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SOLICITATION TOPICS & SUBTOPICS

America's Seed Fund at NSF encourages proposals in all areas of science and engineering. An exact fit into one of these topics or subtopics is not required.

For proposals due June 2018

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Technology Topic Areas:

- Advanced Manufacturing and Nanotechnology (MN)
- Advanced Materials and Instrumentation (MI)
- Biological Technologies (BT)
- Biomedical Technologies (BM)
- Chemical and Environmental Technologies (CT)
- Digital Health (DH)
- Educational Technologies and Applications (EA)
- Electronic Hardware, Robotics and Wireless Technologies (EW)
- Internet of Things (I)
- Information Technologies (IT)
- Medical Devices (MD)
- Semiconductors (S) and Photonic (PH) Devices and Materials
- Other Topics (OT)

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Advanced Manufacturing & Nanotechnology (MN)

Advanced Manufacturing (M)
The Advanced Manufacturing subtopic aims to support all current and emerging aspects of manufacturing innovations that have the potential to develop new areas in advanced manufacturing as well as rejuvenate the nation's manufacturing sector by improving its' efficiency, competitiveness, and sustainability. Proposals should be driven by technological advancements that address societal/market needs and enable new opportunities for growth in manufacturing that are both environmentally friendly and compatible with human health. Proposers must identify both the end users of the proposed technology and a viable pathway to commercialization. Proposals with applicability across all sectors are welcome. Proposals that are based on commercially sustainable technical innovations that primarily aim to create positive and enduring social impact are especially encouraged.

M1. Manufacturing Technologies
Innovative technologies for the processing of a variety of single-component and multi-component materials, including biological materials, flexible electronics, ceramics, polymers, metals, alloys, and novel composites using processes such as casting, forming, machining and joining, and robotics. 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. Unique approaches using augmented reality for teaching and implementing manufacturing procedures are welcome. Proposals involving new process technologies for the production of novel materials may also include (but are 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.

M2. Bio-Inspired Manufacturing
Nature has a multitude of examples of complex materials and systems that go well beyond the current capabilities of synthetic systems. Furthermore, biomimetic concepts will account for an estimated $1.2 trillion in global economic development, and have already contributed to familiar products like Velcro and wind turbines.

While industry has traditionally used "heat, beat, and treat" strategies to build products, Nature, on the other hand, manufactures at ambient temperatures and pressures, with non-toxic chemistry. Materials that are found in Nature display a wide range of properties including responsiveness to the environment, signal transmission, and the ability to adapt to and support life. Learning from Nature, or biomimicry, can be a powerful tool in designing materials, systems, and manufacturing techniques.

Further, in nature, everything is a resource and everything is recycled - one of the most fundamental attributes of sustainability. Bio-inspired manufacturing methods mimic these features and offer significant opportunities from both economic and environmental standpoints. Thus, proposals are invited that employ bio-inspired manufacturing methods to build innovative new products that have the potential to transform the manufacturing industry.

M3. Additive Manufacturing Components & Systems
Additive Manufacturing is the construction of complex three-dimensional parts from 3D digital model data by depositing successive layers of material. Innovations in materials, processes or machines that permit manufacturing through a layering process, including 3D/4D printing, to achieve fabrication of a range of products and the use of metal, polymer, ceramic, and biological materials to manufacture parts of a geometry that cannot be produced by any other manufacturing technology including near net shape products

Proposals that permit the manufacturing of complex multi-material, multi-scale and/or multi-functional products and services for superior performance and productivity are especially encouraged. This topic includes, but is not limited to, 3D printing, layered object manufacturing, selective laser sintering, selective laser melting, LENS, stereolithography, and fused deposition modeling.

Emerging areas in three-dimensional printing of complex biological structures for biological and medical applications such as tissue engineering, cognitive technologies, and the study of biomolecular function with the goal of societal benefit and improvement of human potential will also be considered.

M4. 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.

This topic includes Digital Manufacturing which aims to improve product design and manufacturing processes across the board with seamless integration of information technology systems across the supply chain. Digital manufacturing focuses on reducing the time and cost of manufacturing by integrating and using data from design, production, and product use; digitizing manufacturing operations to improve product, process, and enterprise performance, and tools for modeling and advanced analytics, throughout the product life cycle.

Another focus is the area of Smart Manufacturing which aims to reduce manufacturing costs from the perspective of real-time energy management, energy productivity, and process energy efficiency. Initiatives will create a networked data driven process platform that combines innovative modeling and simulation and advanced sensing and control. Integrates efficiency intelligence in real-time across an entire production operation with primary emphasis on minimizing energy and material use; particularly relevant for energy-intensive manufacturing sectors.

