The National Science Foundation’s SBIR/STTR program provides seed money for startup and small business private ventures. For more information, please visit [http://www.nsf.gov/eng/iip/sbir](http://www.nsf.gov/eng/iip/sbir).

Please note that the topics and subtopics listed here are examples only and are NOT exhaustive. NSF SBIR/STTR encourages proposals in all areas of science and engineering. An exact fit into one of these topics or subtopics is not required!
Smart Health (SH) and Biomedical (BM) Technologies

**Smart Health (SH)**

The need for a significant healthcare transformation has been recognized by numerous organizations, including the President's Council of Advisors on Science and Technology (PCAST), National Research Council (NRC), Institute of Medicine (IOM), Computing Community Consortium (CCC), the National Academy of Engineering and the Office of the National Coordinator for Health Information Technology (ONC). The Smart Health subtopics aim to support the early stage development of novel devices, components, systems, algorithms, networks, applications, or services that will enable the much needed transformation of healthcare from reactive, hospital-centered, and indemnity-based to proactive, person-centered, preventive, and cost-efficient. **The SH subtopics are not aimed at supporting clinical trials, the clinical validation of information technologies, or medical devices or studies performed primarily for regulatory purposes.** Limited studies with human subjects may be acceptable to the extent that they are performed in support of feasibility, proof-of-concept studies of early-stage technologies. **Proposals that request support for clinical studies will be deemed non-compliant with the SBIR/STTR solicitations.**


Proposed projects should include transformative business models that are enabled by novel technologies and are designed for the benefit of healthcare providers, consumers, patients and/or their caregivers. Such technology-driven business models will: reduce the cost of health care; facilitate the shift of public and private incentives toward patient-centric goals; empower patients and healthy individuals to participate in their own health and treatment, such as educating customers, accessing, and visualizing health data and knowledge; reduce the impact of socio-economic status, gender, and ethnicity in the participation of people in their own health treatment. Overall, these new business models are expected to improve health-related behaviors; improve patient-physician communication, patient engagement, and care coordination. Proposed projects must a) focus on the development of technology that enables such novel business model(s); and b) demonstrate the expected economic benefit of the novel business model in user-centered healthcare.

**SH2. Digital Health Information Infrastructure**

Proposed projects may include technologies that will enable: interoperable, distributed, federated, and scalable digital infrastructure; languages and tools for effective sharing and use of electronic health record data, data representation for such including semantic metadata, and networked applications that access such data; continuously extensible universal exchange language for current and future health and wellness data originating from diverse sources in multiple formats; data methods for controlling and maintaining data integrity, provenance, security, privacy, and reliability of original as well as aggregated data, providing trustworthy patient identification and authentication and access control protocols, and maintaining sensitivity to the legal, cultural, and ethical issues associated with universally accessible digital health data in the U.S.; or systems methods for measuring and optimizing operations to improve quality and productivity of healthcare delivery systems.

**SH3. From Data to Decisions**

Proposed projects may include methods and algorithms that: aggregate multi-scale clinical, biomedical, contextual, and environmental data about each patient (e.g., in EHRs, personal health records - PHR, etc.); enable unified and extensible metadata standards; serve as decision support tools to facilitate optimized patient-centered, evidence-based decisions; evaluate the safety, effectiveness, efficiency, and clinical outcomes of mobile health applications; integrate patient information with delivery systems performance
and economic models to support operations management decisions; support inferences based on individual or population health data, multiple sources of potentially conflicting information, while complying with applicable policies and preferences; enable the secondary use of health data to support the assisted and automated discovery of reliable knowledge from aggregated population health records and the predictive modeling and simulation of health and disease. Proposals are encouraged to integrate technological, behavioral, socio-economic, value-driven actions, ethical, and systemic factors that interfere with patients' collaboration in care teams, adherence to treatment, and wellness regimens.

**SH4. Interoperability of Medical Sensors, Devices and Robotics**

Proposed projects may include protocols and interface standards to enable interoperable, temporally synchronized, medical prosthetic and embedded devices and devices for the continuous capture, storage, and transmission of physiological state and environmental data; assistive technology systems and devices for improved health and healthcare that incorporate sensory inputs and computational intelligence ranging from internal and external sensors, wearable prosthetics, and cognitive orthotics to surgical-assist robots and social robots; sensors, analysis tools, and activators needed to assess and limit adverse environmental effects on health and wellbeing; simulation and modeling methods and software tools that aid in the design and evaluation of sophisticated medical devices and how they communicate to medical information systems in the clinic, home, and in and around the person.

**Biomedical Technologies (BM)**

The Biomedical Technologies subtopics aim to support the early stage development of novel products, processes, or services that will enable the delivery of high-quality, economically-efficient healthcare in the U.S. as well as globally. The BM subtopics are not aimed at supporting or conducting clinical trials, clinical efficacy or safety studies, the development pre-clinical or clinical-stage drug candidates or medical devices, or work performed primarily for regulatory purposes. Limited studies with human subjects may be acceptable to the extent that they are performed in support of feasibility, proof-of-concept studies of early-stage technologies. Proposals that request support for clinical studies will be deemed non-compliant with the SBIR/STTR solicitations.

**BM1. Pharmaceutical Manufacturing**

Proposed projects must include new processing or manufacturing devices, components, and systems that will improve the efficiency, competitiveness, and output of the nation's pharmaceutical manufacturing sector; that will reduce the cost, risk, and time-to-market of new pre-clinical and clinical-stage drugs and biological products; or that address major market opportunities in the developing world. Proposed projects may include transformative approaches and methods in manufacturing operations, project management, process development, process engineering, analytical development, or quality control and assurance. Proposals are strongly encouraged to address the net preservation and extension of natural resources, a reduction in the use or release of toxic or harmful constituents, the use of less extreme temperatures or conditions, or a reduction in the production of waste.

**BM2. Materials for Biomedical Applications**

Proposed projects may include biological materials, biomimetic, bioinspired, bioenabled materials and synthetic materials, all intended for biological, medical, veterinary, or healthcare applications. Examples of proposals may include (but are not limited to) the synthesis, purification, functionalization, characterization, development, validation, processing, scale up, and manufacturing of biomaterials. Novel polymeric materials, polymers, plastics, additives, sealants, elastomers, textiles, alloys, ceramic and composite biomaterials, improved implants; coatings for therapeutic applications; or nanomaterials.

**BM3. Tissue Engineering and Regenerative Medicine**

Proposed projects may include enabling engineering and manufacturing approaches, technologies and systems that will advance the research, development, quality control, and production of artificial tissues and their derivatives in scientific, therapeutic, or commercial applications. Proposed projects may also include novel methods or technologies to replace or regenerate damaged or diseased animal or human cells, tissues, or organs to restore or establish their normal function.
BM4. Biomedical Engineering
Proposed project should focus on using engineering approaches to develop transformative methods and technologies that will solve problems in medicine. Proposed projects may include devices and systems that provide new strategies for the prevention, diagnosis, and treatment of health conditions; advance end-of-life or palliative care; reduce drug counterfeiting; and enable new and more efficient risk-management methods to better address safety issues of drugs and medical devices; motion or structural biomechanic technologies for the improvement of human motion, and sensors, actuators, and intelligent systems for surgical robotics. Proposers are encouraged to form an interdisciplinary team that includes relevant engineering as well as biology/health-related expertise.

BM5. Noninvasive Imaging of Brain Function
Proposed projects may include novel, noninvasive technologies and instrumentation for imaging the structure and function of the in vivo human brain. Proposed projects should focus on developing engineering, multidisciplinary, or multi-modality noninvasive brain imaging tools that could overcome current limitations of existing techniques (such as, for example, constraints on subject motion during imaging, requirements for elaborate electromagnetic shielding from the environment, requirements for active cooling of imaging system sensors, and system resolution that is much coarser -millimeter to centimeter scale- than that required to detect activity corresponding to individual neuronal signaling). Projects may also be aimed at developing new data processing techniques or approaches to data interpretation. Technologies not aimed at brain imaging must be submitted under subtopic BM6.

BM6. Medical Imaging Technologies
Proposed projects may include (but are not limited to) novel or improved imaging technologies and/or imaging agents to advance the diagnosis and treatment of disease, and to improve prognosis. Technologies aimed at brain imaging should be submitted under subtopic BM5.

BM7. Diagnostic Assays and Platforms
Proposed projects should focus on transformational diagnostic technologies. Proposed projects may include (but are not limited to) non- or minimally-invasive disease diagnosis, detection and monitoring, software-based diagnostic methods, biomarker development, disease-specific assays, personalized medicine, flexible implantable devices, lab-on-a-chip technologies, and low-cost point-of-care testing for diseases.

BM8. Drug Delivery
Proposed projects may include novel, early-stage, and transformative platforms, chemical formulations, excipients, devices, or methodology for the delivery of drugs or biological products.
Biological Technologies (BT)

BT1. Agricultural and Food Safety Biotechnology
New approaches for meeting the world’s future nutritional needs. For Agricultural Biotechnology, target areas for improvement may include (but are not limited to) drought tolerance, improved nutritional value, enhanced disease resistance, and higher yield. Proposers should use biotechnology in their approach, and should give consideration to technologies that enhance biodiversity, produce less carbon dioxide, and use less water and fertilizer. For Food Safety, this may include handling, preparation, and storage of food in ways that prevent foodborne illness, as well as origins of food including the practices relating to food tracking, hygiene, additives, and certification systems.

BT2. Biosensors
Biosensors are sensors that contain a biologically-based sensing element. Proposed projects might include (but are not limited to) real-time sensors, microbial component-based sensors, sensors for monitoring fluxes of metabolites, nanobiotechnology-based sensors, biomedical sensors, and micro- or nanofluidic-based sensors. Application areas of interest may include (but are not limited to) toxicity testing, food safety, drug evaluation, environmental monitoring, and bio-prospecting. Other types of sensors should refer to the EI topic.

