G E N I

Global Environment for Network Innovations

Solicitation 4 for
GENI Development & Prototyping

Document ID: GENI-GPO-SL-04.0

February 13, 2013

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1   General Information for this Solicitation

1.1   Important: This is a solicitation for engineering, not research

This solicitation is *not* requesting research proposals – rather, it is requesting engineering Development and Prototyping (D&P) proposals to inform GENI's planning and design. As such, this solicitation is requesting proposals for engineering subcontracts, not for research grants. If you have interesting new ideas for research, such as ideas for novel network architectures you should contact NSF CISE directly. The GENI Project Office (GPO) reserves the right to return without review any proposals that do not adhere to the guideline described in this solicitation.

1.2   Stimulating Competition

The GPO intends to **encourage competition**, and will if possible fund **multiple competing efforts** for every major part of GENI.

1.3   Letter of Intent

Not required.

1.4   Proposal Submission and Deadline

Submission: Proposals must be submitted electronically via the link provided on the GENI wiki: http://groups.geni.net/geni/wiki/Solicitation4. The submission site will be available by March 1, 2013.

Deadline: Monday, April 15, 2013, 5pm (Eastern Standard Time).

Confirmation: Proposer should contact the Point of Contact (POC) identified in section 1.7.1 if no email confirmation is received within 3 days after submission.

1.5   Soliciting Organization

The GENI Project Office (GPO) has been formed under a Cooperative Agreement between the National Science Foundation (NSF) and Raytheon BBN Technologies, and has assumed responsibility for project management in GENI's planning phase. Under this agreement, the GPO is issuing the Solicitation for GENI Development & Prototyping Proposals.

1.6   Revision Notes

At present there are no revisions to this solicitation. It is the proposer's responsibility to check http://groups.geni.net/geni/wiki/Solicitation4 for updates to this solicitation.

1.7 Contact Information

1.7.1 Point of Contact (POC)

All administrative correspondence and questions concerning this solicitation must be directed, in writing, to the GENI Proposal Point of Contact (POC), through email to:

proposalpoc@geni.net

1.7.2 GENI Project Officers

- Mark Berman, GENI Project Director, telephone: (617) 873-3675
- Henry Yeh, GENI Project Manager, telephone: (617) 873-4821

1.7.3 GENI Subcontract Representative

Kelly Sarvey
BBN Technologies
10 Moulton Street   Voice: 617-873-2078
Cambridge, MA 02138   Fax: 617-873-3797

1.8 Subcontract Information

This solicitation is *not* requesting research proposals – rather, it is requesting engineering Development and Prototyping (D&P) proposals to inform GENI's planning and design. As such, this solicitation is requesting proposals for engineering subcontracts, not for research grants. If you have interesting new ideas for research, such as ideas for novel network architectures, you should contact NSF CISE directly.

Anticipated Type of Subcontract: It is anticipated that university participants will receive Cost Reimbursement contracts. Other contract types – Firm Fixed Price Contracts (FFP), Cost Reimbursement Contracts (CR), Cost Plus Fixed Fee Contracts (CPFF), and Cost Sharing Contracts (CS) – will be considered for awards to other types of organizations.

While the Proposer shall submit proposals in accordance with one of the anticipated award types, the GPO reserves the right, at the sole discretion of the GENI Subcontract Representative, to make a final determination of the appropriate award instrument.

Anticipated Funding Amount: Refer to the table below and the additional information described in the later sections. All awards are subject to the availability of funds. The GPO oversees the process for identifying, prioritizing and supporting development and prototyping activities as described in this solicitation. Fee is allowed with a maximum cap of 5%.

Estimated Number of Subcontracts: The GPO anticipates awards will be in the ranges shown in the table below. All awards are subject to the availability of funds, and these figures are only preliminary estimates. Although previous GPO solicitations have requested both "large" and "small" classes of efforts, this solicitation requests only proposals of the specific classes identified below. See Section 3 for details of the specific efforts requested.

FIGURES BELOW FOR DISCUSSION ONLY

Topic Area	Duration*	Estimated number of subcontracts[*]	Estimated annual funding range *
A1: Experimenter tools (broad)	24 months	2	$200K - $300K per year (each award)
A2: Experimenter tools (specific)	24 months	6	$50K - $200K per year (each award)
B: Advanced GENI shakedown experiments, prototype services, and applications	24 months	10	$50K - $200K per year (each award)
C: Documentation and training	24 months	5	$50K - $100K per year (each award)
D: Operations transition	24 months	1	$350K per year
E: Transition to self-sustaining community	24 months	5	$50K - $200K per year (each award)

1.9   Eligibility

Any organization meeting the criteria listed in this section, and with an approved United States Government accounting method in place, may submit a proposal. In particular, teams already receiving GPO funding, as well as those not already so funded, are eligible.

1.9.1 Organizations Allowed

Proposals may be submitted by the following types of organizations:

Organization Type	Description
Unaffiliated individuals	Scientists, engineers or educators not employed by, or affiliated with, an organization.
Academic institutions	Universities and two- and four-year colleges, including

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[*] All funding information in this document is preliminary and subject to the availability of funds.

	community colleges, acting on behalf of their faculty members.
Non-profit, non-academic organizations	Independent museums, observatories, private research labs, government research labs, professional societies, and similar organizations associated with educational or research activities.
For-profit organizations	Commercial organizations with strong capabilities in scientific or engineering research.

The GPO strongly encourages participation from teams composed of academic and industrial participants, and strongly urges foreign organizations to be part of a team led by U.S. participants.

1.9.2 Limits on Proposals

Each proposal must identify a single Principal Investigator (PI) who is responsible for the project. However, any number of co-PIs may also be identified.

An individual may appear as Principal Investigator or co-PI on no more than one GENI Development & Prototyping proposal submitted to this solicitation. However, an individual who is PI on one proposal may also participate in other proposals, e.g., as key personnel.

An individual who already serves as PI or co-PI for an existing GENI effort (e.g., funded by Solicitation 1 – 3) is not precluded from serving as PI or co-PI for proposal(s) submitted under this solicitation 4. The PI and Co-PIs should follow the guidelines as stated above.

There is no limit on the number of proposals that an organization may submit.

Note that the GPO reserves the right to return without review any proposals that do not adhere to the spirit of these rules.

1.10 Intellectual Property

Every proposal must explicitly state its acceptance of one of the two (2) GENI intellectual property rights licenses – the GENI Public License or the GENI Project License. The two licenses are posted at http://www.geni.net/office/office_ip.html. The GPO prefers that proposals adopt the GENI Public License whenever possible and may give preference to those that do.

