Exhibit R-2, RDT&E Budget Item Justification: PB 2023 Navy	Date: April 2022
Appropriation/Budget Activity 1319: *Research, Development, Test & Evaluation, Navy* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
Total Program Element	0.000	471.367	523.324	499.116	-	499.116	510.975	530.788	496.339	481.944	Continuing	Continuing
0000: *Defense Research Sciences*	0.000	445.302	472.992	479.583	-	479.583	491.052	510.466	475.610	460.800	Continuing	Continuing
3465: *In-House Lab Independent Res*	0.000	0.000	11.332	19.533	-	19.533	19.923	20.322	20.729	21.144	Continuing	Continuing
9999: *Congressional Adds*	0.000	26.065	39.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	65.065

A. Mission Description and Budget Item Justification

The Office of Naval Research (ONR) was established by Congress in 1946 to plan, foster and encourage scientific research in recognition of its paramount importance to the maintenance of American naval power and national security. ONR manages the Department of the Navy's (DON) portfolio of Basic Research, Applied Research and Advanced Technology Development investments to ensure naval forces can effectively deter conflict, but when called upon, fight, win and come home safely. This Program Element (PE) supports the Basic Research portion of the Department of the Navy (DON) science and technology (S&T) portfolio, laying the foundation for new innovative technologies and future capabilities for naval warfighters. This PE's efforts include theoretical and experimental investigations directed toward increasing knowledge and understanding of the physical, chemical, engineering, environmental and life sciences. The huge majority of the research in this PE are performed by academia and government labs, both of which play significant roles in developing the S&T workforce of tomorrow in addition to delivery new knowledge and scientific discoveries.

This PE, and the rest of Naval S&T, supports higher guidance defined by the National Defense Strategy, and responds to requirements identified by the Secretary of the Navy through research priorities set by the Chief of Naval Research, coordinated across the Naval Research Enterprise (NRE), and outlined in the Naval R&D Framework. In addition, ONR's S&T investment portfolio supports National Naval Responsibilities (NNR) critical to the naval services where the Navy has historically taken the lead (ocean acoustics, undersea weapons, naval engineering, undersea medicine and sea-based aviation) to ensure decisive naval capability in the maritime domain. Scientific breakthroughs within the current research activities:
Atmosphere & Space Sciences;
Mathematics, Computer, & Information Sciences;
Ocean Sciences;
Materials/Processes;
Human Systems;
Medical/Biology;
Science Addressing Hybrid Threats;
Sensors, Electronics & Electronic Warfare (EW);
Air, Ground & Sea Vehicles;
Weapons; and

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Science & Engineering Education, Career Development & Outreach
lead to more advanced aspects of applied research and technology development and become solutions to Navy and Marine Corps technical challenges via the Future Naval Capabilities (FNCs) pipeline, and new capability options for the future via the Innovative Naval Prototypes (INPs) portfolio. Just as today's Sailors and Marines are enabled by past naval S&T investments, current investments hedge against uncertainty, providing the scientific basis for near-term solutions to commanders today and options for an unknown future.

The work in this PE can be classified between Technology Readiness Level (TRL) 1 (basic principles observed and reported) and TRL 2 (technology concept and/or application formulation).

Due to the number of efforts in this PE, the programs described herein are representative of the work included in this PE.

B. Program Change Summary ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Previous President's Budget	487.048	484.421	0.000	-	0.000
Current President's Budget	471.367	523.324	499.116	-	499.116
Total Adjustments	-15.681	38.903	499.116	-	499.116
• Congressional General Reductions	-	-0.097			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	39.000			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-2.788	0.000			
• SBIR/STTR Transfer	-12.893	0.000			
• Program Adjustments	0.000	0.000	0.000	-	0.000
• Rate/Misc Adjustments	0.000	0.000	0.000	-	0.000
• Adjustments to Budget Year	-	-	499.116	-	499.116

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2021	FY 2022
Project: 9999: *Congressional Adds*		
Congressional Add: *Basic Research*	0.000	25.000
Congressional Add: *Defense Research Sciences*	14.480	0.000
Congressional Add: *Silicon-Germanium-Tin Alloy Research*	4.827	0.000
Congressional Add: *Bio-inspired Engineering and Design for Naval Applications*	2.896	3.000
Congressional Add: *Predictive Modeling & Simulation for Next Gen Naval Undersea Vessel and Platform*	1.931	0.000
Congressional Add: *USV Batteries, Materials, and Additive Manufacturing*	1.931	0.000

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Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2021	FY 2022
Congressional Add: *Generally-capable robotics for naval operations*	0.000	4.000
Congressional Add: *Multifunctional structural batteries*	0.000	2.000
Congressional Add: *Silicon-germanium-tin alloy research*	0.000	5.000
Congressional Add Subtotals for Project: 9999	26.065	39.000
Congressional Add Totals for all Projects	26.065	39.000

Change Summary Explanation

Funding: Additional increase in total budget request includes programmed increased investment in Vehicle Technologies; Materials Research; Computational Sciences; Ocean Science; Electronic Materials; and Navy STEM HBCU/MI outreach.

Technical: not applicable

Schedule: not applicable

FY 2023 funding increase reflects the fact that the FY 2022 President’s Budget request did not include out-year funding.

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy										Date: April 2022		
Appropriation/Budget Activity 1319 / 1					R-1 Program Element (Number/Name) PE 0601153N / *Defense Research Sciences*				Project (Number/Name) 0000 / *Defense Research Sciences*			
COST ($ in Millions)	**Prior Years**	**FY 2021**	**FY 2022**	**FY 2023 Base**	**FY 2023 OCO**	**FY 2023 Total**	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027**	**Cost To Complete**	**Total Cost**
0000: *Defense Research Sciences*	0.000	445.302	472.992	479.583	-	479.583	491.052	510.466	475.610	460.800	Continuing	Continuing

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Mathematics, Computer, & Information Sciences;
Ocean Sciences;
Materials/Processes;
Human Systems;
Medical/Biology;
Science Addressing Hybrid Threats;
Sensors, Electronics & Electronic Warfare (EW);
Air, Ground & Sea Vehicles;
Weapons; and
Science & Engineering Education, Career Development & Outreach
lead to more advanced aspects of applied research and technology development and become solutions to Navy and Marine Corps technical challenges via the Future Naval Capabilities (FNCs) pipeline, and new capability options for the future via the Innovative Naval Prototypes (INPs) portfolio. Just as today's Sailors and Marines are enabled by past naval S&T investments, current investments hedge against uncertainty, providing the scientific basis for near-term solutions to commanders today and options for an unknown future.

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The work in this PE can be classified between Technology Readiness Level (TRL) 1 (basic principles observed and reported) and TRL 2 (technology concept and/or application formulation).

Due to the number of efforts in this PE, the programs described herein are representative of the work included in this PE.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Title: Air, Ground and Sea Vehicles	54.209	56.749	56.993	0.000	56.993
Description: Sailors and Marines operate air, ground and sea vehicles in some of the most extreme environments on the planet. Basic research advances the capacity of naval platforms operating under, on and above the seas, and to project power ashore. Ongoing research in the Air, Ground and Sea Vehicles activity will increase platform performance, reliability, improve human-machine teaming, reduce the cost of at-sea operations and enhance the effectiveness of distributed maritime operations. The efforts research focus include: surface and subsurface signatures; free-surface, subsurface, and propulsor hydromechanics; hull life assurance; advanced ship concepts; distributed intelligence for automated survivability; advanced electrical power systems; air vehicles; air platforms propulsion and power; air platforms survivability and signature control; special aviation projects; environmental quality; logistics; power generation, energy conversion, and storage; and advancements in naval technology innovations. ***FY 2022 Plans:*** Aerospace Structures and Materials (Formerly Sea Based Aviation National Naval Responsibility) Research is focused on basic research for developing lightweight, reliable, survivable, sustainable, and affordable airframes for naval and marine corps aircraft and weapons. Research concentration areas are: - Galvanic corrosion and mitigation strategies for metallic airframes in naval environment. - Multiaxial fatigue of hybrid airframes. - High fidelity composites prediction methodologies that span multiple length scales. - Novel out of autoclave and out of oven curing technologies. - Short fiber thermoplastic composite forming and joining. - High strain rate characterization of materials. - Computer assisted iterative material development for armor applications - Lightweight material solutions for multifunctional structures for airframes and weapons Flight Dynamics & Control					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Research will develop theory and analysis methods to better understand the phenomena and natural dynamics of air vehicles operating in the marine environment. Collaborative research will improve our knowledge of control system interactions between piloted aircraft and human performance. Objectives of this basic research portfolio include: increase the operational envelop for air vehicles, tailor airframe dynamics with novel control effectors, improve threat engagement performance, develop fundamentals for coupled human/machine dynamics, adapt to variable airframe conditions, etc. The Focus areas are: - Multibody control systems and the ability to demonstrate guaranteed performance relative to a desired end state; - Robust and precise control in the presence of highly turbulent flow fields; - Algorithms to enable precise ship-relative navigation in GPS-denied environments. Aerodynamics Research will enhance understanding of Naval-unique aerodynamic challenges by developing advanced computational and experimental methods in the following Focus Areas: - Fully coupled aerodynamic interface between ships and aircraft; - Novel state-of-the-art in-situ diagnostics and reduced-order modeling of complex flow fields; - Advanced methods for manipulating precisely the flow fields around air vehicles operating in the maritime environment. - Innovative technologies enabling increased range and/or maneuverability suitable for aircraft operating from the maritime environment and attritable systems such as high-speed weapons. - Interactional and transitional aerodynamics of multi-rotor systems in complex fluid dynamic environments involving multi-body relative motion. Science of Autonomy and Control of Unmanned Systems Research related to critical multidisciplinary autonomy challenges that cut across areas/domains, including air, sea, undersea and ground. This includes multi-disciplinary research into the science of autonomy and it focuses on four interrelated areas: - Scalable and robust distributed collaboration among autonomous systems; - Human/unmanned system collaboration; - Perception-based adaptation across uncertain naval environments; - Embodied and situated intelligence and architectures. - Expand research on agile, theory-based tools and methods for safe, assured, robust, verifiable, and trustable autonomy.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Naval Air Platform Propulsion, Power and Thermal Management (Formerly Air Platform Machinery and Systems) - Continue basic research to advance the technical superiority of Sea-Based Aviation - Propulsion, Power and Thermal management with emphasis on propulsion cycles, subsystems, propulsion integration, turbo machinery and drive systems, and hot section materials and coatings. - Continue basic research to improve the power density, fuel efficiency, speed, range and operating reliability of future large, medium and small engines. - Continue fundamental studies with Rotating Detonation Engines and integration into platforms and weapon systems using thermodynamic models, Computational Fluid Dynamics and sub-scale experiments. - Conduct basic research for high stage-loading and efficient turbomachinery including distortion tolerant fans, casing treatments and advanced methods in blade-disk aerodynamics; advanced cooling and thermal management for engines and auxiliary systems including new concepts of heat collection, distribution and rejection; advanced turbine engine materials and coatings; highly integrated propulsion inlets and exhausts and dust ingestion research, including modeling, separating, deposition, coatings and sensing. - Continue to improve jet engine material durability and temperature rate capabilities in both benign and corrosive environments. - Develop advanced radio-frequency based sensors to provide ingestion and foreign object damage sensing, as well as overall prognostics.					
Platform Design and Engineering Conduct basic research related to platform performance, platform autonomy and control, platform survivability and tactical submarine evolution plan (TSEP) S&T. - Efforts for platform performance, autonomy and control include, but are not limited to, the following: understanding, predicting and controlling turbulent free-surface and stratified wakes leading to mitigation, tools to accurately predict platform maneuvering performance supporting future designs, current platform operational tactics, platform control and "digital twins" and developing reliability-based knowledge and tools to improve performance and affordability of ship hull structural systems from cradle to grave. - Efforts for platform survivability and TSEP S&T include, but are not limited to, the following: structural acoustic and propulsor source characterization, developing signature mitigation technologies, providing state of the art signature and detection range prediction tools that accurately model platforms to emerging threats and developing wideband, light-weight, affordable low observable materials.					
Power, Energy & Propulsion					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Conduct basic research related to heat transfer and thermal management; power generation; energy storage; distribution and control; and motors and actuators. - Efforts include, but are not limited to, the following: wide band gap (WBG) materials growth for next generation power electronic devices, improving power density, efficiency and control authority of WBG SiC Power Electronic Building Blocks by increasing switching frequencies, developing multidisciplinary collaborative ship design tools and nanostructured heat transfer surfaces and materials for enhanced thermal transport. Sustainment and Logistics Conduct basic research to investigate maintenance technology, manufacturing and repair, sustainment technologies and advanced logistics. - Efforts include, but are not limited to, the following: corrosion control, condition-based maintenance and prognostics, repair and component replacement technologies, replenishment at sea and decision support. Materials - Pursue research in computer-aided material design; scarce materials mitigation strategies; electrochemical materials and functional polymeric materials, leading to technological underpinnings for advanced energy capture and power storage and distribution; structural materials for performance improvement and resiliency; identifying new nanoengineered materials and processing for naval applications.					
FY 2023 Base Plans: Aerospace Structures and Materials Research is focused on basic research for developing lightweight, reliable, survivable, sustainable, and affordable airframes for naval and marine corps aircraft and weapons. - Continue research on galvanic corrosion and mitigation strategies for metallic airframes in naval environment. - Continue efforts on multiaxial fatigue of hybrid airframes. - Continue research on high fidelity composites prediction methodologies that span multiple length scales. - Continue work on novel out of autoclave and out of oven curing technologies. - Continue research on short fiber thermoplastic composite forming and joining. - Continue work on high strain rate characterization of materials. - Continue computer assisted iterative material development for armor applications. - Continue investigating lightweight material solutions for multifunctional structures for airframes and weapons. Flight Dynamics & Control					

