Project Development Plan: Readiness Stage

GDD-06-33

GENI: Global Environment for Network Innovations

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Executive Summary

This document describes work that will be undertaken during the *MREFC Readiness Stage* to bring the GENI project to *Preliminary Design* completion. A companion Project Execution Plan describes the GENI project in much greater detail. This document assumes the reader is familiar with the Project Execution Plan.

During the Readiness Stage, the *GENI Planning Group* will focus its attention on six tasks: (1) producing a Preliminary Design for the GENI facility; (2) producing a detailed management plan, including organizational structure and management processes needed by the project; (3) developing a plan to transition responsibility for project management to a Consortium and Project Office that will oversee GENI during its construction; (4) broadening and further engaging the community that GENI will serve; (5) planning for use of GENI in education, and (6) prototyping key design concepts and technologies needed by the GENI facility.

Facility Design: The GENI facility, currently defined at a conceptual level, will be brought to Preliminary Design completion, including the full integration of its core elements: system architecture, backbone, connectivity to edge devices and subnets, network management, user services, and security. This work will be carried out by several *Working Groups*—each responsible for a particular component of the design—and will include documenting requirements and specifications for the construction of each facility component, a work breakdown structure for each component, strategies to mitigate risk, a detailed construction budget (including contingencies), and a sensitivity analysis.

Project Management: The project management plan will be brought to Preliminary Design. This will involve (1) developing a detailed process for a "bottom-up" budget, including risk management, work breakdown, and contingency budgeting; (2) defining the scope of the management office's legal responsibilities and incorporating these into the office's definition; (3) developing a scheduling and tracking process and selection of a *Project Management Control System* (PMCS) for GENI construction; (4) defining a formal *Change Control Management* process; (5) defining the role of business and industry in GENI; and (6) defining a Systems Engineering Office and its interactions with a Technical Advisory Board and its Working Groups. These tasks will be undertaken by the GENI Planning Group during the first half of the Readiness Stage, resulting in a detailed plan that will be implemented by a permanent GENI Project Office (GPO) in the second half of the Readiness Stage.

Consortium and Project Office: Early in the Readiness Stage, NSF will solicit bids for a Computing Community Consortium (CCC) and for a GENI Project Office (GPO). Both of these entities will be established and operational—including the appointment of an Executive Council and Technical Advisory Board, and the hiring of a Project Director and Project Manager—early in the second half of the Readiness Stage. The newly established GPO will then fully implement the management plans developed by the Planning Group.

Community Engagement: Community engagement was started in the Conceptual Design stage with several NSF-sponsored Workshops. This effort will continue in the Readiness Stage, with several additional workshops and "town hall" meetings already planned. The Planning Group

and its Working Groups will also be expanded to include additional communities, including representatives from industry, education, and international partners. These communities will contribute to the definition and design of GENI.

Education: One area of particular importance during the Readiness Stage will be to carefully plan for the use of GENI in education—in the classroom, for the general public, and for training of researchers who will use GENI for their work. The Planning Group will form a new working group for this purpose. This group is expected to be composed of senior educators and scientists with special interest and expertise in the use of facilities such as GENI to further education.

Prototyping: During the Readiness Stage, work will proceed to leverage existing testbeds (e.g., PlanetLab, ORBIT, DETER, Emulab, and others) to experimentally evaluate key concepts, technologies, and designs that may become a part of the overall GENI facility. The purpose of this activity is to reduce the overall risk in designing and deploying GENI by early evaluation of technologies and designs that are being considered. NSF will develop the processes for selecting promising designs and technologies to be further prototyped, in consultation with the GENI Planning Group.

1 Introduction

GENI is an ambitious project. Its goal is to provide a global facility that will revolutionize the research process in global communications networks, potentially leading to a Future Internet that is more secure and robust, easier to use and manage, and better able to support innovative technologies and applications. The reader is referred to the *Project Execution Plan* (PEP) for a detailed description of the entire project. This *Project Development Plan* (PDP) describes work to be undertaken in the *MREFC Readiness Stage* to bring GENI to the completion of *Preliminary Design*.