M5. Cybermanufacturing
Although web-based accessibility has both expanded and transformed most service industries, manufacturing services lag. This topic emphasizes research enabling the commercialization of software tools and systems for making manufacturing services accessible to more customers and more customers available to manufacturers. Current manufacturing software applications are predominantly costly, process-centric, general-purpose programs with the universal applicability needed to justify their development, marketing and acquisition costs. They usually have broad capabilities, but are cumbersome to learn and often provide solutions that need troubleshooting by engineering experts, a major cost of production. There is an opportunity for researchers to accelerate the creation of an interoperating, cross-process manufacturing service layer that enables the bottom-up transformation of access to manufacturing services. Projects may incorporate business models that simplify app development by users and allow the marketplace to drive the evolution towards increased capabilities. A wide range of network-accessed manufacturing services, not limited by the following examples, will be supported:

- Tools that are transparent to users and make it easy for manufacturers to present computer-aided design (CAD) files to conventional browsers in parameterized form, allowing customers to select desired parameters within limits set by the manufacturer to guarantee easy manufacturability;
- Search utilities that link user needs to manufacturing services by evaluating the closeness of match of customer designs to the web-accessible part designs made available by manufacturers;
- Product-specific applications (or “apps”) that simplify the low-cost design, customization or manufacture of products or product components by restricting the design space to guarantee the intervention-free execution of the entire design-to-production process;

M6. Personalized Manufacturing / Maker Manufacturing / Maker to Manufacturer
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) health-related products, clothing, footwear, furniture, ear buds, headbands, hearing aids etc. The resultant products may need to be cost competitive with the relevant mass manufactured products. Proposals may include development of software-as-a-service or workflow-as-a-service tools to assist young personalized manufacturing businesses. Makers represent a wellspring of innovation, creating new products and often 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.

Proposals are invited that are focused on innovative, high-risk technologies that hold the potential to enable small-, medium-, and large-volume manufacturing of cutting-edge, high-value added products leveraging the maker movement. This may include hardware, software, knowledge transfer platforms, and other innovations.

M7. 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. Companies developing cyberphysical systems that provide the foundation necessary for safe, efficient highway transportation systems connecting vehicles, infrastructure, people, and goods in a vibrant, competitive economy will also be considered. The development and commercialization of entirely new modes of transportation such as autonomous vehicles, vehicles powered by sustainable energy and the development of smart and connected communities are also of interest.

M8. Human-Centric Industrial Technologies
New technologies that sense surroundings and learn from data are bringing intelligence to service systems, allowing them to center on people by incorporating individuals' feedback and input. These systems create more value through adaptive and individualized interactions. From healthcare to transportation to advanced manufacturing, service systems make our lives safer, easier and more productive on a daily basis.
Thus, this subtopic seeks proposals aimed at combining the reach of the internet with new ability to directly connect and seamlessly integrate the modern industrial landscape defined by machines, factories, farmlands, and infrastructure. Such proposals may aim at (but are not limited to) development of innovative technologies that would promote creation of entirely new types of industrial jobs requiring complementary human-digital workforce, and create desired products and services at the right scale, speed, and level of personalization.

We seek to support innovative new companies to create and commercialize new service systems that are not only smart, but human-centric. By definition, a human-centered service system interacts with people -- end users, recipients, beneficiaries, providers and/or decision makers -- as it operates.

M9. 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.

M10. 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.
This topic includes 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.

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. Proposals that are based on commercially sustainable technical innovations that primarily aim to create positive and enduring social impact are also encouraged.

N1. Nanomaterials
Proposals may include material innovations in design, scalable synthesis, purification, and processing techniques for the development of innovative hierarchical nanostructures, nanolayered structures, nanowires, nanotubes, quantum dots, nanoparticles, nanofibers, and other nanomaterials and biomaterials and their composite structures. This topic includes rational design using artificial intelligence and other methods to develop materials which are environmentally stable and economically scalable with broad application across industries.

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. Proposals are sought that develop methods for the reliable, economic, and safe mass production of nanostructures that could lead to new technologies in electronics, biotechnology and medicine, energy, and materials including the use of biological materials and robotics for building new structures. Bio-nanomanufacturing, molecular programming and molecular robotics for applications and scale-up of the use of DNA in areas such as nanaosenors, spectroscopy, imaging, and devices for industrial, environmental, and medical applications.

N3. Nanotechnology-Based Solutions to Grand Challenges
Proposals focusing on global technological challenges through development of innovative nanotechnologies are solicited. Examples of such challenges include (but not limited to) desalination of seawater to solve the emerging water crisis, solar energy collection, storage, and conversion for contributing to energy solutions for the future, solid-state refrigeration for reducing global greenhouse emissions and conversion of atmospheric CO2 to useful products.

Advanced Materials and Instrumentation (MI)

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 ceramicmatrix 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.