IMPORTANT – Proposals that do not clearly state their acceptance of one of the two Intellectual Property licenses, unmodified, will not be considered. You must attach a support letter from an official of your sponsored research organization stating the organization's support of the Intellectual Property Rights License selection.

2   Background Information

The Global Environment for Network Innovations – GENI – is a suite of research infrastructure rapidly taking shape in prototype form across the United States. GENI aims to transform experimental research in networking and distributed systems, as well as computationally-driven domain science and emerging research into very large socio-technical systems, by providing a suite of infrastructure for "at scale" experiments in future internets. This section provides a reference to the online repository for all GENI material, background information on GENI's motivation and overview, and the GPO's plans for evolving GENI over time.

2.1   Current GENI Information

Please see www.geni.net for an overview of the GPO's planned spiral development and federation approaches. The GENI Wiki contains documentation on GENI's infrastructure, current status and evolving design; see http://groups.geni.net/geni for intro to GENI and how to get started on using GENI.

Note that some documents in the repository are of historical interest only. In particular, the overall GENI architecture and the design of components are undergoing frequent refinement by the GENI architecture group, the GENI community, and the developers of various components. For information on the GENI architecture and the work of the architects' team, see: http://groups.geni.net/geni/wiki/GeniArchitectTeam. For information on the design and deployment of GENI racks, see: http://groups.geni.net/geni/wiki/GENIRacksHome. For sample experiments and information on tools and resources available to experimenters, see http://geni.net/experiment. Many design presentations and discussions take place in sessions at GENI Engineering Conferences (GECs), and proposers may wish to review the presentation material archived from recent GECs: http://groups.geni.net/geni/wiki/OtherMeetings.

The GPO invites inquiries from proposers via the points of contact identified above in Section 1.7, "Contact Information."

2.2   GENI Overview

The Global Environment for Network Innovations (GENI) is a novel suite of infrastructure now being designed to support experimental research in network science and engineering.

This new research challenges us to understand networks broadly and at multiple layers of abstraction from the physical substrates through the architecture and protocols to networks of people, organizations, and societies. The intellectual space surrounding this challenge is highly interdisciplinary, ranging from new research in network and distributed system design to the theoretical underpinnings of network science, network policy and economics, societal values, and the dynamic interactions of the physical and social spheres with communications networks. Such research holds great promise for new knowledge about the structure, behavior, and dynamics of our most complex systems – networks of networks – with potentially huge social and economic impact.

As a concurrent activity, community planning for the suite of infrastructure that will support network science and engineering experiments has been underway for several years. This suite is termed the Global Environment for Network Innovations (GENI). Although its specific

requirements continue evolve, GENI is now taking shape as a rapidly growing deployment of prototype components and interoperable software. Its core concepts are as follows:

- **Programmability** – researchers may download software into GENI-compatible nodes to control how those nodes behave;
- **Virtualization and Other Forms of Resource Sharing** – whenever feasible, nodes implement virtual machines, which allow multiple researchers to simultaneously share the infrastructure; and each experiment runs within its own isolated slice, created end-to-end across the experiment's GENI resources;
- **Federation** – different parts of the GENI suite are owned and/or operated by different organizations, and the NSF portion of the GENI suite forms only a part of the overall 'ecosystem'; and
- **Slice-based Experimentation** – GENI experiments will be an interconnected set of reserved resources on platforms in diverse locations. Researchers will remotely discover, reserve, configure, program, debug, operate, manage, and teardown distributed systems established across parts of the GENI suite.

As envisioned in these community plans, the GENI suite will support a wide range of experimental protocols, and data dissemination techniques running over resources such as fiber optics with next-generation optical switches, novel high-speed routers, city-wide experimental urban radio networks, high-end computational clusters, and sensor grids. The GENI suite is envisioned to be shared among a large number of individual, simultaneous experiments with extensive instrumentation that makes it easy to collect, analyze, and share real measurements.

2.3   GENI Planning, Design, and Prototyping Cycles

The GENI infrastructure suite currently exists as an evolving conceptual design together with an expanding suite of end-to-end infrastructure and interoperable software systems. As this suite begins its early "at scale" deployment, its design is taking clearer shape, but it will continue to mature over a period of years, during which time networking technology will continuously evolve. Its design must be flexible enough to incorporate new technologies as they develop, but reliable enough to simultaneously support ongoing research. The design must also be flexible enough to operate as new organizations join the GENI effort, allowing resources that are owned and managed by different organizations to be used effectively for individual research projects that themselves may have many users and developers.

Please see www.geni.net for an overview of the GPO's planned spiral development and federation approaches. The GENI Wiki contains documentation on GENI's current status and evolving design; see http://groups.geni.net/geni for getting started on GENI.

Prototypes and integration efforts proposed for this solicitation must explicitly address how they will be integrated with the evolving GENI early "at scale" prototype suite of infrastructure and its interoperable software systems, and accommodate spiral development, federation and interoperability during the funded performance period, including any technical or administrative procedural advantages that differentiate the proposed effort from others. Prototypes and integration efforts funded under this solicitation should build upon the current GENI deployment,

improve interoperability within GENI, provide inputs to the GENI working groups, and reduce technical, operational, and programmatic risks for the GENI system overall.

Because this solicitation funds prototype and integration work in parallel with design work, proposers will need to be actively involved in GENI working groups, and to build in opportunities to incorporate new results from those groups and from other prototype efforts as they develop. Interoperability should be demonstrated early and often, preferably at every GENI Engineering Conference. Proposals must describe how they achieve demonstrable end-to-end interoperability as part of the growing GENI deployment.

2.4 GENI Rack Designs

As GENI expands to more locations across the US, GENI racks are becoming the most consistent element of the GENI platform for experimentation and continued GENI development. Two rack designs, InstaGENI and ExoGENI, are currently being deployed. Each type of rack incorporates the key GENI rack capabilities:

- Virtualized and bare metal computers
- Layer 2 and layer 3 connectivity to GENI core networks
- Experimenter-specified layer 2 topologies with optional SDN control
- Aggregate manager functions via GENI Aggregate Manager API

Each rack type also incorporates unique design features and capabilities. Additional documentation for both rack types is available from the following URL on the GENI wiki: http://groups.geni.net/geni/wiki/GENIRacksHome.

For most topic areas, the GPO **requires** that your proposed project address **both** rack types. For example, experimenter tools must run on both rack types, training materials must address both rack types, etc. The exceptions to this rule are:

- Certain proposals for advanced GENI shakedown experiments. Proposers may choose to use only one rack type if the experiment requires capabilities unique to that rack type. Similarly, experiments using only non-rack GENI resources need not use GENI racks. Your proposal should identify the specific requirements driving rack selection. Where possible, the GPO prefers experiments that will exercise both rack types.
- Proposals for documentation and training for GENI functions not associated with GENI racks.