1.1 Scope of Work

During the *Conceptual Design Stage*, the GENI Planning Group—representing a cross-section of the Computer Science research community—worked for a year to develop the fundamental concepts of GENI. The group was informed by a series of NSF workshops that explored various research challenges faced by the community. The Planning Group identified the basic architecture of the facility, the types of network elements required by researchers, the means by which it could be shared among a large community of researchers, the means by which the network would be managed, and in broad terms, many of the project management issues that would need to be addressed in future planning periods.

In the *Readiness Stage*, these basic concepts will be re-examined and brought to the next level of definition. This effort, scheduled over the next 12 months, will be organized around six principle tasks:

- Producing a Preliminary Design for the GENI facility, including its overall architecture, engineering, principal platforms, network management, and distributed services. The Preliminary Design will also include a detailed work breakdown structure, bottom-up budget, risk analysis, and contingency plans.
- Producing a Preliminary Design for the management of the GENI project, including the further definition of the management team's organizational structure, a detailed plan for defining a work breakdown structure and bottom-up budget, comprehensive risk analysis and contingency plans, and selection of an appropriate project management control system.
- Supporting the establishment of a permanent Computing Community Consortium (CCC) and GENI Project Office (GPO) that will oversee GENI during its construction. Responsibility for GENI's definition and management plan will be transitioned to the CCC and GPO during the Readiness Stage.
- Broadening the community that GENI will serve, and further engaging this community in the definition of GENI. Including more people with security expertise in the planning process is of the highest priority.
- Planning for use of GENI in education, including the classroom, communicating the goals and value of GENI to the public, and training the user community.

- Prototyping key design concepts and technologies needed by the GENI facility, thereby reducing the risk of the less mature concepts.

1.2 Processes and Procedures

The Readiness Stage will consist of two distinct phases. The first phase will be carried out by the current Planning Group (and its Working Groups), augmented by full-time staff with additional management expertise. Additional technical experts will be added to the working groups, as needed. The second stage will begin with the establishment of a Computing Community Consortium (CCC), the appointment of a Project Director (PD) and Project Manager (PM), and the establishment of the GENI Project Office (GPO). The transition from the first to second phase is expected to occur at approximately the midpoint of the Readiness Stage (August 2006).

During the first phase of the Readiness Stage, the project will continue to be led by the Planning Group, with its Chair overseeing and directing the effort. The Working Groups convened during conceptual design stage will continue to work on the definition of the GENI facility, with the Planning Group conducting internal reviews to ensure that all design issues outlined in this document are being addressed. It is expected that additional working groups (and sub-groups) will be formed as needed to address emerging issues (e.g., education). The Planning Group also expects to make judicious use of external experts to address issues where the group does not have the requisite expertise, particularly in the definition of a comprehensive management plan. Overall, the Planning Group will work to ensure that a broad community contributes to the design of and planning for GENI.

In the second phase of the Readiness Stage, the Planning Group will support the transition of responsibility for the GENI project to a CCC and GPO. The CCC will provide community oversight for the project, including the establishment of an Executive Committee (EC) and Technical Advisory Board (TAB). The TAB will then subsume the Planning Group's role of reviewing and directing Working Group activity, and the GPO will take responsibility for implementing the management plan developed by the Planning Group. Finally, the Project Director and Project Manager, in consultation with the TAB and GPO, will compile and reconcile the work breakdown structures, schedules, risk analyses, and construction budgets across the set of Working Groups to produce a *Preliminary Design* for GENI.