Biological Technologies (BT)

BT1. Agricultural and Food Safety Biotechnology
New approaches for meeting the world's future nutritional needs that involve the development of new technology that is primarily based in the biotechnology area. For Plant 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 give consideration to technologies that enhance biodiversity, produce less carbon dioxide, and use less water and fertilizer. For Animal Biotechnology, which includes aquaculture, the target emphasis may include (but is not limited to) animal health and productivity, and reducing environmental impacts. For Food Safety Biotechnology, 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 Sensors in the EW topic.

BT3. Life Sciences Research Tools
Developing novel technologies that will advance scientific research across the biological spectrum. The life sciences area includes tools and reagents for genomics, proteomics, cell biology, epigenetics, metabolomics, stem cells, and antibodies and related areas. 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. Bioinstruments should refer to BT4; computational tools should refer to BT7 (see below).

BT4. Bioinstrumentation
The development of technology for novel or improved instrumentation primarily for biological research applications. This may include analytical, automation, and monitoring devices, which covers but is not limited to virtual instruments, biosensing devices, microfluidics, etc. 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.

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BT8. Advanced Biomanufacturing
The aim of this new area is to standardize the processes for cell-based therapies, especially stem cell therapies, regenerative medicine, and immunotherapies to bring down costs and to make the manufacturing processes more reproducible, scalable, efficient, and sustainable. This may include the development and implementation of advanced technologies in cell processing, cell preservation, distribution, and handling as well as process monitoring and quality control. Novel technologies also may address screening and selection methods, culture media advances, cell expansion, modification and differentiation methods, and separation methods.

BT9. Advanced technologies for functional genomics in organismal systems
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 through-put 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.

BT10. (Formerly BM3). Tissue Engineering and Regenerative Medicine
Proposed projects may include enabling bioengineering and biomanufacturing technologies and systems that will advance the research, development, quality control, and production of artificial tissues and their derivatives in scientific, therapeutic, and/or commercial applications. Proposed projects also may include novel methods or technologies for cell and tissue engineering to replace or regenerate damaged or diseased cells, tissues, or organs to restore or establish their normal function. 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.

Biomedical (BM) Technologies

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 and may be returned without review.**

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. 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.

BM4. 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.

BM5. 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 sensing, the detection, screening, diagnosis, prognosis and monitoring of syndromes and diseases, 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. The following projects are strongly encouraged: New technological paradigms to advance personalized medicine, precision medicine, and the diagnosis and management of rare diseases, neurological conditions and disabilities.

BM6. 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.

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 and competitive advantage vs. existing solutions, 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. Product/process economics and resource/energy inputs should also be addressed as applicable; along with considerations such as scale-up, and whether the product or process is a commodity and impact on the commercialization plan. Identification of key technical and commercial risks is appreciated for evaluation. It is important that the proposed project involve novel, discontinuous, disruptive innovations and be built on a firm framework 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. Bio-based 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 bio-based 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; advanced polymers, bio-based polymers; bioplastics; 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 traditional or 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 and technologies pertaining to Carbon Dioxide and Methane
Proposed approaches could include novel chemical, catalytic, biochemical and/or 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). Other applications, including technologies addressing ways to reduce gas flaring, and applications for gas infrastructure (e.g. pipeline leak reduction) are also welcome.

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 storage and management of any energy sources. 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; 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, Oil & Gas Transformation, Bioenergy, Renewable Fuel Technology
Proposed projects could include novel technology and approaches for the direct capture, production and use of any renewable energy sources such as wind, solar, solar-thermal, marine, tidal, geothermal, bioenergy, etc.; and waste heat recovery. Transformative technologies in oil and gas are also welcome including those that enhance production, reduce environmental impact (e.g. waterless fracking), allow production/optimization in expanded areas, or meaningfully improve efficiencies and yields of current processes. 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.

America's Seed Fund at NSF encourages proposals in all areas of science and engineering. An exact fit into one of these topics or subtopics is not required. Please note that the topics and subtopics listed here are examples and are NOT exhaustive.

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, Handling of Produced Water
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. New nature-inspired processes for energy generation or storage would also fit within this topic. Incorporation of Big Data and Internet of Things capabilities to these approaches is also welcome.

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 chemicals; the removal 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 foot print, 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 retrofittability, 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 examples 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 foot print, 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 and 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.

Digital Health (DH)

The Digital Health subtopics aim to support the early-stage development of novel devices, components, systems, algorithms, networks, applications, or services that will enable the transformation of healthcare from reactive, hospital-centered, and indemnity-based to proactive, person-centered, preventive, and cost-efficient. The Digital Health 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 and may be returned without review.

DH1. Business Models for User-Centered Healthcare

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 healthcare; 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.

DH2. 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 United States; or systems methods for measuring and optimizing operations to improve quality and productivity of healthcare delivery systems. New medical cyber-physical systems that reduce disparities in the access to high-quality and cost-efficient healthcare are encouraged.

