Networking and Information Technology
Research and Development (NITRD)

High End Computing (HEC) Software Sustainability Efforts: Examples of Federal Activities

High End Computing (HEC)
Interagency Working Group (IWG)

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1.0 Introduction

The agencies participating in the Networking and Information Technology Research and Development (NITRD) High End Computing (HEC) Interagency Working Group (IWG) share a strong interest in the sustainability of HEC software that is needed to support the missions of the agencies and the national research enterprise, such as the Future Advanced Computing Ecosystem Strategic Plan.[1] Providing software sustainability is a multi-faceted challenge, including the following:

- Porting and updating of software, accounting for evolving computing systems and best practices, to ensure the continued usability of the software and its integrability into the wider software and technology ecosystem.
- Evolution of software to incorporate new ideas, techniques, technologies, and practices while maintaining robust documentation and using other methods to preserve the knowledge embodied by the software for use in future research and development.
- Support and training of the workforce needed to work on and with the software, enabling both the recruitment and retention of a diverse community of professionals capable of meeting future requirements.

Many agencies have taken concrete steps toward ensuring software sustainability as outlined in the Future Advanced Computing Ecosystem Strategic Plan FY2022 Implementation Roadmap,[2] including the following:

- Establishment of policies and best practices that contribute to sustainability.
- Supplementary funding opportunities and strategic support for important, widely used software packages.
- Support for community organization, engagement, and outreach activities.
- Research to advance innovative techniques for software development and evolution.

This paper[3] highlights some examples of activities in Federal agencies that address these steps for the benefit of a wide spectrum of stakeholders.

2.0 Agency Efforts

2.1 Defense Advanced Research Projects Agency

The Intent-Defined Adaptive Software (IDAS) program within the Defense Advanced Research Projects Agency (DARPA) seeks to develop technologies that capture the intentions of software engineers to support the continual adaptation of Department of Defense (DoD) software-enabled systems. DARPA's program aims to develop new methods for representing the intent

[1] https://www.nitrd.gov/pubs/Future-Advanced-Computing-Ecosystem-Strategic-Plan-Nov-2020.pdf

[2] https://www.nitrd.gov/pubs/FACE-SP-FY22-Implementation-Roadmap.pdf

[3] The title of the document was changed without further changes to the content.

and the abstract constraints of software separately from its concrete instantiation by leveraging automated methods to adjust to a particular instance. Technologies developed within the IDAS program should enable rapid adaptation of software to changes in requirements and/or operating environments. The key idea of IDAS is the separation of problem description (in terms of intentions and constraints) from any particular, concrete instantiation. This intent and constraint model must be semantically accessible to an IDAS toolchain, yet expressive enough to capture the relationships between the problem and the method by which generated software can solve and validate a solution. Through additional automation of specific implementation generation, the software sustainment effort required should be drastically reduced, freeing engineers to focus on the design of the software and on adding new functionality.

Society's infrastructure is increasingly dependent on software deployed on a wide variety of computing devices other than commodity personal computers, such as industrial equipment, automobiles, and airplanes. Unlike commodity computers that have short upgrade cycles and are easily replaceable in case of failure, these computing devices are intended for long service and are hard to replace. The goal of the Assured Micropatching (AMP) program is to create the capability for rapid patching of legacy binaries in mission-critical systems, including cases in which the original source code version and/or build process is not available. AMP aims to create new capabilities to analyze, modify, and fix legacy software in binary form that are capable of producing assured targeted micropatches for known security flaws in existing binaries. Micropatches change the fewest possible bytes to achieve their objective, minimizing potential side effects, and should enable proof that the patches will preserve the original baseline functionality of the system. With these proofs, the time to test and deploy the patched system should be reduced from months to days.

There is a critical need to enhance and replace components of existing software with more secure and more performant code. This includes cases where a key performance or security benefit comes from moving parts of the software to new hardware, such as utilizing hardware accelerators, isolation enclaves, offload processors, and distributed computation. However, introducing enhancements or replacements into large legacy code bases carries a high risk that new code will not safely compose with the rest of the system. DARPA's Verified Security and Performance Enhancement of Large Legacy Software (V-SPELLS) program aims to create a developer-accessible capability for piece-by-piece enhancement of software components with new verified code that is both correct-by-construction and compatible-by-construction, i.e., safely composable with the rest of the system. V-SPELLS tools will enable developers to deliver assured incremental modernization of legacy systems in a manner that leverages verification technologies and reduces rather than raises risk. V-SPELLS technologies will facilitate incremental introduction of superior technologies into systems that cannot be re-designed from scratch and replaced as a whole.