3   Goals of this Solicitation

The GPO has the responsibility for project management to successfully complete all planning, design, and development activities for GENI. The GPO is using a "spiral development" methodology in which a series of integrated prototype systems drive forward GENI design and development. This solicitation offers funding for the computing research community to perform GENI's engineering design, development, prototyping, and integration activities.

Projects funded under this solicitation are expected to play a major role in advancing the maturity of GENI as it progresses through its "at scale" deployment phase. Proposers are invited to work with the GENI community to advance program goals.

- Improve GENI capabilities and usability through tool development.
- Validate and stress-test key GENI features via experiments and prototype services.
- Develop experiments, training, and educational materials that encourage the broader use of GENI throughout the university community – by research faculty, in the classroom, and in the dorm.
- Provide operational support to keep GENI available and reliable for a growing user community.
- Build community structures that will sustain GENI's momentum beyond the project's development phase.

The GPO intends to **encourage competition**, and will if possible fund **multiple competing efforts** for every major part of GENI.

The GPO encourages proposers to form multi-organization teams in order to best tackle some or all of these tasks. Each such team proposal must have a clearly identified, single Principal Investigator who leads the ensemble effort, and must clearly specify the responsibilities, personnel, cost, and schedule for each organization in the team; it must also clearly describe how team members will communicate and interact so that they can function as a team.

3.1   Development and Prototyping Subcontracts

This solicitation requests proposals for GENI Development and Prototyping (D&P) subcontracts that will develop and enhance key GENI capabilities, permit the experimental validation of GENI capabilities, and ensure the continued success of GENI and the GENI community in their post-development period.

The specific areas being solicited are as follows.

3.1.1 Area A: Experimenter tools

This topic area solicits software tools of general use to experimenters employing GENI in their research or classroom experiments. A proposed tool or tool suite may address one or multiple phases of the GENI experiment lifecycle depicted in Figure 1.

Tools must build and/or improve upon existing GENI infrastructure capabilities, such as the GENI aggregate manager API and GENI instrumentation and measurement capabilities. Tools must not be tightly coupled to a single type of GENI resource, but should enable experimenters to use appropriate resources or combinations of resources suited to a particular experiment. In particular, tools addressing GENI computational resources must support both InstaGENI and ExoGENI type GENI racks. In order to facilitate integration with independently developed tools

and with new GENI aggregates, tool developers should make maximum use of existing and emerging GENI standard APIs.

Previous GENI development spirals have developed tools at various levels of maturity and sophistication for various portions of the experiment lifecycle. A summary of the key lifecycle phases, existing GENI tools, and gaps in GENI tool support is provided in Table 2. For additional overview information on the GENI experiment lifecycle, see http://groups.geni.net/geni/wiki/GeniExperiments. For detailed notes on the experiment lifecycle, existing GENI capabilities, and gaps in support, see http://groups.geni.net/geni/wiki/TestTutorialExperimentWorkflow.

Experiment Workflow
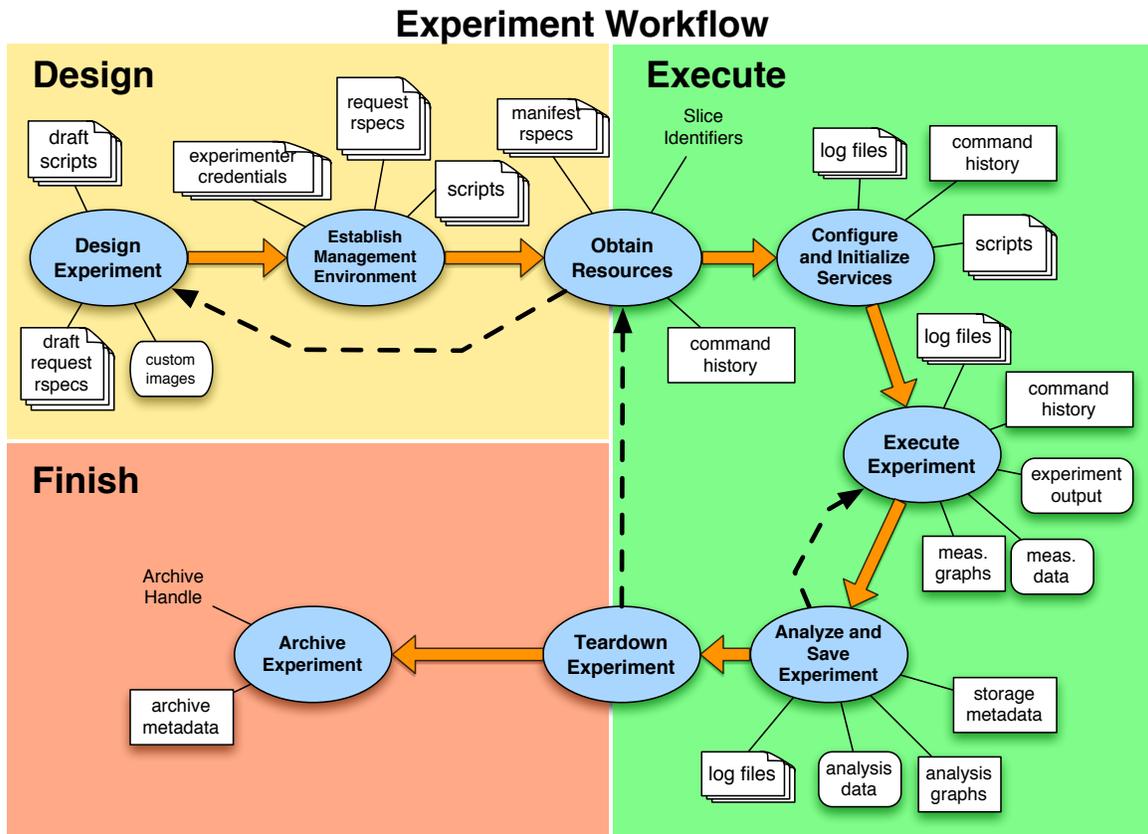
Figure 1: Experiment Lifecycle Steps & Work Products

Proposals for the broad award category (A1) must propose a wide-ranging tool or unified suite of tools covering a large fraction of the experiment lifecycle and supporting many styles of experiment. Proposals for category (A2) may choose to focus on only a portion of the lifecycle and/or specific types of experiment. Proposers should clearly state in which category (A1 or A2) they are proposing.