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Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Research will develop theory and analysis methods to understand the phenomena and natural dynamics of air vehicles operating in the marine environment. Collaborative research will improve our knowledge of control system interactions between piloted aircraft and human performance. - Continue efforts to increase the operational envelop for air vehicles, tailor airframe dynamics with novel control effectors, improve threat engagement performance, develop fundamentals for coupled human/machine dynamics, adapt to variable airframe conditions. - Continue work on multibody control systems and the ability to demonstrate guaranteed performance relative to a desired end state. - Continue work designed to achieve robust and precise control in the presence of highly turbulent flow fields. - Continue developing algorithms to enable precise ship-relative navigation in GPS-denied environments. Aerodynamics Research will enhance understanding of Naval-unique aerodynamic challenges by developing advanced computational and experimental methods. - Continue researching the fully coupled aerodynamic interface between ships and aircraft. - Continue investigating novel state-of-the-art in-situ diagnostics and reduced-order modeling of complex flow fields. - Continue researching innovative technologies enabling increased range and/or maneuverability suitable for aircraft operating from the maritime environment and attritable systems such as unmanned aerial systems and high-speed weapons. - Continue research on the interactional and transitional aerodynamics of multi-rotor systems in complex fluid dynamic environments involving multi-body relative motion. Science of Autonomy and Control of Unmanned Systems Research related to critical multidisciplinary autonomy challenges that cut across areas/domains, including air, sea, undersea and ground. - Continue investigating the scalable and robust distributed collaboration among autonomous systems. - Continue research on human/unmanned system collaboration. - Continue work on perception-based adaptation across uncertain naval environments. - Continue investigating embodied and situated intelligence and architectures. - Continue developing theory-based tools and methods for safe, assured, robust, verifiable, and trustable autonomy. Propulsion, Power and Thermal Management					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Complete research in flow control in offset diffusers. - Continue research to advance the technical superiority of Naval Aircraft - Propulsion, Power and Thermal management with emphasis on propulsion cycles, subsystems, propulsion integration, turbo machinery and drive systems, and hot section materials and coatings. - Continue research to improve the power density, fuel efficiency, speed, range and operating reliability of future large, medium and small engines. - Continue studies with Rotating Detonation Engines and integration into platforms and weapon systems using thermodynamic models, Computational Fluid Dynamics and sub-scale experiments. - Continue research for high stage-loading and efficient turbomachinery including distortion tolerant fans, casing treatments and advanced methods in blade-disk aerodynamics; advanced cooling and thermal management for engines and auxiliary systems including new concepts of heat collection, distribution and rejection; advanced turbine engine materials and coatings; highly integrated propulsion inlets and exhausts and dust ingestion research, including modeling, separating, deposition, coatings and sensing. - Continue to improve jet engine material durability and temperature rate capabilities in both benign and corrosive environments. - Continue to develop advanced radio-frequency based sensors to provide ingestion and foreign object damage sensing, as well as overall prognostics. - Initiate research of fundamental modeling of distributed combustion in the turbine. Platform Design and Engineering Conduct basic research related to platform performance and platform autonomy and control. Efforts include, but are not limited to, the following: - Continue research related to Naval Engineering and Platform Design (NNR), Basic Surface Ship Dynamics, Propulsion Hydromechanics, Basic Subsurface Hydromechanics, Basic Surface Ship Hydrodynamics, Adaptive Control and Centers for Innovative Naval Technology - Continue and expand research associated with Digital Twin Science efforts. Conduct basic research related to platform survivability and tactical submarine evolution plan (TSEP) S&T. Efforts include, but are not limited to, the following: - Continue research related to Structural Reliability Science, Metamaterials, Structural Acoustic Science, Underwater Electromagnetic Signatures, Electromagnetic Signatures, Signature Management Science, Submarine Security S&T - Detectability and Submarine Security S&T - Susceptibility. Power, Energy & Propulsion					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Conduct basic research related to heat transfer and thermal management, power generation, energy storage and power management, distribution and control, and power electronics and electro-magnetics. - Initiate basic research efforts related to climate resiliency and clean energy. Materials - Continue research related to enabling enhanced performance and resiliency of systems and platforms through a collection of related efforts. Work includes Corrosion Control Science (for conventionally and additive manufactured materials) for enhanced resiliency and sustainability of naval platforms and systems; Nano-Engineered Materials for extended performance and sustainability of legacy systems and platforms and emerging opportunities for structural and functional (optical, electro-active, etc.) properties that will enable new system designs; Scarce Materials Mitigation Strategies to explore new compositions to reduce requirements for certain elements; Electrochemical Materials and Functional Polymeric and Organic Materials to understand phenomenology that can be applied to more efficient energy capture and power storage and distribution for a wide distribution of naval emerging requirements, and Computer-Aided Material Design to accelerate research in all areas described here. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** There is no significant change from FY 2022 to FY 2023.					
Title: Atmosphere and Space Sciences	26.026	27.442	27.597	0.000	27.597
Description: Effective Naval operations depend upon accurately understanding the maritime and littoral operating environment and predicting its characteristics at high spatial and temporal resolution in areas that may be inaccessible. Understanding atmospheric phenomena and their impact on the electromagnetic spectrum from the sea surface to space provides a significant warfighting advantage. Efforts include: Battlespace Environments, Marine Meteorology and Prediction and Space Research. These efforts support basic research on physical process studies, fundamental observations, data discovery, and modeling and forecasting of the atmosphere and space with the goal of improving the ability to predict the battlespace environment of the Navy and Marine Corps, anywhere on the globe. Emphasis is placed on the marine atmosphere, the tropics, polar regions, the upper atmosphere and ionosphere and other areas where new understanding is needed in order to overcome predictability barriers that limit the accuracy of current forecast models. Efforts are underway to understand the interactions of physics between the atmosphere, space, land, ocean and ice, represent these coupled processes in models, and extend them across scales from local to planetary, with the goal of					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
extending the skill of predictions up to seasonal and interannual timescales. Recent efforts have also focused on the processes that control tropical cyclone formation, structure and intensity changes and phenomena that affect electromagnetic and electro-optic signal propagation in the marine atmosphere and near space domains. Research results provide the foundation for improved global and regional forecasts of the operational environment and for development of next-generation, fully coupled, high resolution prediction systems. Research areas evolve in response to priorities of the Oceanographer of the Navy. ***FY 2022 Plans:*** Battlespace Environments - Continue to improve the quality of the environmental analysis and prediction provided in support of warfighters by assessing the impact of the atmosphere and ionosphere-thermosphere-magnetosphere on the performance of sensors, platforms and weapon systems, and by advancing our basic understanding of atmospheric processes across spatial scales and the interactions of the atmosphere with the land, sea, wave, ice, and thermosphere. - Continue to exploit environmental observations and to characterize environmental processes more accurately, thus providing improved forecast models for the Navy and Marine Corps in regions where operations take place including: the littoral zone, where complex topography and air-sea-land contrasts impact the environment on very short time and space scales; the tropics and sub-tropics; and the Arctic, where longer time scale atmospheric changes affect short-term weather events. - Initiate new research on atmospheric or Earth system coupled processes that are not well understood, including cloud and aerosol interaction, marine boundary layer and coastal prediction, and diurnal and mesoscale variability to improve their representation in forecast models. - Continue to investigate the distribution, transport and time evolution of aerosols in the atmosphere and their impact on atmospheric visibility and laser propagation. - Initiate new research on coupled processes in the high atmosphere, between the troposphere and stratosphere and the stratosphere and ionosphere and their effect on weather and space weather prediction. Marine Meteorology and Prediction - Continue the Land-Air-Sea Interaction research initiative to improve our understanding and prediction of coupled near-shore atmospheric and oceanographic phenomena impacting naval littoral operations. - Continue to investigate key physical processes, including clouds and moisture phenomena, in order to improve their representation in atmospheric predictive models. Efforts will be focused on those phenomena that affect the predictability of parameters of highest relevance to naval operations.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Investigate new and non-conventional observational data sources and explore novel methodologies to assimilate these data into operational predictive models. - Conduct deployment of observing systems in the upper troposphere, middle and upper atmosphere and the near-space environment, providing information that will allow us to extend our prediction systems into the middle and upper atmosphere and provide longer and higher fidelity forecasts that will impact naval mission planning. - Continue using major observing experiments to understand the processes that contribute to the poorly predicted rapid intensification of tropical cyclones. - Continue field and modeling initiatives that focus on the origin, evolution and effects of Arctic cyclones believed to have a strong influence on Arctic sea ice motion and extent. Space Research Perform innovative sensor development and physics-based modeling and forecasting R&D (research and development) that is integrated across three environmental areas: geospace, heliospace, and high-energy space. R&D efforts are motivated and guided by innovative concepts for future resilient, distributed Naval operations, with metrics to increase technology readiness and rapid prototyping, for accelerated delivery. The programs include: Geospace: - Continue research into affordable small-sat sensors to investigate and specify the three dimensional structure and evolution of the electromagnetic signal propagation environment in the ionosphere, including ionospheric bubbles. Employ stereo imaging and tomographic reconstruction to access the three dimensional structure and evolution of the upper atmosphere and ionosphere, relevant to Naval communications, intelligence, surveillance and reconnaissance, and geolocation. - Continue development of our understanding and computational representation of upper atmospheric, ionospheric relevant plasma processes and their coupling to the lower atmosphere and solar inputs, towards a future physics-based ionospheric prediction capability for Naval forces. - Initiate a small-sat investigation into improved ionospheric observation and understanding through use of new signal processing approaches, based on anomalous refraction of Global Navigation System transmissions. Heliospace: - Continue efforts to advance the understanding, and advance the forecastability of, the solar radiation and particle fluxes, and magnetic fields. Investigate how they influence the near-Earth environment and the relevant Naval systems that rely on that environment. High-Energy Space: - Continue efforts to understand particle acceleration mechanisms in high energy solar flares by studying gamma-ray and neutron emissions that are measured in space.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate efforts to leverage millisecond pulsars as stabile timing sources for precision navigation and timing applications.					
FY 2023 Base Plans: Battlespace Environments - Continue to improve the quality of the environmental analysis and prediction provided in support of warfighters, including the assessment of the impact of the atmosphere and ionosphere-thermosphere-magnetosphere on the performance of sensors, platforms and weapon systems, and the advancement of our basic understanding of atmospheric processes across spatial scales and the interactions of the atmosphere with the land, sea, wave, ice, and thermosphere. - Continue to exploit environmental observations and to characterize environmental processes more accurately, thus providing improved forecast models for the Navy and Marine Corps in regions where operations take place, including: the littoral zone, where complex topography and air-sea-land contrasts impact the environment on very short time and space scales; the tropics and sub-tropics; and the Arctic, where longer time scale atmospheric changes affect short-term weather events. - Continue research on the coupled processes in the high atmosphere, between the troposphere and stratosphere and the stratosphere/mesosphere and ionosphere and their effect on weather and space weather prediction. - Continue research on atmospheric or Earth system coupled processes that are not well understood, including cloud and aerosol interaction, marine boundary layer and coastal prediction, and diurnal and mesoscale variability to improve their representation in forecast models. Marine Meteorology and Prediction -Continue to investigate key physical processes, including clouds and moisture phenomena to improve their representation in atmospheric predictive models. -Continue exploration of new and non-conventional observational data sources and novel methodologies for their assimilation into operational predictive models. -Continue deployment of observing systems in the upper troposphere, middle and upper atmosphere and the near- space environment to allow extension of prediction systems into the middle and upper atmosphere and provide longer and higher fidelity forecasts. -Continue observing experiments to understand the processes that contribute to the poorly predicted rapid intensification of tropical cyclones. -Continue field and modeling initiatives that focus on the origin, evolution and effects of Arctic cyclones believed to have a strong influence on Arctic sea ice motion and extent.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
-Continue to investigate the distribution, transport and time evolution of aerosols in the atmosphere and their impact on atmospheric visibility and laser propagation. -Complete the Land-Air-Sea Interaction research initiative to improve understanding and prediction of coupled near- shore atmospheric and oceanographic phenomena impacting naval littoral operations. -Initiate new research in cloud processes, predictability and uncertainty and utilization of nontraditional space-based and airborne sensors towards these goals. Space Research Perform innovative sensor development and physics-based modeling and forecasting integrated across three environmental space areas: geospace, heliospace, and high-energy space. Geospace: - Continue research into affordable small-sat sensors to investigate and specify the three dimensional structure and evolution of the electromagnetic signal propagation environment in the ionosphere, including ionospheric bubbles. Employ stereo imaging and tomographic reconstruction to access the three dimensional structure and evolution of the upper atmosphere and ionosphere, relevant to Naval communications, intelligence, surveillance and reconnaissance, and geolocation. - Continue development of our understanding and computational representation of upper atmospheric, ionospheric relevant plasma processes and their coupling to the lower atmosphere and solar inputs, towards a future physics-based ionospheric prediction capability. - Continue a small-sat investigation into improved ionospheric observation and understanding through use of new signal processing approaches, based on anomalous refraction of Global Navigation System transmissions. Heliospace: - Continue efforts to advance the understanding, and advance the forecastability of, the solar radiation and particle fluxes, and magnetic fields. Investigate how they influence the near-Earth environment and the relevant Naval systems that rely on that environment. - Continue to investigate efforts to improve solar event warning times, using newly available observations. - Continue efforts to understand particle acceleration mechanisms in high energy solar flares by studying gamma-ray and neutron emissions that are measured in space. - Continue efforts to leverage millisecond pulsars as stabile timing sources for precision navigation and timing applications. - Initiate efforts to improve solar event warning times, using newly available observations. High-Energy Space:					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate efforts to investigate new high-energy radiation and neutron detector materials for space-based observations. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** There is no significant change from FY 2022 to FY 2023.					
Title: Science Addressing Hybrid Threats	23.361	24.460	24.248	0.000	24.248
Description: Naval expeditionary forces increasingly face hybrid adversaries using conventional weapons combined with terror, crime, cyber, information operations, etc. A hybrid adversary is flexible and adapts quickly to synchronize advanced state weapons systems, disruptive commercial technologies, cheap expedient homemade weapons, and a variety of novel tactics. The Sciences Addressing Hybrid Threats (SAHT) (formerly Counter Improvised Explosive Device (IED)) activity seeks to establish and nurture science to counter these growing challenges, while collaborating with and leveraging results from more traditional Naval research portfolios. The SAHT Sciences program provides research for Naval Forces to fight hybrid threats and adversaries in expeditionary operations. Naval Expeditionary Forces need science advances to address a range of research challenges that result from physical and operational environmental limitations so harsh that solutions push basic discovery and invention. Naval Forces able to operate amphibiously and in the littoral will have all of their capabilities exposed to degrading sea and land physical effects. Expeditionary forces must be agile and lethal but will be constrained by size, weight, and power requirements and must be sustained across large areas. Research efforts include: machine perception, reasoning and collaborative behavior; artificial intelligence enabling future intelligent systems; optics, electronics, and photonics research to enable revolutionary spectral awareness in small low power sensors; computer and network science to enable expeditionary computing; fundamental chemistry and materials science research to advance technologies to support sustainment; materials research to explore and improve armor and structural materials; electrochemical energy conversion and storage research to sustain the force; chemistry and physics to provide disruptive energetics for expeditionary fires; and biology, physiology, and cognitive sciences addressing Naval Expeditionary warfighter capabilities. ***FY 2022 Plans:***					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Conduct basic research in sensors and sensing technologies to enable stand-off detection and rapid neutralization of explosive hazards in multiple expeditionary mission environments while maintaining operational tempo. - Continue to extend exploring concepts, techniques and methods, for the design, growth, and characterization of electronic and electro-optic sensors to counter improvised explosive devices (IEDs). - Continue research into reconstructing human physiological features from audio samples based upon brain science to pair vocal tract features with identifiable facial characteristics. - Continue research into enabling secure and efficient sharing of computer hardware accelerators in systems restricted by size, weight, area and power. - Conduct research novel energetic materials that provide order of magnitude increases over current conventional energetics in reactive, explosive, and propulsive phenomena including high-energy ingredient synthesis, modeling, characterization, and the fundamentals of initiation mechanisms for these materials. - Conduct research to explore new, rugged, low cost, and high specific power sources, for example solar cell technologies, including investigation into the stability of the solar cells. -Conduct research and develop theories for creating swarming behavior in heterogeneous multi-domain autonomous systems. - Discover methods to identify coherent courses of action from Artificial Intelligence (AI) agents. - Formalize Artificial Intelligence (AI) hybrid learning theories for the purpose of creating heterogeneous multi-agent collaborative autonomy. - Conduct work in immersive sciences for automated methods for generating content, behaviors, and conduct research studies to examine questions of training effectiveness to increase understanding and use of Mixed Reality for naval applications.					
FY 2023 Base Plans: - Continue basic research in sensors and sensing technologies to enable stand-off detection and rapid neutralization of explosive hazards in multiple expeditionary mission environments while maintaining operational tempo. - Continue research into reconstructing human physiological features from audio samples based upon brain science to pair vocal tract features with identifiable facial characteristics. - Continue research into enabling secure and efficient sharing of computer hardware accelerators in systems restricted by size, weight, area and power. - Continue work in immersive sciences for automated methods for generating content and behaviors, and conduct research studies to examine questions, such as usability and training effectiveness, to increase understanding and use of Extended Reality (XR) technologies for naval applications.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue research into methods to identify coherent courses of action with effective outcomes using Artificial Intelligence (AI) agents. - Continue investigating learning theories to enable complex, collaborative, human-robot interactions. - Continue research for modeling autonomy, for the purpose of creating systems that operate in complex undersea/surface/land/air/space domains. - Continue research methods that model how diverse autonomous systems interact with each other in complex environments. - Continue work on means and methods for evaluating the reliability and effectiveness of collective decision making by autonomous systems and humans. - Continue researching the creation of Artificial Intelligence (AI) hybrid learning theories for the purpose of creating heterogeneous multi-agent collaborative autonomy. - Continue research to create theories for multi-agent collaborative autonomy that mimic the organizational principles found in social insects/birds/fishes. - Complete exploring concepts, techniques and methods, for the design, growth, and characterization of electronic and electro-optic sensors to counter improvised explosive devices (IEDs). - Initiate a follow-on and focused research effort on investigation on security aspect of non-volatile main memory usage for future computing systems. - Initiate research to provide fundamental understanding of biological olfactory sensing and processing of relevant odor representation in order to apply toward chemical sensor design and processing principles. - Initiate research of ultra-low size, weight, and power communications in a contested environment. - Initiate research to explore robotic behaviors for locating and mitigating threats from hazards in building clearing. - Initiate a follow-on and focused research effort for the machine learning investigation of multifactorial information environment parameters in order to automate the process of detecting, identifying and distinguishing intent. - Initiate a follow-on and focused research effort for discovery research on multi-class, multi-objective deep reinforced learning algorithms with automated training. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** There is no significant funding change from FY 2022 to FY 2023.					
Title: Human Systems	18.142	20.907	20.310	0.000	20.310