2.2 DoD High Performance Computing Modernization Program

The DoD High Performance Computing Modernization Program (HPCMP) is the provider of high-performance computing (HPC) resources for Army, Navy, Air Force, and a number of DoD agencies. HPCMP provides compute resources at the Unclassified, Secret, and Top Secret levels for DoD researchers. The program supports a mix of commercial software, community codes, and user-developed software. The predominant computing language (more than 75 percent) used across HPCMP is Fortran. Incorporation of graphics processing units (GPUs) and accelerators has been slow but is seeing some growth.

The largest software development effort within HPCMP is through the Computational Research and Engineering Acquisition Tools and Environments (CREATE™) program that has been part of HPCMP since 2008. The CREATE program supports all DoD armed services for the development, deployment, and maintenance of software in response to critical DoD capability requirements. It is supported by a cross-functional team consisting of scientists, engineers, and computer scientists, ensuring that products are sustainable and can evolve over time to support government, industry, and academia.

When funding is available, HPCMP has also historically sponsored institutes for concentrated software development efforts. Institutes are typically three- to five-year efforts during which new software is developed to meet DoD mission-critical needs, with a nominal funding level of around $2 million per year. Several of the CREATE program areas began as institutes. HPCMP currently funds the Hypersonic Vehicle Simulation Institute to address challenges in hypersonic vehicle simulation.

One of the key thrust areas for software sustainability in HPCMP is to encourage the incorporation of GPUs and accelerators into user codes. To that end, the Productivity Enhancement and Training (PET) team (the user support team for HPCMP) helps users take advantage of accelerators in their codes as appropriate. To encourage adoption, a higher priority is given to support requests for which accelerator implementation is the target. Programmers in the CREATE program have also taken advantage of PET support, and accelerators are being added to many of the CREATE software applications.

Given the prevalence of Fortran codes throughout the organization, HPCMP is actively investigating the capabilities being developed under the LLVM compiler infrastructure project. LLVM began as a research project at the University of Illinois in the early 2000s and has been developed continuously by the LLVM community. HPCMP is interested in the functionalities of the Fortran front-end compilers Flang, based on pgfortran, and F18, both of which were designed to be interfaced with LLVM. This is a work in progress and shows promise in alleviating some of the problems of rewriting Fortran code for emerging architectures.

2.3 Department of Energy

The Department of Energy (DOE) develops and maintains a large body of software, both in direct service of its mission needs and as essential artifacts of sponsored research. DOE's

National Nuclear Security Administration (NNSA) Office of Advanced Simulation and Computing (ASC) and Office of Science (SC) Advanced Scientific Computing Research (ASCR) program have invested for decades[4] in developing both novel software technologies and associated best practices for development, verification and validation, and maintenance. Starting in 2014, ASCR, in collaboration with the SC Biological and Environmental Research program, sponsored the Interoperable Design of Extreme-scale Application Software (IDEAS) program. IDEAS researches best practices for software development, addressing both productivity and sustainability challenges, for computational science and engineering on high-performance computers. IDEAS has further contributed to the best practices adopted by the Exascale Computing Project (ECP).

ECP, which began in 2016 and is scheduled to run through 2023, has developed and sustained an important set of scientific applications and enabling software technologies for the DOE's upcoming exascale supercomputers and the wider scientific-computing ecosystem. Aligned with long-standing ASC-ASCR Open Source Software policy, much of the ECP-developed software is released as open source to mitigate a wide spectrum of risks, encourage sustainable developer and user communities, enable agile technology transfer and commercialization, and support reuse and scientific reproducibility.

Open source alone, however, is viewed as neither necessary nor sufficient for software sustainability. Rather, ECP's strategy includes investments in research and development associated with individual software projects and cultivation of an integrated portfolio. This includes a combination of specific integration metrics and milestones; support for integration technologies, including the Spack package manager, software development kits (e.g., Extreme-scale Scientific Software Development Kit), and the Extreme-scale Scientific Software Stack; and support for adoption-enabling activities including hackathons and other training, comprehensive documentation, and robust testing combined with continuous integration. Through the ECP and ASCR Small Business Innovation Research (SBIR) portfolio, DOE is also investing in several commercialization efforts that build on ASCR-funded software.