DH3. 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 electronic health records - 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.

DH4. Interoperability of Health Record Systems, 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.

DH5. Empowering Individuals and Communities

This subtopic aims to support health communications and informatics innovations that focus on reducing disparities and increasing patient literacy and adherence in the healthcare continuum from prevention, screening and diagnosis to treatment and survivorship. Proposed projects must, without exception, be informed by socio-economic and behavioral principles underlying current disparities in patient participation in healthcare and wellness. Specifically, proposed projects must employ the theories, methods, and analytic techniques of the social, behavioral, economic, and learning sciences in order to commercialize products and services that address the barriers that hinder, and the factors that enhance, our ability to broaden access of individuals and communities to healthcare in the United States.

This subtopic strongly encourages multidisciplinary projects that will develop new quantitative and predictive approaches to empowering patients to participate in their own health and treatment such as custom-educating, accessing and visualizing health data and knowledge; assisting people to participate in their own health treatment by limiting the impact of socio-economic status, gender, ethnicity or education. Successful projects will develop technology solutions to challenges in the management of underserved public health conditions; organizational and service system deficiencies encountered by community healthcare providers; lack of effectiveness in rehabilitation strategies and programs for socio-culturally diverse individuals who have widely varying goals, material and social resources and clinical needs. Non-limiting examples of applications are: chronic disease, mental disease, cognitive and behavioral intervention drawing on a lineage of psychological therapy, domestic violence, substance abuse, or community reintegration for people with psychiatric disabilities. Finally, this subtopic strongly encourages projects that develop novel culture-sensitive, user-tailored and context-aware human-computer interfaces for a variety of tasks including patient, family and caregiver access to electronic health records (EHRs) and personal health records (PHRs).

Educational Technologies and Applications (EA)

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 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. Efforts based on similar or existing products or systems offered by the proposer or their competitors are also not likely to resonate well in a review panel.

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, middle school, high school, robotics, reading, math, computer science, and so on.

Education Applications and Technology (EA) Topics

- EA1 – Pre K-12 Education
- EA2 – Global, Distance, and Higher Education
- EA3 – Simulations and Gaming Technologies
- EA4 – Entrepreneurial, Informal and Maker Education
- EA5 – Information, Computer Science, and Engineering
- EA6 – Emotional Intelligence (EI) Enhancing Educational Innovations
- EA7 – Education & Training for the Emerging Fourth Sector Eco-system
- EA8 – Topical Education of Citizens

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

EA1. Pre K-12 Education

EA1 topics can include but are not limited to applications and technologies for young students that 1) leverage and commercialize the education research investments made to educational institutions by the National Science Foundation and other government agencies; 2) provide innovative delivery, applications, content, devices, products, services, and curricula for STEM (science, technology, engineering, and math); 3) automate the sharing, and repurposing of information, content, curation, pedagogies, and experiences that are long-term and sustainable; and 4) provide advance learning technologies and environments that better motivate and enhance the self-esteem and learning performance of students.

EA2. Global, Distance, and Higher Education

EA 2 topics can include but are not limited to educational applications and technologies related to efforts in 1) augmented reality with the layering of data over 3D spaces; 2) virtual reality using computer generated environments; 3) affective computing especially in innovative online and other learning environments that use human and computer interactions, and 4) learning environments for emerging technologies in the biosciences, computer sciences, robotics, and programming. Highly innovative and technically advanced portable devices and related applications in learning analytics and adaptive learning that are substantially differentiated in the marketplace may be considered.

EA3. Simulations and Gaming Technologies

EA3 topics can include but are not limited to 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) innovative single-player, small-groups, or massively multiplayer online gaming applications that foster cooperation and can include card, board, or digital games as well as those that combining physical and electronic elements; and 3) serious games, immersive games, simulation based games, and

games that support experimental learning or transfer knowledge while providing intrinsic motivation for student participation.

EA4. Entrepreneurial, Informal and Maker Education
EA4 topics can include but are not limited to education based 1) entrepreneurship and training in innovation methodologies and other applications that use technologies that are strongly differentiated from what is available in the marketplace and can be significantly scaled for broad impact; 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.

EA5. Information, Computer Science, and Engineering
EA5 topics can include but are not limited to 1) 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; 2) innovative and unique cloud based services and applications that support collaboration, teacher and student productivity; 3) 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; 4) 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; and 5) systems and applications that address privacy concerns of educators and students including the safeguarding of personal data in connected education environment.