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Description: Sailors and Marines operate across multiple domains: under, on and above the seas. This Activity focuses on understanding the human aspects of Naval operations with the objective of planning and execution for mission success. The long-term goal of this research is to increase total system performance by maximizing the effectiveness of human-machine systems to ensure mission effectiveness. Research areas include: attention and decision making in goal-directed behaviors, computational and neural foundations of cognitive skills and underlying processes, information exchange processes in human-human and human-machine teaming tasks, human interactions with autonomous systems, preparation and adaptation to novel challenge, new approaches to training and training assessment, personnel assessment, information conflicts, and humanitarian assistance/disaster relief. ***FY 2022 Plans:*** Command Decision Making - Conduct basic research to identify the components of Naval missions or tasks (e.g. environmental, logistical) that will impact mission planning and re-planning and, therefore, mission success. The long-term goal is to develop tools that are proactive in providing relevant information to support tactical to strategic decision making. Cognitive Science for Human-Machine Teaming - Conduct basic research to understand the foundation of human intelligence that enables innate functions, such as communication, social interaction, and context understanding. Empirical research in computational modeling and natural language processing will support the framework and architecture necessary to develop higher-level intelligence in robotic and autonomous systems. The long-term goal of these efforts is to develop machines that are not just tools that extend human capabilities, but also teammates that enable better team performance. Schoolhouse Training - Conduct basic research to discover novel theories, methodologies, and models for learning. This research will identify enabling technologies to improve generalized problem solving (e.g., adaptive generalized tutors that introduce new content and facilitate deeper understanding that applies to other knowledge areas) and decision making under risk and uncertainty; and characterize (e.g., the magnitude and time course of skill decay), model, and predict skill decay in Navy-relevant areas to provide appropriate training interventions. The long-term goal of these efforts is to develop enabling technologies that will assist warfighters in generalized problem solving, rapid learning, and skill retention.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Computational Neuroscience - Conduct basic research to identify and understand neural circuits and pathways that will be used to develop models of sensorimotor control and spatial navigation. The long-term goal is to understand the neural foundation of intrinsic cognitive skills, such as attention, memory formation, perception, and problem solving in order to develop novel intelligent systems. Human Interaction with Autonomous Systems and Human-Machine Teaming - Explore principles of warfighter collaboration with autonomous and mission-capable robotic systems. - Conduct basic research to explore training of robots to perform complex manipulation skills using machine learning and human demonstration. The long-term goal is to provide better interfaces with autonomous systems, as well as provide transfer of control of autonomous platforms and payloads amongst operators. Attention in Sensory Processing and Intelligent Sensing: - Conduct basic research in novel deep-learning techniques applied to computer vision. The long-term goal is rapid and accurate object identification in any Naval-relevant environment. Social, Cultural, and Behavioral Modeling - Conduct basic research to improve current methods (e.g., algorithms, models) for detecting adversarial information maneuvers across social media platforms. The result will produce a better understanding of how covert actors inflict hysteria, crowd manipulation and group polarization on vulnerable audiences. The long-term goal is to gain a better understanding of how human sociocultural behavior informs and affects operational solutions in Naval-relevant contexts. Social Networks and Computational Social Science - Conduct basic research to improve the computational efficiency and effectiveness in modeling human behavior, perception of information, and cyber warfare. Investigate novel techniques for effective information environment exploitation and strategic communication. The long-term goal is to understand the impact of the digital information age on the Naval response to conflict, civil instability, and humanitarian assistance. Manpower, Personnel, Training and Education for Future Warfighting: - Conduct basic research to understand the underlying sociological, experiential, psychological, and neurobiological concepts that optimize an individual's intellectual readiness and adaptability to military-relevant emerging technology (e.g. Artificial Intelligence, autonomous systems). Investigate new modeling approaches to support management of the Naval workforce including through novel means of real-time monitoring, observation,					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
and comprehension of unit behavioral health. The long-term goal is to establish a cohesive strategy for optimizing the readiness and effectiveness of the human capital enterprise.					
FY 2023 Base Plans: Command Decision Making - Continue context-based decision making research for mission planning & execution. - Complete research to explore Command and Control (C2) human-machine collaboration and management of algorithms that adapt recommendations using machine learning (ML). - Complete work to utilize machine learning algorithms for analysis and forecasting of "what if" planning scenarios. - Initiate research for creating Collaborative Artificial Intelligence and investigate methods that enable algorithms to learn task procedures and task context from human explanations. - Initiate research into methods to "close-the-loop" where decision support AI can explain recommendations and context to the user. Cognitive Science for Human-Machine Teaming - Continue research to understand the foundation of human intelligence that enables cognitive functions, such as communication, social interaction, and context understanding. - Continue research in computational modeling and natural language processing to support the framework and architectures necessary to develop higher-level intelligence in robotic and autonomous systems. - Complete work into modeling structured goals for monitoring the performance of autonomous agents. Schoolhouse Training - Continue efforts to create novel models for learning aimed at producing durable learning. - Continue to create skill decay models that can be used to predict when refresher training is needed for maintenance procedures. - Continue to investigate individual differences to optimize training techniques. - Continue efforts to understand how to facilitate the acquisition of generalized problem solving. - Complete research that created computationally-executable model of processes required for training dynamic maintenance tasks. Elements include attention, planning, memory, and motor action. - Complete research to measure the impact of video games on enhancing cognitive and perceptual skills. - Initiate researching neuro-psychometric tests that can reliably predict complex skill learning (e.g., second language & computer programing). - Initiate research to discover neuro-imaging analytical techniques to assess learning from written passages.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate work to create new training techniques for spatial ability which facilitates learning STEM skills. Computational Neuroscience - Continue research to identify and understand neural circuits and pathways that will be used to develop models of sensorimotor control and spatial navigation. The long-term goal is to understand the neural foundation of intrinsic cognitive skills, such as attention, memory formation, perception, and problem solving in order to develop novel intelligent systems. - Complete research on neural basis of spatial navigation. - Initiate efforts to explore the neural basis of the control of reaching, grasping and manipulation to inform robotics. Human Interaction with Autonomous Systems - Continue exploring the principles of warfighter collaboration with autonomous and mission-capable robotic systems. - Continue research to explore training of robots to perform complex manipulation skills using machine learning and human demonstration. The long-term goal is to provide better interfaces with autonomous systems, as well as provide transfer of control of autonomous platforms and payloads amongst operators. - Complete the analysis of human impressions (e.g., trust) of robotic teammates. - Initiate research exploring the combination of robot mobility with dexterous manipulation in assisting humans on Naval relevant tasks, such as shipboard maintenance and building clearing of hazards. Attention in Sensory Processing and Intelligent Sensing - Continue efforts on attention in intelligent sensing with a focus on the auditory modality, both with reflected and radiated acoustic signals on underwater targets. - Complete research in novel, brain-inspired deep-learning techniques applied to computer vision. - Initiate explorations into novel Artificial Intelligence-based approaches for Adaptive Training. Social, Cultural, and Behavioral Modeling - Continue research to improve current methods (e.g., algorithms, models) for detecting adversarial information maneuvers across social media platforms. - Complete research on detection of computer algorithms (bots) that manipulate social media traffic to influence content. - Initiate research on emerging and novel threats in cyberspace and in key military operations to include humanitarian assistance/disaster relief, civil stability, counter-terrorism and countering influence operations.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate work to explore anthropological, sociological and socio-psychological research to improve blunting, mitigating and defeating influence operations against US interests abroad. Social Networks and Computational Social Science - Continue research to improve techniques in influence discernment, and the creation of effective communications strategies in the face of information conflict, modeling human behavior, the perception of information and cyber warfare. - Complete research on global models to monitor and explore social media. - Initiate research to explore social science methods and techniques to detect, mitigate, blunt, and defeat influence campaigns. - Initiate research and models on the impact of hybrid warfare and geo-political shifts on the future of conflict in the next decade. Manpower, Personnel, Training and Education for Future Warfighting - Continue research to understand the underlying mechanisms that optimize an individual's intellectual readiness and adaptability to military-relevant emerging technologies (e.g., Artificial Intelligence, autonomous systems) or novel operational challenges. - Continue research to improve psychometric properties of selection/assessment for high performance in military settings. - Continue research to improve analytical approaches to understand human behavior based on unstructured, interdependent, and complex data. The long-term goal is to establish a cohesive strategy for optimizing the readiness and effectiveness of the human capital enterprise. - Complete research evaluating the feasibility of virtual reality (VR) and augmented reality (AR) gaming technology to improve mental health outcomes and transition research results. - Initiate research exploring innovative technologies for real-time sensing and observation of individual behavioral responses to social and operational stressors. - Initiate research into methods to predict and detect destructive social behaviors, with a focus on novel theoretical frameworks and approaches, conducive to application in military settings. - Initiate research to create integrated modeling approaches to support management of the Naval workforce, leveraging real-time monitoring, observation, and comprehension of unit behavioral health.					
FY 2023 OCO Plans: N/A					
FY 2022 to FY 2023 Increase/Decrease Statement:					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
There is no significant change from FY 2022 to FY 2023.					
Title: Mathematics, Computer, and Information Sciences	53.712	60.256	61.701	0.000	61.701
Description: This activity includes basic research efforts directed toward increasing scientific, mathematical, and computational foundations for integrated command, control, communications, cyber intelligence, surveillance, reconnaissance and targeting. The purpose is to sustain U.S. Naval Science and Technology (S&T) superiority, provide new technological concepts for the maintenance of naval power and national security, and help avoid scientific surprise. Efforts include: Scientific foundations and understanding for robust communications and networking; foundations for novel computing hardware, including nanoscale materials, emerging devices and circuits, emerging computational architecture and nanofabrication; basic research on novel techniques for controlling quantum states; algorithms for analyzing massive datasets in real time and heterogeneous information integration; science base and computational methods for building versatile intelligent agents; theory, algorithms and tools for decision support; mathematical optimization for resource allocation and usage; modeling and computation of complex physical phenomena; computation and information foundations for cyber defense; secure and reliable information infrastructure for command and control; information assurance; and research to extend state-of-the-science in artificial intelligence for the unique challenges of the Naval domain. ***FY 2022 Plans:*** Communications and Networking Continue developing the scientific foundation and understanding of wireless communications and networking technologies that enable the naval warfighter to maintain access to mission critical information in contested environments. Research thrust areas include: Tactical Communications: - Continue developing new techniques for wireless distributed computing and device-to-device communication. - Complete development of new algorithmic framework for signal retrieval using non-uniform sparse array geometries. - Complete novel wireless communications methods across air-water boundary. - Initiate novel coding and modulation techniques to improve the efficiency, capacity and/or resilience of wireless communications. Tactical Networks					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue developing a feedback control model to determine the limit of fast adaptive traffic engineering. - Continue investigations in to new algorithms, protocols and middleware for dynamic and scalable multi-hop ad hoc wireless networking in contested environments, - Continue Artificial Intelligence/Machine Learning techniques for multi-dimensional Quality-of-Service optimization. - Continue development of cognitive methods and algorithms to maintain network resiliency under link disruptions without adding excess overhead. Networked Sensing The primary focus of the Networked Sensing program is to conduct basic research in optical components and infrared technologies to enable significant leap-ahead capabilities for the survivability and lethality of Naval forces in complex environments. - Continue efforts exploring advanced photonics techniques to maximize information extraction from individual photons and through tailored optical beams with the goal of being able to image at long-ranges and in degraded conditions. - Continue efforts on fundamental implications of classical entanglement on imaging and metrology. - Continue efforts to discover highly-sensitive, multi-spectral detector materials and active sensing modalities for imaging through clouds, fog, haze and dust. - Initiate efforts to explore novel optical processing architectures to significantly increase signal processing bandwidth and to enable novel, real-time, distributed sensing applications. Nanoscale Computing Devices and Systems - Continue research on ultra-low power nanoelectronic devices, circuits and systems. - Continue research on atomic precision control of graphene nanostructures using chemical synthesis techniques. - Continue research on spin based electronics, focusing on single atom and single molecule level control. - Continue research on carbon based quantum systems that are compatible with bottom-up chemical synthesis paradigm. - Initiate research combining molecular quantum science and synthetic electronics. Quantum Information Sciences - Continue research on novel techniques for controlling quantum states to improve performance of information processors, sensors and clocks.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue research on demonstrations of systems having a quantum advantage in the solution of optimization problems and quantum simulation of complex physical systems. - Initiate research on the utilization of photonic and phononic devices for high performance quantum information processing. Mathematical Data Science - Continue basic research in mathematics, probability, statistics, signal processing, machine learning, data engineering, and information theory. - Continue to develop advanced algorithms for analyzing massive datasets in real time, identify real patterns and avoid false positives. - Continue to develop advanced methods that can integrate and extract common features from large heterogeneous domains. - Initiate research on privacy in complex networks. Machine Learning, Reasoning and Intelligence - Continue developing the science base and computational methods for building versatile intelligent agents, which can function autonomously in uncertain, unstructured, uncontrolled, open-world environments, and can collaborate seamlessly with humans and other agents. - Continue basic research in developing new mathematical methods for principled design of deep learning architectures and analysis of their behavior. This program is expected to develop techniques for predicting performance learning-based systems, to improve their generalization abilities, and to reduce the need for empirical verification. -Initiate basic research for developing robust computer vision systems, based on human vision, for automated understanding of surveillance imagery, perception for autonomous agents, and managing image/video libraries for after-action analysis and planning. Mathematical Optimization and Operations Research - Continue investigations on discrete and nonlinear-continuous programs for which input parameters are known with certainty, but for which the acquisition of optimal decision strategies can be computationally intensive. - Continue research on optimizing stochastic programs that, due to incomplete or partial information, have input parameters that are not known with certainty. - Continue to identify exploitable mathematical structures within specific decision problems for the purpose of devising superior solution algorithms.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Complete advances to special continuous nonconvex programs wherein both the objective to be optimized and the restrictions that enforce the system characteristics are expressed in terms of decision variables that are allowed to realize a continuum of values. - Complete advances to stochastic optimization that include a framework for distributed decomposition of different classes of large-scale problems, and the solving of real-size instances of nonlinear chance-constrained stochastic programs. - Complete the development of new families of cutting planes that effectively remove infeasible or non-optimal solutions from consideration. - Initiate new methods for strategically formulating and solving optimization problems that arise in resource allocation, logistics, and system planning. - Initiate new techniques that utilize convex optimization and duality theory to solve non-convex optimization problems. Applied and Computational Analysis - Conduct basic research in developing analytical and computational tools for models of physical phenomena of critical interest to the Navy waves, flows, materials, structures and information processing. - Continue to develop robust, reliable and near-real-time computational models for predicting environmental behavior in atmospheric and oceanic processes. - Continue to develop theoretical and computational tools to predict the onset of extreme events, whether in materials, such as formation of shocks, cracks and other discontinuities. - Continue to develop reduced models to enable speed up of computational models in acoustics, electromagnetics and optics, in regimes of special interest to the Navy. - Initiate research to develop mathematically rigorous algorithms for employing variable-precision computations in very large-scale multi-physics problems. Cyber Security and Complex Software Systems - Continue to investigate and develop novel computing concepts that lead toward robust, resilient, and dependable cyber systems. - Continue further development of tools and environment for programmability of heterogeneous multiple instruction set architecture systems. - Continue to explore novel application of ONR's concept of hybrid, formal-statistical machine learning (Learn2Reason) in cyber security and software systems environment. - Continue to explore physics-based approaches to various security aspect of cyber-physical systems, including authentication, vulnerability testing, and exploit resilience.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue critical emphasis on improving scalability and capability of bottom-up formal analysis that would enable users to prove security properties about binaries directly. - Complete research on computer-driven exploration of cryptographic algorithms, as the work has been successful in changing community thinking. - Initiate research on novel methods for attack surface maneuver for cyber physical systems and systems with complex apertures and sophisticated sensing apparatus, to include lightweight decoy synchronization and other resilience techniques. Science of Artificial Intelligence: - Explore principled frameworks for integrating domain knowledge and machine learning for fast, robust learning of diverse complex concepts and tasks with light supervision. - Explore artificial intelligence to advance the scientific understanding of collaborative, complex decision-making that is typical of naval command decision making. Explore formal verification and validation methods for artificial intelligence in the naval domain to enhance trust. Explore explainable artificial intelligence to enhance human-machine collaboration. Explore decentralized perception and planning in dynamic environments to develop a unified framework perception and planning for resources distributed across multiple platforms, autonomous systems and agents. Explore new brain-inspired artificial intelligence algorithms and architecture that provide richer computational capabilities than current deep learning networks, with an emphasis on memory systems and higher vision. Explore neuromorphic spiking neuron hardware designs based on brain models that are suitable for future edge computing and signal processing in small naval platforms. Explore autonomous problem solving and curiosity driven search for robust performance under unexpected conditions. Information Technology: - Continue development of improved methods for producing, analyzing, and securing Naval software systems. - Continue to design new concepts for future Naval tactical communication systems and networks. - Continue research in intelligent autonomy and improved interaction with autonomous systems, and improved methods for information analysis, fusion, and presentation.					
FY 2023 Base Plans: Communications and Networks - Continue developing the scientific foundation and understanding of wireless communications and networking technologies that enable the naval warfighter to maintain access to mission critical information in contested environments. Research thrust areas include Tactical Communications and Tactical Networks.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Tactical Communications - Continue developing new techniques for wireless distributed computing and device-to-device communication. - Continue novel coding and modulation techniques to improve the efficiency, capacity and/or resilience of wireless communications. Tactical Networks - Continue developing a feedback control model to determine the limit of fast adaptive traffic engineering. - Continue investigations in to new algorithms, protocols and middleware for dynamic and scalable multi-hop ad hoc wireless networking in contested environments. - Continue Artificial Intelligence/Machine Learning techniques for multi-dimensional Quality-of-Service optimization. - Continue development of cognitive methods and algorithms to maintain network resiliency under link disruptions without adding excess overhead. Spectrum Superiority / Networked Sensing - Continue efforts exploring advanced photonics techniques to maximize information extraction from individual photons and through tailored optical beams with the goal of being able to image at long-ranges and in degraded conditions. - Continue efforts on fundamental implications of classical entanglement on imaging and metrology. - Continue efforts to discover highly sensitive, multi-spectral detector materials and active sensing modalities for imaging through clouds, fog, haze and dust. - Continue efforts to explore novel optical processing architectures to significantly increase signal-processing bandwidth and to enable novel, real-time, distributed sensing applications. - Initiate efforts into direct measurement of current and phase at optical and infrared light frequencies to enable wider flexibility in signal extraction and waveforms. Nanoscale Computing Devices and Systems - Continue research on ultra-low power nanoelectronic devices, circuits and systems. - Continue research on spin based electronics, focusing on single atom and single molecule level control. - Continue research combining molecular quantum science and synthetic electronics. - Continue research on experimental routes to topologically-protected quantum computation with non-abelian any on quasiparticles in solid-state devices. - Complete research on atomic precision control of graphene nanostructures using chemical synthesis techniques.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Complete research on carbon based quantum systems that are compatible with bottom-up chemical synthesis paradigm. - Initiate research on device physics enabling probabilistic computing in stochastic networks. Quantum Information Sciences - Continue research on novel techniques for controlling quantum states to improve performance of information processors, sensors and clocks. Continue research on demonstrations of systems having a quantum advantage in the solution of optimization problems and quantum simulation of complex physical systems. - Continue research on the utilization of photonic and phononic devices for high performance quantum information processing. - Initiate research exploring the distribution of entanglement in a quantum network and applications thereof. Mathematical Data Science - Continue basic research in mathematics, probability, statistics, signal processing, machine learning, data engineering, and information theory. - Continue to develop advanced algorithms for analyzing massive datasets in real time, identify real patterns and avoid false positives. - Continue to develop advanced methods that can integrate and extract common features from large heterogeneous domains. - Continue research on privacy in complex networks. - Initiate development of scalable reinforcement learning. - Initiate research in approximate dynamic programming. Machine Reasoning and Intelligence - Continue developing the science base and computational methods for building versatile intelligent agents, which can function autonomously in uncertain, unstructured, uncontrolled, open-world environments, and can collaborate seamlessly with humans and other agents. - Continue basic research in developing new mathematical methods for principled design of deep learning architectures and analysis of their behavior. This program is expected to develop techniques for predicting performance learning-based systems, to improve their generalization abilities, and to reduce the need for empirical verification.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue basic research for developing robust computer vision systems, based on human vision, for automated understanding of surveillance imagery, perception for autonomous agents, and managing image/video libraries for after-action analysis and planning. - Initiate basic research in machine self-learning for intelligent agents, inspired by human learning, for understanding real-world environments. Optimization and Discrete Mathematics - Continue to identify exploitable mathematical structures within specific decision problems for the purpose of devising superior solution algorithms. - Continue investigation into methods for strategically formulating and solving optimization problems that arise in resource allocation, logistics, and system planning. - Continue investigations into new techniques that utilize convex optimization and duality theory to solve non-convex optimization problems. - Complete investigations on discrete and nonlinear-continuous programs for which input parameters are known with certainty, but for which the acquisition of optimal decision strategies can be computationally intensive. - Complete research on optimizing stochastic programs that, due to incomplete or partial information, have input parameters that are not known with certainty. - Initiate research on integrating machine-learning techniques with algorithms for stochastic and combinatorial optimization. - Initiate research on developing novel first-order methods for solving general classes of problems that include saddle point problems, problems with a large number of constraints, and machine learning problems. - Initiate investigations into applying topological data analysis to combinatorial optimization problems. Applied and Computational Mathematics - Continue basic research in developing analytical and computational tools for models of physical phenomena of critical interest to the Navy waves, flows, materials, structures and information processing. - Continue to develop robust, reliable and near-real-time computational models for predicting environmental behavior in atmospheric and oceanic processes. - Continue to develop theoretical and computational tools to predict the onset of extreme events, whether in materials, such as formation of shocks, cracks and other discontinuities. - Continue to develop reduced models to enable speed up of computational models in acoustics, electromagnetics and optics, in regimes of special interest to the Navy. - Continue research to develop mathematically rigorous algorithms for employing variable-precision computations in very large-scale multi-physics problems.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Complex Software Systems and Cybersecurity - Continue to investigate and develop novel computing concepts that lead toward robust, resilient, and dependable cyber systems. - Continue to explore novel application of ONR's concept of hybrid, formal-statistical machine learning in cyber security and software systems environment. - Continue to explore physics-based approaches to various security aspect of cyber-physical systems, including authentication, vulnerability testing, and exploit resilience. - Continue critical emphasis on improving scalability and capability of bottom-up formal analysis that would enable users to prove security properties about binaries directly. - Continue research on novel methods for attack surface maneuver for cyber physical systems and systems with complex apertures and sophisticated sensing apparatus, to include lightweight decoy synchronization and other resilience techniques. Complete development of tools and environment for programmability of heterogeneous multiple instruction set architecture systems. - Initiate research on autonomous cyber operations to explore what facets of cyber activities can be done fully autonomously or semi autonomously with human input. Science of Artificial Intelligence - Continue to explore principled frameworks for integrating domain knowledge and machine learning for fast, robust learning of diverse complex concepts and tasks with light supervision. - Continue to explore artificial intelligence to advance the scientific understanding of collaborative, complex decision-making that is typical of naval command decision making. - Continue to explore formal verification and validation methods for artificial intelligence in the naval domain to enhance trust. - Continue to explore explainable artificial intelligence to enhance human-machine collaboration. - Continue to explore decentralized perception and planning in dynamic environments to develop a unified framework perception and planning for resources distributed across multiple platforms, autonomous systems and agents. - Continue to explore new brain-inspired artificial intelligence algorithms and architecture that provide richer computational capabilities than current deep learning networks, with an emphasis on memory systems and higher vision. - Continue to explore neuromorphic spiking neuron hardware designs based on brain models that are suitable for future edge computing and signal processing in small naval platforms.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue to explore autonomous problem solving and curiosity driven search for robust performance under unexpected conditions. - Initiate research to identify, characterize and model adversarial AI. - Initiate research exploring theory and algorithms for learning and decision making in multi-agent systems, particularly in adversarial situations. Information Technology - Continue development of improved methods for producing, analyzing, and securing Naval software systems. - Continue to design new concepts for future Naval tactical communication systems and networks. - Continue research in intelligent autonomy and improved interaction with autonomous systems, and improved methods for information analysis, fusion, and presentation. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Increase due to increased focus on Networks and Communications.					
Title: Materials/Processes ***Description:*** Lighter, faster, stronger is a winning combination. Naval materials research produces quieter submarines, fuel-efficient ships/vehicles and systems capable of operating under extreme temperature and chemical environments. New materials will result in warfighting advantages, as well as, systems that ensure environmental compliance, improved system reliability/resilience, stealthier materials, reduced manufacturing/ maintenance and lower total ownership costs. The Materials/Processes activity generates fundamental scientific understanding for new, advanced and improved materials, and to accelerate materials-driven concepts essential to Naval superiority. The research is conducted in a cross-cutting and interdisciplinary manner covering Structural Materials, Functional Materials, Manufacturing, Chemistry and Undersea Materials to ensure future Naval power and maritime superiority. Fundamental challenges include understanding atomic-scale to meso-scale phenomena; developing robust, accurate and validated computational modeling and simulation capabilities; and translating this understanding into materials composition, synthesis, processing, properties and performance design principals for engineered devices, components and systems. This activity also includes peer-review basic research to develop innovative solutions and enhance the science and engineering base.	54.618	57.519	59.945	0.000	59.945