BT3. Life Sciences Research Tools
Developing novel technologies that will advance scientific research across the biological spectrum. This may include enabling technologies for drug discovery (high-throughput screening assays and platforms, and high-content screening assays and platforms; novel high-content screening technologies based on characterization of physical properties of cells are of high interest). Proposals should focus primarily on the development of innovative consumables, processes, and services where there is significant market opportunity.

In addition, we are interested in new tools for brain research, especially those that aid in addressing fundamental neurobiological questions about brain function, laying the groundwork for advancing treatments for nervous system disorders or traumatic brain injury, and for generating brain-inspired "smart" technologies to meet future societal needs.

BT4. Bioinstrumentation
The development of technology for novel or improved instrumentation primarily for biological research applications. In addition, this may include low cost instruments for science and engineering that are aimed at students or others in working in low resource settings.

BT5. Synthetic Biology and Metabolic Engineering
Using synthetic biology to engineer novel biologically-based (or inspired) functions that do not exist in nature. Proposed projects may include creating new manufacturing capability by designing microorganisms, plants, and cell-free systems for the production of novel chemicals and biomolecules. Applications may include (but are not limited to) health-care products, food ingredients, chemicals, and other biomaterials such as enzymes and bio-based polymers.

BT6. Fermentation and Cell Culture Technologies
Proposed projects might include (but are not limited to) novel or improved microbial fermentation or mammalian and plant cell culture technologies, bioreactors, processes, scale-up, development of expression platforms, and purification. This may include technology development for pilot and large scale manufacturing of biopharmaceutical and other products.

BT7. Computational Biology and Bioinformatics
Developing and applying computationally intensive techniques (e.g., pattern recognition data mining, machine learning algorithms, and visualization) and may include (but are not limited to) sequence alignment, gene finding, genome assembly, drug design, drug discovery, protein structure alignment, protein structure prediction, prediction of gene expression and protein-protein interactions, genome-wide association studies, and the modeling of evolution. Proposed projects might include the creation and
advancement of databases, algorithms, computational and statistical techniques, and theory to solve problems arising from the management and analysis of biological data.

**BT8. Advanced Biomanufacturing - New Topic!**
The aim of this new area is to standardize the processes for tissue-engineered regenerative medicine therapies to bring down costs and to make the manufacturing processes more reproducible, economical, efficient, and sustainable. This may include the development of manufacturing technology for tissue engineering, including the construction of whole human tissues and organs for drug screening and transplants, as well as cell-based and personalized therapies, or regenerative medicine, that use cells as part of patches and implants.

The aim of this program is to support the development of tools, reagents, and resources for emerging plant and animal model systems. These products are needed to expedite the identification of genes that control development, behavior, and physiology. Projects of interest include high throughput phenotyping, technologies and tools to enable the genetic manipulation of novel species, strategies for identifying causative genes, and the development of new functional assay systems.
Chemical and Environmental Technologies (CT)

The Chemical and Environmental Technologies (CT) topic covers a wide range of technology areas of current and emerging commercial significance pertaining to the broad chemical industry, the environment and related industrial sectors. Phase I proposals would typically be at the proof of concept/technical feasibility stage on new or novel technology concepts and innovations when submitting to this overall topic area. A proposal should present a clear value proposition, the market opportunity, a strategy for commercialization of the innovation, a business case for how the innovation could rapidly lead to revenue generation for the small business, a clear and detailed description of the technical innovation and the key technical challenges that need to be overcome with SBIR/STTR funding, and finally, a clearly defined research and development (R&D) program detailing tasks, timelines and success metrics for a Phase I R&D program. It is important that the proposed project involve novel, discontinuous, disruptive innovations and be built on a firm framework of sustainability involving chemistry and chemical engineering approaches. The project should focus on addressing clear commercial and societal needs, with strong potential to catalyze and accelerate U.S. job creation through scalable business growth.

CT1. Biobased Chemicals and Biochemical Processes
Relevant projects could involve novel chemical/biochemical/biotechnological/cell-free bioprocess technologies for the conversion of raw material sources to cost-competitive products that represent new products or represent sustainable alternatives to existing commercial industrial commodity, intermediate, specialty, fine chemicals and pharmaceuticals products made from non-renewable sources. Relevant proposals could involve new and novel biochemical routes to making any commodity, intermediate, specialty, fine, consumer chemicals, polymers, plastics, polymeric materials and composites with unique and novel properties and advanced functionality for any existing or new use. Technology proposed should also be built on sustainable, energy efficient, and waste minimization or waste elimination paradigms with scalable process technologies for the production of biobased chemicals and material products.

CT2. Chemicals, Polymers, Plastics and Derivatives
Projects may involve (but are not limited to) the development of inorganic and organic chemicals, novel polymeric materials; biobased polymers; biobioplastics; biosurfactants; coatings; sealants; elastomers; adhesives; composites; biopesticides and herbicides, insecticides; pharmaceuticals; fibers; self-healing barrier films improving environmental and/or corrosion protection and life; protective coatings with sensing functionality; multifunctional polymers and polymeric materials for any field of use; sustainable packaging materials for food and non-food applications; bioengineered polymers/plastics and biochemically produced chemicals, monomers, and polymers that lead to more sustainable, greener replacements to current products/materials. Projects may focus on novel approaches that possess superior cost and performance characteristics compared to an existing commercial technology/product; chemicals, polymeric, or plastic-based materials that show enhanced end-of-life biodegradability and superior recyclability. Projects of interest may seek to develop technologies that facilitate recycle and conversion of post-consumer waste, industrial, agricultural, and food waste, waste polymeric materials, plastics, etc., into cost-competitive products for commercial use.

CT3. Novel Catalysts and Processes
Proposals may involve the development of novel catalysts and catalyst materials aimed at new or existing applications that could have a disruptive, transformative commercial impact. Proposals may involve processes and technologies that chemically or biochemically (including catalytic/bio-catalytic approaches) produce products from renewable and abundant natural resources with substantially improved process, energy efficiency, reduced capital and operating costs, and reduced environmental impact compared to current approaches. Proposals may involve development of novel homogeneous and heterogeneous catalysts and biocatalysts, co-catalysts, promoters, and/or novel supports that are highly active, selective, and have longer lifetimes compared to the state-of-the-art. Proposals may seek to develop sustainable catalysts that are based on environmentally friendly and non-toxic materials, non-metallic, and earth-abundant elements; catalysts enabling the simplification of complex multistep chemistries into fewer steps and ideally a single step with high selectivity, productivity, and life.

CT4. Chemicals from Carbon Dioxide and Methane
Proposed approaches could include novel chemical/catalytic/biochemical/biotechnological routes to achieving the industrial scale conversion of carbon dioxide and/or methane to useful commercial products/materials. Proposals of interest could seek to develop and commercialize processes for efficient carbon dioxide capture and its conversion to cost-competitive chemicals and materials resulting in net carbon sequestration on a life cycle analysis. Proposals of interest could also include those with catalytic process technologies for the conversion of methane (from natural gas, landfills, wastewater treatment, etc.) to industrial chemicals; novel catalytic or biochemical/bio-catalytic process technologies to directly convert captured carbon dioxide to methanol through non syngas routes, as well as novel technologies to convert methane directly to methanol and hydrocarbons and cost competitive chemicals (through non syngas routes).

**CT5. Food Technology**
Proposals of interest could involve developing new production and manufacturing innovations in food processing and finished product production that focus on precision nutrition technologies to achieve enhanced nutrient bioavailability, bioefficacy and bioactivity, nutrient content, and quality and flavor in food products; food technology innovations involving novel process technology for sustainable production of new and existing food products; novel process designs, unit operations, separations, and purification approaches; upgrading food and agricultural waste to higher value products; process intensification innovations; technology for improved process monitoring and control, and sensing technologies for production quality and safety; innovations that conserve the food supply and lead to lower wastage in the supply chain from farm to consumer; sustainable packaging materials; intelligent/active/smart packaging for food safety and protection in the supply chain; real-time microbial contamination sensing and control, improvements in speed, reliability, and efficacy in the detection of contamination, adulteration, and chemical degradation; technologies to enhance process safety and sanitation; new materials and benign protective coatings for food processing, handling, and storage in industrial and domestic use; food ingredient traceability; real-time detection of chemical and microbiological hazards.

**CT6. Energy Efficiency, Capture, Storage and Use**
Proposed projects could include novel technology and approaches for the direct capture, conversion, storage, and use of any renewable energy sources such as wind, solar, solar-thermal, ocean, geothermal, bioenergy, etc.; and waste heat recovery. Projects may include novel technology that leads to substantial enhancement in energy storage capacity, energy use efficiency, smart energy management, thermal management, and insulation; superior energy recovery from waste streams compared to currently available technologies in any application, including (but not limited to) residential, commercial, and industrial applications. Technologies may include innovations in (but not limited to) combinations of mechanical, electrical, electrochemical, chemical/material, and biochemical approaches to improving energy efficiency in any commercially relevant application with potential for significant scalable societal impact. Innovations for existing or novel energy storage and conversion technologies (such as batteries, capacitors, supercapacitors, novel fuel cells/engines, etc.) are also relevant; nature-inspired processes for sustainable energy generation or capture; materials innovations in energy applications; lubrication/tribology innovations leading to enhancing energy efficiency; innovations in insulation materials; and off-grid portable energy generation and storage technologies that completely rely on renewable sources to allow supporting industrial energy needs in remote and underdeveloped economic regions. Proposals may also cover new or novel system level optimization/monitoring/control approaches to enhancing sustainability and energy usage and efficiency of any industrial process and manufacturing technologies.