EA6. Emotional Intelligence (EI) Enhancing Educational Innovations
Many of the major drivers of transformation currently affecting global industries are expected to have a significant impact on jobs, ranging from significant job creation to job displacement, and from heightened labor productivity to widening skills gaps. These disruptive changes to business models will have a profound impact on the employment landscape over the coming years. In this context, Emotional Intelligence (EI) is likely to become critical to all students and anyone who wants to stay relevant in their field or reskill oneself. Innovative education and training proposals are invited that address, enhance one or more aspects of EI, and scale its impact for students of all ages.

EA7. Education & Training for the Emerging Fourth Sector Eco-system
Numerous studies point to an increasing demand among majority of people, in various capacities, to align their economic choices with their values. This need to fundamentally upgrade our outdated and unsustainable economic systems to meet today's challenges has led to number of pioneering efforts that are disrupting the boundaries that separate the traditional public, private, and social sectors, and giving rise to a new, fourth sector of the economy. This rapidly growing fourth sector combines the institutional logics of the traditional three sectors, and use market-based approaches and private capital to solve the world's most urgent social and environmental problems. Like nonprofits and governmental agencies, the fourth sector enterprises pursue a wide range of social and environmental objectives as their primary purpose. Like for-profits, they primarily earn their revenues by selling a broad range of products and services that improve quality of life for consumers, create jobs, and contribute to the economy. Proposals are invited that innovatively disseminate fourth sector concepts and know-how through creative and scalable educational and training platforms that would support a robust fourth sector ecosystem.

EA8. Topical Education of Citizens
Our civilization has reached a point where information about many complex and critical topics is generated at a rate faster than human capacity to assimilate it through a reflective approach that is clear, and open-minded. As a result, polarization of views is becoming more common when confronted with significant societal problems, including those involving science and technology, causing dysfunction in the governance of society. New, innovative, non-traditional ways of providing topical public education germane to those issues to the social marketplace are likely needed. Proposals are invited that address the above need and provide education not only about the problems but also potential solutions, including those spurred by interdisciplinary R&D approaches. The resultant product or service must be financially sustainable. A small sampling of such topical issues includes violence, automation, literacy, and sustainability.

Electronic Hardware, Robotics and Wireless Technologies (EW)

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. Techniques for establishing a hierarchy for data from multi-sensor platforms; newer modalities for transduction (e.g. time-based measurements for pressure and acceleration); packaging interfaces for sensor-to-outside world; cost-effective, cheap, high-throughput post-manufacturing calibration (trimming, biasing, offset correcting); traceability through built-in secure tagging from component through packaging to end-use; automation and miniaturization; and sensor systems for situational awareness are of interest.

Sensor types of interest include mechanical sensors for dead-reckoning, touch and tactile sensors, failure prediction, autonomous cars; optical/image sensors for proximity, medical diagnostics, retinal implants, biomimetic, and particulates; smell sensors - environmental safety, food quality control, noninvasive health monitoring; asset tags; and other types of sensors such as chemical, proximity, magnetic, current/voltage, light, radiation, accelerometer/gyroscopes, cloud sensors, and bio-signals (e.g. ECG, EMG, PPG, EEG). In the area of sensor devices and signal processing, proposals are sought in new sensing modalities (sensing physics/chemistry, target specific); self-powered (power harvesting) and energy efficient; sensors for extreme environments; sensor fabrication techniques such as 3D printing and self-assembly; sensor signal read out, conditioning, and processing; and biodegradable sensors. For sensor systems and algorithms, tomographic processing, 3D array, autonomous sensing, sensor fusion, extreme environment materials sensing, and remote sensing parametric inversion are of interest.

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. Energy Harvesting, Storage and Management

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). Proposals involving energy storage from the scale of wearable devices to power plant (chemical or non-chemical), and energy conversion (harvesting, cooling) are encouraged.

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. Smart Grids, Infrastructure, and Power Management

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 for micro grids, integration of diverse energy sources, and self-healing networks 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 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, and generators for higher efficiency, smaller size and power factor corrections are encouraged.

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 board components and passive components, techniques for board assembly, and applications of techniques to packaging and systems integration for optoelectronics and wireless systems. Memory continues to be a critical element in the full range of VLSI applications from big data to mobile applications to wearable devices. Recent trends, including process technology scaling limits, new memory applications, and evolving high-performance and low-power requirements, have driven the development of emerging memories, and their attendant packaging requirements.

