

Prioritising the use of Nanomaterials in the Space Industry

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Britten Consulting Limited



Tuesday 14th September, 2010 - 7th ESA Round-table on MNT for Space Applications

The Consortium



- National Physical Laboratory (NPL)
 - The UK's National Measurement Institute, with over 100 years experience in materials metrology, more recently in nanomaterials
- Institute of Nanotechnology (IoN)
 - Established in 1997, one of the world's first independent nanotechnology information providers, and now a world leader.
- Britten Consulting Itd.
 - A small consultancy with extensive experience in the space industry

..... The Technology Push team

(the **Application Pull** team are up next)





Evaluate, Quantify, Prioritise and Roadmap nanomaterials for use in future space applications

This project explicitly excluded MEMS or NEMS or any other nano-related electronics

Stage One

- Review various nanomaterials groups and their properties (ISO TC 229 WG)
- Identify potential European suppliers for each nanomaterial group
- Produce a searchable supplier database



Nanomaterials Review

- Nanoceramics
- Nanocomposites
- Nanotubes
- Nanoparticles
- Nanoclays
- Fullerenes
- Nanofibres for reinforcement
- Electronic Nanowires
- Quantum dots
- Dendrimers
- Hard-metal nano-alloys

Nanomaterials	Database										
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National Physical Laboratory

Nanomaterials for space applications



- This task looked at the **specific requirements** of the space community
- What are the existing space materials problems?
- Can nanotechnology help?
- If so, where and how?
- How quantifiable are these improvements?
- A Round Table meeting was used
- To discuss and validate proposals with ESA engineers and scientists
- To educate the space industry on what can be expected from nanotechnology



Possible improvements





Near future

- Reduce Mass and improve strength (Structural Materials)
- Improved thermal protection systems (Thermal conductivity)
- Electromagnetic compatibility (Charging, Radiofrequency)
- Radiation Shielding
- Active Materials (Thermoelectrics)

Longer term

- Energy storage
- Coatings (barrier or re-enforcement)

These were used to define the activities in the **Nanomaterials Roadmap.....**

Roadmap development



Time-bound descriptions of specific activities to develop a technology that can improve properties for specific space applications



Activities Technology Improved properties **New applications**

Each activity has an attached General Activity Description (GAD) which defines the activity, the cost, and the duration involved

TRLs and Nano



- TRL 1 Basic principles observed and reported
- most nanomaterials-based technologies are currently at this stage
- TRL 5 Component and/or breadboard validation in relevant environment
- the predicted position for some nanotechnologies in 5 + years
- TRL 8 Actual system "Flight proven" through successful mission operations
- with appropriate R&D, nanomaterials-based technologies could be here in a 10-15 year horizon

WP 3: Nanotechnology Roadmap



- NPL O
- 5 year timescale
- 10 Action Areas
- 31 Individual Activities
 each detailed in a
 General Activities
 Description
- Aims to increase the TRL of nanomaterialsbased technologies

Nanomaterials Development Roadmap

Action	Technology Description	Priority	Present	2011		2012		2013		2014		2015		2016	
NANO 1	Polymer based nanocomposite for structural applications		TRL 2	TRL 2	TRL 2	TRL 2	TRL 3	TRL 3	TRL 4	TRL 4	TRL 4	TRL 4	TRL 5	TRL 5	TRL 5
1.1	Industrialise dispersion of carbon nanotubes in polymer matrix	1													
1.2	Improve strength and toughness CNT-CFRP materials	1										l			
13	Validation of a structural model for nanocomposites	2												1	
1.5	valuation of a structural model for handcomposites														
NANO 2	Ceramic nanocomposites for harsh environment		TRL 1	TRL 1	TRL 2	TRL 3	TRL 3	TRL 3	TRL 3	TRL 4	TRL 4				
2.1	Industrialise sintering techniques suitable for nanoceramic composites	1							-						
2.2	Improved toughness and wear resistance in nanoceramics composite	2				_	l				_				
2.3	Develop nanoceramics bonding on metal substrate	2]							
2.4	Characterize fracture mechanism in nanoceramics and delamination in ceramics coating	2			•				•						
NANO 3	Improved thermal insulation using nanomaterials	1	IRL 1	IRL 1	IRL 1	TRL 2	TRL 2	IRL 3	IRL 3	IRL 3	IRL 4	IRL 4	IRL 4	TRL 5	TRL 5
3.2	Design and produce nanocoatings for improved TPS	1													
NANO 4	Improved thermal transport in nanomaterials		TRL 1	TRL 1	TRL 1	TRL 2	TRL 2	TRL 3	TRL 3	TRL 3	TRL 4	TRL 4	TRL 4	TRL 5	TRL 5
4.1	Improved heat transport in carbon nanotubes / epoxy composites	1													
4.2	Develop anisotropic thermal transport materials	2													
NANO 5	Electro-conductive polymeric nanocomposite Demonstrate reduced ESD sensitivity in polymer		TRL 1	TRL 1	TRL 1	TRL 1	TRL 2	TRL 2	TRL 2	TRL 2	TRL 3	TRL 3	TRL 3	TRL 4	TRL 4
5.1	composite using nanofillers	2	-												
5.2	highly RF conducting CNT/CNF materials	2													
5.3	Conductive nanocoating for ESD mitigation on satellite housing	1	-												
	Nano-Thermoelectric materials for energy	3													
6.1	TE Materials Development activity	1						INLS						INL 3	
6.2	Characterisation of Efficient nanostructured thermoelectrics	1					1								
6.3	Prototyping Ultra-high efficiency thermoelectric generator	1													
NANO 7	Improve radiation / EM shielding using nanomaterials		TRL 1	TRL 1	TRL 1	TRL 2	TRL 2	TRL 2	TRL 3	TRL 3	TRL 4	TRL 4	TRL 5	TRL 5	TRL 5
7.1	Characterize space radiation effects on nanocoating	1	-										•		
7.2	nanocoating	2													T
NANO 8	Improve bonding properties of nanocoatings		TRL 1	TRL 1	TRL 1	TRL 2	TRL 2	TRL 2	TRL 3	TRL 3	TRL 4	TRL 4	TRL 5	TRL 5	TRL 5
8.1	Develop low friction surface coatings	2													
NANO 9	Improved energy storage		TRL 1	TRL 1	TRL 1	TRL 1	TRL 2	TRL 2	TRL 2	TRL 3	TRL 3	TRL 4	TRL 4	TRL 4	TRL 4
9.1	batteries	2													
9.2	nano-enhanced batteries	2	-												
9.3	based supercapacitor	3			1										1
NANO 10	Characterisation Techniques and fundamentals of nanomaterial		TRL N/A												
10.1	Characterization of buried interfaces Validated tools to measure transport across	2													
10.2	interfaces	3													
10.3	Couple theory/modelling and experiment System integration - Understand and bridge multiple	2													
10.4	length scales	1													
10.5	Test Thermal stress and characterise failure mode	1													
10.6	on nanomaterials	2													
110.7	Validated quality control methods for nanocoating	3	1	1		1		1		1		1			4