**CT7. Energy Generation, Bioenergy, Renewable Fuel Technology**
Proposed projects might include new and novel methods to generate energy from (but not limited to) marine, plant, algal, biomass, and microbial bio-energy sources; microbial hydrogen production, delivery, and storage; novel fuel cell technologies; innovations in high-yielding biomass crops for energy and chemicals production that do not compete with food supply. Proposed projects might involve the development of new, commercially viable renewable fuel options with reduced environmental impact relative to existing fuels, including (but not limited to) drop-in replacements to petroleum-based transportation fuels.

**CT8. Separation Technology**
Relevant projects could involve any separation technology that enables and/or enhances the efficiency of separations in existing or new process technologies in any industrial application. Proposals may focus on facilitating particularly challenging separations resulting in economically significant improvements in selectivity, throughput, energy efficiency, capital/operating costs, and environmental impact. Application areas include (but are not limited to) air separations; separations for multi-component streams; multiphase streams; separation technologies in both inorganic and organic chemical applications; novel purification processes; materials that permit effective separations; recycle and recovery of higher value materials from
material waste; separations of toxics from waste; recycle and recovery of critical and strategic materials and metals; and plastics separation for recycle and reuse. Novel separation techniques as disruptive improvements to current established separation technologies are encouraged, including (but not limited to) organic/inorganic membranes materials, novel materials, and biologically mediated separations. Applications of the proposed technologies could belong in any industrial sector, including (but not limited to) drinking water and wastewater treatment; food, medical, pharmaceutical, chemicals, metals/mining, natural resource extraction, materials processing, waste recycling, and biochemical/biotechnological processes.

CT9. Resource and Water Conservation, Treatment and Reuse, Waste Minimization and Environmental Sustainability
Proposed projects may present novel process and product technologies for pollution prevention; technologies that dramatically reduce water usage in industrial and domestic/municipal use; technologies that lead to more efficient use of water as a resource; and technologies leading to substantial reduction or even elimination of industrial water usage by developing sustainable alternatives. Technologies proposed could involve improvements in the energy efficiency of water/wastewater treatment approaches; remove challenging pollutants from industrial and municipal wastewater that have a significant short term and/or long term environmental, ecological, and economic impact. Technologies proposed should be significant breakthroughs or enhancements relative to the current state of the art and seek to address current and emerging industrial/municipal and agricultural challenges with water conservation, use, recycle, and treatment. The proposed technology projects could span a broad spectrum of operational arenas including point of use, portable, off-grid, and fixed installations for domestic, municipal, industrial, and agricultural applications to enhance waste minimization, water and wastewater treatment, water resource recycle, reuse, and conservation. Projects of interest may seek to develop technologies that facilitate recycle and possibly recover valuable products from (but not limited to) reprocessing of waste from agricultural operations, food processing, post-consumer and industrial waste, municipal solid wastes; waste chemical, plastics, polymeric materials, plastics, etc.; recycle of precious metals, critical and strategic metals from industrial waste. Projects may include the development of technologies (smart sensors, novel process equipment, novel process technology designs, etc.) that facilitate more efficient operation of production processes and waste minimization in any aspect of commerce or industrial production/manufacturing operations.

CT10. Environmental Sensing, Environmental Pollution Control and Mitigation
Proposed projects may include methods to reduce human ecological and environmental impacts; microbial contamination sensing and control; the detection of toxic and hazardous compounds from the environment and from consumer products to enhance human/animal health and safety; pathogen and toxin diagnostics technologies; novel bioremediation technologies; air pollution monitoring, mitigation, and removal of gaseous pollutants and particulates; explosives detection; technologies that reduce and remove greenhouse gases by converting them to useful products; improvements in environmental compatibility and sustainability of manufacturing/production/processing operations; and novel barrier coatings to protect against environmental damage. Projects could involve real-time sensing; internet-enabled, distributed, and networked systems and smart devices/sensors/analyzers/detectors for local and remote environmental (soil, water and air) pollution/emissions monitoring, control and minimization; innovations that use big data and Internet of Things approaches for pollution tracking and monitoring; technologies that enhance safe monitoring of hazardous and toxic chemicals; innovations that provide superior end-of-life handling and disposal technologies of equipment/material, etc., that eliminate pollution, environmental, and public health impact would be relevant. New or novel sensors for chemical species and environmental factors in any and all applications for monitoring, measurement in (but not limited to) commercial, industrial, personal, and healthcare applications; printed, flexible, and organic sensors; portable sensors in wearable, personalized health, and medical applications and chemical sensors that are significant enablers of new or novel applications that are not effectively served with current technology options in areas including but not limited to safety, reliability, efficiency, and productivity.

CT11. Plant-Based Products and Sustainable Agricultural Innovations
Proposed projects may seek to develop novel technologies that allow for the more effective use of renewable forestry and agricultural feedstocks through biochemical, bioengineered, or green chemistry pathways for the production of plant and wood based industrial chemicals, cellulosic fibers, lignin-based materials, plastics from cellulose, packaging and building materials, coatings, sealants, elastomers, adhesives, etc. Crop protection technologies involving synthetic chemistry and biotechnology approaches; plant and agricultural biotechnology innovations that not only focus on productivity but also increase crop nutrient quality, bioavailability, nutrient content, storage stability, and shelf life; improved drought tolerance and resistance; precision agriculture innovations; crop, soil, environmental sensing, and monitoring technologies that
improve agricultural crop management and productivity, reduce carbon footprint, and enhance the sustainability of silviculture/agricultural practices.

**CT12. Chemical Production Efficiency and Productivity**
Proposals may seek to develop innovative process equipment and technology across all chemical and industrial manufacturing operations that lead to significant process simplification, intensification, enhanced efficiency, productivity enhancement, waste minimization or waste elimination, lower carbon footprint and greener, more sustainable processes; systems that lead to substantially improved energy efficiency and substantially improved transport characteristics in challenging heat transfer, mass transfer, mixing and reaction applications, including but not limited to systems involving multiple phases and complex rheology; novel unit operations, improved heat transfer and insulation technology; reaction technology and process design innovations in the production of (but not limited to) commercial chemicals, metals, materials, food, pharmaceutical, commodities, and finished products; novel micro reactors; process miniaturization, lab on a chip approaches; process automation systems that facilitate the safe conduct of complex and hazardous chemistry through novel system designs that include (but are not limited to) process simplification, capital efficiency, and retrofitting, leading to greener and more efficient process technology in new and existing manufacturing/production facilities. The effective use of big data and Internet of Things paradigms for enhancements in chemical process technology and manufacturing systems; improvements in managing the sustainability of industrial supply chains; dynamic production and supply chain optimization; smart systems that use process data from sensors for real-time and dynamic process optimization and control; enhancing process safety; process control; fault detection, tolerance, and mitigation; operational reliability and efficiency would be relevant to this topic.

**CT13. Sustainable Chemistry and Green Engineering Technology**
This topic seeks to broadly capture innovative technology development projects that are seeking to develop engineered products, technologies and system solutions involving green engineering and green chemistry approaches that may also involve cross-cutting and multidisciplinary approaches to addressing significant commercial and societal needs through technological solutions. Projects may propose innovations that enhance sustainability through any combination of reducing carbon footprint, energy intensity, natural resource use, pollution, toxicity, safety hazards, and environmental impact. Projects may include any breakthrough technology development that will result in new solutions to significant societal needs, or significantly enhancing or replacing existing commercial products/technologies/processes with greener, sustainable alternatives.

**CT14. Emerging Technologies and Applications**
Proposers are encouraged to submit SBIR/STTR proposals to this topic as a way to catalyze funding support in new emerging technology areas. This topic is intended to capture ideas that involve the applications of broad fields of chemistry, biochemistry, chemical engineering, and interdisciplinary science and engineering areas on emerging technology innovations and applications that may not have a clear fit within the named topics listed above.
Educational Technologies and Applications (EA)

Administrative Information

Submitted proposals for education applications should provide detailed descriptions of how the proposed application will work and provide examples of how users would interact with the application and how learning takes place. Projects that propose technologies or products similar to those in the marketplace or those similar to existing products and processes must make the case that the project has a strong innovative technical component. Projects that can be easily replicated by potential competitors such as curricula, tutorials, and generic content may not resonate with the review community and are not likely to be funded without sufficient technical innovation. Systems that simply combine known knowledge with existing technologies tend to lack innovation and are unlikely to be funded. NSF uses EA topic areas and keywords to help find reviewers familiar with your project's innovation and commercial potential to help provide you with an objective proposal review. When submitting a proposal to the EA Topic, also indicate the corresponding subtopic where the strongest case for the project's technical innovation can be made. For example, use EA1 for proposed projects that are in the area of "Pre K-12 Education" followed by appropriate keywords such as K-3, Grade 2, chemistry, robotics, etc.

Education Applications and Technology (EA) Topics

- EA1. Pre K-12 Education
- EA2. Global, Distance, and Higher Education
- EA3. Simulations and Gaming
- EA4. Entrepreneurial, Informal, and Maker Education
- EA5. Information Management, Assessment, and Adaptive Learning
- EA6. Computer Science and Engineering

The subtopics provide are listed to simply generate ideas for the types of projects NSF may fund. Any educational project with a strong innovative component that has a superior commercial potential will be seriously considered by NSF's SBIR/STTR program.

EA1. Pre-K - 12 Education

EA1 topics can include 1) technology transfer of innovative and sustainable products and services that leverage and commercialize the education research investments made to educational institutions by the National Science Foundation and other government agencies; 2) authentic and active learning approaches that are more student-centered in environments that are familiar to learners that provide solutions which address the needs of a variety of learners for pre K-12 students, 3) innovative delivery, applications, content, and curricula on STEM (science, technology, engineering, and math) that provides new or alternative forms of sharing and repurposing information, content, pedagogies, and experiences that are long-term and sustainable; 4) learning technologies that motivate and enhance the self-esteem and learning performance of students; 5) innovative applications that better enable classroom management, recordkeeping, and standards-aligned planning, and facilities management, 6) applications that ease the burden of the ever increasing roles and responsibilities that educators and enables them to more effectively use educational resources; 7) systems and tools that may better enable education leaders to implement change across institutional settings; 8) authoring systems and content generators that easily allow educators to create, distribute, and share new resources across multiple platforms; and 9) digital badges and other credentialing mechanisms that motivate students to achieve desired outcomes and aid teachers in professional development efforts.