The GPO is keenly interested in the usability of proposed tools, ranging from the ease of tool access (e.g., Are tools web based? Readily installed on experimenter or GENI resources?) to the seamless integration of tools within the experimenter's workflow. The GPO recognizes that there is not an optimal one-size-fits-all approach to tool design. While a simple graphical user interface may be most accessible to novice users and small-scale experiments, scripted tools may better serve experimenters desiring unattended execution, large-scale configurations, and/or multiple

experiment trials. Combination approaches such as providing a simplified front end to a fully scripted or command-driven tool may address a wider range of needs. Proposers should indicate what portion of the spectrum from simple to complex experiments their proposed tools will best serve. Proposers should identify their planned approach to usability engineering in tool design and development, either by incorporating usability expertise in their teams or by working with a GPO-assigned experiment workflow team. Accordingly, the GPO also invites proposals for an experiment workflow team, incorporating expertise in experiment design and usability.

Proposers are cautioned that it is not within the mission of the GPO to support research in underlying tool capabilities that have little or no GENI-specific content. For example, although data analysis and visualization capabilities are clearly valuable to GENI experimenters, the GPO does not believe that best value to the project will be achieved by developing new analytic or visualization techniques. Instead, proposers are strongly encouraged to derive leverage from commonly used existing tools. Continuing the same example, a proposal might offer to improve the process of transferring GENI experiment data into gnuplot, MATLAB, Microsoft Excel, or the "R" statistical computing environment.

3.1.2 Area B: Advanced GENI shakedown experiments, prototype services, and applications

GENI's "meso-scale" deployment has been available for use by experimenters for approximately two years, and it has seen substantial use in a variety of experiments. This use has necessarily been limited by the size, capability, and maturity of the existing deployment. As GENI progresses through its early "at scale" deployment, significant gains in size, capability, and maturity are expected. The GPO is soliciting experiments, prototype services, and applications that enable the validation of key GENI features by employing specific capabilities or combinations of capabilities that are unique to GENI or difficult to achieve in other environments.

Because it is an explicit goal of GENI to support many different types of experiments, services, and applications the GPO may seek to fund a broad selection of experiments, prototype services, and applications including, but not limited to the following.

- Larger-scale experiments/services/applications that scale with the deployment of additional GENI resources, particularly GENI racks.
- Experiments/services/applications based on IP-compatible and IP-incompatible protocols.
- Laboratory-style repeatable experiments and service trial experiments subject to "in the wild" conditions.
- Experiments/services/applications involving opt-in user participation.
- Long-lived experiments/services/applications and sequences of related experiments.

In order to ensure that lessons learned are passed along to the GENI community, awardees will be expected to provide frequent informal and formal feedback addressing overall progress and subjective assessments of the ability of GENI to meet project needs. Awardees should include the following activities in their planned efforts.

- Maintain an ongoing log or electronic lab notebook, including project results as well as anecdotes of likely use to GENI development community. For example, how easy or hard is training a new project team member? Changing an experiment configuration? Identifying the data needed for experiment analysis?

- Report highlights frequently (monthly) to GPO – may include non-public information if required.
- Report at each GEC on project progress and GENI lessons learned.

3.1.3 Area C: Documentation and training

The GPO desires documentation and training materials showing how to apply multiple GENI capabilities for a particular experimental or educational purpose. Materials should be suitable for use by experimenters, educators, and/or students. Proposers are encouraged to consider multiple media types and delivery modes (e.g., screencasts, step-by-step online tutorials) in addition to traditional static text-and-figure documents. The GPO seeks material targeting a variety of different levels of knowledge and experience.

3.1.4 Area D: Operations transition

The GPO seeks competitive proposals to assume responsibility for ongoing operation of the physically or conceptually centralized portions of GENI, including, but not limited to:

- network operations
- status monitoring for GENI network and aggregates
- clearinghouse management
- incident response coordination
- help desk
- establishment and maintenance of archival storage for experimental and monitoring data.

See Table 3 for a more detailed list of these areas and current status. Proposers should plan to address each of these areas.

Subject to the availability of funds, the GPO plans to award two-year subcontracts. The GPO anticipates that the awardee will work closely with the GPO during to develop plans and procedures for transitioning GENI to an operational capability. The GPO anticipates retaining primary responsibility for GENI operations through the first year of subcontract execution, with the awardee taking over primary responsibility for operations for the second year.

At the conclusion of the subcontract, the awardee will deliver documented operational procedures adequate to enable handoff of future GENI operations to a qualified third party. The intent is to permit the GPO or future GENI management authority to competitively procure ongoing GENI operations services beyond the life of this subcontract.

3.1.5 Area E: Transition to self-sustaining community

Define and manage ongoing activities that will enable the GENI community to thrive beyond the completion of GENI's major development and deployment phase. During this period, the GENI community has begun the transition from its initial primary focus on *building GENI* towards the new focus on *using GENI* in experiments and education. As GENI continues toward at-scale deployment, this transition will continue. The GENI community will be driven less by the GPO and developers and more by the growing cadres of experimenters and educators using GENI in their everyday work. The GPO seeks proposals to encourage the long-term success of this community.

3.2   Specific Areas for this Solicitation

This section illustrates the kinds of proposals that may be submitted. The list below is not exhaustive as we recognize that there could be many other good ideas. However, every proposal must directly respond to one or more specific areas being solicited. **Proposals that suggest efforts outside of these identified areas may be rejected without a full review.**

GENI's current architecture is documented on the architects' page of the GENI wiki (see http://groups.geni.net/geni/wiki/GeniArchitectTeam). Additional design information is available elsewhere in the GENI wiki: http://groups.geni.net/geni/wiki. Please do not hesitate to contact the GENI Project Office if you wish to discuss ideas prior to writing a proposal.

Topic Area	Specific areas solicited
Area A: Experimenter Tools	• Several tools have been developed to support GENI experimenters in one or more steps of the experiment lifecycle. However, not all of these tools have achieved a high level of maturity and interoperation, and some portions of the experiment lifecycle are not well covered by available tools. See Table 2 for a summary of experiment lifecycle stages, existing support capabilities, and gaps in support. Particular areas of interest for tool development include, but are not limited to the following. 　○　Long-lived experiments or sequences of related experiments 　○　Tools supporting experiment "recipes" (archive and retrieval of experiment configuration procedures, data, results) and repeated execution 　○　Experiments involving opt-in users 　○　Classroom use (e.g., tools for instructors and TAs to establish starting environment or instructional scaffolding, receive and grade assignments, manage multiple students) • An integrated experimenter environment comprising a single tool or group of related tools support a large portion of the experiment lifecycle. For example, the capability to design an experiment requiring many trials across a period of weeks or months, permitting both manual and scripted execution, release and re-acquisition of GENI resources, and automation-assisted data analysis and archival. • Experiment workflow team: coordinate with the GPO and with GENI tool developers to assemble and document a capable, smooth, and efficient experiment workflow suitable for many GENI experimenters. Consult with GENI tool developers to improve usability and interoperability.
Area B: Advanced GENI shakedown experiments, prototype services, and applications	The GPO is soliciting proposals to validate and push the limits of key GENI capabilities by conducting actual experiments in the emerging GENI deployment. Because GENI is intended to support a wide variety of experiments, including laboratory experiments, "in the wild" experiments, and experimental services and applications, you may propose any or a combination of these. Although proposed experiments, services, and applications should be realistic and meritorious, it is equally important that they contribute to validating and improving GENI. Your proposal must clearly identify the GENI capabilities that will be incorporated into your plans. You should