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Research directions in the Focus Area are selected to generate new, advanced and improved materials that enable innovative new technologies or can close critical technology gaps. Successes provide breakthroughs for higher performing, cost effective and/or timely technologies supporting Navy and Marine Corps acquisitions, operations and sustainment. Accomplishments and plans described below are examples for each effort category. ***FY 2022 Plans:*** Structural Materials - Continue foundational research in basic materials science on metals, ceramics and composites advances in 2D and 3D materials imaging across spatial scales; multiphysics/multiscale modeling, model reduction strategies and machine learning techniques. This advances Integrated Computational Materials Engineering methods, accelerating materials and process design methods. Novel synthesis and processing routes are also being developed using new temperature, pressure, electromagnetic, aerosol deposition and additive manufacturing strategies. Progress in these areas will enables new high strength and corrosion resistant steel and compositionally complex alloys. Advanced nanoscale core-shell powders promise high temperature performance for hypersonic system components. New microscale composite architectures are pursued which efficiently dissipate energy to enable lighter weight blast, ballistic and impact protection for individuals and vehicles. Functional Materials - Conduct research on high speed energy efficient information processing by advances in magnetic, electronic and optical materials. Development of nanoscale control of two dimensional materials, interfaces, heterostructures, dopants and defects is used to demonstrate fundamental priniciples necessary for advanced Naval technologies. Key elements of these efforts are single atom control of multi-atom and quantum systems, fast phase transition materials, novel computational simulation strategies, quantum computing algorithms of material physics, machine learning and artificial intelligence for materials design. Advanced lithographic methods are used to experimentally fabricate and demonstrate novel device concepts and performance. Progress enables advances in low Size-Weight-Power and Cost (SWAP-C) information processing for advanced magnetic, chemical, biological, radiological and explosive sensors, Naval edge computing and decision systems for autonomy, communications and networking, energy harvesting and photovoltaics. Manufacturing					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Conduct basic manufacturing science research to develop a fundamental understanding of materials and processes necessary for emerging manufacturing technologies relevant to Navy systems. Results will advance Navy opportunities to design and produce validated and verified, low production volume replacement engineered parts for aircraft and ships; new gradient, composite and metamaterial architectures expanding design optimization space; and complex shapes enabling new conformal structural, acoustic and thermal component designs. Efforts are structured around multidisciplinary research on new manufacturing processes, using Integrated Computational Materials Engineering (ICME) approaches and techniques, to advance materials and component production. This includes understanding and modeling key relationships between additive manufacturing alloy chemistry, microstructure, process parameters, part design, high quality properties and certification strategies while minimizing or eliminatoing the need for post processing. Materials and chemistry - Develop the scientific foundations for molecular-level understanding of materials synthesis, processing, and physical properties aimed at propelling, equipping and sustaining the US Navy and Marine Corps with tactical and strategic advantage. Nanoparticle surface chemistry for plasmonic mediated reactions, photocatalysis, hydrogen storage, energetic materials, and fuel additives enables new high power and energy density generation, storage, release and harvesting materials and technologies. These fuel generation, energetic, fuel cell and battery material will enable next generation Navy autonomous undersea and air vehicles. Research on combustion and reacting transport, coupled with advanced mutiphysics computational simulation, will advance fire suppression for damage control as well as liquid and solid-fueled power and energy for hypersonics. Combinatorial and multivariate chemical approaches inform sensor system designs for aviation fuel surety and complex shipboard atmosphere environment monitoring. Advanced quantum computing simulations of quantum systems are modeling aqueous chemistries to allow design of anti-corrosion additives. Understanding fundamental electrochemistry, (tribo)corrosion, and biofouling will guide materials solutions for fleet sustainment through manpower and life-cycle cost reductions. Undersea Warfare - Conduct laboratory and theoretical/numerical work focusing on creation of new techniques for understanding, predicting, and controlling the interactions between acoustic and elastic waves and the processing routes for associated new materials. A key goal is advanced underwater material coupling architectures that achieve a broad range of passive and active acoustic impedances and control. Success will enable new material technologies and methodologies for achieving acoustic stealth. Creation of high performance source transducer materials, such as textured ferroelectric ceramics, should achieve high power receiver performance at reduced					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
cost and complexity. This would enable high throughput production of high performace tranducer ceramics, providing alternatives to current costly and difficult to produce single crystal technology. The creation of high efficiency silicon-based thin film thermoelectric modules for undersea warfare applications will also be pursued by exploiting nanocrystallization and multilayering to control thermal conductivity. This will enable solid-solid thermal management and new options for submarine and Underwater Unmanned Vehicle (UUV) power generation. ***FY 2023 Base Plans:*** Structural Materials - Continue foundational research that provides the underpinnings for robust systems and platforms, exploring and understanding phenomenology of structural properties as functions of with the aim to improve performance and predict and mitigate component degradation, captured in quantitative data and physics-driven models that utilize an Integrated Computational Materials Engineering (ICME) approach and support machine learning. Research domains include Basic Materials Research, Structural Metals, Polymer Composite Materials, Propulsion Materials, Materials for Additive Manufacturing, Sensors & NDE Prognostics, and Alternative Hull Materials & Structures. - Complete efforts in Structural Cellular Materials and Solid Mechanics, as technology areas have matured and attention turns to other emerging research areas. Functional Materials - Continue research to explore opportunities for controlling material composition and atomic structure through characterization and modeling enabling and utilizing an ICME approach to enhance electro-mechanical coupling for next generation Acoustic Transduction Materials; better understand the chemical and mechanical properties of Material Science for Environment Quality; and accelerate research efforts through Computer Aided-Material Design - Functional Materials. Manufacturing - Complete basic manufacturing science research efforts, migrating fundamental work to portfolios of the relative disciplines including Structural Metals and Materials for Additive Manufacturing. Materials and Chemistry Continue the development of the scientific foundations for molecular-level understanding of materials synthesis, processing, and physical properties aimed at propelling, equipping and sustaining the US Navy and Marine Corps with tactical and strategic advantage. These efforts include:					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
-Continue efforts into nanoparticle surface chemistry for plasmonic mediated reactions, photocatalysis, hydrogen storage, energetic materials, and fuel additives which will enable new high power and energy density generation, storage, release and harvesting materials and technologies. These fuel generation, energetic, fuel cell and battery material will enable next generation Navy autonomous undersea and air vehicles. -Continued research efforts on combustion and reacting transport, coupled with advanced mutiphysics computational simulation, will advance fire suppression for damage control as well as liquid and solid-fueled power and energy for hypersonics. Combinatorial and multivariate chemical approaches inform sensor system designs for aviation fuel surety and complex shipboard atmosphere environment monitoring. -Continue advancements into quantum computing simulations of quantum systems which1 model aqueous chemistries to allow design of anti-corrosion additives. Understanding fundamental electrochemistry, (tribo)corrosion, and biofouling will guide materials solutions for fleet sustainment through manpower and life-cycle cost reductions. Undersea Materials - Continue laboratory and theoretical/numerical work focusing on creation of new techniques for understanding, predicting, and controlling the interactions between acoustic and elastic waves and the processing routes for associated new materials; high performance source transducer materials that achieve high powered performance with reduced cost and complexity; and high efficiency silicon-based thin film thermoelectric modules for undersea warfare applications. - Continue research into high performance source transducer materials, such as textured ferroelectric ceramics, that should achieve high power receiver performance at reduced cost and complexity. This would enable high throughput production of high performace tranducer ceramics, providing alternatives to current costly and difficult to produce single crystal technology. - Continue the creation of high efficiency silicon-based thin film thermoelectric modules for undersea warfare applications by exploiting nanocrystallization and multilayering to control thermal conductivity. - Complete research on advanced underwater material coupling architectures that achieve a broad range of passive and active acoustic impedances and control. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** The funding increase from FY 2022 to FY 2023 is due to increased focus on Materials Chemistry and Dynamics.					
Title: Medical and Biological Sciences	18.895	15.997	15.675	0.000	15.675

