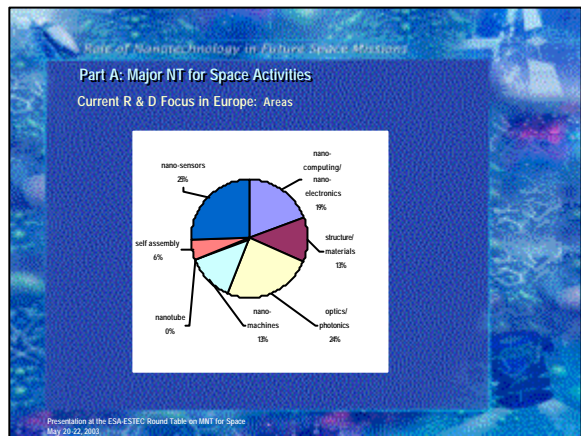
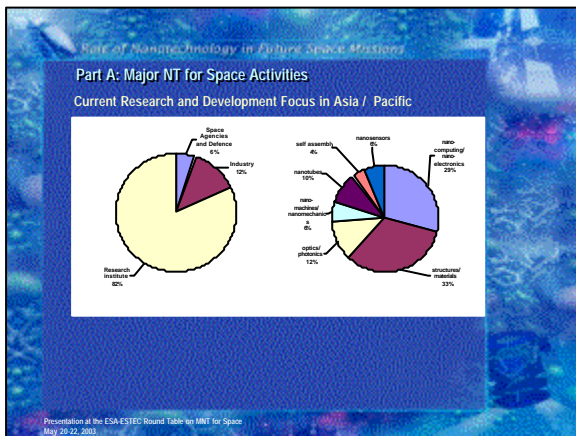
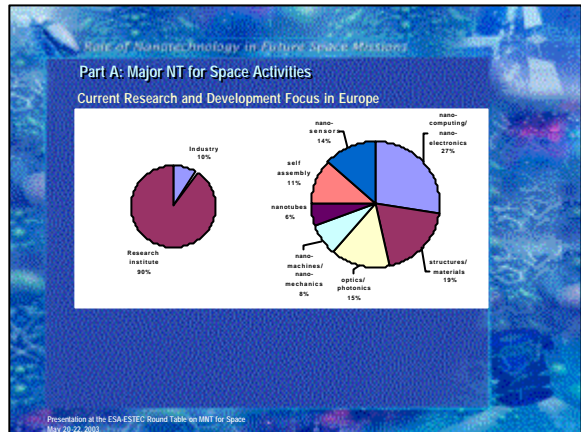
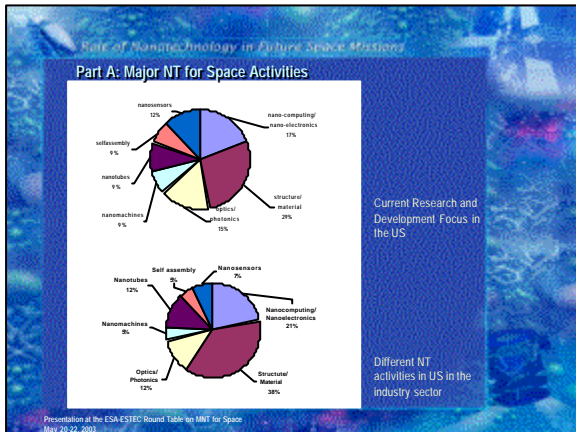


Rate of Nanotechnology in Future Space Missions

Mission - Function	Operation Requirements	Typical Concepts	Technology Utilization
1. Space Transportation 2. Transit 3. Injection/Correction 4. Descent 5. Landing 6. Ascent 7. Return	1. Long Duration - Years 2. Abort 3. Radiation/Micrometeorites 4. Zero Gravity 5. Logistics/Maintenance 6. CO2 7. Accommodations 8. Consumable	1. Trans-Habitat 2. Dual mode high impact/continuous Acceleration 3. Asteroid/Rotor 4. In-Situ Ascent Stage 5. Rotor and Chutes 6. micro-spacecraft Communication Networks and Rovers	NT are applicable but interplanetary space Qualified
2. Earth Orbital 3. Space Facilities 4. Earth Resources 5. Navigation 6. Surveillance 7. Communication	1. Long Duration - Years 2. Radiation/DEU 3. Zero Gravity 4. Space Debris 5. Survivability 6. Reconfiguration	1. Constellations 1.1 Spacecraft bus 1.2 Micro Satellites 1.3 Nano Satellites 2. Large Space Structures 2.1 Inflatable Modules 2.2 Inflated versus not inflated 2.4 Reconfigurable	NT are applicable
3. Earth-to Orbit 4. Ascent 5. Re-entry 6. Descent 7. Landing	1. Short Duration - Hours to Days 2. Availability - Hours 3. Turnaround Times - Hours to Days 4. Range and Abort	1. Reusable 1.1 Single Stage 1.2 Multi Stage 1.3 Rescue Vehicles 2. Expendable 2.1 Partial	NT are applicable
4. Planetary 5. Habitat 6. Laboratory 7. Factories 8. Mobility	1. Enormous 2. Resources 3. Ingress/Egress 4. Logistics/Maintenance 5. Mobile Communications 6. Land Transportation	1. Surface 1.1 Rigid 1.2 Erectable/Inflatable 2. Subsurface - Rigid 3. Delivered versus In-Situ/Resources	NT are applicable