	plan for the possibility of delays or disruptions associated with the use of an emerging infrastructure. In addition to any research results produced, you will be expected to provide the GENI community with feedback, advice, and suggestions for improvement arising from your experience.
	The following areas are of particular interest. However, proposals for interesting experiments, prototype services, and applications in other areas are also encouraged.
	• Opt-in user participation
	• Deeply programmable, distributed layer two networking
	• Multi-site, deeply programmable SDN
	• Novel WiMAX-based services
	• Highly mobile architectures
	• Non-IP layer 3 protocols
	• Scalable experiments that grow with the deployment of additional GENI resources.
Area C: Documentation and Training	GENI development to date has produced chiefly documentation oriented to a specific capability, augmented by a modest library of tutorials and sample experiments. A thriving body of up-to-date documentation and training materials can greatly accelerate adoption of GENI in the experimenter and educational communities. Possible areas include:
	• Introductory experimenter guide ("GENI for Dummies") with a focus on introducing and developing literacy in basic GENI concepts and tools.
	• Intermediate experimenter guide ("A practical guide to GENI").
	• Classroom support materials (e.g., "Curriculum modules using GENI").
	• Sample experiments. Note that experiments in this topic area differ from "Advanced GENI shakedown experiments" because their results are largely known in advance. Your proposal should address the packaging of sample experiments for quick and reliable reproduction as an educational exercise or for training experimenters to use GENI.
	Remember that proposed documentation, training materials, and sample experiments must apply to and/or run on both types of GENI racks. You are encouraged to consider the use of non-traditional and/or multiple delivery media. Your proposal should address the recommended approach for most effective dissemination of your products.
Area D: Operations Transition	Limited support and operational procedures have been established and are currently in place for GENI. Additional process development is needed, as are operations support services. See Table 3 for a more detailed list of these areas and current status.
	Procedures for ongoing management should be documented in sufficient detail to permit an efficient handover of operational responsibility to a third party at the conclusion of the proposed award.
Area E: Transition to self-sustaining	In addition to ongoing support of the GENI infrastructure, the long-term viability of the GENI community will be best served by the

community	establishment of self-sustaining community support structures. Some may be specific to the GENI community (e.g., GENI-themed conferences like the current GENI Engineering Conferences). Others may be incorporated into a broader community context (e.g., GENI workshops or tutorials at non-GENI conferences).
	• Ongoing GENI Engineering and/or User Conferences
	• Experimenter community support activities (e.g., workshops)
	• Community training (e.g., summer camps, TA training sessions, on-campus tutorial sessions, tutorial presence at non-GENI conferences)
	• Online community building activities, such as the following.
	o Community-curated repositories of GENI experiments, resource specifications (rspecs), code fragments, &c.
	Your proposal should identify both how you plan to initiate the proposed activity and your strategy for ensuring its continuation beyond the funding period of your proposed effort.

Table 1: Specific Areas Solicited

The following table presents summary information on the GENI experiment lifecycle, available capabilities, and identified gaps.

Experiment Lifecycle Step	Existing GENI capabilities	Identified Gaps in Capability
Design Experiment	Resource inventories – web pages, limited maps. Archived sample topologies, resource specifications (rspecs) and code. Experiment templates on GENI wiki.	Semantic resource inventories. Curated, searchable sample experiment and experiment design artifact repository. Experiment design and description tools. Tools for designing scalable, elastic, and long-lived experiments (e.g., experiments exploring a parameter space over many trials, elastic resource configuration and changing participant set over time).
Establish Management Environment	Credential management via clearinghouse and portal tools. Limited user workspace software installation tools.	Resource availability tools to compare and map desired resources to available resources.
Obtain resources	GENI AM API-based tools for requesting resources: omni (CLI), Flack (GUI), GENI portal.	Advanced tools for resource requests and management, supporting such capabilities as time-aware resource reservation, heterogeneous resource configurations, sophisticated mixed layer 2, layer 3, and OpenFlow-enhanced topologies. Long-lived experiment management tools, supporting ongoing monitoring of experiment results and modification of existing slice resources and topologies. Tools for verifying correct setup and configuration of resources and services.

Configure and Initialize Services	Limited code deployment tools. Automated install / startup script execution. GENI user shell (GUSH). Static and semi-automated slice instrumentation tools.	Tools for verifying correct setup and configuration of resources and services. Tools to facilitate deployment of slice-specific instrumentation and measurement capabilities.
Execute Experiment	Limited manual, semi-automated, and fully automated code execution and instrumentation tools: GUSH, OMF (on selected platforms). Live instrumentation data display tools: GEMINI, GIMI.	Generalized event-driven execution tools. Long-lived experiment management tools, supporting ongoing monitoring and modification of existing slice resources and topologies. Tools for verifying correct setup and configuration of resources and services. Tools supporting management of opt-in user participation.
Analyze and Save Experiment	Real-time data collection and display tools: GEMINI, GIMI. Storage services: CNRI handle system for unique & persistent identifiers, iRODS for archival storage.	Tools / structure for organizing multiple analytic and visualization functions (but see caution in section 3.1.1 above). Tools facilitating execution of multiple experimental trials. Meta-data generation for stored information.
Teardown Experiment	GENI AM API-based resource reservation tools: omni (CLI), Flack (GUI), GENI portal.	None.
Archive Experiment	Archive services: iRODS.	Tools to facilitate data archival, meta-data generation, and archive search.

Table 2: Summary of GENI experiment lifecycle, with existing capabilities and gaps.

The following table presents additional information on task areas for GENI operations.