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Description: The health and performance of Sailors and Marines is a top priority. Extensive research in the medical and biological sciences discover and leverage breakthroughs to improve Naval warfighter performance, so they can fight, win and come home safe. Sailors and Marines operate in the harshest working environments at sea and around the world. Conducting research to gain a better understanding of the biologic challenges of warfighters in their operating environments will ensure optimal performance, prevent injury, and equip the DON to provide the best care for its warfighters. Research areas include: bio-inspired autonomous systems; bioengineering; biophysics; microbial synthetic biology; microelectronics; microbial electrophysiology; microbiome research; bio-inspired multi-spectral camouflage and sensing; sensory neuroscience and physiology; Naval force health protection; undersea medicine; stress responses, health monitoring and modeling research; and health and welfare of the Navy's marine mammals. ***FY 2022 Plans:*** Bio-Inspired Autonomous Systems and Soft Robotics - Conduct basic research to explore novel bio-inspired sensing, control, and fluid dynamics of underwater propulsion and control systems to expand capabilities of underwater autonomous and unmanned systems. This research will include: (i) Exploration of experimental sensing capabilities and modeling for bio-sensing to enable sensorimotor control including fish schooling for passive swarm coordination in underwater vehicles; (ii) Exploration of bio-inspired locomotion from amphibious animals to enable technologies for amphibious and cross-domain vehicles; (iii) Investigation of bio-inspired design principles of distributed sensing, actuation, and control in soft biological structures for underwater propulsion and manipulation; and (iv) Design bio-inspired soft robots (e.g. worm-like robots) to characterize and measure geotechnical properties of the ocean floor. The long-term result will be bio-inspired propulsion and control systems to enable high-lift, stealthy propulsion without propellers and achieve high maneuverability for underwater vehicles. Bioengineering and Life Sciences - Conduct basic research that explores manipulation of biologically-based material design, synthesis, and system assembly. The result of this research will be to discover novel methods and approaches to leverage synthetic biology (e.g., bioengineering and bionanotechnology) to enable material characterization, optimized biomimetic/bio-inspired underwater adhesives, fabricating complex, functional materials from living organisms (e.g., bacteria); endow living mammalian cells with computational capabilities (e.g., information storage), and energy harvesting, storage, conversion, and actuation.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Naval Biosciences and Synthetic Biology for Naval Applications - Conduct basic research to investigate synthetic biology approaches to design microbes/microbial communities to enhance warfighter resilience (e.g., metabolic regulation, stress response, and preventing musculoskeletal injury), sensory capabilities (e.g., olfactory enhancement), and enabling novel technologies for warfighter tools such as electronic sensing, signaling, rapid environmental monitoring, energy harvesting/storage, and biogenic synthesis and sequestration of electronic materials (including rare-earth metals). The long-term goal of this research is to expand the natural capabilities of living organisms (e.g., microbes) to purpose-specific organisms for environmental sensing and monitoring; energy generation, information processing, and material harvesting (important for supply chain security). Warfighter Augmentation - Conduct basic research to investigate novel bio-inspired mechanisms for multi-spectral camouflage including adaptive texture/shape, color adaptation, and near- to mid- infrared concealment. The long-term result of this research will provide novel enabling materials to protect warfighters from detection in the field. Sensory Neuroscience and Physiology - Conduct basic research efforts to advance understanding of auditory processing. The long-term goal is to enhance communication, understanding, and mission success in noisy military environments. Physiological Monitoring and Modeling - Conduct basic research to discover novel sensing capabilities and biomarkers to improve warfighter performance including real-time sensing and monitoring of individual biological functions and physiological responses to environmental and operational stressors across domains and in extreme environments. The result of this research will be to improve sensing capabilities, enhance current signal monitoring capabilities, enable physiological monitoring to predict individual outcomes; discover methods and approaches in quantum biology to incorporate into physiological monitoring and modeling; and autonomously collect, distribute, and integrate information about human teams (including the individuals and environment). The long-term goal of this research will be to discover the next generation of sensing capabilities to collect, understand, distribute, and integrate real-time information on the biological / physiological / cognitive status of both individuals and teams for command and leadership situational awareness and action. Naval Force Health Protection					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Conduct basic research to discover methods for: (i) Modeling and simulation approaches to improve Warfighter protection and injury treatment; (ii) Autonomy for medical care and logistics; (iii) Maritime casualty prevention; and (iv) Wearable technologies and protective equipment for maritime casualty prevention. The long-term goal of this research will be to integrate models of non-invasive sensors, biomarkers, simulations, and biophysical mechanisms to detect injury and identify preventive/mitigating mechanisms for safer protective equipment and vehicles. Investigate nanotechnologies, microelectronics, and autonomy for use in medical care of combat casualties to repair damage at the scale of cells, tissues, and whole body. Understand use of composite materials, additive manufacturing, and microelectronics to enhance warfighter protective equipment by providing increased biomedical sensing of warfighter status and greater operator situational awareness. The long-term goal of this research is to explore to optimize medical treatment, logistics, and casualty evacuation in the tactical environment. Undersea Medicine - Conduct basic research to identify novel technologies to improve performance of naval divers under extreme conditions (e.g, thermal, extended diving operations). The long-term goal of this research will provide understanding of human physiology (and leverage insights from comparative physiology studies of marine mammals) in extreme conditions experienced in the undersea environment; create synthetic biology approaches for thermal protection during dive operations; and identify novel technologies to support underwater breathing apparatus to include utilizing resources naturally present in the ocean for gas management (e.g., oxygen supply and carbon dioxide disposal). Another long-term goal of this research is to understand gas physiology of high partial pressures (e.g., oxygen, carbon dioxide and nitrogen to include metabolic dysfunction) and discover advantageous comparative physiology factors to enhance diver performance, and provide novel pathways and technologies to improve dive operations. Stress Response - Conduct basic research to understand the clinical, neurobiological and genetic factors that predict differences in stress reactivity and investigate how the interaction of chronically stressful environments and changes in light/dark periods affect the circadian system to regulate the central stress response system. The results of this research will provide validated predictive factors of stress reactivity in healthy, young subjects and the effects of photoperiod changes (model of circadian disruption) on the stress axis reactivity. The long-term goal is to explore the biological mechanisms of stress vulnerability, and research stress resilience for prevention and effective treatment of stress-related disorders. Physiological Monitoring and Modeling:					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue to research the use of nucleic acid cleavage in creation of detection systems for the Warfighter. This will enable easily adapted nucleic acid detection with orders of magnitude lower sensitivity and specificity. Bio-derived Materials - Continue research on biomolecule embedding and control of cells and membranes will enable advanced biomaterials, biolelectronics and biotic-abiotic system interfaces. This would provide new biomimetic sentinel molecules for Navy chemical and optical sensor/actuator devices and biorobotic systems. The resulting chemical, biological, radiological, and explosive sensors will enable sensitive operating environment surveillance.					
FY 2023 Base Plans: Bio-Inspired Autonomous Systems and Soft Robotics - Continue research to explore novel bio-inspired sensing, control, and fluid dynamics of underwater propulsion and control systems to expand capabilities of underwater autonomous and unmanned systems. This research will include: (i) Exploration of experimental sensing capabilities and modeling for bio-sensing to enable sensorimotor control including fish schooling for passive swarm coordination in underwater vehicles; (ii) Exploration of bio-inspired locomotion from amphibious animals to enable technologies for amphibious and cross-domain vehicles; (iii) Investigation of bio-inspired design principles of distributed sensing, actuation, and control in soft biological structures for underwater propulsion and manipulation; and (iv) Design bio-inspired soft robots (e.g., worm-like robots) to characterize and measure geotechnical properties of the ocean floor. The long-term result will be bio-inspired propulsion and control systems to enable high-lift, stealthy propulsion without propellers and achieve high maneuverability for underwater vehicles. - Complete investigation of fish lateral line pressure sensing for navigation and obstacle avoidance of underwater vehicles. - Initiate research to explore multi-fin control, propulsion and maneuver with robotic fish prototypes. Bioengineering and Life Sciences - Continue the exploration of computational tools and fabrication methods for producing materials with targeted properties from the molecular level (nanometers) to the macroscopic level (meters) for Naval applications. - Continue investigation of bioinspired and biomimetic adhesives and reversible adhesives that cure in seawater for underwater applications. - Continue the exploration of computational design tools and characterization methods for nanostructures made from DNA, and their application to optical computing, data storage, and cell-free bioconversion systems for bioproduct manufacturing.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue experimentation with synthetic biology to establish new biomanufacturing strategies for complex and living materials. - Continue the exploration of water absorption-evaporation cycling in biomaterials to develop hydro- and thermo-responsive textiles and as a power source for maritime sensing surveillance systems. Naval Biosciences and Synthetic Biology for Naval Applications (This thrust includes the efforts previously listed under Warfighter Augmentation in the FY22 plan.) - Continue research to investigate: (i.) bio-inspired mechanisms for multi-spectral camouflage (adaptive texture/ shape, color, and near- to mid- infrared concealment), and (ii.) bioengineering bacteria for sensing, materials, and functionalized microbial communities. - Continue researching the construction of bacterially synthesized biomaterials for capturing and enriching rare earth elements to establish a secure source of these critical materials for defense-related applications. - Continue the investigation of novel materials and electroactive bacteria to improve energy generation from bacteria powered fuel cells and for use of components in synthetic biology applications. Auditory Science for the Naval Domain (This thrust was previously part of the Sensory Neuroscience and Physiology FY22 plan. The name was changed to more accurately describe the research.) - Complete studies that led to the discovery of small molecule therapeutics for the potential treatment of auditory system injuries associated with noisy Naval environments. - Initiate studies investigating how biological systems use acoustic camouflage and design bio-inspired acoustic dampening metamaterials. Physiological Monitoring and Modeling - Continue to research the use of nucleic acid cleavage in creation of detection systems for the Warfighter. This will enable easily adapted nucleic acid detection with orders of magnitude lower sensitivity and specificity. - Complete research on innovative communications capabilities for discreet transmission of individual and team health and geolocation data. - Initiate research to characterize new physiologic signal monitoring capabilities. - Initiate research into innovative technologies for real-time sensing and observation of individual responses to environmental and operational stressors. Naval Force Health Protection					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue research into methods for modeling and simulation approaches to improve Warfighter protection and injury treatment. - Continue to investigate nanotechnologies, microelectronics, artificial intelligence, and autonomy for use in medical care of combat casualties to repair damage at the scale of cells, tissues, and whole body. - Continue research to understand use of composite materials, additive manufacturing, and microelectronics to enhance warfighter protective equipment by providing increased biomedical sensing of warfighter status and greater operator situational awareness. The long-term goal of this research is to explore to optimize medical treatment, logistics, and casualty evacuation in the tactical environment. - Continue use of fundamental principles of physics to determine material properties of biological tissues. Undersea Medicine - Continue studies to enhance our understanding of human physiology (and leverage insights from comparative physiology studies of marine mammals) in the undersea environment. - Continue work to create synthetic biology approaches for thermal protection during dive operations. - Continue research to identify novel technologies to support underwater breathing apparatus to include utilizing resources naturally present in the ocean for gas management (e.g., oxygen supply and carbon dioxide disposal). - Complete research that identified the role of specific gas channels (AQP1 and 4) now being explored as potential targets for limiting oxidative stress caused by elevated oxygen exposures encountered in dive operations. - Initiate research on respiratory plasticity in relation to metabolic efficiency, immunologic resilience and thermal tolerance with a particular focus on respiratory loads in altered breathing gas states (e.g., hyperoxia, hypercapnia, hypoxia). Stress Response - Continue to investigate the clinical, neurobiological, and genetic factors that predict differences in stress reactivity for constructing a multi-modal predictor of stress responsiveness, and for identifying targets for intervention. - Continue to examine the interaction of a chronically stressful environment and changes in light/dark periods on the function of the stress response system. - Continue to explore the feasibility of continuous and unobtrusive stress detection, tracking, and mitigation for a wearable closed-loop system capable of monitoring stress and providing bioelectronic therapy.					
FY 2023 OCO Plans:					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** There is no significant change from FY 2022 to FY 2023.					
Title: Ocean Sciences	79.801	83.529	84.272	0.000	84.272
Description: Understanding and predicting oceanographic and acoustical phenomena provides significant warfighting advantages to naval forces. Ocean Sciences research addresses the full spectrum of acoustics and oceanography to enable observation, modeling, and prediction of the maritime environment. Efforts include: studying common operating areas for naval forces in the open oceans, the Arctic, the littorals, and nearshore and river mouths and inlet environments; elucidating the coupling between oceanographic, geophysical and acoustical phenomena relevant to such mission areas such as Anti-Submarine Warfare and Mine Warfare; development of global, regional and local predictive models that fully couple the ocean-atmosphere-wave-ice domains; development and use of autonomous systems and sampling technologies for the collection of environmental observations and continuing support to research vessels of the U.S. Academic Research Fleet to enable at-sea oceanographic science. Research within the Ocean Sciences subactivity responds to mission needs of the Navy and Marine Corps as guided by the Oceanographer of the Navy. At-sea research involves ancillary studies to ensure full compliance with environmental requirements. ***FY 2022 Plans:*** Littoral Geosciences and Optics Areas of research include the highly nonlinear and coupling between atmospheric phenomena and surface gravity and internal waves; the transport of sediment by waves and currents; and the bathymetric evolution of the nearshore and coastal environment. Field, modeling, experimental and remote sensing studies are all used. - Continue modeling and field studies of high spatial and temporal resolution coastal land-air-sea interactions and their role in creating atmospheric electromagnetic ducting. - Continue studies of surface gravity waves, currents, tides and internal wave processes along rocky coastlines. - Continue autonomous, scalable, hydrographic charting and coastal parameter sampling studies with concomitant remote sensing for data-assimilative coastal models. - Continue research using airborne and satellite active and passive microwave sensors, overhead optical sensors, and ship or shore-based radars to observe coastal and nearshore phenomena. - Continue field studies of coastal oceanographic phenomena using sonar-equipped autonomous underwater vehicles in conjunction with ground-based, airborne and satellite remote sensing.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue research to predict physical, geological, geochemical, geoacoustic and geotechnical properties of the seafloor in shallow-water coastal environments. Physical Oceanography and Prediction Areas of research include ocean circulation, thermodynamics and mixing, and the dynamics of surface gravity waves, nonlinear internal waves and the interaction of waves with sea ice in order to understand the sub-mesoscale physical oceanography parameters from the tropics to the poles. Sub-mesoscale understanding of the ocean is necessary to support the required fidelity and accuracy of ocean feature inputs to Naval warfighting applications. - Continue study of three-dimensional Lagrangian ocean circulation and the prediction of vertical pathways in field experiments in the Mediterranean Sea. - Continue exploration of novel expeditionary ocean instrumentation to support targeted observing. - Continue study of ocean fronts, eddies and turbulence; ocean thermodynamics including mixing and acoustic impacts; and ocean boundary layer processes and surface gravity waves. - Continue study of the rapid evolution of the upper ocean in the high North Atlantic between Iceland and the European continent to understand the physical processes that control vertical and horizontal density structures in the upper ocean. - Continue study of the seasonal variability of processes that control sea surface temperature in the Arabian Sea to understand the relevant space and time scales that enable improved ocean and weather forecasts through the reduction of ocean temperature biases in coupled models. - Complete study of sources and sinks of near-inertial shear and energy in the ocean in the Greenland, Iceland, United Kingdom (GIUK) region. - Initiate studies to explore the cascade of energy in the sub-mesoscale ocean, including the physics and dynamics of ocean features such as current meanders, vortices, and filiaments, with a field program in the Western Pacific, to expand the knowledge of the lifecycle of these features and enable improved predictions. Arctic Sciences Areas of research include the complex processes governing the interaction of the arctic atmosphere, ocean, and sea ice, including formation, deformation, and melting. Physical processes in the arctic are inherently different from those in non-polar regions. - Continue studies to characterize the behavior of sea ice, including melt and reformation, ice rheology and motion, and interactions with ocean stratification, surface waves and the atmosphere.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue development of Arctic System models and data assimilation techniques for improved prediction of the Arctic region and development of new sensors and unmanned platforms to collect observations of the Arctic environment. - Continue development of algorithms enabling the space-based remote sensing of bulk properties of Arctic sea-ice that previously could be sampled only by localized in-situ methods. - Initiate studies of the circulation of the Arctic Ocean to explore the fate of heat flowing in through the Bering Strait and the impact on the upper ocean density structure of the Beaufort Sea. Ocean Acoustics Areas of research contribute to the understanding of the oceanographic parameter, including physical, seafloor and biological, that impact acoustic propagation and scattering in the ocean. Accurate acoustic predictions are required to keep our undersea assets undetected as well as to enable the detection and tracking of adversary assets. - Continue research to understand propagation and scattering of acoustic energy in shallow-water ocean environments, including shallow-water scattering mechanisms; seabed acoustical measurements for geophysical properties; acoustic propagation through internal waves and the development of unified ocean/seabed/acoustical models. - Continue investigation of optimal representation of information contained in acoustic data and the sparse encoding of underwater acoustic data to enable efficient analysis and compact representation of acoustic scenes. - Continue research on auralization to understand the full spectrum of physical, biological and anthropogenic sources of sound in the ocean environment, and to enable modeling and simulation of virtual undersea soundfields. - Complete research on the stability, statistics, spatial distribution, and predictability of broadband acoustic signals in the vicinity of seamounts, ridges and other bathymetric features. - Continue investigation of acoustic propagation and ambient noise in the Arctic conditions, particularly in under-ice environments, using data from a trans-Arctic basin experiment. - Continue joint physical oceanography and acoustic field studies to investigate the propagation and scattering in regions characterized by complex bathymetry and/or meteorological and oceanographic forcing. Specific efforts will include processes studies with the objective of linking observed ocean and acoustic phenomena over multiple temporal and spatial scales. - Continue studies to acoustically characterize and forecast seabed properties, including development and verification of geoacoustic models and inference techniques for soft sediment properties derived from experiments.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate a joint acoustics and oceanographic experiment to infer full water column and seabed waveguide geoacoustic parameters in a dynamic ocean. Marine Mammals Areas of research include monitoring and detection, integrated ecosystem, and effects of sound on marine mammals. - Continue development and testing of new and existing technologies to detect, classify, localize and potentially track marine mammals. - Continue multidisciplinary ecosystem research including tagging, visual surveys, and passive acoustics to collect baseline measures of marine mammal behaviors and distributions relative to environmental features and marine mammal prey fields. - Continue research on sound reception mechanisms in large whales. - Continue research on the effects of sound include behavioral, physiological and population-level consequences of sound exposure on marine life. - Continue studies to characterize and quantify the cumulative effects of multiple stressors on marine mammal populations. Battlespace Environments - Continue research is to improve basic understanding of physical, seafloor and biological oceanographic processes on space and time scales of naval interest. Emphasis is on improved measurements, laboratory and model based experiments to quantify and understand important oceanographic processes that lead to the development of ocean dynamic/thermodynamic models from global to sub-mesoscale scales, and to couple these oceanographic models with atmospheric, ice, biological, sediment response, and optical models. While today's numerical analysis and prediction systems are more capable of resolving and predicting highly variable phenomena than were the systems of 10-20 years ago, there are still oceanographic processes that are not well understood and must be studied including aspects of ocean circulation (fronts, eddies and turbulence), thermodynamics (mixing and acoustic impacts), waves (including their impact on sea ice and rogue waves), sea ice (including landfast ice) as well as ocean boundary layer processes. Navy and Marine Corps requirements also include: a) an improved use of overhead (airborne and satellite) active and passive microwave sensors, overhead optical sensors, surface-based (ships and ground-based) grazing angle microwave sensor, b) use of remote sensing of bulk properties of Arctic sea-ice over broad two-dimensional areas that previously could					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
be sampled only at spot locations by in-situ sampling, and c) use of newly available higher resolution (sub-mesoscale) oceanographic data. ***FY 2023 Base Plans:*** Littoral Geosciences and Optics Areas of research include the highly nonlinear coupling between atmospheric phenomena and surface gravity and internal waves; the transport of sediment by waves and currents; and the bathymetric evolution of the nearshore and coastal environment using integrated field observations, modeling, experimental and remote sensing studies. - Continue studies of surface gravity waves, currents, tides and internal wave processes along rocky coastlines. - Continue autonomous, scalable, hydrographic charting and coastal parameter sampling studies with concomitant remote sensing for data-assimilative coastal models. - Continue research using airborne and satellite active and passive microwave sensors, overhead optical sensors, and ship or shore-based radars to observe coastal and nearshore phenomena. - Continue field studies of coastal oceanographic phenomena using sonar-equipped autonomous underwater vehicles in conjunction with ground-based, airborne and satellite remote sensing. - Continue research to predict physical, geological, geochemical, geoacoustic and geotechnical properties of the seafloor in shallow-water coastal environments. - Initiate studies of the dynamics of shallow coastal inlets; specific areas include their formation and maintenance processes by tides, waves, currents, discharge and sediment type and supply. Physical Oceanography and Prediction Areas of research include ocean circulation, thermodynamics and mixing, and the dynamics of surface gravity waves, nonlinear internal waves and the interaction of waves with sea ice in order to understand the sub-mesoscale physical oceanography parameters from the tropics to the poles. Sub-mesoscale understanding of the ocean is necessary to support the required fidelity and accuracy of ocean feature inputs to Naval warfighting applications. - Continue study of three-dimensional Lagrangian ocean circulation and the prediction of vertical pathways in field experiments in the Mediterranean Sea. - Continue exploration of novel expeditionary ocean instrumentation to support targeted observing. - Continue study of ocean fronts, eddies and turbulence; ocean thermodynamics including mixing and acoustic impacts; and ocean boundary layer processes and surface gravity waves.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue study of the rapid evolution of the upper ocean in the high North Atlantic between Iceland and the European continent to understand the physical processes that control vertical and horizontal density structures in the upper ocean. - Continue study of the seasonal variability of processes that control sea surface temperature in the Arabian Sea to understand the relevant space and time scales that enable improved ocean and weather forecasts through the reduction of ocean temperature biases in coupled models. - Complete study of sources and sinks of near-inertial shear and energy in the ocean in the Greenland, Iceland, United Kingdom (GIUK) region. - Initiate studies to explore the cascade of energy in the sub-mesoscale ocean, including the physics and dynamics of ocean features such as current meanders, vortices, and filiaments, with a field program in the Western Pacific, to expand the knowledge of the lifecycle of these features and enable improved predictions. Arctic Sciences Areas of research include the complex processes governing the interaction of the arctic atmosphere, ocean, and sea ice, including formation, deformation, and melting. Physical processes in the arctic are inherently different from those in non- polar regions. - Continue studies to characterize the behavior of sea ice, including melt and reformation, ice rheology and motion, and interactions with ocean stratification, surface waves and the atmosphere. - Continue development of Arctic System models and data assimilation techniques for improved prediction of the Arctic region and development of new sensors and unmanned platforms to collect observations of the Arctic environment. - Continue development of algorithms enabling the space-based remote sensing of bulk properties of Arctic sea-ice that previously could be sampled only by localized in-situ methods. - Initiate studies of the circulation of the Arctic Ocean to explore the fate of heat flowing in through the Bering Strait and the impact on the upper ocean density structure of the Beaufort Sea. Ocean Acoustics Ocean Acoustics continues as one of five National Naval Responsibilities (NNR). Research and education supported under this PE contributes to a vigorous science and technology base to ensure continuing U.S. leadership in the critically important discipline of Ocean Acoustics. Areas of research contribute to improved basic understanding of the physical, seafloor and biological parameters that impact acoustic propagation in the ocean. Accurate acoustic predictions are required to keep our undersea assets undetected as well as to enable the detection and tracking of adversary assets.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue research to understand propagation and scattering of acoustic energy in shallow-water ocean environments. Specific efforts include shallow-water scattering mechanisms related to reverberation and clutter; seabed acoustic measurements supporting geoacoustic inversion; acoustic propagation through internal waves and coastal ocean processes and the development of unified ocean/seabed/acoustic models, including scattering from rough surfaces, biologics and bubbles; and penetration/propagation within the porous seafloor. - Continue the investigation in optimal representations information contained in acoustic data. Specific efforts will include the investigation summary statistics and sparse encoding of underwater acoustic data. The objective is to enable efficient analysis and compact representations of acoustic scenes. - Continue efforts in naturalization applicable to the ocean battlespace. Specific efforts will include investigations into source separation, characterization, and recombination along with physical, biological, and anthropogenic sound generating mechanisms. The objective is to model and simulate acoustic phenomena in undersea environments to be rendered as virtual soundfields. - Continue research into the effects of environmental variability induced by ocean internal waves, internal tides and mesoscale processes, and by bathymetric features including seamounts and ridges, on the stability, statistics, spatial distribution, and predictability of broadband acoustic signals, as well as the coherence and depth dependence of deep-water ambient noise. - Continue investigations into the effects of Arctic conditions on acoustic propagation and ambient noise, particularly in under-ice environments. - Continue the joint physical oceanography and acoustic field studies to investigate propagation and scattering in regions characterized by complex bathymetry and/or meteorological and oceanographic forcing. Specific efforts will include processes studies with the objective of linking observed ocean and acoustic phenomena. An objective is to characterize oceanographic phenomena and the effects on acoustic propagation and scattering at different frequencies. - Continue efforts in characterizing and forecasting sediment acoustic properties. Specific efforts will include investigations aimed at linking local physical and biological processes to acoustic observables. Continue analysis efforts related to acoustic seabed characterization experiment. Specific efforts will include development and verification of geoacoustic models and inference techniques for soft sediments based on experimental evidence. - Initiate analysis of data from a previous trans-arctic basin collection effort to extend studies of under-ice environments. Marine Mammals and Biology The Marine Mammals and Biology Program conducts basic research to understand and characterize the effects of sound exposure on marine mammals to enable Navy to meet operational training and testing objectives in an					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
environmentally responsible and legal manner. Areas of research include monitoring and detection of marine mammals, integrated ecosystem research, hearing in large whales, and effects of sound on marine mammals. - Continue development and testing of new and existing technologies to detect, classify, localize and potentially track marine mammals. - Continue multidisciplinary ecosystem research including tagging, visual surveys, and passive acoustics to collect baseline measures of marine mammal behaviors and distributions relative to environmental features and marine mammal prey fields. - Continue research on sound reception mechanisms in large whales. - Continue research on the effects of sound include behavioral, physiological and population-level consequences of sound exposure on marine life. - Continue studies to characterize and quantify the cumulative effects of multiple stressors on marine mammal populations. - Continue research to develop framework for understanding the ecology of eDNA, including the origin, state, transport, and fate of extraorganismal genetic material. - Initiate studies to design appropriate primers and bioinformatics workflows to effectively and efficiently detect and identify target biological communities and ecosystems, and advance our understanding of the relationships between eDNA and the abundance of marine megafauna. Battlespace Environments - Continue research is to improve basic understanding of physical, seafloor and biological oceanographic processes on space and time scales of naval interest. Emphasis is on improved measurements, laboratory and model based experiments to quantify and understand important oceanographic processes that lead to the development of ocean dynamic/thermodynamic models from global to sub-mesoscale scales, and to couple these oceanographic models with atmospheric, ice, biological, sediment response, and optical models. While today's numerical analysis and prediction systems are more capable of resolving and predicting highly variable phenomena than were the systems of 10-20 years ago, there are still oceanographic processes that are not well understood and must be studied including aspects of ocean circulation (fronts, eddies and turbulence), thermodynamics (mixing and acoustic impacts), waves (including their impact on sea ice and rogue waves), sea ice (including landfast ice) as well as ocean boundary layer processes. Navy and Marine Corps requirements also include: a) an improved use of overhead (airborne and satellite) active and passive microwave sensors, overhead optical sensors, surface-based (ships and ground-based) grazing angle microwave sensor, b) use of remote sensing of bulk properties of Arctic sea-ice over broad two-dimensional areas that previously could					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
be sampled only at spot locations by in-situ sampling, and c) use of newly available higher resolution (sub-mesoscale) oceanographic data. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** The funding increase from FY 2022 to FY 2023 is due to increased focus on Underwater Acoustics and Geophysical Processes.					
Title: Science and Engineering Education, Career Development and Outreach	41.127	44.948	47.405	0.000	47.405
Description: The Science and Engineering Education, Career Development and Outreach activity addresses the critical need to grow and maintain a highly skilled technical naval workforce. These efforts inspire, engage, educate and attract participants to pursue naval careers and build the extramural performer base. DON Science, Technology, Engineering and Math (STEM) education and outreach is designed to increase the number of students and naval civilians with naval-relevant skills and degrees, expand capabilities of the current and future workforce by developing curricula and augmenting education, and augment awareness of Naval opportunities through localized education and outreach initiatives that foster the talent pipeline. This activity supports both the Naval Research Enterprise Intern Program (NREIP) for college students and the Science and Engineering Apprenticeship Program (SEAP) for high school students to encourage participants to pursue science and engineering careers. The objective is to further education via mentoring by laboratory personnel and their participation in research, and to make them aware of Department of the Navy (DON) research and technology efforts. This program serves as a recruitment tool for employment within the DON. Participating students at 45 DON laboratories will spend eight to ten weeks during the summer conducting research. The separately-managed Department of the Navy's (DON) Historically Black Colleges and Universities/Minority Institutions (HBCU/MI) program oversees the Navy's efforts to engage and support research in our nation's HBCU/MIs and is responsible for developing and managing efforts that strengthen and support the capabilities of HBCU/MIs to participate in basic, applied, and advanced development research programs within the Naval Research Enterprise. The ONR Young Investigator Program (YIP) attracts outstanding faculty members to the Department of Navy's basic research program by identifying individuals that show exceptional promise for doing creative research					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
and encourage their teaching and research careers through long term support. Young Investigator awards are for a period of three years. Proposals are solicited annually via a funding opportunity announcement open to tenure-track faculty in science, engineering, and mathematics. YIP awardees are competitively selected based on faculty achievements, technical proposal, benefit to the Navy and Marine Corps, and university endorsement. The Naval Research Institution was established through a Memorandum of Understanding between the United States Naval Academy (USNA) and the Office of Naval Research. This effort contributes to the technical education of midshipmen by providing a research experience in STEM and its impact on fleet and forces capabilities. This activity also supports the Office of Naval Research Global mission to serve as the enduring Navy and Marine Corps global presence in technical and operational communities, investing in trusted partnerships to discover and connect science and technology leaders for sustained maritime security. This is accomplished by establishing quality, relevant connections between the international research and development community, Naval fleet/forces, Department of Defense, other US Government agencies and international partners. The direct impact of this investment is to leverage international basic research during increasingly dynamic global interdependence and improve the ability to solve DON Science & Technology challenges through shared knowledge with partners. ***FY 2022 Plans:*** Conduct Science, Technology, Education and Mathematics (STEM) initiatives to foster and cultivate a diverse, world-class STEM workforce in order to maintain the U.S. Navy and Marine Corps' technological superiority. - Continue existing successful efforts, while examining approaches to further scale up these efforts to achieve greater impact across the Department Of the Navy (DON). - Continue transparent and accountable coordination of DON STEM efforts aligned with the DON STEM strategy. - Continue activities targeting regional efforts to augment awareness of naval opportunities and increase diverse workforce opportunity for the naval science and technology community. - Continue to support programs that provide hands-on and virtual research experiences in STEM fields for United States Naval Academy (USNA) midshipmen and faculty members to enhance the midshipmen's educational environment at the USNA. - Initiate the development of highly scalable pilot efforts to expand STEM education and outreach through the development of new virtual and in-person curricula as well as virtual and in-person experiential learning activities.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate new outreach and communication approaches to significantly broaden and increase awareness of naval STEM opportunities and careers. Naval Enterprise Partnership Teaming with Universities for National Entrepreneurship (NEPTUNE) program: - Continue to sponsor Naval educational institutes (e.g. Naval Postgraduate School) to conduct research that provides Navy Energy Education & Training for students and promotes the use of entrepreneurial practices to accelerate the delivery of technologies to the warfighter. Historically Black Colleges and Universities / Minority Institutions (HBCU/MI): - Continue to provide robust research opportunities, such as faculty fellowships and student internships that address critical Naval S&T challenges through collaborations with Naval scientists, engineers and academic researchers. Through the coordination of symbiotic engagements between Naval researchers, industry partners and minority serving institutions to advance Naval-relevant research, this program cultivates long-term partnerships that leverage knowledge sharing and empower scientific global discovery. - Develop new outreach plans to increase the number of HBCU/MI white paper and grant proposal submissions. Establish a HBCU/MI Post-doctoral program that supports the efforts of increasing the number of HBCU/MI students working within the Navy STEM related fields. - Increase the number of science fairs at HBCU/MI that have partnerships with local schools. Young Investigator Program (YIP): - Continue YIP awards to 25 to 35 assistant professors that show exceptional promise for performing creative research. Topics are competitively selected based on faculty achievements, technical proposal, benefit to the Navy and Marine Corps, and institution support. Ongoing efforts cover a wide range of topics of Naval S&T interest. Recent topics include innovative technical approaches to: next generation wireless technology, symbolic deep learning, safe autonomous navigation, artificial intelligence in weather prediction, underwater artificial gills, scalable Ytterbium tweezer arrays, high-speed liquid-fueled combustion, remote sensing and forecasting in coastal environments, multi-frequency high-power microwave, van der Waals metamaterials, heat transfer in nanomaterials, 3-D accelerated tissue repair, and automated machine intelligence. These and other research topics will benefit today's and the next generation warfighter by improving lethality, survivability, and communications. Additionally, many of these investigators will provide long-term support and knowledge in solving Naval related S&T challenges. - Complete Young Investigator Program projects initiated in fiscal year 2020. ONR Global					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue international outreach efforts to foster collaboration through PhD-level scientists located in Asia, Europe, South America and Australia, providing coverage in these regions by awarding grants in innovative basic research to discover, access and assess revolutionary, high-payoff technologies for future Naval missions and capabilities.					
FY 2023 Base Plans: Science, Technology, Education and Mathematics (STEM) - Continue existing successful efforts, while examining approaches to further scale up these efforts to achieve greater impact across the DON. - Continue the development of highly scalable pilot efforts to expand STEM education and outreach, with a focus on reaching underrepresented students, through the development of new virtual and in-person curricula as well as virtual and in-person experiential learning activities. - Continue activities targeting regional efforts to augment awareness of naval opportunities and increase diverse workforce opportunity for the naval science and technology community. - Continue to support the Naval Research Institution efforts that provide hands-on and virtual research experiences in STEM fields for United States Naval Academy (USNA) midshipmen and faculty members to enhance the midshipmen's educational environment at the USNA. - Continue NREIP and SEAP opportunities for students to participate in Navy and Marine Corps-relevant research at Naval Warfare Centers and Laboratories by expanding the number of participating sites, mentors, and interns. Historically Black Colleges and Universities / Minority Institutions (HBCU/MI): - Continue to provide innovative research opportunities, such as faculty fellowships and student internships that address critical Naval S&T challenges through collaborations between academic researchers and Naval scientists and engineers. - Continue to advance Naval-relevant research, by cultivating long-term partnerships that leverage knowledge sharing and empower scientific global discovery. - Continue new outreach initiatives to increase the number of HBCU/MI white paper and grant proposal submissions. - Initiate new efforts to increase applications and participants in the HBCU/MI Post-doctoral program that impacts the number of HBCU/MI PhD candidates working within the Navy STEM related fields. - Initiate new efforts to increase the number of science fairs at HBCU/MI that have partnerships with local junior and high schools.					