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Rate of Nanotechnology in Future Space Missions

Part A: Major NT for Space Activities

Current Research and Development Focus in Asia / Pacific in Industry

	Government Policy	Industry Policy	Commercial Application	Highlights	NT R&D Funding (US\$M)
Japan	Nanoelectronic/Nanomaterials	NEC, Hitachi, NTT, Fujitsu, etc. Electronics	Prototypes of CNT-FED, SET memory Nanopowder	Molecular Motor, SET, CNT, Nanopowder	320
Korea	Nanoelectronics	samsung	CNT-FED	CNT-FED	40
china	Nanomaterials	samsung	Nanopowder	Nanopowder	13
Taiwan	Nanomaterials / Nanoelectronics			Nanoelectronics	15
Australia			Biosensor/Nanopowder	Biosensor/ Aligned CNT	12
Singapore				CNT for H ₂ storage	10

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Role of Nanotechnology in Future Space Missions


Part B: Comparative evaluation of MNT missions

Based on Review and Analysis of 50 MNT Based Missions Worldwide:
 Either Completed or Planned
 Between Year 1999 and 2006
 Some example of MNT Missions

Mission: Ionospheric Observation Nanosatellite

Organization: Utah State University - Washington University
 Virginia Tech - AFOSR - DARPA

Features: 4-8 CMOS cameras, Telemetry board, Cpu board, I/O board



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Role of Nanotechnology in Future Space Missions


Part B: Comparative evaluation of MNT missions

Some example of MNT Missions

Mission: XSS-10

Organization: AFRL

Features: MEMS based guidance and control components, Very lightweight reaction wheels, Infallible solar arrays, Pumped propulsion system with non-toxic fuels, Multi-optic sensor systems for range, altitude and rate information at different distances from space object



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Role of Nanotechnology in Future Space Missions


Part B: Comparative evaluation of MNT missions

Some example of MNT Missions

Mission: PICOSAT

Organization: DARPA

Features: Miniature reaction wheels ("torque tube"), Microthrusters (MEMS digital, MEMS cold gas), 3-axis MEMS gyro/MEMS accelerometer, MEMS MCM DC switching array, MEMS TIR switch

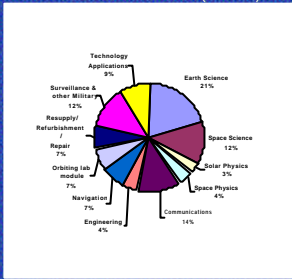


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Role of Nanotechnology in Future Space Missions

Part B: Comparative evaluation of MNT missions

Results of Investigation: Distribution of the MNT Applications Areas for Micro-Nano-Satellite Missions (1999-2006)



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Role of Nanotechnology in Future Space Missions

Part B: Comparative evaluation of MNT missions

Analysis of the Results:

Application Areas:

- Earth Sciences is the area, where the MNT Missions tend to be most interesting to the Scientific Community
- Communication Sector as well as Defense and Space Science for Mission Planners

Analysis of the Results:

Major MNT Functions in the Application Areas:

- Navigation (18.59%) is the dominant Field
- Telecommand and Telemetry (TT&C) (17.23%)
- Micropropulsion at 11.56%
- Nanosensors at 0.45%

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Role of Nanotechnology in Future Space Missions

Part C: Possible Role of NT in Future Space Explorations, and Mission Applications

- Earth Science
- Aeronautics and Space Transportation
- Space Science and Technology
- Human Exploration and Development of Space
- Astrobiology: Search for Signature of Living Systems in Space

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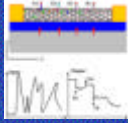
Role of Nanotechnology in Future Space Missions

Part C: Possible Role of NT in Future Space Explorations, and Mission Applications

A. Earth Science

Earth Science applications include, among other options, two very interesting possibilities.

- In a future nanotechnology it should be possible to build sensors in balloon borne systems approximately the size of bacteria; these systems are known as "smart dust".
- The Earth Observing System (EOS) uses satellites and other systems to gather data on the earth's environment. An extended EOS may need to process and archive more than one Terabyte data per day for the coming years.



Carbon nanotube chemical sensors—K. Cho, Stanford


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Role of Nanotechnology in Future Space Missions

Part C: Possible Role of NT in Future Space Explorations, and Mission Applications

B. Aeronautics and Space Transportation

- B.1 Nanocomposite Materials
- B.2 Nanotechnology enabled Avionics
- B.3 Active surfaces for aeronautics control
- B.4 Swarms or Utility Fog for Payload Handling
- B.5 Launch Vehicle Autonomous Maintenance
- B.6 Energy and Fuel Storage Systems
- B.7 Communication



Use of carbonnanotubes in many components for next generation of space craft: NASA Ames

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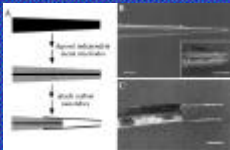
Role of Nanotechnology in Future Space Missions

Part C: Possible Role of NT in Future Space Explorations, and Mission Applications

C. Space Science and Technology

Much of the applications in this category have been described above in the context of developments in nanotechnology. Here we briefly enumerate them.