EA2. Global, Distance, and Higher Education

EA 2 topics can include 1) innovative applications that use online learning, hybrid learning, crowdsourcing, collective intelligence, and collaborative models with new tools with the potential to deliver new and powerful educational opportunities in STEM disciplines; 2) learning environments that allow students to control and experiment with educational situations in relationship to their personal learning style to acquire...
knowledge anytime, anywhere; 3) technologies that enable innovative forms of educational collaboration across national boundaries and promotes international awareness, diversity, and understanding; 4) learning applications that provide for better decision making and informed judgments about problems and situations affecting global issues related to theory and education technology; 5) projects in which technology allows the tailoring of learning experiences to special needs and interests of groups or individuals or allows expanding formal education beyond classroom settings; 6) virtual and remote laboratories that enhance the physical science laboratory for use in global and distance learning to leverage time and availability of equipment that may otherwise be unavailable; and 7) personal learning environments that allow students to control their environment in relationship to their personal learning style in order to acquire knowledge with consideration of their mentor’s expectations.

**EA3. Simulations and Gaming Technologies**
EA3 topics can include 1) Science, Technology, Engineering, and Mathematics (STEM) related innovative educational gaming and simulation applications that enable engaging learning experiences, digital literacy, collaboration, problem solving, communications, critical thinking, and skill improvement; 2) single-player, small-groups, or massively multiplayer online gaming applications that foster cooperation and can include card, board, or digital games; 3) serious games, simulation based games, and entrepreneurial related games with substantial innovations that go beyond porting current knowledge, processes, and applications towards existing technologies and delivery platforms; 4) games that target the assessment of student knowledge while providing intrinsic motivation for student participation; 5) games that better enable entrepreneurs to learn and effectively compete in a global economy and to manage and control complex technical projects; 6) games that support immersive and experimental learning; 7) simulations and role-playing games where students can participate in providing creative solutions to difficult or complex situations; and 7) laboratory simulations that accurately reflect similar physical environments that may otherwise be costly, use precious resources, expose students to dangerous environments, or otherwise be unavailable for general student use.

**EA4. Entrepreneurial, Informal, and Maker Education**
EA4 topics can include 1) entrepreneurship education and training that integrates diverse topics as strategic planning, business model development, opportunity recognition, product design development and entry, intellectual property, project management, legal requirements, custom manufacturing, production scale-up, crowdsource funding, and business constraints in new and innovative ways for success in the contemporary global economy; 2) maker empowerment with education and innovative tools for citizens and institutions who create things such as entrepreneurs, scientists, engineers, inventors, researchers, educators, and students to dream, design, create, manufacture, and commercialize products and services or to provide life-long learning experiences; 3) educational tools and services that teach, promote, and develop creativity to foster and accelerate new innovations; 4) innovative techniques and systems that can increase the participation or demonstration in hands-on learning related to citizen science, engineering, technology, and entrepreneurship of technical products and services; 5) innovative tools to learn or judge the effectiveness and validity of external resources for research, product launch, and effective operations of technological and education related products and services; 6) devices and tools that enable expanded dimensional learning such as 3D modeling, 3D scanning, and both 3D and bio printing, laser and high tech cutters, computer aided design (CAD), as well as new materials and technologies for science, engineering, and technological learning environments; 7) applications that better enable informal and traditional learning or applications that help bridge formal and informal learning environments or effectively promote positive behavior changes; 8) tools that better enable cross-disciplinary collaboration in formal, informal, and makerspace education environments; 9) tools and platforms enhancing cultural awareness and the need to manage and direct innovation; 10) tools to better enable the scaling of technologies developed in the makerspace; and 11) innovative tools and systems that may better enable small companies in the education space to successfully market and distribute their products and services more efficiently.

**EA5. Information Management, Assessment, and Adaptive Learning**
EA5 topics can include 1) data-driven learning and assessment using new sources of data for a personalized learning experience and the assessment and measurement of performance, 2) learning analytics tools to process and analyze data streams to modify learning goals and strategies in real time; 3) adaptive learning environments combined with assessments that provide alternative paths of instruction; 4) big data, searching, data mining, data analysis, intelligent agents, knowledge modeling, user models, mobile tools, and decision support systems that improve the understanding of teaching and learning to improve student performance, retention, and transfer in environments that may include one-to-one, one-to-many, and many-to-many relationships; and 5) collecting, analyzing, sharing, and managing data that promotes learning or leads to designed learning environments; 6) tools that build real-time information from data-mining on complexity, diversity, and similar types of information to generate knowledge that can be used to
revise curricula and teaching; 7) cloud-based services and applications that support collaboration, file
storage, teacher and student productivity, data collection, data security, data privacy, and ubiquitous access
to information in secure environments in an educational setting; and 8) tools that leverage new information
management techniques to enable educational institutions to discern patterns in behavior, usage, and other
analytics to guide education efforts and facility operations.

**EA6. Computer Science and Engineering**

EA6 topics can include 1) education tools that benefit from objects having their own IP address or location
based services for new types of communications, assistive technologies, and new applications of benefit
primarily to education; 2) wearable information centers, power sources, flexible displays, jewelry, glasses,
output devices, and input tools that allow students to interface with computers and other devices in creative
new ways that help overcome natural and physical barriers to learning; 3) interoperable mobile learning
environments that enable students to access and connect to vast resources of knowledge wherever they
may be located through smart phones, tablets, wearable devices, or tools that have yet to be developed; 4)
virtual assistive technologies that may combine developments in engineering, computer science, and
biometrics that add substance to both formal and informal learning situations; 5) systems and applications
that address privacy concerns of educators and students including the safeguarding of personal data in a
connected education environment; 6) innovative tools to quickly automate and allow for rapid conversion of
educational media for easy archival and porting to multiple devices and formats; 7) innovations that allows
students and others to use technologies that may improve their performance, knowledge, expertise, and
provide for a rich educational experience; 8) content curation and distribution systems that provide just-in-
time resources for learners of any age; 9) sensors and systems that detect student engagement, frustration,
or boredom while providing real time feedback to both students and teachers; 10) systems and components
that could provide for enhanced capabilities and otherwise add to the infrastructure development and
increased connectivity of educational environments; 11) natural voice, video, and online learning tools that
humanize the online learning experience such as mimicking and detecting face-to-face experiences and
interactions to communicate more authentically in a global environment; and 12) gesture-based computing
applications, semantic analysis, and intuitive technology tools that enable individual and collaborative work
with multiple students interacting on content simultaneously.
Electronic Hardware, Robotics and Wireless Technologies (EW)

Sensors (SE)
Recent technological advancements in materials science and bioengineered systems have made inexpensive, powerful, and ubiquitous sensing a reality. Examples range from truly smart airframes and self-evaluating buildings and infrastructure for natural hazard mitigation to large-scale weather forecasting, self-organizing energy systems, and smart devices that self-assemble into networks leading to the first electronic nervous system that connects the Internet back to the physical world. New detection technologies that overcome barriers of time, scale, materials, and environment, and emphasize self-calibration, selectivity, and sensitivity are solicited. With the convergence of MEMS, wireless, wearables, and the Internet of Things, the sales of sensors in the U.S. alone are expected to climb to nearly $15 billion in 2016.

Wireless Technologies (WT)
Wireless has become the platform for many applications with direct impact on virtually every aspect of life, evolving well beyond mobile phones and PDAs to other devices, services, channels, and content. Microwave circuits afford wider frequency spectrum and very short antennae. With GaAs and SiGe, entire microwave transceivers can be inexpensively placed on a single chip. Modulation methods like spread-spectrum and orthogonal frequency-division multiplexing bring greater spectral efficiency and more bits/Hz of bandwidth, and lead to less susceptibility to noise, interference, and multi-path distortion. On-chip DSPs allow new signal-processing functions. RFID chips are providing improvements in warehousing, materials handling, and shipping operations, replacing bar-code labels in many areas.

WT1. Systems and Devices
Proposals that involve next generation wireless communication technologies requiring systems with high data rates, low cost, and that support a wide variety of applications and services, while maintaining full mobility, minimum latency, and long battery life are sought. Innovations that improve spectral efficiency on an instantaneous basis, such as mitigation of unwanted emissions, improvements in filter technology, interference cancellation, etc., and improvements on a system-wide basis, such as dynamic spectrum access, frequency re-use, and innovative millimeter wave and THz frequency devices and systems. Reconfigurable wireless platforms, such as cognitive radio, software-defined radio, novel hardware/software co-design, adaptive antennas, etc., to dynamically implement incentive mechanisms and spectrum policy, facilitate the coexistence of multiple dynamic spectrum access networks, and optimize network performance. Innovative solutions for systems may include medical devices, surveillance, and remote sensing. New technology that can result in improvements in spectrum efficiency and access will require new test and measurement solutions and standards and regulatory validation. In addition, measurements and metrics to establish existing and future levels of spectrum occupancy and efficiency will be required. New and novel measurement-based spectrum management techniques, including agent-based systems, policy-based spectrum management, and local and scalable spectrum management are welcome. Novel network radio architecture facilitating the interplay between network layers and enabling more network functionalities, e.g., network topology awareness, network coding, cross-layer optimization, and multiple-input-multiple-output (MIMO) are also welcome.

