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THE BENEFITS AND PROMISES OF NANOTECHNOLOGY TO THE AEROSPACE SYSTEMS

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Abstract:
Nanotechnology rivets the manipulation of matter at atomic level to deploy miniscule devices with better performance characteristics. The recent advancements in nanotechnology can have the ability to change the paradigm design of future aerospace systems and it is witnessed for the tremendous growth in the field of aerospace systems due to its desirable material properties such as high tensile strength, light weight, high thermal conductivity and multifunctional structures. These advancements in nanotechnology can improve the efficiency, performance, safety, damage tolerance and environmental durability of the aerospace systems by reducing the vehicle mass, power consumption and launch costs. Hence in this paper an attempt has been made to discuss the benefits and promises of nanotechnology to the aerospace systems.

Keywords:
Nanotechnology, Nanomaterials, Nanosensors, Multifunctional Structures, Aerospace Systems.

1. Introduction
In the past two decades, the advancement in nanotechnology playing a significant role in the field of aircraft, spacecraft, satellites, planetary rovers, due to its light weight, small in size (devices are ranging from 1 nm to 100 nm) and multistructured functions. The aerospace system incorporates electrical, Heating, Ventilation, and Air Conditioning (HVAC), Computer, and Control Systems in a Mobile Volume of fixed size which demands the technology that offers improvement in the efficiency, performance, safety, damage tolerance and environmental durability by reducing the vehicle mass and power consumption. Nanotechnology is one such technology in which nanomaterials can also provide corrosion, weathering, and thermal resistance that allows the aerospace products to function in a variety of environments while maintaining required lifespan [1]. In aerospace systems, the nanotechnologies are used in the areas of weaponry, protection and communication. Nanotechnology can be used to produce military devices, structures, and materials with smaller, lighter, smarter, stronger, cheaper, cleaner and more precise. Also, it can be used in military systems to minimize weaponry or used as weaponry like micro fusion missiles, thus increasing the efficiency of military weaponry and reducing production and transportation costs [2]. In the area of protection, it can be used to produce body armors with light, thin, solid and strong enough to resist the impact of a high speed bullet.
In aerospace systems the nanotechnology is used in the areas of advanced materials for coatings, including thin film optical coatings, light weight, strong armor and missile structural components, embedded computing, and smart structures, nanoparticles for explosives, warheads, turbine engine systems and propellants to enhance missile propulsion, nanosensors for autonomous chemical detection and nanotube arrays for fuel storage and power generation [3]. Further, in the area of communications the focus is on less bulky communication devices that are able to be inserted in the ear and permits the soldier to hear sound on the battlefield. [4]. Hence in this paper, the attempt has been made to discuss the benefits and promises of nanotechnology to the aerospace systems. The rest of the paper is organized as follows. Section 2 explains the benefits of Nanotechnology to the

Aerospace Systems. Section 3 gives a brief insight of promises of nanotechnology to the Aerospace Systems and Section 4 Concludes the paper.

2. Benefits of Nanotechnology to the Aerospace Systems

The space environment and extreme costs of space missions place new demands on materials and electronics used in aerospace systems. This led the researchers and scientists to identify new material and electronic devices which can operate under extreme radiation and temperature swings with reduced payloads. The lightweight and high strength properties of nanomaterials and fast operating speeds of nanoelectronics are currently being examined to support aerospace applications. The mechanical and electronic properties, electrical and thermal conductivity of nanostructured materials can enable the development of lightweight, multifunctional structures which revolutionize the design of future aerospace systems. Thus, the nanotechnology has broad impact on aerospace system for robust fault tolerant electronics, high sensitivity, low power sensors for planetary exploration and high thrust propellants [5].

2.1 Reduced Vehicle Mass

The replacement of conventional aerospace materials with advanced composites derived from durable nanoporous matrixes and low density high strength and stiffness fibers can reduce aircraft and spacecraft component weight by one third. Additional weight savings can be realized by replacing heavy copper wiring, which accounts for 4000 lb of weight on a Boeing 747 and about one third of the weight of large satellites with low density carbon nanotube wiring cables. Further, the use of structural aerogel insulation in place of Multi Layer Insulation (MLI) for cryotanks can eliminate the need for external foam insulation and associated parasitic weight and production costs.

2.2 Improved Functionality and Durability

Nanoelectronic devices based upon graphene, carbon nanotube, semiconductor nanowires, quantum dots /semiconductor nanocrystals and rods supports more radiation, fault tolerant and higher speeds than conventional CMOS electronics with lower power requirements. Integration of nanoelectronics and nanotechnology derived emission sources and detectors support to deploy more advanced spectrometers and imagers which are one to two orders of magnitude lighter than conventional instrumentation with twice the sensitivity and resolution and half the power requirements. Further, the quantum structure enhanced solar cells supports 50% more efficiencies.