- C.1 Fuel, power and energy harvesting and storage
- C.2 Nano-Electromechanical Actuators and Sensors
- C.3 Thermal Protection



Nanowires made with Carbon nanotubes

C. Lieber, Harvard

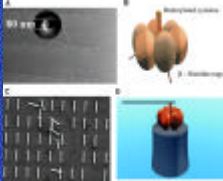
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Role of Nanotechnology in Future Space Missions

Part C: Possible Role of NT in Future Space Explorations, and Mission Applications

D. Human Exploration and Development of Space

- D.1 Health -Care for Astronauts
- D.2 Self-healing Structural Materials
- D.3 On Demand Spares and Tools
- D.4 Waste Recycling



Synthetic bio-molecular motor use bio-mimetic processing to convert bio-chemical energy into mechanical work.

C. Montemagno, UCLA

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Role of Nanotechnology in Future Space Missions

Part C: Possible Role of NT in Future Space Explorations, and Mission Applications

E. Astrobiology: Search for Signature of Living Systems in Space

The mission or scope of astrobiology is much broader than what has been defined in this study. However, discoveries in astrobiology, such as, extremophile proteins and bacteria, have started to fuel developments in nanotechnology materials and devices. For example, heat shock proteins, have initially been studied and discussed in the context of living under extreme conditions.

Transforming, or adjusting the environment on another planet to suit the requirements of human living conditions, is necessary for long-duration space exploration and settlement.




Hydrothermal Vents: chemicals And nutrients for bacterial growth. In extreme (volcanic) environments. Origin of life on earth.

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Role of Nanotechnology in Future Space Missions

Part D: Concluding Remarks

Potential Challenges and Opportunities Related to NT for Space Future Space Missions: Proposal by CANEUS Organization



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Role of Nanotechnology in Future Space Missions

Part D: Concluding Remarks

How to Achieve "NT for Space" Challenges and Opportunities: Proposal by CANEUS Organization

1. The first stage of implementation will be by working groups

Multiple working groups consisting of membership from CANEUS and participating MNT organizations will be commissioned to examine current and planned areas of MNT development for Aerospace applications. The end product of the working groups will be reports containing the following deliverables:

- Detailed descriptions of the current and future MNT investment portfolio within each member country.
- Development of a focused plan for development / investment into MNT for Aerospace applications. This investment is to be coordinated with the overall MNT development / investment by other CANEUS member organizations, and based on a roadmap for the rapid infusion of MNT technologies in Aerospace applications.
- Identify potential partnerships between the MNT organizations within CANEUS member states for bringing together complementary technologies for joint and efficient system development and mission.
- Recommend MNT program.
- Propose quantifiable metrics for evaluating the future development and efficient resource utilization.

Presentation at the ESA ESTEC Round Table on MNT for Space
May 20-22, 2003

Role of Nanotechnology in Future Space Missions

Part D: Concluding Remarks

How to Achieve "NT for Space" Challenges and Opportunities: Proposal by CANEUS Organization

2. Developing Coordinated Strategy

As participating members of the CANEUS organization will be intimately involved in the development of a joint roadmap for the rapid infusion of MNT in Aerospace applications. A step-by-step approach would be followed for the gradual implementation of this program. First, a "pilot program" is proposed for implementing the initial partnerships recommended by the Working Group. Lessons learned during the pilot program will be crucial for future efforts.

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3. Technical and Programmatic Conferences

The CANEUS organization has an important role to play in facilitating the coordinated MNT investment development strategy. CANEUS will convene regularly scheduled technical and programmatic conferences to enhance the knowledge base of the stakeholders by rapidly integrating new and existing technical developments.

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Role of Nanotechnology in Future Space Missions

Part D: Concluding Remarks

How to Achieve "NT for Space" Challenges and Opportunities: Proposal by CANEUS Organization

5. Furthering MNT Education Worldwide

CANEUS has an important role to play in furthering MNT education worldwide, not only to keep the existing workforce at the cutting edge, but also for the development of a well-trained future workforce.

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Role of Nanotechnology in Future Space Missions

Part D: Concluding Remarks

How to Achieve "NT for Space" Challenges and Opportunities: Proposal by CANEUS Organization

4. Publications

CANEUS publications would include electronic and printed newsletters, scholarly journals, professional text books, operational manuals, technical reports as well as Conference / workshop proceedings.

Presentation at the ESA ESTEC Round Table on MNT for Space
May 20-22, 2003

Role of Nanotechnology in Future Space Missions

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Thank you

Thoughts for Discussion :