WT2. Spectrum Usage
Appropriate for this subtopic are spectral accounting techniques enabling equitable sharing; the development and enhancement of RFI detection and suppression techniques for use in RFI cancellation and filtering, matched filtering, and polarization-based algorithms and multiple antenna algorithms so that more spectrum can be shared with active services. Proposal involving advanced spectrum sensing techniques to quickly and accurately identify transmission opportunities over a very wide spectrum pool that may host a large number of different wireless services are sought. Security and privacy solutions in the context of spectrum sharing are also appropriate, in addition to mechanisms that can enforce the proper operation of dynamic spectrum access and are robust against malicious attacks. Coexistence with legacy systems, such as backwards and forward interoperability and compatibility will be important. A major challenge of moving to a new and more efficient spectrum-use model will be a lengthy and complex transition period that will allow for the co-existence of novel systems and regulations with the multitude of existing legacy systems and regulations. Special-purpose wireless systems may be difficult to accommodate within bold new spectrum-use models because of fundamental limitations on frequency agility due to basic operational
requirements, extreme sensitivity to interference, or potentially drastic consequences due to failure of a radio frequency (RF) link. Energy-efficient and robust spectrum sensing and allocation mechanisms and protocol support will be needed.

Energy and Power Management (EP)
In the power electronics realm, as CMOS chips go to finer lithography with each new generation, their multiplying transistors require lower voltages and higher currents. These trends have driven up power demands on printed circuit boards and placed constant pressure on power-supply and power-system developers to increase the efficiency and power or current density. At the same time, the trends toward lower voltages and higher currents have encouraged migration from centralized to distributed and portable power architectures.

EP1. Electronic Devices, Boards and Interfaces
Newer chips with lower supply-voltage requirements has greatly complicated power-system and power-supply design. Innovations in the areas of low-power device design and manufacturing as well as printed circuit and other boards that will operate at lower power and longer lifetimes are welcome.

EP2. Sustainable Energy Harvesting, Storage and Management - Device and System Level
Proposals are solicited in the areas of electronic systems for portable energy sources for mobile technologies and off-grid type applications, including new energy sources. Proposals in the areas of power management systems for energy scavenging/harvesting and compact energy conversion systems, conversion from renewable resources, interface devices between batteries and super-capacitors as well as smart power demand-response management systems are welcome. Proposals with ideas on nature-inspired processes for sustainable energy solutions and carbon storage, reducing the carbon and resource intensity of hydrocarbon extraction, energy conversion, and its uses are sought. Innovative projects may include new critical devices, components, and systems for energy harvesting and conversion from renewable resources (excluding solar technologies). Refer to PH topic for solar technologies.

EP3. Smart Grids and Infrastructure
Proposals that address innovations in new technologies that support smart infrastructures (such as materials, sensors, devices, and control systems) to ensure efficient and sustainable energy transmission, distribution, monitoring, and management are sought.

Innovations in the areas of (but not limited to) novel voltage conversion, micro-inverters and DC-DC voltage converters, and compact hi-voltage, hi-power systems, and wireless transmission of electricity are welcome. Proposals covering new energy sources for portable and mobile devices, smart power demand-response management systems (e.g. smart grids, buildings, and circuits), inverters, motors, compact nuclear fusion reactors, and generators for higher efficiency, smaller size and power factor corrections are encouraged.

Robotics and Human Assistive Technologies (RH)
Considerable progress will be made if robots possessed the high intelligence needed to cope with uncertainty, learn from experience, and work as a team. Robot designers are borrowing features from insect nervous systems, and engineers and computer scientists collaborate with biologists, neuroscientists, and psychologists to exploit new knowledge in the study of the brain and behavior. Some robots will help people do what they can't or would rather not do. Other robots will tackle complex projects by working as teams. Robots will help protect critical infrastructure and monitor the environment as mobile, intelligent sensors. High-performance processors, hardware to provide situational awareness, and improved artificial intelligence (AI) are enabling researchers to create lifelike robots with an entire gamut of facial expressions.

RH1. Learning, Intelligence and Motion
Proposals addressing robot intelligence and experiential learning, particularly those in the areas of high-performance processors/hardware to provide situational awareness, and improved artificial intelligence, are welcome. Innovations in voice, obstacle and image recognition, emotional response, eye-hand coordination, deep learning, neuromorphic computing, brain operating systems, human-robot interaction, mechanized intelligent analysis to promote self-knowledge, and face recognition technology are encouraged. Proposals describing projects that borrow features from other animal nervous systems and include biologists, neuroscientists, and/or psychologists in their team in order to exploit new knowledge in the study of the brain and behavior are encouraged.

RH2. Robotic Applications
Proposals involving robotics and intelligent machines having complex, human-like behavior for applications
such as the protection of critical infrastructure or the monitoring of the environment while using mobile technologies and sensors networks are sought. Innovations in areas such as improved time imaging, visualization, dexterity and manipulation, anthropomorphic robots, naturally inspired, biomimetic, neuro-mechanical robotics, haptic, real-time and bio-inspired feedback are also welcome. Other applications include (but are not limited to) precision agriculture, automated sewing of clothes and shoes or commercial drones, or teaching robots how to compensate for any damage to themselves so that, guided by an understanding of their physical selves, robots can adapt to all manner of injuries.

**RH3. Robotics in Agile Manufacturing**

Proposals that address next-generation automation, the flexible and rapid reconfiguration of assembly lines allowing mass customization, the use of advanced control, scheduling, modularization, and decentralization with agile, mobile robotic systems that can enable the cost-effective manufacture of small lot-size products are sought.

**RH4. Co-Robots**

Innovations in the development of co-robots, robots that work symbiotically (beside, in direct support, or cooperatively) with people (social robotics), to extend or augment human capacities are welcome. Proposals describing the next generation of robotic systems able to safely co-exist in close proximity to humans in the pursuit of mundane, dangerous, precise, or expensive tasks; for sensors and perception, actuators and control, intelligence, machine learning techniques, architectures, systems, human/robot interfaces, and other developments that either realize or help to realize co-robots in manufacturing, service, construction, exploration, and assistive applications are encouraged.

**RH5. Control and Architecture**

Proposals involving novel and advanced approaches to sensing, perception, and actuation in embedded and highly distributed systems; intelligent control architecture for robotic systems; the development of human-robot interfaces; communication and task sharing between humans and machines, and among machines; and self-diagnosing, self-repairing robots, are sought.

**RH6. Human Assistive Technologies and Bio-Robotics**

Proposals to support the physical and educational needs of individuals with disabilities - e.g. vision, hearing, cognitive, motor related - are sought. Robotic applications in healthcare (tele-robotics, robotic prosthesis, robot-assisted rehab, miniature robotics, high-throughput technologies - imaging, screening of drugs, surgical procedures) are appropriate. Medical devices that provide new capabilities to doctors including surgery; robotic exoskeletons to enhance human strength; personal robots with an emphasis on human-centered end use and interaction, increased autonomy; robots of augmentation are welcome. Proposals that address concepts for protecting human hands (in various extreme environmental conditions), and haptic, real-time and bio-inspired feedback concepts and mechanisms are also sought.

**Micro-electronics Packaging, Thermal Management & Systems Integration (MT)**

Proposals are solicited on more efficient means of integrating semiconductor components and devices into systems. The growth in chip density, coupled with the demand for high performance, small size, light weight, and affordable reliability has placed enormous pressure on interconnect technology and packaging at all levels. Innovations include (but not limited to) improved techniques for interconnect and packaging at the board level, packaging approaches for the board components, the passive components, techniques for board assembly, and applications of techniques to packaging and systems integration for optoelectronics and wireless systems.
The Internet of Things (IoT) is a rapidly evolving field that involves the interconnection and interaction of smart objects (objects or devices with embedded sensors, onboard data processing capability, and a means of communication) to provide automated services that would otherwise not be possible. IoT is not a single technology, but rather involves the convergence of sensor, information, communication, and actuation technologies.

Today, most of what we consider as IoT is a variety of largely stand-alone devices and isolated systems, such as wearable fitness monitors, home thermostats and lighting, remote video streaming, smartphones, and smart watches. Emerging IoT implementations will use smaller and more energy-efficient embedded sensor technologies, enhanced communications, advanced data analytics, and more sophisticated actuators to collect and aggregate information and enable intelligent systems that understand context, track and manage complex interactions, and anticipate requirements.

IoT is expected to become ubiquitous, with implementations in the smart home - management of energy use, control of appliances, monitoring of food and other consumables; consumer applications - health and fitness monitoring, condition diagnosis; manufacturing and industrial settings - supply chain management, robotic manufacturing, quality control, health and safety compliance; utility grids and other critical infrastructure - grid optimization, automated fault diagnosis, automated cyber security monitoring and response; and automotive/transportation - optimization for driving conditions, assessing driver alertness, collision/accident avoidance, managing vehicle health.

Proposals are encouraged that address key challenges across the full range of IoT applications.

IoT1. IoT Sensors and Actuators
IoT is on track to connect 50 billion "smart" things by 2020, and one trillion sensors soon after. This subtopic includes (but is not limited to) innovations in device and materials technology to enable new sensor functionality, further sensor miniaturization, improved sensor performance or more efficient energy use; actuator technologies to enable new IoT functionalities; and device packaging innovations that enable further sensor or actuator miniaturization and embedding in a greater range of smart objects and devices.

IoT2. IoT Energy and Power Systems
Many of the components that enable IoT will have to operate in severely power constrained network edge environments, requiring improvements in energy efficiency in simple, low-cost systems. In many cases, the devices will not have a consistent power supply, and local energy harvesting will therefore be required. This subtopic includes (but is not limited to) novel power management integrated circuits aimed at miniaturizing devices and increasing energy efficiency; power management systems for energy harvesting to enable mobile or remote IoT devices and systems; and smart power protocols for IoT devices. This subtopic can also include broader categories of energy-efficient technologies to enable mobile IoT applications, such as displays, power efficient IC’s, and innovative mobile battery solutions.