Operational Service (24 x 7 x 365)	Example Requirements	Current Status
Help Desk for experimenters	Slice and experiment visibility, resource/component troubleshooting, online and phone help	Limited operations at Indiana University with escalation to GPO
Help Desk for IT site technical staff	Aggregate visibility, network/resource troubleshooting, online and phone help	Limited operations for OpenFlow and GENI Rack sites, with escalation to GPO, RENCI and University of Utah

Health reporting for GENI resources	Collect, process and display monitoring information on GENI aggregates. Provide interface for GENI participants to download full or partial monitoring information. Display public monitoring information dynamically on the web.	In development, partial prototype running at Indiana University
New site provisioning, installation, integration, and testing	Add OpenFlow switches and GENI Racks to new campus, regional and core network sites.	Requirements documented, procedures in development
Incident response, troubleshooting, event and outage tracking and resolution	Ticket tracking and notification (scheduled and unscheduled), analysis, escalation, review, emergency stop	Prototype operating with Indiana University, RENCI, University of Utah, and GPO
Legal, law enforcement and regulatory response	Maintain LLRR response procedures, security response expertise, restricted access ticketing and tracking	Prototype operating with NCSA, ISI, and Indiana University
Usage reporting and forecasting	Report usage dynamically on the web. Provide daily, weekly, and monthly usage summaries. Conduct monthly review and forecasting	In development
Clearinghouse, portal and federation support	Maintain clearinghouse and portal infrastructure (hardware and software). Process experimenter and aggregate requests, and maintain history. Provide engineering escalation for complex requests and incident response.	Needs prototype
Web resource maintenance (e.g. www.geni.net)	Maintain GENI web site, GENI Wikis, GENI repositories, GENI audio/video materials	Standard commercial service coordinated by GPO

Change Management	Software: GENI repositories, release and package management, release testing, updates and tracking procedures. Components: property tracking, firmware version testing, updates and tracking. Systems: VLAN, IP address and Autonomous System allocation, tracking and change procedures. Other: geni.net domain, mailing lists, GENI certificates, site contact information.	In development, partial prototypes
Coordination/peering with other research organizations (e.g. ESNet, Internet2, National LambdaRail, InCommon)	Implement operations plans and integration to support specific GENI expansion, experiments, demonstrations, policy enforcement and traffic exchange.	In development, partial prototypes
Archival storage for experimental and monitoring data	Establish and maintain storage for raw and condensed data arising from ongoing GENI monitoring and from experiments conducted on GENI. Support web-based access (via GUI and API) for both public and restricted data, based on requesters' GENI credentials.	Limited archival storage is available via GRNOC web page and API. Mixed access control via credentials and username / password

Table 3: Operations Transition Task Areas

3.3   Important Note: Subcontracts are NOT Research Grants

This solicitation is *not* requesting research proposals – rather, it is requesting engineering Development and Prototyping (D&P) proposals to inform GENI's planning and design. As such, this solicitation is requesting proposals for engineering subcontracts, not for research grants. If you have interesting new ideas for research, such as ideas for novel network architectures, this solicitation is not the right venue.

Successful proposals will receive *subcontracts,* rather than research awards, with the following implications:

- Proposals must show realism for the management approach, and practical understanding of the effort, as well as technical merit.

- Specific deliverables and associated milestones must be clearly described.

- Proposals should emphasize concrete, near-term results.

- Leveraging existing infrastructure (software, testbeds, etc.) is *good* because it reduces the risk of failure and may also reduce the cost.

- Clever ways to avoid new development work are *good* because they reduce the risk of failure and may also reduce the cost.

- Funded efforts will receive ongoing review by the GPO for GENI-relevant progress.

- Efforts with ongoing inability to make progress will be terminated.

Subject to the availability of funds, the GPO intends to structure subcontracts as follows: one year of funding, followed by an option year which will be exercised (funded) if the GPO determines that the subcontract is making useful progress. The GPO reserves the right to change this approach during negotiation of subcontracts.

4   Proposal Format

This section specifies how proposals must be prepared and submitted.

Proposals should be written in English, fonts size 11 point or larger, formatted for American letter paper size (8.5 x 11 inches) with reasonable margins. They must be submitted in Portable Document Format (PDF).

The technical part (sections I, II, and III) of the proposal must not exceed ten (10) pages including figures, charts, graphs, maps, photographs, and other pictorial representations. Proposals of $100,000 budget or less should have a technical part no longer than 5 pages. This page limit does not include the budget section or letters of support, which has no page limit.

The proposal **MUST** contain the following sections with the headings and contents as shown below. Non-conforming proposals may be rejected without review.

4.1   Section I. Header

Section / Heading	Required Contents
Section I. Title and Proposer List	Proposal title; name, organization, address and contact information for the Principal Investigator and contracting officer; name, organization, and contact information for all subcontractors, if any; Period of Performance; total cost

4.2   Section II. Contributions of Key Personnel in Past 3 Years

Section / Heading	Required Contents
Section II. Contributions of PI & Key Personnel in Past 3 Years	For the Principal Investigator and other Key Personnel, provide a brief biographical sketch that discusses relevant work, e.g.: • Experience with advanced networking infrastructure planning, construction, deployment and operations; • Effective project management, on-schedule and within budget; and • Effective management of software-intensive or rapid hardware prototyping projects.

4.3   Section III. Proposed Activities

Section / Heading	Required Contents
III.1 Scope of Work	Define the scope of work that you are proposing; identify and discuss project goals and associated milestones. State clearly what you are proposing to deliver. Identify specific analysis, development and/or prototyping activities. Describe the methods/metrics that will be used to evaluate work-product. If there are subcontractor(s) on the team, clearly state who is responsible for what tasks and

	deliverables.
III.2 GENI Relevance	Provide a clear rationale for these activities and how they tie into GENI's vision and its evolving deployment. Describe in detail how you will integrate your project into GENI, how researchers in network science and engineering will take advantage of your efforts as they perform experiments, and concrete, near-term advantages that your work will bring. Explain how GENI technical risk is reduced by your proposal.
III.3 Deliverables	List the important technical deliverables and goals that you plan to achieve and demonstrate. Where possible, deliverables and milestones should be coordinated with GENI Engineering Conferences (GECs). It is expected that performers will deliver the relevant work-product to GENI. Deliverables must also include periodic reports and a final report. All deliverable documents will be published on geni.net with proper credit. (See Section 7.2.)
III.4 Technical Approach	Describe in detail your technical approach, with a particular emphasis on how and when your work will become fully interoperable with the expanding GENI deployment, and (if relevant) when it will first be available for NSF researchers to use in their experiments. Detailed plans, with dates of major milestones, are required. If your project requires integration of software components, hardware, end-to-end systems, etc., please describe in concrete terms how and when such integrations will occur and when they will be demonstrated. Please describe specific, high-level, numerical metrics (e.g., uptime, number of experimenters supported, response time, number of students trained) that you will use to assess the success of your project.
III.5 Additional criteria	Provide a concrete, explicit description of how the proposed effort meets this solicitation's additional review criteria (sec. 6.1). These criteria are important and may form a fundamental part of the proposal strategy (e.g. may drive team formation).
III.6 Outreach Plan	Provide a concrete, explicit description of your plan for involving under-represented institutions, geographic areas and communities.
III.7. Project Schedule	Provide a Gantt chart identifying key milestones and major activities over the project period. All projects are expected to deliver major, usable functionality during the first year of the proposed effort, with the second year emphasizing improvements, hardening, additional feature development, etc. Key milestones should be no more than 4 months apart, aligned with GENI Engineering Conferences if possible, and their success should be clearly demonstrable. We strongly recommend demonstrations at every GENI Engineering Conference. Identify and discuss the critical path for development over proposed duration. The schedule should show the sequencing of all **major** activities to be conducted in sufficient detail to justify the proposed budget.
III.8 Intellectual Property	Clearly state acceptance of one of the following intellectual property rights for GENI participants: _____ GENI Public License