Packaging, thermal management, and systems integration for sub-7nm CMOS, thin film/organic transistors, nanoscale III-V MOSFETs, 3D integrated circuits, silicon photonics; CMOS microfluidics, 3D flash memory, portable functional brain imagers, and biosensor arrays are of interest. Proposals that address packaging issues that involve power management circuits; wireless power transfer; energy harvester circuits; ultra-low voltage, low power circuits; neuromorphic circuits; advanced memory circuits, neural interface circuits; SoCs for mobile vision, sensing, and communications; micro-vacuum electronics; thin-film growth/epitaxy; novel IC films; ion implantation advanced RF circuit design and architectures (SOI, SiGe, GaAs); micro-valves and micro-turbines; and electrostatic discharge protection are also of interest. Higher current at lower voltage drives thermal management needs of electronic devices. Proposals that address novel packaging concepts such as graphene wrapper versus hermetic or plastic modules; passive and active heat sinks; nanowire patterning and processing; layer transfer (removing active IC and transferring to a different substrate (e.g. heat sink); through-silicon via for placement versus added capacitance; robust surface-mount PCB technology; flip chip versus wire bond through wafer vias; novel high thermal conductivity films on chip (e.g. SiC, graphene, borene); and novel hi-kappa fluids for cooling.

Proposals that involve or consider heat sinking from SOI (off-current reduction, logic standby current reduction); advanced electro-thermal circuit simulation packages beyond high frequency structural simulators (HFSS); energy harvesting devices such as ZnO; reduced harmonic loss at high power to meet FCC specifications; integrated device micro-cooling: ferroic magnetocaloric, electrocaloric, strain-induced cooling; micro-cooled FET and bipolar circuit boards; self-powered devices; advanced circuitry involving electronic duty cycle feedback control; nano-fans and piezo micro-blowers; and structured packaging design optimization system are of interest.

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 cannot 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. Human-Machine Interfaces and Control/Architecture

Automated setup and personalization; self-learning machine interfaces; distributed sensor fusion of active sensors; passive environment sensing; emergent pattern detection algorithms; probabilistic algorithms; virtual design and prototyping; touch and force feedback; programmable manipulators; and automated vehicle navigation systems are of interest. Proposals addressing additional areas such as virtual cockpits; human/machine speech interfaces; personal navigators; remote places simulator, and holodecks are welcome. 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.

RH2. Robotic Applications

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, and eye-hand coordination are encouraged. Proposals describing projects that borrow features from other animal nervous systems and include biologists, neuroscientists, and/or psychologists on their team in order to exploit new knowledge in the study of the brain and behavior, are encouraged.

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 sensor networks, are sought. Innovations in areas such as improved time imaging, visualization, deep learning, neuromorphic computing, bio-robotics, brainOS, brain-on-a-chip; brain-computer interfaces; artificial synapses; human-robot interaction, dexterity and manipulation, anthropomorphic (human-shaped) robots, naturally inspired, biomimetic, neuromechanical robotics, haptic, real-time and bio-inspired feedback are also welcome. Other applications, including (but not limited to) precision agriculture; real-time operating systems; self-driving vehicles; wearable computers; self-charging and repairing drones; on-demand multipurpose autonomous taxis; security drones: chaperone, security guards, policing; on-demand garbage collection; and door-to-door deliveries are also appropriate.

RH3. Robotics in Agile Manufacturing, and Co-Robots

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, and on-demand parts manufacturing are sought. Innovations in the development of co-robots, robots that work symbiotically (beside, in direct support, or cooperatively) with people, 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. Cognitive robots for health care, training, and therapeutic/physical therapy are also appropriate.

RH4. Human Assistive Technologies and Bio-related 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, personal caregiving and increased autonomy; and 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.

Wireless Technologies (WT)

Spectrum continues to be the resource that is in the greatest demand to meet the voracious needs of a data-hungry mobile public. Exponential growth in mobile data demand, in conjunction with the spectrum needs of upcoming bandwidth-intensive applications envisioned for 5G, necessitate the availability of newly licensed spectrum pools. With the advent and popularity of the smartphone, mobile data usage has been steadily increasing year over year, a trend that's unlikely to subside anytime soon. Although technology continues to advance to improve spectrum efficiency, it will not be enough to reduce the need for additional spectrum. Ideally, most of the new spectrum should be in licensed bands, with additional unlicensed spectrum used to offload traffic from licensed bands. 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 a wider frequency spectrum and extremely short antennae. With GaAs and SiGe, entire microwave transceivers can be inexpensively put 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 applications.

With 5G targeting improvements across three fronts, enhanced mobile broadband, massive-scale connectivity, and ultra-reliable low latency service, there will be different spectrum needs than previous generations of cellular technology. The ever-growing need for use of wireless applications everywhere and the need for higher throughputs, drives the need for not only higher swaths of spectrum, but, also the spectrum that has reasonable propagation characteristic that allows wide area use. Millimeter wave bands provide an excellent resource for large swaths of spectrum, but generally, are not considered as suitable for wide area coverage. To meet the projected data demand and requirements for all use cases cellular operators will need both breadth of spectrum assets across all these type of bands and depth of spectrum assets within bands. Spectrum sharing is another opportunity. Incumbents that do not utilize their spectrum very often in both the temporal or geographical domain could share those channels with mobile services when the incumbent is not operating. Future spectrum should be allocated in bands where it can provide the most benefit to wireless consumers.