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Young Investigator Program (YIP): - Continue YIP awards to 25 to 35 assistant professors that have demonstrated exceptional promise for performing creative research. Recent YIP topics include innovative technical approaches to: autonomy, deep learning, optimization, artificial intelligence, wireless communications, energetics, power and energy, propulsion, turbulence, hypersonics, remote sensing, bio-sensors, bionic composites, nanocomposites, ocean sciences, marine mammal health, multi-function materials and additive manufacturing. These and other research topics will benefit today's and the next generation warfighter by improving lethality, survivability, and communications. Additionally, many of these investigators will provide long-term support and knowledge in solving Naval related S&T challenges. - Complete Young Investigator Program topics initiated in previous fiscal years. - Initiate Young Investigator Program topics selected in fiscal year 2023. ONR Global - Continue international outreach efforts to foster collaboration through doctoral-level scientists located in Europe, South America, Canada, Asia and Australia, providing coverage in these regions by awarding grants in innovative basic research to discover, access and assess revolutionary, high-payoff technologies for future Naval missions and capabilities. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** The funding increase from FY 2022 to FY 2023 is due to increased investment in HBCU/MI Navy STEM sponsored opportunities and participation.					
Title: Sensors, Electronics and Electronic Warfare (EW) ***Description:*** Basic research efforts directed toward increasing knowledge, components and algorithmic advances for electronics, sensing and EW ensuring the Navy can counter current and future threats. These efforts are applicable to sensing and EW on individual Naval platforms, as well as, efforts that aggregate capabilities in a Distributed Maritime Operation. The efforts research focus include: sensing, diagnostics, and detectors; navigation and timekeeping; nanoelectronics; wide band gap power devices; real-time targeting; Electro-Optical/Infra-Red (EO/IR) electronics; EO/IR electronic warfare; EO/IR sensors for surface/aerospace surveillance; Radio Frequency	50.845	53.650	55.113	0.000	55.113