	_____ GENI Project License Each quarterly report and final report must also include copyright-free images and description of work performed (suitable for publication on the web at geni.net, in brochures, etc); proper credit will be given.
III.9 Management Plan, Organizational Structure, and Project Staffing	All information in this section is required for any proposal with a budget of $100,000 or greater. Information in this section is optional for proposals with budgets below $100,000. However, because dependency upon unidentified project staff can increase a project's schedule risk, all proposers are encouraged to provide at least basic staffing information. The GPO may give preference to proposals with clearly identified personnel. Describe the project organizational and management structure. Proposal should include a table that provides the following information for each individual participating in the project: name, position/title on the project, level of effort (monthly and annually), activities assigned, and responsibilities for achievement of key project goals and milestones. Provide a functional project budget in tabular form showing how resources will be allocated.
III.10 Letters of Support	1. Campus CIO. All proposals that involve opt-in users on an academic campus or require the use of campus resources beyond the proposer's laboratory are required to include a letter of support from the campus Chief Information Officer (CIO) or equivalent. The letter should indicate awareness of the project and state that the needed resources will be provided for the proposed project, either at no cost or at the cost identified in the proposed budget. 2. Contracts Representative. All proposals are requested to include a letter of support from the lead organization's contracts personnel, stating organizational support of the selected Intellectual Property License. This requirement will be waived for those organizations already under subcontract from the GPO that already have the relevant licenses in place.

4.4 Section IV. Budget

Your cost proposal should have sufficient detail to allow a thorough understanding of the pricing methodology used and assumptions made. The GPO will conduct a cost analysis of each proposal and any unsupported costs may be deducted from the proposer's total budget.

Provide the basis of estimate for proposed hours, labor rates, indirect costs and other direct costs as appropriate. State any assumptions upon which the estimates of your costs were based. Specifically state whether any Government furnished equipment, facilities, data or software is required. If any portion of the research is predicated upon the use of Government Owned Resources of any type, the proposer shall specifically identify the property or other resource required, the date the property or resource is required, the duration of the requirement, the

source from which the resource is required, if known, and the impact on the research if the resource cannot be provided. If no Government Furnished Property is required for conduct of the proposed research, a statement to that effect will be included in the basis of estimate section of the cost proposal.

Section / Heading	Required Contents
IV.1 Type of Subcontract Requested	Specify the Subcontract instrument requested: Firm Fixed Price Contracts (FFP), Cost Reimbursement Contracts (CR), Cost Plus Fixed Fee Contracts (CPFF), or Cost Sharing Contracts (CS)
IV.2 Period of Performance	For budgetary purposes assume a start date of November 1, 2013. Specify your estimated period of performance, as "Month Year through Month Year," such as "November 2013 through October 2015."
IV.3 Direct Labor Cost (PI, Co-PI Name and Senior Personnel)	List of individual labor category or person, with associated labor hours (or percentage of time for non-profit educational institutions) and unburdened direct labor rates;
IV.4 Direct Labor Cost for other Personnel	List of total post doctoral, other professionals, graduate students, undergraduate students, administrative support, etc. with labor category or person, associated labor hours (or percentage of time for non-profit educational institutions) and unburdened direct labor rates;
IV.5 Other Direct Cost	Include itemization for materials & supplies, publication costs, consultant services, computer services, and other. An explanation of any estimating factors, including their derivation and application, shall be provided, as well as a brief description of the Proposer's procurement method to be used. If none, state "none."
IV.6 Equipment Purchases	List item and dollar amount for each item exceeding $2500.00. Itemize with costs, including quantities, unit prices, proposed vendors (if known), and the basis of estimate (e.g. quotes, prior purchases, catalog price lists, etc.).
IV.7 Material Purchases	Itemize with costs, including quantities, unit prices, proposed vendors (if known), and the basis of estimate (e.g. quotes, prior purchases, catalog price lists, etc.)
IV.8 Travel	List domestic and foreign estimated travel (# of trips, purpose and cost). All successful proposers must participate in GENI Working Groups (by email lists) and attend 3 GENI Engineering Conferences per year. Please budget travel costs in this section; estimate travel costs by assuming that engineering conferences are 3 days long, and take place in hotels in major cities across the US. Number of trips, number of travelers and days per trip, departure and arrival destinations, etc. Per diem rates must not exceed those published in the Federal Travel Regulations (or costs must be consistent with university travel policies).
IV.9 Participant support costs	Include any participant support costs.
IV.10 Consultants	If consultants are to be used, proposer must provide consultant agreement or other document which verifies the proposed loaded

	daily/hourly rate. If none, state "none".
IV.11 Subcontractors	If subcontractors are to be used, proposer must provide a cost proposal as detailed as the Proposer's cost proposal to be submitted by the subcontractor. If none, state "none".
IV.12 Indirect Costs	Estimate indirect Costs, by category – Fringe Benefits, Overhead, General and Administrative Expense, Cost of Money, etc. (Must show base amount and rate.) If none, state "none".
IV.13 Fee or Cost Sharing	State fee in dollars and as a percentage; if none, state "none". If proposing cost sharing, include both dollar amount and percentage and explain the basis for the estimate.
IV.14 Total	Amount of total funds requested.
IV.15 In-kind Contributions	In-kind contributions are desirable but not required. If you provide such contributions, state clearly what is being contributed, and provide a reasonable estimate with your rationale for the stated value. If none, state "none".

NOTE:

REPRESENTATIONS AND CERTIFICATIONS

In accordance with FAR 4.1201, prospective proposers shall complete electronic annual representations and certifications. Electronic annual representations and certifications must be maintained current at the System for Award Management (SAM) at www.sam.gov.