WT1. Wireless Systems

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. Examples include low-energy Bluetooth; IrDA point and shoot communications; light wave communications (Li-Fi for >10 Gigabits/second); near-field communications; self-sustaining technologies; super Wi-Fi; technologies that enable IPv6 and IPv7; inter/intra vehicular communication; smart shopping systems; smart vehicles, traffic control, and parking; body area networks; smart appliances and textiles; smart drones and drone networks; human body vital signs monitoring; and resilient wireless networks.

WT2. Wireless Devices and Components

Devices and subsystems that increase data throughput rates via cell density, increased spectrum, MIMO, and massive MIMO; new "antenna" concepts: embedded, fabric, dot antennas, 3D, multiferroic, biological; Modulation and demodulation techniques for signal generation and reception through spectral efficiency, noise immunity, jamming immunity, and power efficiency; RF pollution: device and circuit (RF, microwave, mm-wave and optical); processing algorithms - 3D spatial control (targeted volume transmission/receiving and sensing; high resolution 3D localization); high efficiency (low heat) devices such as micro-TWT, smart dust, and inductive couplers. Proposals in the areas of spectrum-related research and development activities that improve the efficiency by which the radio spectrum is used, and the ability of all members of the public

to access spectrum-related services. Mobile and automotive radar, smart solar panels, on-panel DC-AC converters, and self-testing and self-networking devices are also of interest mobility, minimum latency, and long battery life are sought.

Internet of Things (I)

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.

Market verticals that are potentially impacted by innovations in this area include Connected Cities and Homes, Smart Transportation, Smart Agriculture, Industrial IoT, and Retail IoT. 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 dataefficient 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.

Information Technologies (IT)

Information technology is increasingly impacting almost every aspect of our lives, from communicating with friends and family to manufacturing of the products 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, transmission 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 IT13. Proposals that do not fit these subtopics can be submitted under the subtopic "IT14: Other"

IT1. 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.
Included in this subtopic are the technical sub-specialties of 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.

There are many technical approaches to AI, and an even greater diversity of potential applications. Examples of relevant technical fields include (but are not limited to): deep learning; artificial neural networks of various types; supervised, semi-supervised and unsupervised machine learning; machine learning algorithms; pattern recognition; image recognition; machine vision; fuzzy logic; uncertain reasoning using probabilistic methods; named entity recognition; 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 of AI include (but are not limited to): robotics, including in automated manufacturing; industrial controllers; self-driving cars; analysis of online commentary; stock market analysis; optimization of finance operations and stock investments; analysis of medical records; clinical decision support systems for medical diagnosis; automated interpretation of medical test data (e.g. ultrasound scan data); cybersecurity; intrusion detection – in software systems, communications networks and sensor systems; fraud detection; cyber-physical control systems; improvements in human-computer interaction; automated document classification, indexing and retrieval; customer recommendation systems; personalization of customer services; intelligent virtual assistants; search engines, including image-based search; translation services (including speech-to-speech translation).

IT2. 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. 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 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; pattern 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.

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.

IT3. Quantum Information Technologies

This subtopic focuses on innovations in information and communications technologies that rely fundamentally on quantum mechanical properties and interactions. Typically, such innovations will involve the generation, detection or manipulation of quantum states in order to provide faster, more efficient or more secure information processing and communications.

Included in this subtopic are innovations at the component, sub-system and system level that result in substantial and usable improvements in the generation, transmission, detection, storage or processing of information, or the security and privacy of information.

Proposed innovations must offer the potential for robustness, reliability, scalability, and operation at temperatures that are practical within the constraints of the intended application. Innovations at the component and sub-system level should aim for compactness and energy efficiency, consistent with the requirements of the intended application.

Examples of relevant technical fields include (but are not limited to): single photon sources and detectors; generation, transmission and detection of qubits; entangled photon sources; generation, manipulation and detection of entangled qubits; quantum repeaters; quantum memories; quantum frequency conversion (e.g. to telecoms wavelengths); superdense coding; quantum error correction; quantum information processing; quantum algorithms. This subtopic covers a wide range of technical sub-specialties, and these examples are intended only to be indicative.

Applications will in general fall into one of the four broad areas of quantum sensing, quantum communications, quantum simulation and quantum computing.

Proposals submitted to this subtopic must be aimed ultimately at commercialization, and should address the likely timeline to develop a minimum viable product or service. Proposals should also address practical problems that will need to be overcome in order for the proposed innovation to be commercially feasible.

IT4. 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 IT5).

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.

Authentication refers to the reliable authentication of persons using the internet and devices connected to the internet, while privacy refers to the protection against compromise of personal information and user data.

Examples of relevant technical fields include (but are not limited to): detection of cyber vulnerabilities – for example, related to critical infrastructure or financial networks; detection and prevention of cyber-attacks; human factors analytics – to assess people-based 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.