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
(RF) sensors for surface/aerospace surveillance; solid state electronics; vacuum electronics; and RF electronic warfare. ***FY 2022 Plans:*** Electronics Continue to create new knowledge and understanding and explore new concepts, components, techniques and methods, for the design, growth, and characterization of electronic, electromagnetic, quantum phenomenology, and electro-optical materials, fabrication processes, electronic and electro-optic components, including novel electromagnetic concepts and techniques, and plasma phenomena and theory. - Continue efforts in nitrogen-polar GaN materials and device development. - Continue efforts in superconducting GaN materials and device development. - Continue efforts in plasmonic photomixer devices and circuits. - Continue effort to use generative neural networks to design topology-optimized metasurfaces and apply results to generate dual-level short-wave infrared antireflective coatings. - Continue efforts to develop novel materials for linear, low-power, broadband switches, including phase-change materials such as GeTe, as well as two-dimensional hexagonal boron nitride. - Continue to utilize the unique quantum properties of superconductors and photonics to deliver new devices and integrated circuits, which enable real time, software defined, wide band, and simultaneous signal, receive functionality. - Continue to investigate how to realize increased receiver dynamic range over entire DC to 200 GHz spectrum. Stimulate demonstrations of increasingly complete receive capabilities. These systems will be applicable to all the RF applications while being most important to Surveillance, Electronic Warfare (EW), signal intelligence (SIGINT). - Continue work on squeezed lasers, optical cooling, and new superconducting sensors of magnetic field sources, even if cloaked. - Initiate work on quantum entanglement and measurement as applied to RF signal analysis. - Initiate device reliability studies of nitrogen-polar GaN devices. - Initiate studies on superconducting GaN functional circuits. - Initiate efforts to create new knowledge and understanding for quantum computing algorithms and their use to create new understanding of materials by design, process optimization, and quantum simulation. Quantum Information Sciences - Continue the development of protocols for sensing and timekeeping devices based on quantum systems, including clocks with improved short and long-term performance and electromagnetic field sensors.					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue the development of inertial and gravity sensors based on light-atom interferometry. Electromagnetic Warfare Continue research efforts with the overarching objective of establishing the mathematical constructs, techniques, computational procedures, and scientific foundations for analysis/design of signal, image, control, and data generating systems for use in Navy, other DoD, dual-use, or commercial development programs. Each project has defined objectives within the contexts of the Naval Research Enterprise Research and Development Strategic Framework and Marine Corps S&T Strategic Plan. - Continue developing ultrafast, efficient, and accurate time domain (TD) algorithms to predict the ultra-wideband radar cross-section (RCS) of complex naval platforms by solving the long-standing late-time instability problem. - Continue investigating mathematical, statistical and algorithmic issues associated with performing robust and adaptive detection and discrimination of targets when sensed by multiple, resource-constrained, unmanned vehicle sensors operating in a decentralized fashion and in highly cluttered environments. - Continue research to establish basic feasibility of novel emerging non-linearized imaging and feature extraction techniques with respect to existing and/or realistic multi-static sensing geometries, research to utilize and enhance the understanding and applicability of topological techniques to enable improved capabilities for target detection, object identification, and data fusion. - Continue research to enable the imaging of self-illuminating thermal objects occluded by walls by sensing non-specular reflections from rough surfaces such as open doors and around corners, to allow for asymmetric warfare through image recovery in previously denied conditions. - Continue research to develop advanced multi-dimensional Convolutional Neural Network approaches and algorithms to investigate and demonstrate improved means of analyzing high-dimensional data resulting in improved results for classification, segmentation, anomaly/ target detection. Materials and Chemistry - Continue to design novel experiments and robust theoretical models necessary to enable new warfighter capabilities through advanced sensors and electronics. - Complete target identification algorithms utilizing nonlinear dynamics. - Understand and demonstrate the principles and mechanisms of DNA-based molecular-scale machines to amplify detection of biochemical agents. - Complete the fabrication of single atomic layer of materials to create 2-dimensional ferromagnets and semiconductors. The material of choice will be single layer MoS2 for utilization as indirect gap semiconductors. - Complete research on unique single stage accelerator mass spectrometer to evaluate the fine scale detection limits of fusion products and isotopes.					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Complete research to recognize the protein-surface interactions leading to highly sensitive biosensors. - Complete the development of principle theoretical models to understand the principles governing the interactions between surfaces and small molecules. Prior studies in these areas have demonstrated success in designing biological and chemical sensors with parts per trillion sensitivity as well as understanding of electronic mobility of graphene due to the effects of edge and defects. - Initiate the design and fabrication of single-monolayer or low-dimensional materials with unique and useful fundamental properties distinct from bulk materials, e.g. ferromagnets and semiconductors, capable of being functionalized for high performing sensors, computer memory elements or electronic components. - Initiate the use of precision molecular placement and orientation to design and create bio-inspired materials exploiting quantum phenomena to perform functions such as ultrasensitive photon detectors and energy generation - Initiate highly sensitive measurement and modeling techniques to design, detect, diagnose and/or quantify physical, chemical and biological processes and properties affected by trace impurities, subtle composition changes and chemical species with high spatial resolution, sensitivity, and precision. Undersea Warfare - Continue to conduct laboratory, field, and theoretical/numerical studies to investigate physical phenomena related to acoustic propagation and scattering in oceanic environments such as: prediction of the scattering signature of a structure using noise sources of opportunity; fundamental physical phenomena of wave propagation in ocean environments; approaches to separate an acoustical field from turbulent flow on an acoustic array; new structural acoustics theory for scattering from large, complex undersea objects; and creation of new approaches to monitoring the acoustic signature and structural state of undersea vessels.					
FY 2023 Base Plans: Electronics Technology - Continue to create new knowledge and understanding and explore new concepts, components, techniques and methods, for the design, growth, and characterization of electronic, electromagnetic, quantum phenomenology, and electro-optical materials, fabrication processes, electronic and electro-optic components, including novel electromagnetic concepts and techniques, and plasma phenomena and theory. - Continue efforts in nitrogen-polar GaN materials and device development. - Continue efforts in superconducting GaN materials and device development. - Continue efforts in plasmonic photomixer devices and circuits. - Continue effort to use generative neural networks to design topology-optimized metasurfaces and apply results to generate dual-level short-wave infrared antireflective coatings.					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue efforts to develop novel materials for linear, low-power, broadband switches, including phase-change materials such as GeTe, as well as two-dimensional hexagonal boron nitride. - Continue work on squeezed lasers, optical cooling, and new superconducting sensors of magnetic field sources, even if cloaked. - Continue work on quantum entanglement and measurement as applied to RF signal analysis. - Continue device reliability studies of nitrogen-polar GaN devices. - Continue studies on superconducting GaN functional circuits. - Continue efforts to create new knowledge and understanding for quantum computing algorithms and their use to create new understanding of materials by design, process optimization, and quantum simulation. - Continue to improve full spectrum, real time, fully adaptive reception of many simultaneous signals-of-interest by exploiting the unique quantum properties of superconductor microelectronics and photonics. - Continue to investigate how to realize increased receiver dynamic range over entire DC to 200 GHz spectrum and enhance functional density to produce lighter and smaller receivers. - Initiate research in epitaxial synthesis of p-type crystalline metal nitrides. - Initiate transport studies of p-type and crystalline metal nitrides. - Initiate investigations into p- and n-type crystalline metal nitrides heterostructures. - Initiate architectural studies for implementing priority based processing utilizing the combination of wideband reception and machine learning algorithms. Such systems will be applicable to all RF applications while being most important to Surveillance, Electronic Warfare (EW), signal intelligence (SIGINT). Quantum Measurement Architectural Devices (formerly Quantum Information Sciences) - Continue the development of protocols for sensing and timekeeping devices based on quantum systems, including clocks with improved short and long-term performance and electromagnetic field sensors. - Continue the development of inertial and gravity sensors based on light-atom interferometry. - Initiate research on the capabilities of non-equilibrium many-body systems for novel metrology. Electromagnetic Warfare - Continue research efforts with the overarching objective of establishing the mathematical constructs, techniques, computational procedures, and scientific foundations for analysis/design of signal, image, control, and data generating systems. - Continue the development of ultrafast, efficient, and accurate time domain (TD) algorithms to predict the ultra-wideband radar cross-section (RCS) of complex naval platforms by solving the long-standing late-time instability problem.					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Continue research efforts to enable the imaging of self-illuminating thermal objects occluded by walls by sensing non-specular reflections from rough surfaces such as open doors and around corners, to allow for asymmetric warfare through image recovery in previously denied conditions. - Complete the research to develop advanced multi-dimensional Convolutional Neural Network approaches and algorithms to investigate and demonstrate improved means of analyzing high-dimensional data resulting in improved results for classification, segmentation, anomaly/ target detection. Complete the investigation of mathematical, statistical and algorithmic issues associated with performing robust and adaptive detection and discrimination of targets when sensed by multiple, resource-constrained, unmanned vehicle sensors operating in a decentralized fashion and in highly cluttered environments. - Complete research efforts to establish basic feasibility of novel emerging non-linearized imaging and feature extraction techniques with respect to existing and/or realistic multi-static sensing geometries, research to utilize and enhance the understanding and applicability of topological techniques to enable improved capabilities for target detection, object identification, and data fusion. - Initiate the investigation into novel approaches to deep-generative machine learning-based algorithms and architectures for multistatic radar imaging to enable better noise robustness and resolution performance. Materials and Chemistry - Continue the design and fabrication of single-monolayer or low-dimensional materials with unique and useful fundamental properties, e.g. ferromagnets and semiconductors, distinct from bulk materials and capable of being functionalized for high performing sensors, computer memory elements and electronic components. - Continue the use of precision molecular placement and orientation to design and create bio-inspired materials exploiting quantum phenomena to perform functions such as ultrasensitive photon detectors and energy generation - Continue highly sensitive measurement and modeling techniques to design, detect, diagnose and/or quantify physical, chemical and biological processes and properties affected by trace impurities, subtle composition changes and chemical species with high spatial resolution, sensitivity, and precision. Undersea Warfare - Continue to conduct laboratory, field, and theoretical/numerical studies to investigate physical phenomena related to acoustic propagation and scattering in oceanic environments such as: prediction of the scattering signature of a structure using noise sources of opportunity; fundamental physical phenomena of wave propagation in ocean environments; approaches to separate an acoustical field from turbulent flow on an					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 0000 / *Defense Research Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
acoustic array; new structural acoustics theory for scattering from large, complex undersea objects; and creation of new approaches to monitoring the acoustic signature and structural state of undersea vessels. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** The funding increase from FY 2022 to FY 2023 is due to increased focus and investment in Electronic Materials and Interfaces.					
Title: Weapons ***Description:*** The Weapons activity focuses on a number of fundamental scientific areas aimed at expanding the underlying understanding of disciplines that are broadly useful for a wide range of naval weapon applications, including undersea weaponry; air weaponry; energetic materials and solid rocket propulsion; both laser and high power microwave directed energy systems; counter directed energy phenomena; and hypersonic aerodynamics and materials to address the unique challenges of extreme temperatures and air flow. ***FY 2022 Plans:*** Undersea Weapons (USWs) - Conduct basic research to understand science and technology that will contribute to undersea and surface vehicle swarm autonomy, undersea weapons (USWs) and advanced concepts for sea warfare. This research will allow further development of technologies for legacy and next-generation offensive and defensive USWs and payloads capable of engaging threat submarines, surface ships and torpedoes. - Additionally, the Naval Undersea Research graduate-level STEM program will continue to support the development of the Navy lab workforce. Air Weaponry - Basic research will focus on the areas of solid and hybrid rocket propulsion, advanced structural and aperture materials, navigation, aerodynamics, single and multi-missile control, and power management. Specific research in the area of multi-functional material structures include making missile skins with embedded (woven in) antennas, sensors, power sources, computational resources, and energetic materials. These efforts will enable missiles with greatly increased speed, range and lethality to meet future naval warfare needs. Directed Energy and Counter Directed Energy	24.566	27.535	26.324	0.000	26.324