Some of ECP's investments are expected to have a lasting positive impact on the tools available to help with software development and maintenance. For example, the Flang project is developing new capabilities for the analysis, compilation, and transformation of programs written in the Fortran programming language. X-Stack, an ASCR basic research funding opportunity focused on innovative software stack technologies for scientific computing, has further invested in methods for software testing and parallel-programming-model translation, which are key activities in maintaining software and transitioning the software to new computing systems.

Beyond the ECP effort (after 2023), the NNSA ASC program will continue to develop its exascale-enabled software packages and technologies that are crucial to its mission-critical application codes, including, but not limited to, Kokkos, RAJA, Flux, MFEM, hypre, Spack, ParaView, and Visit.

[4] https://computing.llnl.gov/ascr-at-40; https://www.energy.gov/sites/default/files/2022-10/20221013 ASC 25-year Accomplishments Report.pdf

For the 2022 SBIR and Small Business Technology Transfer Program, ASCR included a topic on Accelerating the Deployment of Advanced Software Technologies, with specific subtopics on the "Deployment of ASCR-Funded Software" and the "Integration of ASCR-Funded Libraries." Projects funded under this topic potentially aid the sustainability of software packages that ASCR has previously funded.

The Advanced Scientific Computing Advisory Committee (ASCAC), ASCR's federal advisory committee, has formally recommended that ASCR develop a program focused on software stewardship and sustainability (Recommendation A.1 in the Transitioning ASCR after ECP report). In 2021, ASCR released a public Request for Information (RFI) on Stewardship of Software for Scientific and High-Performance Computing. The RFI solicited input related to how ASCR might implement ASCAC's recommendations and outlined a broad scope that ASCR is considering for a software stewardship program. The RFI details the potential scope of stewardship activities, including the following:

- Training on software development and use
- Workforce support
- Infrastructure for common development needs
- Curation and governance processes
- Sustainment of situational awareness
- Shared engineering resources
- Project support

Additionally, to better understand opportunities related to new software technologies and best practices, and how that understanding can be informed by quantitative study, ASCR sponsored the Workshop on the Science of Scientific-Software Development and Use in 2021. The Better Scientific Software (BSSw) website curates information on best practices for scientific software development. In collaboration with the National Science Foundation (NSF), DOE now also sponsors the BSSw Fellowship Program to provide recognition and funding to leaders and advocates of high-quality scientific software.

2.4 Food and Drug Administration

In 2002, the Food and Drug Administration (FDA) released "General Principles of Software Validation; Final Guidance for Industry and FDA Staff," which covers software lifecycle activities. Additionally, in November 2021, the FDA issued draft guidance on the content of premarket submissions for device software functions.

The FDA Center for Devices and Radiological Health HPC center employs staff who help users optimize their software applications by creating job-scheduler scripts and using special techniques to automatically switch computing nodes to an energy-efficient mode depending on demands to computational resources. The center staff use their accumulated knowledge of the in-house, commercial, and open-source applications that make up the center's workload to help users scale those applications, including scaling on GPUs. The center staff contribute to sustaining the relevant applications and computational resources, employing a hybrid approach to add cloud resources to the overall set of available center capabilities.

2.5 National Aeronautics and Space Administration

To support sustainability, the National Aeronautics and Space Administration's (NASA's) High-End Computing Program has multiple efforts across its two centers: NASA Advanced Supercomputing facility at NASA Ames Research Center and NASA Center for Climate Simulation at Goddard Space Flight Center. One major effort has focused on porting codes to newer architectures, such as general-purpose GPUs, by initially conducting characteristic analysis of user applications and workflows to identify potential codes that could benefit from such architectures. To jump-start the porting effort, computer engineers and domain scientists work together to design and create mini applications from the full-scale applications. They then incorporate programming approaches using high-level frameworks (e.g., OpenMP® and Kokkos) or low-level languages (e.g., CUDA and SYCL™) to validate the predicted performance potential. To increase interaction and improve productivity, annual GPU hackathons, coupled with focused bootcamps, have been organized in collaboration with vendors and national laboratories. After validation through these combined approaches, the knowledge gained is then applied to the development of the full applications. Another effort focuses on gaining access to emerging architectures as soon as possible by acquiring small testbeds for testing new hardware and techniques.

NASA is also investigating the use of the GridTools domain-specific language (DSL) framework, embedded in C++, as a high-level approach for portable codes. An initial effort is focusing on the Goddard Earth Observing System Global Circulation Model (GCM). The goal is to create a portable and high-performing GCM that can easily be executed on a wide variety of central processing units (CPUs) and GPUs. In addition, the DSL will enable a higher level Python programming interface that abstracts the details of parallel computing from the scientists.