WP 3: Nanotechnology Roadmap



DURATION PRESENT **ACTION TECHNOLOGY DESCRIPTION** 2016 66 months TRI 2 TRL 5 NANO 1 Polymer based nanocomposite for structural applications NANO 2 54 months TRL 2 TRL 3 Ceramic nanocomposites for harsh environment NANO 3 48 months TRI 1 TRL 4 Improved thermal insulation using nanomaterials TRI 1 TRL 3 NANO 4 Improved thermal transport in 42 months nanomaterials TRL 1 TRL 3 54 months NANO 5 **Electro-conductive polymeric** nanocomposite 48 months TRL 1 TRL 4 NANO 6 Nano-Thermoelectric materials for energy generation TRL 4 NANO 7 TRL 1 48 months Improve radiation / EM shielding using nanomaterials NANO 8 18 months TRL 4 TRL 3 Improve bonding properties of nanocoatings NANO 9 48 months TRL 1 TRL 3 Improved energy storage TRI N/A **NANO 10 Characterisation Techniques and** 54 months TRL N/A fundamentals of nanomaterials

Examples: Nanocomposites



NANO 1: Polymer based nanocomposite for structural applications TRL 2 TRL 5

66 months

- 1.1: Industrialise dispersion of carbon nanotubes in polymer matrix
- 1.2: Improve strength and toughness of CNT-CFRP materials
- 1.3: Validation of a structural model for nanocomposites

.... Very active research area with support from industry (e.g. aviation and automotive)

NANO 4 Improved thermal transport in nanomaterials

42 months

TRL 1 TRL 3

- 4.1: Improved heat transport in carbon nanotubes / epoxy composites
- 4.2: Develop anisotropic thermal transport materials

.... Although improved thermal properties have been demonstrated, this has a much smaller research base

Thermal Nanomaterials



NANO 3 Improved thermal insulation using nanomaterials

48 months **TRL1 TRL4**

- 3.1: Develop thermal insulation nanomaterials
- 3.2: Design and produce nanocoatings for improved TPS

NANO 4 Improved thermal transport in nanomaterials

42 months **TRL1 TRL3**

•4.1: Improved heat transport in carbon nanotubes / epoxy composites

•4.2: Develop anisotropic thermal transport materials

Examples: Nanostructured materials



- Nanotechnology can improve existing properties mechanical, thermal and electrical
- It can also improve complex transport properties high efficiency thermoelectrics, photovoltaics, batteries...
- On the long-term, it may bring new functionalities, such as sensing or self-repairing properties

NANO 6 Nano-Thermoelectric materials for energy generation TRL 1 TRL 4

48 months

- 6.1: Thermoelectric Materials Development
- 6.2: Characterisation of efficient nanostructured thermoelectrics
- 6.3: Prototyping Efficient Thermoelectric Generator (TEG)

Qualification of Nanomaterials



NANO 10 Characterisation Techniques and fundamentals of nanomaterials 54 months - TRL N/A

 There are seven separate activities which come under the heading of "fundamentals of nanomaterials"

- Each of these activities will provide tools to design, develop and validate emerging nanomaterials
- These tools are key to good engineering and are currently missing

These will not further the TRL of the nanomaterials technologies, but are **vital to ensure buy-in** from the space community

Conclusions



- Database: Europe is well-placed for nanomaterial production, with over 200 different types of "off the shelf" nanomaterials produced
- Potential improvement: Four key areas identified

Structural

Thermal

Electrical

Active Materials

- We have proposed an action plan to increase the TRL of nanomaterials for specific applications
- Some classes of nanostructured materials can be flight-qualified (TRL 7 – 8) on a 10 - 15 yr timescale, including
 - Nanocomposites for structural applications
 - Nano-thermoelectric materials (for energy)
 - Thermal nanomaterials (for insulation)
- Characterisation, metrology (validation) and design tools for must be developed

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