2.3 Enhanced Power Generation and Storage and Propulsion

Nanotechnology affords the possibility of creating high surface area materials with inherently higher surface activities and reactivity that can significantly enhance the performance of batteries and fuel cells and improve the handling characteristics of propellants. Use of nanostructured metal fuel cells can increase their energy density by 50%. Use of nanoporous materials and nanocomposites could enable the development of new batteries that can operate over a wide temperature range from -100 to 100°C to provide surface power for rovers. Nanoscale metal based propellants could replace cryogenic propellants and hypergolics leading to simplified storage, transfer and handling and reduced launch pad and inspace operational requirements.

2.4 Improved Astronaut Health Management

Nanoporous materials with tailored pore size and shape and surface chemistries leads to the development of more efficient systems for the removal of carbon dioxide and other impurities from breathing air and organic and metallic impurities from drinking water. Distributed autonomous state and chemical species detectors might discover use in air and water quality monitoring systems and in astronaut health monitoring. Nanofluidics based devices enables the development of real time, minimally invasive medical diagnostic systems to monitor astronaut health and aid in diagnosing and treating illness. Electrospun nanofibers with demonstrated potential to support tissue engineering and regenerative medicine can expand and radically change astronaut health management methods. Boron nitride or carbide based nanocomposites might be used to rover structure, providing radiation shielding and Micro Meteoroid Object Damage (MMOD) protection.

3. Promises of Nanotechnology to the Aerospace Systems

The research efforts were started across a wide spectrum of basic materials and causes revolutions in Materials Science and have a massive impact in medical, defense, commercial, consumer and other applications [6]. The materials development and fabrication are being performed in the areas of Nanophase Metals & Ceramics, Nanostructured Polymers, Carbon Nanotube Systems, Structural Nanocomposites, Nanoenergetic Materials, Self-Assembled Materials, Hierarchically-structured Materials, Bio-inspired Materials, 3-D nanofabrication, etc., [7]. These developments enables the aerospace related technologies are [8]: Application Specific Integrated Microinstruments (ASIM), Micro Electro Mechanical Systems (MEMS) gyros, Accelerometers, and Vibration Sensors, Miniature inertial sensors, Miniaturized command and data handling systems and embedded processing systems, High energy density storage systems, Extremely low power RF/EO/ Analog and digital electronics, Unlimited processing, Self Healing Fault Tolerance and Learning Machines, Dynamically Reconfigurable Systems, etc to perform light weight and multistructured functions.

3.1 Development of Scalable Methods for the Controlled Synthesis and Stabilization of Nanopropellants

High surface area and reactivity nanoparticles coreactants or gelling agents can be used to develop alternatives to cryogenic fuels and hypergolics. Nanopropellants have the potential to be easier to handle and less toxic than conventional propellants, leading to simplified storage and transfer.

3.2 Development of Hierarchical Systems Integration Tools across Length Scales

High sensitivity and low power sensors (ppb to ppm level at μW - nW), high speed (hundreds of GHz) electronics and measurement enabling nanocomponents for miniature instruments are bound to interface with larger (micro, meso, and higher) systems to accomplish desired operation. System integration issues at that level can pose significant challenges and require the design of devices and processes that are suitable for both nano and microstructure fabrication schemes such as chemical, thermal, and mechanical issues, structural integration techniques that are mechanically and thermally robust and the development of efficient interconnects.

3.3 Development of Integrated Energy Generation, Scavenging and Harvesting Technologies

The use of quantum structures to enhance absorption of solar energy and carbon nanotube to improve charge transport and develop transparent electrodes will enable the development of flexible, radiation firm solar cells with greater than 50% efficiencies. Nanostructured electrode materials, self assembled polymer electrolytes and nanocomposites enable the development of new ultra capacitors to support 5 times energy density. Incorporation of flexible, conformal photovoltaic and improved efficiency, lightweight, flexible batteries into Extra Vehicular Activity (EVA) suits and habitats would lead to enhanced power and reduced mass.

3.4 Development of Nanostructured Materials 50% Lighter than Conventional Materials with Equivalent or Superior Properties

Carbon nanotube derived high strength and modulus, low density carbon fibers and lightweight, high strength and durability nanoporous polymers and hybrid materials enable the development of advanced composites which can reduce the weight of aircraft up to 30%.

3.5 Development of Graphene based Nanoelectronics

Graphene based nanoelectronics can enable the development of radiation hard, high speed devices, flexible electronic circuits and transparent electrical conductors that would find broad applications in exploration and aeronautics.

These advancement in nanotechnologies can provide facilities for aerospace systems are virtually unimaginable, some of the facilities that can expect in future aerospace systems are: 24×7 situational awareness on the ground, air and space, Multi-mission/survivable capability, Unlimited maneuverability in space, Hypersonic transportation, Unrefueled around the world air transportation, Voice/ Thought commanded flight control, Deep penetrating weapons, Sensor to weapon operations in real time, Miniature airspace vehicles for surveillance and other capabilities.

4. Conclusion

The aerospace industry has implemented the aerospace system using nanomaterials on a large scale to offers high technology protection and survivability capabilities with lightweight and more flexibility. The nanotechnology can have the potential to increase the efficiency and damage tolerance by reducing the production and transportation costs of the system. Also, the nanotechnology enables multifunctional materials, robust fault tolerant electronics, high sensitivity and low power sensors for better performance of the aerospace systems.

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