NASA's new program, Open-Source Science Initiative (OSSI), focuses on the open sharing of data, information, and knowledge within the scientific community and the wider public to accelerate scientific research and understanding. OSSI is a comprehensive program of activities to facilitate and support moving science toward openness, including making policy adjustments, supporting open-source software, and enabling cyberinfrastructure.

As part of the OSSI, NASA will be supporting an ambitious mission to train scientists in open science best practices, including open-source software practices, called Transform to Open Science (TOPS). TOPS begins with the Year of Open Science in 2023 and will provide training

through workshops, society meetings, and online events. The TOPS mission is aligned with recommendations from NASA's Strategy for Data Management and Computing for Groundbreaking Science 2019–2024; the National Academies reports on open science, reproducibility, scientific software; and the 2021 United Nations Educational, Scientific and Cultural Organization draft Recommendation on Open Science synthesis report.

In addition, NASA's Research Opportunities in Space and Earth Sciences (ROSES) funding solicitation supports the sustainability of open-source software that underpins scientific research activities. In 2021, the first year of the program, 8 proposals were selected that support 14 different libraries. ROSES-2022 Cross-Division Research includes the following program elements:

- Support for Open-Source Tools, Frameworks, and Libraries (F.7): The improvement and sustainment of high-value, open-source tools, frameworks, and libraries that have made significant impacts to the Science Mission Directorate (SMD) science community.
- Supplemental Open-Source Software Awards (F.8): To encourage the conversion of legacy software into modern code to be released under a generally accepted, open-source license (e.g., Apache-2, BSD-2-clause, GPL). The supplement would add a software component to an existing "parent" research and analysis award.
- High Priority Open-Source Science (F.15): To support innovative open-source tools, software, frameworks, data formats, and libraries that will have a significant impact on the SMD science community, with work expected to complete within one year.
- Supplement for Scientific Software Platforms (F.16): For supplemental support to existing awards for usage of scientific analysis platforms, which are defined as interactive environments accessible through a web browser that provide access to data and computing resources to support scientific analysis and processing.

2.6 National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST) has highly distributed software development efforts resulting in widely varying software development practices. An indication of the scope of NIST's software development efforts is indicated by the NIST GitHub site, which lists over 920 public repositories. This is only a partial list, as many other packages reside on specialized division websites such as the Applied Computational and Mathematics Division's Guide to Available Mathematical Software (GAMS), which includes both NIST- and non-NIST developed packages. As is the case with several other NIST software packages, GAMS is not actively maintained. NIST also operates an open-source software (OSS) portal as part of implementing best practices for research software and welcomes contributions to NIST-led OSS from the general public.

There are also a wide variety of efforts related to computing and software at NIST that relate to software sustainability:

- NIST recently initiated an effort for reviewing data and software. The first-generation review process is geared toward manually reviewing data and software used in publications. The process will later be augmented with automated methods that are essential in reviewing data and software at scale.
- NIST released Interagency Report 8397, Guidelines on Minimum Standards for Developer Verification of Software, in response to Executive Order 14028, *Improving the Nation's Cybersecurity*.
- NIST has efforts dedicated to developing techniques on how to refactor software for new architectures. These include imaging-related projects such as Image Stitching for Microscopy Images and Analysis, and Feature Detection & Classification of Very Large Microscopy Images on high-end workstations with high-core-count CPUs and GPUs, and a joint project with the Scientific Computing and Imaging Institute at the University of Utah to extend dataflow and task graph based approaches from such high-end workstations to clusters of such nodes.
- NIST is examining how research computing is supported at the institute. There is no formal central support for research computing at this time; rather, there is some limited fee-for-service support provided by NIST's Office of Information Systems Management.

2.7 National Institutes of Health

The National Institutes of Health (NIH) promotes the development and broad dissemination of research products, including NIH-funded and/or NIH-developed research software. As part of their research projects, investigators often produce innovative, scientifically valuable software. Frequently, these valuable tools are developed under conditions that are not optimal for reuse or are no longer optimal in a rapidly changing technical and scientific landscape. Additionally, investigators lack the resources to adapt and revise software to take advantage of new technologies and computing paradigms. To address these concerns, the NIH Office of Data Science Strategy (ODSS), along with other NIH Institutes and Centers, has supported programs that supplement existing NIH awards to enhance software tool development for open science since 2020.