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Conduct basic research in high-energy lasers, optical components, infrared technologies and high power microwaves to enable significant leap-ahead capabilities for the survivability and lethality of naval forces. Efforts will explore advanced photonics and optical techniques that vary energy levels in individual photons at energy density levels significantly above those needed for other applications, advanced photonics techniques to maximize extraction of the highest energy levels available from individual photons, and advanced photonics from unique sources otherwise not commercially viable. - There will be continued exploration of computational and photonic creation that model next-generation waveform interactions and power conversion designs. - Additional basic research will contribute to identifying new nanostructured materials and coatings processing for naval applications and investigate unique interactions of photons with materials and coatings. Energetic Materials and Rocket Propulsion - Basic research will investigate advanced energetic materials, which provide reactive, explosive, and propulsive phenomena including high-energy ingredient synthesis, modeling, characterization, and the fundamentals of initiation, decomposition and combustion/shock. This research will include synthetic methodology for new energetic materials and material concepts with superior specific energy / energy density, brisance, and insensitivity for useful warhead fills and solid rocket propellants. - Additional research in novel diagnostic methods for improved understanding of formulations and dynamic combustion/shock and related energetic materials dynamic phenomena will be conducted. - Finally, further efforts in advanced modeling and simulations on energetic materials, along with new methods and instrumentation for characterization will continue. Hypersonics - Basic research will address technologies needed for long-range weapon components that are able to survive high temperature exposure for several minutes and thwart anti-access/ area denial countermeasures. - Additional research will be conducted in hypersonic boundary-layers and shock-wave / boundary-layer interactions, prediction of hypersonic weapon flight performance and control, environment-material interactions, exploration of ultra-high temperature materials, and technologies needed for high-speed propulsion.					
FY 2023 Base Plans: Undersea Weaponry - Continue research on Undersea Warheads (characterization and modeling of explosive formulations), Advanced Concepts for Sea Warfare and Weapons (unconventional power and energy technology), Cooperative					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Autonomous Swarm Technology and the Naval Undersea Research graduate-level STEM program, which supports the development of the Navy lab workforce. Air Weaponry - Continue efforts in the areas of solid and hybrid rocket propulsion, advanced structural and aperture materials, navigation, aerodynamics, single and multi-missile control, and power management. - Continue research on multifunctional material structures include making missile skins with embedded (woven-in) antennas, sensors, power sources, computational resources, and energetic materials. These efforts will enable missiles with greatly increased speed, range and lethality to meet future naval warfare needs. -Initiate research to develop models and tool to provide robust bearings without oil. Directed Energy and Counter Directed Energy Directed energy weapons are defined as electromagnetic systems capable of converting chemical and/or electrical energy to radiated energy and focusing it on a target, resulting in damage that degrades, neutralizes, defeats, or destroys an adversarial capability. Directed Energy Weapons efforts include High Energy Lasers that emit photons and High Power Microwaves that release radiofrequency waves. The ability to focus the radiated energy reliably and repeatedly at range, with precision and controllable effects, while producing measured physical damage, is the measure of effectiveness - requiring understanding of the basic sciences in high energy physics, optics, quantum mechanics and material sciences. The U.S. Navy applies the basic research knowledge through follow on applied technology programs for power projection and integrated defense missions. Energetic Materials and Rocket Propulsion - Continue research investigating advanced energetic materials, which provide reactive, explosive, and propulsive phenomena including high-energy ingredient synthesis, modeling, characterization, and the fundamentals of initiation, decomposition, combustion and shock. - Continue and expand research in energetic material ingredients and material concepts with superior specific energy / energy density, brisance, and insensitivity for useful warhead fills and tactical propulsion. - Continue and expand research in novel diagnostic method development for improved understanding of energetic material combustion, shock response, and related dynamic phenomena. - Continue and expand efforts in advanced modeling and simulations on energetic materials to further understand and predict energetic material properties, response to stimuli, and performance. - Complete efforts in ingredient development, experimental diagnostics, and modeling that have not shown promise.					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate research focused on novel synthetic methodology development for carbon/hydrogen/nitrogen/oxygen-based energetic ingredients in addition to new metal based fuel particle design and other inorganic and hybrid energetic material concepts; - Initiate research into fundamental understanding of material interfacial physics/chemistry relevant to energetic formulation development and advanced manufacturing. Hypersonics - Continue research that will address technologies needed for long-range weapon components that are able to survive high temperature exposure for several minutes and thwart anti-access/ area denial countermeasures; - Continue investigating the hypersonic boundary-layers and shock-wave / boundary-layer interactions, prediction of hypersonic weapon flight performance and control, environment-material interactions, exploration of ultrahigh temperature materials, and technologies needed for high-speed propulsion. High Energy Lasers - Continue the exploration of the physics of photonic creation, materials interaction, energy release and interactions with optical materials via computational and mathematical modeling methods, including machine learning. - Continue research on next-generation photon waveform and mode shaping interactions with materials, including metamaterials, examining high efficiency energy conversion designs within unique nanostructured materials with goal of increasing efficiency from source to release. - Continue examination of high energy laser-launched collimated photon interactions with the atmosphere, which are unique in propagation within the maritime domain, examining unique physical and optical interactions related to absorption, reflectance, scatter and turbulence often seen in expeditionary and at-sea conditions; - Continue research that will contribute to identifying new nanostructured materials, metamaterials and optical coatings processing for naval applications and investigate unique interactions of high energy photons with materials and coatings; High Power Microwaves - Continue research into solid-state and vacuum electronic based sources and amplifiers, antennas, high voltage storage/switching components and power supplies, novel high power capable materials, radio-frequency coupling and electronic device interaction physics, predictive effects and modeling tools along with novel sensors and instrumentation. Ultra Short Pulse Laser					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
- Initiate research on interaction of intense laser pulses with nanostructured surfaces, the role of disorder in promoting synchronization in technological systems of relevance to the Navy, hybrid quantum devices with the greatest technological impact to photonics and solid-state laser components, and extension of mode-locked laser and optical frequency comb technologies from the traditional near-infrared regime to new spectral regions. - Initiate research on generation of high-average power ultra-broadband radio frequency and mid-infrared radiation in dielectrics and plasmas, effects of atmospheric turbulence on the propagation of laser beams having orbital angular momentum, demonstration of a compact solid-state laser source, demonstration of highly efficient frequency conversion of ultrashort pulse laser sources, and demonstration of ultrahigh peak power compact ultrashort sources in specific spectral ranges via advanced mode locking and chirped pulse amplification techniques. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** There is no significant change from FY 2022 to FY 2023.					
Accomplishments/Planned Programs Subtotals	445.302	472.992	479.583	0.000	479.583

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not applicable.

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy			Date: April 2022
Appropriation/Budget Activity 1319 / 1	R-1 Program Element (Number/Name) PE 0601153N / *Defense Research Sciences*	Project (Number/Name) 3465 / *In-House Lab Independent Res*	

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
3465: *In-House Lab Independent Res*	0.000	0.000	11.332	19.533	-	19.533	19.923	20.322	20.729	21.144	Continuing	Continuing

Note

Effective in FY 2022, In-house Laboratory Independent Research (ILIR) funding and associated requirements are realigned from Program Element (PE) 0601152N, Project 0000 to PE 0601153N, Project 3465.

A. Mission Description and Budget Item Justification

The In-house Laboratory Independent Research (ILIR) initiative seeks to improve the quality of defense research conducted predominantly through the Naval Warfare Centers/Laboratories. It also supports the development of technical intellect and education of engineers and scientists in disciplines critical to national defense needs through the development of new knowledge in a military laboratory environment. Initial research focus is often conducted in an unfettered environment since it is basic research, but many projects focus on applying recently developed theoretical knowledge to real world military problems with the intention of developing new capabilities and improving the performance of existing systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Title: In-House Laboratory Independent Research (ILIR)	0.000	11.332	19.533	0.000	19.533
Description: The In-house Laboratory Independent Research program provides opportunities to strengthen the Naval Science and Engineering workforce through basic research conducted at the Naval Warfare Centers and Laboratories. These research efforts address high risk/high payoff warfighter science and technological needs, as well as attract the next generation of researchers to consider employment within the Department of the Navy. ILIR also provides opportunities for advanced degrees, technical publications, presentations, and patents. ***FY 2022 Plans:*** Further develop and maintain the Science and Engineering workforce by providing funding to Naval Warfare Centers and Laboratories to foster high risk/ high reward basic research initiatives of Naval interest. Each of the Naval sites will evaluate existing research projects and propose new topics. All efforts will be selected based on warfighter needs, researcher capabilities, and science and technology alignment. ***FY 2023 Base Plans:*** Continue: Further develop and maintain the Science and Engineering workforce by providing funding to Naval Warfare Centers and Laboratories to foster high risk/ high reward basic research initiatives of Naval interest. Each naval					

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 3465 / *In-House Lab Independent Res*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
site conducts peer reviews for existing research projects, assess the quality of the research, and determine if projects should continue. Complete: Conclude research topics that initiated in FY 2021. Assess opportunities for technology transition through coordination with various resource sponsors. Transfer successful efforts to research, development, test, and evaluation-sponsored programs. Initiate: The participating warfare centers or laboratories generate new three-year research topics where priority is given to warfighter needs, technology alignment, high quality research, and the recruitment and retention of outstanding scientists and engineers. Topics cover a broad range of naval relevant research areas critical to the support of warfare center and laboratory missions. ***FY 2023 OCO Plans:*** N/A ***FY 2022 to FY 2023 Increase/Decrease Statement:*** The funding increase from FY 2022 to FY 2023 will be used to initiate and expand basic research topics across a broad range of naval relevant science and technology focus areas. The funding is critical to providing adequate support for the successful accomplishment of each topic, measured by the advancement of new knowledge that addresses warfighter needs and challenges. Research topics include key areas such as advanced ship design, multifunction materials, environmental sciences, ocean acoustics and signature reduction, hydrodynamics, aerodynamics, hypersonics, casualty management, mine countermeasures, machine learning and artificial intelligence, data science, navigation and timing, radar and RF propagation, energetics, fuels and combustion, energy storage, additive manufacturing, high temperature alloys, cognitive science, and hypoxia.					
Accomplishments/Planned Programs Subtotals	0.000	11.332	19.533	0.000	19.533

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy											Date: April 2022	
Appropriation/Budget Activity 1319 / 1					R-1 Program Element (Number/Name) PE 0601153N / *Defense Research Sciences*				Project (Number/Name) 9999 / *Congressional Adds*			
COST ($ in Millions)	**Prior Years**	**FY 2021**	**FY 2022**	**FY 2023 Base**	**FY 2023 OCO**	**FY 2023 Total**	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027**	**Cost To Complete**	**Total Cost**
9999: *Congressional Adds*	0.000	26.065	39.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	65.065

A. Mission Description and Budget Item Justification

Congressional Interest Items not included in other Projects.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022
Congressional Add: Basic Research ***FY 2021 Accomplishments:*** N/A ***FY 2022 Plans:*** Conduct basic research efforts including scientific study and experimentation directed toward increasing knowledge and understanding in national security related aspects of physical, engineering, environmental and life sciences. Basic research effort subject areas include: Autonomous Systems; Artificial Intelligence/Machine Learning; Command, Control, Communications and Computers (C4); Marine as a System; Information Analysis and Decision Support; Intelligence, Surveillance and Reconnaissance; Logistics; Materials; Operational Environments; Platforms; Power and Energy Technology; Sensors and Electronics; Warrior Performance and Protection; Weapons and Support (Education and Outreach).	0.000	25.000
Congressional Add: Defense Research Sciences ***FY 2021 Accomplishments:*** Conduct multidisciplinary basic research to enable the U.S. Navy to maintain its technological superiority. FY21 efforts include grants such as "Synthesis Planning and Reaction Discovery for Photochemistry and Chemistry in Novel Environments". This basic research grant produced 9 peer-reviewed publications and support to 6 graduate students and 4 post-doctoral fellows. By employing cutting edge computational methods to identify unusual reaction pathways and retrosynthetic path generation, new ways to discover viable reactions and their use in synthesis planning are taking shape. ***FY 2022 Plans:*** N/A	14.480	0.000
Congressional Add: Silicon-Germanium-Tin Alloy Research ***FY 2021 Accomplishments:*** Conduct basic research on Silicon-Germanium-Tin Alloy ***FY 2022 Plans:*** N/A	4.827	0.000
Congressional Add: Bio-inspired Engineering and Design for Naval Applications ***FY 2021 Accomplishments:*** This research project will be on mobility, maneuverability and agility, and will focus on locomotion and mechanics (e.g., fin-based swimming, flapping flight and legged locomotion), modalities of distributed sensing and processing (visual, echolocation, lateral-line and vibrissae "imaging" and cognitive-	2.896	3.000

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 9999 / *Congressional Adds*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022
neural processing, neuroscience and machine learning), and distributed actuation (neural activation and muscle mechanics, hard and soft robotics). ***FY 2022 Plans:*** Conduct basic research on mobility, maneuverability and agility, with focus on locomotion and mechanics (e.g., fin-based swimming, flapping flight and legged locomotion), modalities of distributed sensing and processing (visual, echolocation, lateral-line and vibrissae "imaging" and cognitive-neural processing, neuroscience and machine learning), and distributed actuation (neural activation and muscle mechanics, hard and soft robotics).		
Congressional Add: Predictive Modeling & Simulation for Next Gen Naval Undersea Vessel and Platform ***FY 2021 Accomplishments:*** This effort will advance naval warfare capabilities by providing focused research on experimentally validated, multi-physics and multi-fidelity predictive modeling to support undersea smart systems design. Augmented by machine learning capabilities the research will support applications such as digital twin, situational awareness and vessel health monitoring. ***FY 2022 Plans:*** N/A	1.931	0.000
Congressional Add: USV Batteries, Materials, and Additive Manufacturing ***FY 2021 Accomplishments:*** The research will focus on developing: (i) multifunctional batteries, which offer lightweight energy storage that could enhance the range and performance of undersea vehicles, including their potential integration with hybrid and regenerative energy sources; (ii) metamaterials with tunable acoustic properties, structural materials with computationally optimized microstructures and advanced coatings for extreme marine environments such as extended exposure to sea water and high strain-rate deformation; (iii) transformative multi-material (multi-metal and multi-polymer) additive manufacturing methods for fabrication of materials and structures with designed microstructures at micro-scale spatial resolution. ***FY 2022 Plans:*** N/A	1.931	0.000
Congressional Add: Generally-capable robotics for naval operations ***FY 2021 Accomplishments:*** N/A ***FY 2022 Plans:*** Conduct basic research focused on generally-capable robotics for naval operations	0.000	4.000
Congressional Add: Multifunctional structural batteries ***FY 2021 Accomplishments:*** N/A ***FY 2022 Plans:*** Conduct basic research in multifunctional structural batteries	0.000	2.000
Congressional Add: Silicon-germanium-tin alloy research	0.000	5.000

Exhibit R-2A, RDT&E Project Justification: PB 2023 Navy		Date: April 2022
Appropriation/Budget Activity 1319 / 1	**R-1 Program Element (Number/Name)** PE 0601153N / *Defense Research Sciences*	**Project (Number/Name)** 9999 / *Congressional Adds*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022
FY 2021 Accomplishments: N/A		
FY 2022 Plans: Conduct basic research on silicon-germanium-tin alloys		
Congressional Adds Subtotals	26.065	39.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A