IoT3. IoT Communications
Enabling ubiquitous connectivity and the aggregation of IoT data presents key data processing and communications challenges as the industry tries to simplify and define how "smart" things interact. A wide variety of communication solutions, both wired and wireless, will likely emerge. This subtopic includes (but is not limited to) innovations that will substantially improve the underlying technical performance, or extend the functionality, of IoT communication systems. Particular emphasis is placed on low-power and data-efficient communications schemes, as these are required to enable IoT in resource-constrained environments. Examples of relevant technical fields include (but are not limited to): short range and long distance transmission technologies - optical, RF, microwave or ultrasonic; communication signal sources and detectors - optical (lasers, LEDs, photodetectors), RF, microwave or ultrasonic; and electronic or optoelectronic signal processing technologies to facilitate efficient low-power data transmission or reception.
**IoT4. IoT Integrated Systems**
Many of the benefits of IoT require the full integration of complex systems to enable developers to build innovative service delivery platforms. This subtopic includes (but is not limited to) new design and development platforms that facilitate widespread adoption of IoT; IoT systems with the flexibility to allow rapid development and deployment of new use cases and functionalities; and shared platforms designed for lean, power-constrained environments that enable the easy integration of sensors and actuators, communication technologies, and data processing to create new business models for IoT.

**IoT IT. Cloud, Big Data and Security and Privacy (see IT portfolio topics)**
Data is rapidly emerging as the most important currency driving IoT. Offloading computation to the cloud, providing overall system security, and guaranteeing the privacy of users remain key challenges in IoT. Companies developing innovations in these spaces should refer to the IT topics of this SBIR/STTR solicitation.
Introduction
Information technology is increasingly impacting almost every aspect of our lives, from communicating with friends and family to manufacturing of the products that we use, the efficient supply of food, the provision of healthcare services, and the performance of financial markets and our nation's economy.

The past decade has seen explosive growth in the generation of data and the creation of usable information from that data. This growth is expected to accelerate into the foreseeable future, fueled in part by the increasing interconnectedness of the products and services that we use.

This topic encourages the submission of proposals that present ground-breaking innovations in the generation, analysis, use, or protection of information, where such innovations offer the potential for substantial commercial returns and a positive impact on society and the world in which we live. The subtopics below provide specific examples of technologies and applications, although given the enormous range and diversity in the field of IT these examples are inevitably incomplete. Proposals are encouraged under any of the specific subtopics IT1 to IT12. Proposals that do not fit these subtopics can be submitted under the subtopic "IT13: Other".

IT1. Big Data; Advanced Data Analytics
This subtopic focuses on information technology innovations in the fields of big data and advanced data analytics. These fields cover a wide range of technical sub-specialties and applications, and the examples provided are indicative only.

Examples of relevant technical fields include (but are not limited to): predictive analytics; simulation; optimization; data visualization; network visualization; visual data analytics and optimization (image and video); data fusion and integration. Applications are many and varied - examples include (but are not limited to): predicting buying patterns and trends, insurance claims, mortality rates, tax fraud, traffic patterns and delays, equipment failure, election outcomes, criminal/terrorist activities, and the spread of disease; improving healthcare outcomes; optimization of equipment performance and maintenance scheduling; optimization of manufacturing processes; predicting and optimizing traffic flow (internet traffic, road traffic, etc.); internet search; business informatics; logistics management; supply chain management; visualization of utility networks; climate modelling; geographic information systems (GIS); crowdsourcing; detecting and preventing cyber-attacks.

IT2. Cloud Computing; High-Performance Computing
Cloud computing is characterized by the allocation of internet-based distributed computing resources on an as-needed basis across a shared platform. Multiple computing cores may be dedicated in parallel to achieve the required computing performance levels for a specific task. Similarly, high performance computing usually relies on the use of a large number of co-located or distributed cores running in parallel. To achieve the highest levels of performance, massively parallel supercomputers may employ many thousands of cores.

This subtopic focuses on innovations that result in substantial improvements to cloud computing or high performance computing platforms. These improvements may be in terms of computing power, energy management, network storage requirements, the use of hybrid clouds, latency, data integrity and availability, cost, or any other factor of importance in such platforms, and may result from software- or hardware-based innovations.

Examples of applications that typically require the levels of computing power available through cloud computing or high performance computers include (but are not limited to): stock market analysis and prediction; cryptanalysis; weather forecasting; fluid dynamic modelling, acoustic modelling and other computationally intensive engineering modelling; advanced speech processing; advanced video processing.

IT3. Cloud-based IT Services
This subtopic focuses on innovations that enable the provision of new or improved cloud-based IT services
to address issues of commercial and societal importance. Such services may be directed primarily to businesses or consumers. Examples include (but are not limited to): processing of medical data such as X-ray, ultrasound, MRI or CT scans; business data analytics; sentiment analysis; analysis of financial documents; customized alerts regarding news events or stock market announcements; translation services; document indexing and retrieval; computing services; location-based services; retail recommendations.

**IT4. Artificial Intelligence; Machine Learning; Natural Language Processing**

This subtopic focuses on information technology innovations in the field of artificial intelligence (AI), which refers to intelligence exhibited by machines or software. AI is usually limited or targeted in nature, with general machine-based intelligence remaining an elusive long-term goal.

There are many technical approaches to AI, and an even greater diversity of potential applications. Current fields of use include (but are not limited to): intrusion detection -- in software systems, communications networks, and sensor systems; the finance industry -- optimizing operations and stock investments; medicine -- clinical decision support, computer-aided interpretation of medical images; industry -- robotics and automation, process management, quality control; machine vision; cyber-physical control systems; improvements in human-computer interaction; automated assistants e.g. for online/telephone customer service.

This subtopic includes a particular focus on machine learning and natural language processing (NLP), both of which are disciplines within the broader field of artificial intelligence. Machine learning refers to processes in which an automated system can learn from data, rather than following a pre-specified set of rules, and in many cases can predict outcomes relating to the learned process. The aim of NLP is to extract information or derive meaning from human language (written or spoken) or to generate human language.

Examples of relevant technical fields within machine learning include (but are not limited to): supervised machine learning; semi-supervised machine learning; unsupervised machine learning; neural networks; machine learning algorithms -- e.g., decision tree learning; robot learning; pattern recognition; image recognition. Examples of technical fields within NLP include (but are not limited to): parsing; named entity recognition; data extraction from text; sentiment analysis; natural language understanding; natural language generation; automatic summarization; language translation; analysis of structured or unstructured text; speech recognition; speech analysis; speech processing.

Applications across both technical fields include (but are not limited to): automated manufacturing; self-driving cars; analysis of online commentary; stock market analysis; healthcare -- analysis of structured and unstructured medical records, diagnosis support; document classification, indexing and retrieval; deduplication of stored data; customer recommendation systems; personalization of customer services; stock market analysis; search engines; fraud detection; translation services (including speech-to-speech translation).

**IT5. Image and Video**

This subtopic focuses on information technology innovations that enhance the acquisition, processing, interpretation and use of images or video. This includes both innovations in human perception and use of images or video, and innovations in machine vision (e.g., improved algorithms or hardware). The terms "image" and "video" should be interpreted in their broadest sense -- image or video simply refers to static or time-varying data (respectively) that are representative of certain properties of the subject and that may be acquired optically or via ultrasound, X-ray, MRI, PET, or any other observational measurement technique.

Applications are many and varied, ranging from cell-phone based 3D modeling to medical image processing for improved diagnostic accuracy and enhancements for robotic manufacturing systems. Deployment platforms may range from mobile devices (cell phones and tablets) to industrial settings (manufacturing plants).

Examples of relevant technical fields include (but are not limited to): automated image/video indexing and retrieval; object recognition; facial recognition; recognition of human actions and behavior (e.g., in video surveillance applications); automated video categorization; video summarization; generation and manipulation of 3D models; image/video enhancement; image/video feature extraction and identification; pattern recognition.

Many innovations in image and video processing rely on underlying methods developed more broadly in the
field of artificial intelligence. Innovations employing artificial intelligence technologies should be submitted to this subtopic if they are primarily aimed at image or video based applications.

**IT6. Cybersecurity; Authentication; Privacy**

This subtopic is intended to cover the major aspects of security related to the internet (except for Internet of Things cybersecurity, which is covered under subtopic IT7).

Cybersecurity refers to security applied both to the internet (including servers and connected devices) and to data stored in or transmitted over the internet. Generally this refers to security against malicious attacks rather than security against (for example) inadvertent data leakage. Cybersecurity is growing in importance due to a confluence of factors, including (i) increased use of the internet to monitor and control critical infrastructure, (ii) increased incidence of cyber-attacks against government and major institutions, (iii) the growing reliance by the general public on internet-based services.

Personal authentication and privacy refer to the reliable authentication of persons using the internet, and the protection of personal data and user information against compromise.

Examples of relevant technical fields include (but are not limited to): detection of cyber vulnerabilities -- particularly related to critical infrastructure and financial networks; detection and prevention of cyber-attacks; human factors analytics -- to assess people risk; mobile device security; device-cloud security infrastructure; cloud computing security; security/privacy policy compliance; security for BYOD (bring-your-own device) and BYOC (bring-your-own-cloud); big data security; data loss prevention; information assurance; data integrity; encryption; key generation, key management and key distribution; access authorization; identity management; personal authentication -- biometrics, multi-factor authentication.

**IT7. Cybersecurity for the Internet of Things**

The Internet of Things (IoT) is widely touted as the next wave of internet expansion, connecting embedded sensing and control electronics in everyday products ranging from cars to refrigerators, televisions, wearable electronics and other smart objects, as well as enabling new system visibility and control in industrial applications such as utility grids (the so-called “smart grid”) and improved healthcare through smart health applications (e.g., heart monitoring implants and implanted continuous glucose monitoring sensors). ABI Research estimates that the number of active connected devices will exceed 40 billion by 2020, more than double the estimated number in 2014, with roughly 75% of the growth coming from sensor nodes and other network-edge devices -- i.e., IoT devices. Each IoT device provides an access point to the internet and therefore also offers an opportunity for cyber-attack. Currently most IoT devices incorporate little or no security, which combined with their increasing ubiquity presents an alarming scenario for future internet security, particularly because IoT devices are expected to influence or even control many aspects of our lives.