The supplements do the following:

- Support robustness, sustainability, and scalability of existing biomedical research software tools and workflows.
- Invest in research software tools with recognized value in a scientific community to enhance their impact by leveraging best practices in software development and advances in cloud computing.
- Support collaborations between biomedical scientists and software engineers to enhance the design, implementation, and "cloud readiness" of research software.

Examples noted in NOT-OD-22-068 address one or more challenges in building robust software suitable for open science and modern computing included the following:

- Adding application programming interfaces and services to software, containerization, and tool registry, refactoring software for portability
- Incorporating standard interfaces and data formats, providing documentation and configurations that make software components more usable
- Reducing coupling and complex shared states, enabling configuration of services into environment variables, etc.
- Implementing standard logging models to enhance performance and optimization and to take advantage of various architectures
- Enhancing standard unit and functional testing support and sample datasets for testing patches and upgrades.
- Employing standard security that relies on cloud identity and access management models and developing other improvements in privacy and security protection.

In support of an open software community, NIH has created best practices for sharing research software and source code, developed under research grants in any stage of development, in a free and open format. Information about these programs and best practices can be found on the ODSS Tools & Analytics webpage.

Additionally, funding opportunities covering hardening and sustainment are available in specific areas. For example, the National Cancer Institute (NCI) funding opportunity RFA-CA-22-024 (U24 Sustainment) supports the continued development and sustainment of high-value informatics research resources to serve current and emerging needs across the cancer research continuum. Examples of activities appropriate to the sustained operations of informatics technology in support of research are as follows:

- Providing community outreach and engagement, user training, and user help desk support
- Hosting tools in conjunction with relevant datasets and supporting collaborative/shared analysis.
- Establishing interoperability with other research resources.
- Implementing new resource functionality in support of evolving user needs.
- Performing general maintenance, including bug fixing and technical upgrades, on the underlying software and infrastructure.
- Improving the stability, security, and/or performance of the informatics tools.
- Providing software installation support for locally hosted instances.
- Supporting open-source development

Available NCI funding opportunities covering software sustainment and other phases of development are listed on NCI's Funding Opportunities webpage.

Finally, NIH supports short-term workshops or seminars for undergraduate, graduate/medical students, postdoctoral researchers, medical residents, and faculty that emphasize computational and analytical research methods. For example, the National Institute on Drug Abuse funding opportunity RFA-DA-23-027, supports training on computational and analytical research methods, including on topics such as biostatistics, machine learning, artificial intelligence, and mechanistic modeling related to drug addiction.

2.8 National Oceanographic and Atmospheric Administration

To increase collaboration, National Oceanographic and Atmospheric Administration (NOAA) is simplifying and improving its infrastructure to acquire, build, and deploy its operational model software. This effort is intended to make it easier for a university, other government agency, or private sector collaborator to improve the modeling software via new algorithms or other innovations.

The Software Engineering for Novel Architectures project is intended to support the refactoring of modeling software for architectures other than traditional CPUs. The principal focus is currently on GPUs with two efforts: The first employs Fortran with directives, and the second adopts a DSL. Both efforts are focused on NOAA's flagship global model with an intention of providing some level of performance portability.

2.9 National Science Foundation

The National Science Foundation (NSF) has several current programs targeted at or related to software sustainability. The programs include Cyberinfrastructure for Sustained Scientific Innovation (CSSI), Pathways to Enable Open-Source Ecosystems (POSE), and Sustaining Infrastructure for Biological Research (Sustaining). Other active programs throughout NSF have significant software components and may also address sustainability issues.

The NSF CSSI program supports the development and deployment of robust, reliable, and sustainable data and software cyberinfrastructure. A recent internal study of the program and its predecessor programs showed that funded projects that succeeded in long-term sustainability transitioned to various forms of long-term support and were not directly funded by NSF or other Federal agencies indefinitely. That study, and other factors, led to a new class of projects in the most recent CSSI solicitation, NSF 21-617, that focuses on transition to sustainability. The goal is not to cover the daily operational costs of software projects to sustain them, but to implement a well-defined plan that will lead to self-sustainability over the long term by diversifying funding sources and creating alternative avenues of support. Activities in these projects can include community outreach and engagement; user training, documentation, and technical support; and improvements in code quality, scalability, and accessibility.