IT5. 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 new and innovative approaches to providing cybersecurity for IoT systems. Proposed solutions should not be limited to conventional cybersecurity techniques – the unique 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.

IT6. 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; network-based data storage and retrieval technologies; anywhere/anytime access to data and services; agile networking; machine-to-machine networking; peer-to-peer device networking; networking technologies for resource-constrained sensor-dense 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.

IT7. 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; device-cloud architecture; context-relevant analytics and services – i.e., involving situational and environmental information; data analytics and data processing to facilitate the Internet of Things; vehicle-based computing platforms.

America's Seed Fund at NSF encourages proposals in all areas of science and engineering. An exact fit into one of these topics or subtopics is not required. Please note that the topics and subtopics listed here are examples and are NOT exhaustive.

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.

IT8. 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, computing efficiency, 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. Included in this subtopic are innovations that will enable continued improvement in the performance of HPC platforms in the so-called post- Moore's Law era. Examples of applications that typically require the levels of computing power available through cloud computing or high-performance computing 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 audio and video signal processing.

IT9. 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; data storage services; location-based services; retail recommendations.

IT10. Big Data; Advanced 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.

Areas of application 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; enhancements to geographic information systems (GIS); crowdsourcing; detecting and preventing cyber-attacks.

IT11. 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; 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. These technologies may be implemented on wearable devices such as smart watches, smart glasses and health trackers.

Virtual Reality involves providing 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.

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.

IT12. Social Media; Collaborative Networking
This subtopic focuses on commercially viable 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 networking tools; visual content optimization (image and video) for social media; video sharing.

IT13. Software
This subtopic focuses on information technology innovations that are embodied in software and provide important new or enhanced capabilities that will usually be generalized, rather than directed to a specific use case. Examples of such capabilities 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.

IT14. 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.

Medical Devices (MD)

The Medical Devices subtopic aims 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 MD subtopic is not aimed at supporting or conducting clinical trials, clinical efficacy or safety studies, the development of 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 and may be returned without review.

MD1. Medical Devices

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, monitoring, and treatment of health conditions (such as sensors, actuators, implantable and bioelectronic devices for therapeutic monitoring, theranostics, or electroceuticals); 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 biomechanical 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.

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, organic or quantum dot), 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.

America's Seed Fund at NSF encourages proposals in all areas of science and engineering. An exact fit into one of these topics or subtopics is not required. Please note that the topics and subtopics listed here are examples and are NOT exhaustive.

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.

Other Topics (OT)

The Other Topics area is intended to be a home to any proposed project which does not seem to fit into one of the other technology topic areas, but still seems to meet the NSF SBIR/STTR goals of supporting research and development of innovative, risky, unproven technology, with commercial viability and the potential to benefit society.

If you are not sure if your project fits into one of the other technology topic areas, please feel free to send an email to Senior Program Director Ben Schrag (bschrag@nsf.gov), and he can then recommend the best point of contact or path forward.

For Other Topics projects on Distributed Ledger and Blockchain, possible submission topics include, but are not limited to: distributed ledger technologies, including blockchains, sidechains, DAGs (directed acyclic graphs) and other implementations; security, anonymity and identification; scalability and efficiency solutions; consensus methods; business innovation; smart contract innovations; organizational structure and collaboration; ease of use and simplification.

If you have questions about a project involving **Distributed Ledger and Blockchain**, please email Dr. Brady-Estevez.

Subtopic areas: Distributed Ledger and Blockchain

Distributed Ledger and Blockchains- Distributed ledger technologies, including blockchains, sidechains, DAGs (directed acyclic graphs), and other distributed ledger implementations.

Security, Anonymity and Identification- Both privacy and transparency solutions including those which enhance security and anonymity; identification and validation.

Scalability and Efficiency Solutions- Innovations to further the scalability of blockchains, and other distributed ledger technologies. Proposed methods to enhance the efficiency of distributed ledger technologies.

Consensus Methods- New consensus methods or improvements of existing consensus methods for distributed ledger (e.g. proof of work, proof of stake, proof of importance and other implementations).

Applications- Business models applying blockchain **/ DAGs** for innovation in any number of fields such as: energy, chemicals, power, agriculture, environment, "*sharing economy*", artificial intelligence, robotics, IOT, pharmaceuticals, supply chain, scientific research, defense, government applications. Smart contract innovations also of interest. Submissions relevant to **other** sectors and opportunities are also welcome.

Organizational Structure and Collaboration- Innovations to support new collaboration models, methods of value creation and related supporting organizational structures. Interest also extends to such models that can enhance technology development and dissemination.

Ease of use, simplification: Solutions and modifications that make distributed ledger technology and applications more accessible and useable for innovators and users alike.