Most IoT devices operate in resource constrained environments. Usually they are subject to severe energy usage limits, with low bandwidth (and sometimes sporadic) communications to the internet, limited computing power and little on-board data storage. These characteristics present unique operational challenges and also unique challenges in providing an effective defense against cyber-attacks.

This subtopic calls for innovative new approaches to providing cybersecurity for IoT systems. Proposed solutions should not be limited to conventional cybersecurity techniques -- the unconventional characteristics of IoT systems are likely to require new and unconventional cybersecurity methods. Proposing companies are encouraged to think outside the box.

Note: This subtopic is focused on cybersecurity innovations pertaining to IoT. Hardware innovations related to IoT should be submitted to the Internet of Things (I) topic.

**IT8. Human-Computer Interaction; Virtual Reality; Augmented Reality**

These three closely related fields encompass technologies that facilitate interactions among humans, computers and the external world and thereby enable many societally beneficial uses of information technology. The field of Human-Computer Interaction (HCI) is focused on improving the efficiency and effectiveness of human-computer interfaces through the development of novel software and hardware designs to recognize and interpret human characteristics and behavior. Improvements in HCI technology can lead to enhanced virtual reality (VR) and augmented reality (AR) experiences by providing more natural and
efficient ways for a user to interact with a real or virtual environment.

Technical sub-specialties within HCI are broad and varied, including (but not limited to): machine learning to anticipate and meet a user's needs; wearable devices -- smart watches, smart glasses, health trackers; speech recognition; voice control; gesture recognition (e.g., hand or eye tracking); behavior recognition; behavioral analytics; mood/emotion recognition; virtual assistants; visualization and display technology; tactile displays; haptics; biometric sensing; bioacoustic sensing; biosignal detection and processing.

Virtual Reality provides sensory input to a user that replicates being present in a real or imagined environment. Most commonly the sensory input is limited to sight and sound, but it can also include other senses such as touch. Augmented Reality, on the other hand, involves a live direct or indirect experience of an environment, overlaid with computer-generated sensory input usually in the form of graphics, video and/or sound. Possibly the best known application of AR is the yellow first-down line in televised football games.

Applications of VR and AR include (but are not limited to): education -- enhanced learning experiences; medical and healthcare -- treatments for PTSD, phantom pain, anxieties and phobias, autism in children; support for complex tasks such as surgery, equipment assembly, or maintenance and repair by adding relevant information to the field of view of the user; training for medical personnel, law enforcement, military, and emergency responders; architectural design -- experiencing a virtual building before it's built; engineering and design; telepresence -- for meetings and remote workers; market research -- experiencing a virtual product that doesn't yet exist; entertainment - cinema, music, and sports; tourism; product advertising and promotion; computer games.

**IT9. Networking Technology**

This subtopic focuses on information technology innovations that will enhance the performance, functionality and monitoring of information networks, with particular emphasis on the Internet and Internet of Things (IoT) networks.

Examples of relevant technical fields include (but are not limited to): software-defined infrastructure -- including software defined networking and software defined storage; software-defined data centers; analytics to optimize network performance; network visualization; network protocols; technologies to reduce network congestion and improve network resiliency; machine-to-machine networks; network-based data storage and retrieval technologies; anywhere/anytime access to data and services; agile networking; networking technologies specifically for sensor-dense but resource-constrained environments such as in IoT applications.

Note: This subtopic includes IT-based innovations pertaining to IoT networking technology. Hardware innovations related to IoT should be submitted to the Internet of Things (I) topic.

**IT10. Mobile Computing; Internet of Things**

This subtopic focuses on information technology innovations that will improve the performance or functionality of mobile devices and devices that operate in resource-constrained environments -- such as in Internet of Things (IoT) applications. While there is some overlap with other subtopics, proposals submitted to this subtopic should be focused on innovations specifically intended for these platforms.

Examples of relevant technical fields include (but are not limited to): location technology; image recognition and processing; video processing; speech recognition and generation; translation services; improved human to mobile device interfaces; gesture and expression recognition and processing; bio-signal processing; crowdsourced storage; crowdsourced processing; peer-to-peer device networking; device-cloud architecture; context-relevant analytics and services -- i.e., involving situational and environmental information; mobile commerce; data analytics and data processing to facilitate the Internet of Things; vehicle-based computing platforms.

Note: This subtopic includes IT-based innovations pertaining to IoT devices. Hardware innovations related to IoT should be submitted to the Internet of Things (I) topic.

**IT11. Social Media; Collaborative Networking**

This subtopic focuses on information technology innovations that will add value to social, professional,
business, or technical interactions over the internet.

Examples of relevant technical fields and applications include (but are not limited to): services based on crowdsourced information; collaborative healthcare; the sharing economy; professional networks; B2B networking; image and video centric networks; micro video; social media advertising and marketing; social networking tools; visual content optimization (image and video) for social media; video sharing.

**IT12. Software**

This subtopic focuses on information technology innovations that are embodied in software and provide important new or enhanced capabilities. Usually these capabilities will be generalized, rather than directed to a specific use case. Examples include (but are not limited to): enhanced computational speed or efficiency; new or improved functionality; improved or extended performance; increased ease of use and accessibility.

The range of possible innovations under this subtopic is too broad to attempt to describe here. Past examples of significant software innovations cover a wide range of technical approaches and resulting new capabilities, and include (but are obviously not limited to): Object-Oriented Programming; the GUI; HTTP; HTML; TCP/IP; SQL; internet search engine(s); the spreadsheet; word processing; MapReduce; virtualization.

**IT13. Other**

This general subtopic is intended to capture any information technology innovations that are not covered in the preceding subtopics and that have the potential to generate substantial commercial returns and lead to a positive societal impact.
Semiconductors (S) and Photonic (PH) Devices and Materials

**Photonics (PH)**
The Photonics topic addresses the research and development of new materials, devices, components, and systems that have the potential for revolutionary change in the optics and photonics industries. Proposals should be motivated by market opportunity, a compelling value proposition, clearly identified end users and customers of the proposed technology, and a viable pathway to commercialization.

**PH1. Lighting and Displays**
Subtopic includes (but is not limited to) solid state lighting and smart lighting systems and controls, energy efficient display technologies, light emitting diodes (inorganic or organic), display backplane technology, and transparent conductors.

**PH2. Communications, Information, and Data Storage**
Subtopic includes (but is not limited to) optical communication and networking infrastructure and components, photonic integrated circuits, new materials and systems for data storage, novel components for network applications, and multifunctional and other novel optical fibers implementations.

**PH3. Energy**
Subtopic includes (but is not limited to) photovoltaic materials and devices, systems for smart glass applications, breakthrough thermophotovoltaics, metamaterials, and materials and systems for solar thermal applications.

**PH4. Advanced Metrology and Sensors**
Subtopic includes (but is not limited to) sources and detectors for advanced IR systems, advanced remote sensing systems, sources and detectors for advanced microscopy, novel camera systems for 3D metrology, and advanced imaging systems.

**PH5. Advanced Optical Components and Systems**
Subtopic includes (but is not limited to) the building blocks for next generation optical components and systems, such as new photonic materials, breakthrough process technologies, nanophotonics, biophotonics, plasmonics, photonic integrated circuits, and manufacturing techniques to enable low-cost breakthroughs for advanced photonic components. Proposals in this area should take special care to clearly highlight real market opportunity and a compelling value proposition for the technology.

**Semiconductors (S)**
The Semiconductors topic addresses the research and development of new designs, materials, devices, and manufacturing systems that have the potential for impactful change in the semiconductor industry. Proposals should be motivated by market opportunity, a compelling value proposition, clearly identified end users and customers of the proposed technology, and a viable pathway to commercialization. The program encourages cooperation with the semiconductor industry to address current challenges as well as new frontiers.

**S1. Electronic Materials**
Subtopic includes (but is not limited to) novel semiconductor materials, magnetic materials, advanced thermal management materials for device integration, materials for advanced lithography, and materials for high-temperature, high-power, or high-frequency applications.

**S2. Electronic Devices**
Subtopic includes (but is not limited to) advanced semiconductor devices, bioelectronics and biomagnetics, quantum devices, magnetic and multiferrous and spintronics devices, memory devices, power electronics, flexible electronics, and nanoelectronic devices.
S3. Processing and Metrology Technology
Subtopic includes (but is not limited to) processing and metrology technologies that enable low cost, high performance or novel, advanced semiconductor devices.

S4. Integrated Circuit Design
Subtopic includes (but is not limited to) low power circuits and architecture, novel chip architectures, and the integration of nano- to micro-scale devices on circuits.
Advanced Materials and Instrumentation (MI)

Introduction
The Advanced Materials and Instrumentation (MI) topic addresses the development of new and improved materials and instruments for a wide variety of commercial and industrial applications. Proposals in Advanced Materials may focus on the creation of innovative material systems and/or on critical fabrication, processing, or manufacturing challenges involved in the successful commercialization of materials. Proposals in Instrumentation may focus on new instruments for use in scientific, industrial, engineering, or manufacturing environments, among others. Types of instruments that will be considered include systems and tools designed for the purposes of detection, characterization, measurement, processing, control, and/or monitoring. A wide variety of applications areas will be considered as part of this topic.

MI1. Metals and Ceramics
Material innovations to improve the performance of and/or allow new functions in metallic and ceramic materials. This topic includes bulk materials (e.g. superalloys, ceramics, and composites) and coatings (e.g. thermal and environmental barrier coatings, and tribological coatings), as well as other morphologies (e.g. foams). This subtopic also includes composites of metallic and ceramic materials (metal-matrix and ceramic-matrix composites).