The goal of NSF's POSE program is to harness the power of open-source development for the creation of new technology solutions for problems of national and societal importance. The program will fund new open-source ecosystem (OSE) managing organizations, each responsible for the creation and maintenance of infrastructure needed for efficient and secure operation of an OSE based around a specific open-source product or class of products. In that the program supports translation from research results, it is led by the Directorate for Technology, Innovation and Partnerships with participation from all NSF directorates. It serves a similar purpose as that of the CSSI transition to sustainability track, to enable long-term sustainability by catalyzing community-driven development and growth of the subject OSEs.

Examples of NSF-funded open-source research projects and products that have transitioned into OSEs with broad measurable impact include Apache Spark™, a unified analytics engine for large-scale data processing that has transformed big data analytics and is in use in many industrial cloud facilities; Galaxy, a scientific workflow, data integration and analysis, and publishing platform that makes computational biology accessible to researchers who do not have computer programming or systems administration experience; and RISC-V®, an open standard instruction set architecture that enables researchers, developers, and manufacturers to design and experiment with building hardware on a proven and freely available architecture. The inaugural POSE solicitation, NSF 22-572, has two types of projects, allowing teams to (1) propose specific activities to scope the development of an OSE (Phase I) and (2) develop a sustainable OSE based on a mature open-source product that shows promise in the ability both to meet an emergent societal or national need and to build a community to help develop it (Phase II).

The Sustaining program supports the continued operation of existing research infrastructure that advances contemporary biology in any research area supported by the Directorate for Biological Sciences (BIO) at NSF. One of the focuses of the Sustaining solicitation, NSF 21-503, is on sustaining critical research cyberinfrastructure, mainly software, that is broadly applicable to a wide range of researchers. Projects are expected to ensure continued availability of existing, mature cyberinfrastructure resources that will enable important science outcomes achieved by users representing a broad range of research supported by BIO and its collaborating organizations. This program is different from the other previously mentioned NSF programs in that its intent is to directly sustain software and other cyberinfrastructure for use by the relevant research community. However, the program does expect that resources supported under the program will make efforts to generate revenue through the development of a business plan that will spread some of its operating costs onto its user community or other funding sources in a manner that does not unduly restrict open and fair access for research, education, and the public.

NSF, in collaboration DOE, sponsors the BSSw Fellowship Program to provide recognition and funding to leaders and advocates of high-quality scientific software.

List of Abbreviations and Acronyms

Item	Spell-out
AMP	Assured Micropatching (DARPA)
ASC	Advanced Simulation and Computing (DOE)
ASCAC	Advanced Scientific Computing Advisory Committee (DOE)
ASCR	Advanced Scientific Computing Research (DOE)
BIO	Directorate for Biological Sciences (NSF)
BSSw	Better Scientific Software (DOE)
CISE	Directorate for Computer and Information Science and Engineering (NSF)
CPU	central processing unit
CREATE	Computational Research and Engineering Acquisition Tools and Environments (DoD)
CSSI	Cyberinfrastructure for Sustained Scientific Innovation (NSF)
DARPA	Defense Advanced Research Projects Agency (DoD)
DoD	Department of Defense
DOE	Department of Energy
NNSA	National Nuclear Security Administration (DOE)
SC	Office of Science (DOE)
DSL	Domain Specific Language
ECP	Exascale Computing Project (DOE)
FDA	(U.S.) Food and Drug Administration
GAMS	Guide to Available Mathematical Software (NIST)
GCM	Global Circulation Model (NASA)
GPU	graphics processing unit
HEC	High End Computing (IWG)
HPC	high-performance computing
HPCMP	High Performance Computing Modernization Program (DoD)
IDAS	Intent-Defined Adaptive Software (DARPA)
IDEAS	Interoperable Design of Extreme-scale Application Software (DOE)
IWG	Interagency Working Group
NASA	National Aeronautics and Space Administration

Item	Spell-out
NCI	National Cancer Institute (NIH)
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NITRD	Networking and Information Technology Research and Development
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
ODSS	Office of Data Science Strategy (NIH)
OSE	open-source ecosystem
OSS	open-source software (NIST)
OSSI	Open-Source Science Initiative (NASA)
PET	Performance Enhancement and Training (DoD)
POSE	Pathways to Enable Open-Source Ecosystems (NSF)
RFI	request for information
ROSES	Research Opportunities in Space and Earth Sciences (NASA)
SBIR	Small Business Innovation Research
SMD	Science Mission Directorate (NASA)
Sustaining	Sustaining Infrastructure for Biological Research (NSF)
TOPS	Transform to Open Science (NASA)