ADMINISTRATIVE INFORMATION (to be filled-in then attached with your proposal)

1. Signature of authorized individual _____
   Name of Individual _____
   Title of Individual _____
   Name of Organization _____
   Type of Organization _____

2. Organization Information
   First Line Address: _____
   Street Address: _____
   City/State/Zip Code: _____

3. Identifying Numbers
   Taxpayers Identification Number (TIN) _____
   Corporate and Government Entity Code (CAGE) _____
   North American Industrial Classification System (NAICS)
   _____
   DUNS Number _____

4. Administrative Contact Information
   Name of Offerors' Point of Contact: _____
   Title of Point of Contact: _____
   Telephone Number of Point of Contact _____
   Email address of Point of Contact _____

5. Proposed Costs
   a. Cost: _____
   b. Profit/Fee or (Cost Sharing) _____
   c. Total: _____

6. Provide the Following
   Place of Performance: _____
   Period of Performance: _____

7. Name of Administrative Contract Office: _____

    Street Address: _____

    City/State/Zip Code: _____

    Point of Contact: _____

    Telephone number: _____

8. Name of Audit Office: _____

    Street Address: _____

    City/State/Zip Code: _____

    Point of Contact _____

    Telephone Number: _____

9. Accounting System approved for federal cost-type contracting

    ☐Yes   ☐No

10. Negotiated Indirect Rate Agreement, or other Rate Agreement, is attached

    ☐Yes   ☐No

11. Purchasing System approved for federal contracting

    ☐Yes   ☐No

12. Billing System approved for federal contracting

    ☐Yes   ☐No

13. Estimating system approved for federal contracting

    ☐Yes   ☐No

14. Pricing based on established catalog or commercial pricing

    ☐Yes   ☐No

15. OMB-133 Audit Results attached

    ☐Yes   ☐No

5   Proposal Review

All proposals will be treated as confidential.

Proposals will first be evaluated for compliance to the specific areas being solicited. Those not found relevant to a specific area may be rejected without a full review.

Those found relevant will be assigned to panels of appropriate reviewers drawn from the academic and industrial research community. All relevant proposals will be carefully reviewed, typically by three to five people who are experts in the particular fields represented by the proposal. GPO officials charged with the oversight of the review process will select the reviewers, taking care to ensure that reviewers have no conflicts with the proposer.

5.1   GENI Review Criteria

Review Criteria for this solicitation are as follows:

Criterion	Discussion
Relevance to GENI Development & Prototyping	How well do the proposed work and its outcome meet the GPO's stated goals for this solicitation?
Best Value	How much value does the proposed work provide for its cost? Potential areas of value includes high impact, enabling a broad range of research, near-term demo of integration & trials, etc.
Type of IPR license	Which Intellectual Property Rights (IPR) license is proposed? The GENI Public License is preferred over the GENI Project License.
Cost and schedule realism	Are the costs and schedule reasonable? Reviewers will be asked to evaluate the proposed costs in relation to reasonableness, technical and management approaches.
Probability of success and high impact	Does the proposer demonstrate a practical understanding of the technical challenges? Is success likely? Will a successful effort have a high impact on enhancing GENI and/or reducing its risk? Does the proposer list clear metrics for measuring success?
Academic / industrial team	Combined academic / industrial teams will be preferred over other types of teams.

In addition, the following criteria will be considered:

Criterion	Discussion
Active involvement of under-represented institutions, geographic areas, communities, etc.	Proposals with strong, clear plans for actively involving under-represented institutions, communities, and areas will be preferred over those that present vague plans or no plans at all.
Additional mechanisms, e.g., involvement of high schools, interns, etc.	Proposals that present strong, clear plans to further core NSF interests such as education, involvement of high schools, an active involvement of interns in the projects, etc., will be preferred over those that present vague plans or no plans at all.
Letters of Support	All letters of support as requested in this solicitation, potentially including letters from the relevant integration partners, academic campus Chief Information Officer (CIO) or equivalent, and contracts personnel.

5.2   Review and Selection Process

Proposals will be reviewed by external reviewers as indicated in section 6. After scientific, technical and programmatic review and consideration of appropriate factors, the reviewers will advise the GPO whether the proposal should be declined or recommended for Subcontract. The GENI Project Director will make the final determination and will submit a proposal for NSF review.

A summary rating and accompanying narrative will be completed and submitted by each GPO-assigned reviewer. In all cases, reviews are treated as confidential documents. The proposer will receive a notification of the decision to award or decline funding.

In cases of programmatic approval, the proposals recommended for funding will then be forwarded to the GENI Contracting Officer for review of business, financial, and policy implications and the processing and issuance of an agreement. (See Section 7.1)

6   Award Administration

6.1   Notification of the Subcontract

The GPO will notify the submitting organization of the selection for subcontract. The GPO will inform, as promptly as possible, organizations whose proposals are declined.

Proposers are cautioned that only the GENI Contracting Officer or the Senior Manager of Subcontracts may make commitments, obligations or awards on behalf of the GPO or authorize the expenditure of funds. No commitment on the part of the GPO should be inferred from technical or budgetary discussions with a GENI Project Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a subcontract signed by the GENI Contracting Officer or Senior Manager of Subcontracts does so at its own risk.

6.2   Estimated Timeline

The GPO currently expects to announce its selections by late summer 2013 and start subcontract negotiation soon after. For budget purposes, you should use November 1, 2013 as the project start date. This date is subject to adjustment during negotiations.

6.3   Reporting Requirements

For all Subcontracts, the Principal Investigator is expected to report current project status in person at every GENI Engineering Conference (GEC), which are held three times annually, and must submit periodic and final project reports to the GENI Project Officer. The projected schedule and locations for upcoming GECs are available via the GENI wiki site (http://groups.geni.net/geni). Periodic reports are due two weeks after each GEC. The final report is due within 30 days after expiration of a Subcontract.

Each periodic report and final report must also include copyright-free images and description of work performed (suitable for publication on the web at geni.net, in brochures, etc); proper credit will be given. Other forms of publication material are also encouraged.

Failure to provide the required periodic project reports may affect any future funding increments as well as any pending proposals for that PI. PIs should examine the formats of the required reports in advance to assure availability of required data.

The periodic reports will be submitted electronically via http://geni.net. Such reports provide information on activities and findings, project participants (individual and organizational) publications and other specific products and contributions. For the periodic reports, PIs will not be required to re-enter information previously provided. Submission of the report via http://geni.net constitutes certification by the PI that the contents of the report are accurate and complete. Report is not complete until the GENI Project Office has reviewed and accepted via electronic email notification. The GPO will notify the PI within 10 days of receiving the report submission confirmation with either "accept" or "additional information is requested".

6.4   Other Information

The geni.net website provides the most comprehensive source of information about the GENI initiatives. Consultation of this website by potential proposers is strongly encouraged.