MI2. Structural and Infrastructural Materials
Material and process innovations to improve the performance of materials in structural applications. Includes (but is not limited to) materials for civil infrastructure (e.g. cement, concrete, structural panels, etc.) and polymer composites for various applications. Structural materials that are metallic or ceramic should be submitted under topic MI1.

MI3. Coatings and Surface Modifications
Material and process innovations in surface modifications and coatings. Includes (but is not limited to) coatings for improved corrosion and wear resistance, anti-microbial and anti-fouling coatings, surface modifications for specialized applications such as superhydrophobic or biologically/chemically active surfaces, and techniques to improve manufacturability and reduce cost. Refer to the MI1 topic for proposals related to inorganic coatings.

MI4. Multiferroics and Specialized Functional Materials
Innovations related to multiferroics or other functional materials for specialized applications. Includes (but is not limited to) piezoelectrics, ferroelectrics, thermoelectrics, magnetostrictives, or electrochromics, shape memory alloys, ferrofluids, materials for high or low thermal conductivity applications, novel materials for active device or energy harvesting applications, functional thin films, and novel materials for sensing or instrumentation.

MI5. Materials for Sustainability
Material innovations designed for improved sustainability, mitigating adverse environmental impacts, and/or improved public health. Includes (but is not limited to) new processes and techniques that allow for new or increased use of recycled, renewable, non-toxic and/or environmentally-benign materials. Proposals are also encouraged for new innovations that reduce overall energy consumption or waste, or that increase recyclability or reusability at end-of-life.

MI6. Other Materials
New innovations in materials that do not fit into any of the above five materials topics but that nevertheless meet the intellectual merit and broader/commercial impact criteria of the NSF SBIR/STTR program.

MI7. Instrumentation for Characterization and Imaging
New innovations in instrumentation whose primary purpose is measurement, characterization, or imaging.
Includes (but is not limited to) optical and electron microscopy, scanning probe methods, magnetic imaging (NMR, MRI, etc.), spectroscopic and chemical methods, and other scientific instrumentation.

**MI8. Instrumentation for Detection, Actuation, Control, and Manipulation**
New innovations in instrumentation whose primary function is detection, control, or manipulation. Includes (but is not limited to) new instruments for use in industrial processes, manufacturing, research, engineering, military, and/or consumer applications.

**MI9. Other Instrumentation**
New innovations in instrumentation that do not fit into either of the above two instrumentation topics but that nevertheless meet the intellectual merit and broader/commercial impact criteria of the NSF SBIR/STTR program. Refer to the BT topic for bioinstrumentation.
Advanced Manufacturing & Nanotechnology (MN)

Advanced Manufacturing (M)
The Advanced Manufacturing (MN) subtopic aims to support all current and emerging aspects of manufacturing innovations that have the potential to rejuvenate the nation's manufacturing sector and also improve its efficiency, competitiveness, and sustainability. Proposals should be driven by societal/market needs and opportunities, and should identify both the end users of the proposed technology and the proposed pathway to commercialization. Proposals that are responsive to strong societal needs while meeting commercial sustainability thresholds are also encouraged.

M1. Personalized Manufacturing
Proposals centered on innovative, new-to-the-world manufacturing methods and machines leading to mass customization are invited. The applications may include (but are not limited to) clothing, footwear, furniture, ear buds, headbands, hearing aids etc. The resultant products may need to be cost competitive with the relevant mass manufactured products. Technologies focused on rapid and lower cost production of personalized biomedical implants, and human assistive products that support the unique needs of individuals with disabilities are also encouraged. Proposals may include development of software-as-a-service or workflow-as-a-service tools to assist young personalized manufacturing businesses.

M2. Maker Manufacturing
Makers represent a wellspring of innovation, creating new products and eventually manufacturing them. Proposals having roots in such activities, involving innovations in one or more stages of design, engineering, and manufacturing and having significant commercialization potential are solicited. Commercially sustainable ideas that seek to address significant local, national, or global societal problems (e.g., energy/water/resource conservation, youth unemployment), or enable spreading of citizen science through such innovations are especially encouraged.

M3. Additive Manufacturing
Innovations in processes or machines that permit manufacturing through a layering process, including 3D printing, to achieve fabrication of a range of products including near net shape products. Proposals by young companies to develop sustainable businesses based on 3D printing are especially encouraged. Proposals are also encouraged that permit the manufacturing of complex multi-scale and/or multi-functional products for superior performance and productivity.

M4. Manufacturing for Emerging Markets
Transformative technological innovations that enable the manufacturing of ultra-low-cost products designed to tap into the vast commercial potential of global underserved markets. The proposals must aim to produce products that are affordable and that have significant societal impact in the intended markets such as enhancing accessibility, reducing environmental impact, improving health etc.

M5. Modeling & Simulation
Innovations in the modeling and simulation of enterprise operations, manufacturing processes for intermediate or finished products, machines and equipment, predictive modeling of tooling and machine performance and discrete event simulation of manufacturing systems. Innovative approaches that bring the benefits of cloud computing and/or big data analytics to the manufacturing sector are especially encouraged. Virtual manufacturing software products that allow designers to create a three-dimensional (3-D) model of a product and then virtually test the efficiency of its performance are also relevant. Technologies enabling real-time prediction or optimization are also encouraged.

M6. Sustainable Manufacturing Technology
Proposals may cover technologies that present new process and system design paradigms, employ internet-of-things to dynamically optimize complex industrial manufacturing processes, enhance environmental sustainability with reductions in carbon footprint and/or water usage, and promote the sourcing, use, and recycle of materials and energy streams; technologies that take a systems approach to green engineering for industrial, residential, and commercial infrastructure, industrial manufacturing infrastructure design innovations; novel tools for the real-time analysis of system performance and the dynamic global
optimization of system performance; innovations in technologies for the improved efficiency, control; new
technologies (involving materials, sensors, devices, and control systems) that support smart infrastructures
to ensure efficient and sustainable energy transmission, distribution, monitoring, and management.

**M7. Manufacturing Processes**
Innovative technologies for the processing of a variety of materials, including metals, alloys, ceramics,
polymers, and novel composites using processes such as casting, forming, machining, and joining. Proposals
that lead to significantly improved efficiency (in terms of materials, energy, time, or money) and
sustainability are encouraged. The topic also includes on-line detection and/or control of defects in those
processes.

**M8. Rare Earths and Critical Materials Processing Technology**
Proposals of interest would involve production technologies enabling the development of new sources for
rare earths, metals, and critical materials of strategic national importance; improving the economics of
existing sources; accelerating the development and deployment of alternatives to rare earths and critical
materials currently in use; technologies and processes for more efficient use in manufacturing; recycling and
reuse; new processes for critical and strategic metals and minerals extraction; novel purification processes;
recycle and recovery by separation of rare earths and strategic materials from waste; novel ways to reduce
the amount of critical materials currently utilized in current and emerging technology products.

**M9. Transportation Technologies**
Proposed projects might include (but are not limited to) the reduction of engine emissions; the reduction of
greenhouse gases resulting from combustion; vehicle weight reduction; vehicle components; improved
engine and fuel efficiency; reduction of SOx, NOx, and particulates resulting from combustion; reduction in
wear and environmental pollutants. Projects may include technologies of commercial importance for low-
temperature combustion, flexible fuel and fuel blends for automotive applications, improved atomizers and
ignition characteristics, low heat-loss (coatings, materials, etc.) engines, on-board energy harvesting (e.g.,
thermoelectric generators), energy conversion and storage, improved catalyst systems, and other
alternative technologies to improve fuel efficiency, reduce energy loss, and reduce environmental emissions;
advanced batteries for transportation, including radically new battery systems or breakthroughs based on
existing systems with a focus on high-energy density and high-power density batteries suitable for
transportation applications.

**M10. Manufacturing Technologies involving Chemical Transformations**
New process technologies for the production of novel materials include (but not limited to) high-performance
bio-materials, inorganic and composite materials, alloys, novel materials with optimized design at an atomic
scale, nano- and micro-scale metallic materials, and nano-materials and metallurgical products of
commercial relevance.

**M11. Machines and Equipment**
Innovative machines and equipment in a range of operations for making nano-, micro-, and macro-scale
products in all industries, from biomedical engineering and flexible electronics, to manufacturing, mineral
processing, agriculture, construction, and recycling. Innovative equipment modification or retrofitting to
enable manufacturing of completely new products is encouraged.

**Nanotechnology (N)**
The Nanotechnology subtopic addresses the creation and manipulation of functional materials, devices, and
systems with novel properties and functions that are achieved through the control of matter at a
submicroscopic scale (from a fraction of nanometer to about 100 nanometers). Proposals should be driven
by market needs and demand and should identify both the end users of the proposed technology and the
pathway to commercialization.

**N1. Nanomaterials**
Proposals may include material innovations in scalable synthesis, purification, and processing techniques for
hierarchical nanostructures, nanolayered structures, nanowires, nanotubes, quantum dots, nanoparticles,
nanofibers, and other nanomaterials.

**N2. Nanomanufacturing**
Proposals that seek to develop innovative processes, including self-assembly, nanolithography, nano-
patterning, nano-texturing, nano-3D printing etc., techniques, and equipment for the low-cost, large-area or
continuous manufacturing of nano-to micro-scale structures and their assembly/integration into higher order
systems are encouraged.

**N3. Nano-enabled Commercial Solutions to Global Problems**

Proposals focusing on global problems through innovative nano-enabled processes are solicited. Examples of such problems include desalination of seawater to solve the emerging water crisis, solar energy collection, storage, and conversion for contributing to energy solutions for the future, and solid-state refrigeration for reducing global greenhouse emissions.