1.3 Documentation and Reporting

Requirements, specifications, and management processes developed during the Readiness Stage will be documented and shared with the National Science Foundation, experts in the broad technical and management communities, and the broader research and education community. This includes a series of regular project reviews, reports to interested communities, workshops, and presentations at technical conferences. All requirement and specification documents that are appropriate for community review and comment will be published in a *GENI Design Documents* (GDD) series modeled after Request for Comments (RFC) series published for today's Internet.

In addition to publishing the GDD series, reporting to the NSF will include: (1) weekly conference calls for project updates, (2) written monthly progress reports; (3) face-to-face quarterly reviews; (4) monthly prototyping status reports; (5) timely sharing of information from Town Hall meetings, including how meeting results will be used to update facility design; and (6) collaboration with NSF's Cyber Security Working Group related to security designs for GENI.

During the final three months of the Readiness Stage, the individual documents and reports identified in this PDP will be compiled into a complete MREFC Readiness Stage Preliminary Design for GENI. The specific elements are identified in Section 3, and include (1) Facility Design Requirements and Specifications, (2) Management Requirements and Specifications, (3) Bottom-up Construction Budgets, (4) Work Breakdown Structures for Construction, and (5) assorted Management Plans.

1.4 Project Teams & Personnel

Readiness Stage tasks will be undertaken by a combination of project teams and personnel, which we now summarize:

- **Planning Group**: The set of researchers and management experts responsible for this PDP and the companion PEP. This group will oversee and direct further development of GENI during the first phase of the Readiness Stage, including external review of documents produced by the *Working Groups* and *Project Management Team*. The responsibilities of the Planning Group will transition to various entities within the Computing Community Consortium and GENI Project Office once they are established. The Planning Group Chair is responsible for coordinating the group's work.
- **Working Groups (WG)**: A set of focused groups responsible for various aspects of GENI's design. These groups report into the Planning Group today, but will report to the Technical Advisory Board (TAB) of the Consortium once it is formed. These groups will be augmented with professional staff that will assist the Working Groups in achieving their deliverables. Working Groups include:
    - **Research Coordination Working Group (RCWG)**
    - **Facility Architecture Working Group (FAWG)**
    - **Distributed Services Working Group (DSWG)**
    - **Backbone Network Working Group (BNWG)**
    - **Wireless Subnet Working Group (WSWG)**
    - **Education & Outreach Working Group (EOWG; to be established)**
- **Project Management Team (PMT):** A new team to be formed during the Readiness Stage to focus on developing a management plan for GENI. The PMT will consist of members of the current Planning Group, augmented by full-time staff with the necessary management expertise. The PMT will primarily define the requirements for project management during the first phase of the Readiness Stage, with the actual implementation left to the GPO during the second phase.

- **Computing Community Consortium (CCC):** A community consortium that will provide community oversight for the project, including the establishment of an Executive Committee (EC) and Technical Advisory Board (TAB). The EC will be responsible for appointing a Project Director (PD) and Project Manager (PM). We expected the CCC to be created near the midpoint of the Readiness Stage and subsume responsibility for GENI during the second phase of Readiness.
- **Technical Advisory Board (TAB):** Is responsible for the technical design of the GENI facility, with members appointed by the CCC's Executive Committee. Includes leaders of the various Working Groups. The TAB subsumes responsibility for GENI's design from the Planning Group near the midpoint of the Readiness Stage. The chair of the TAB serves as "Chief Architect" for the facility.
- **GENI Project Office (GPO):** Is responsible for the management of GENI during construction, and subsumes responsibility for implementing the management plan developed by the PMT near the midpoint of the Readiness Stage.
- **Project Director & Manager (PD/PM):** Appointed by the CCC, the Project Director and Project Manager direct the construction of GENI, assuming responsibility from the chairs of the Planning Group and PMT near the midpoint of the Readiness Stage. The PD and PM, in consultation with the TAB and GPO, will compile and reconcile the work breakdown structures, schedules, risk analyses, and construction budgets across the set of Working Groups to produce a *Preliminary Design* for GENI.

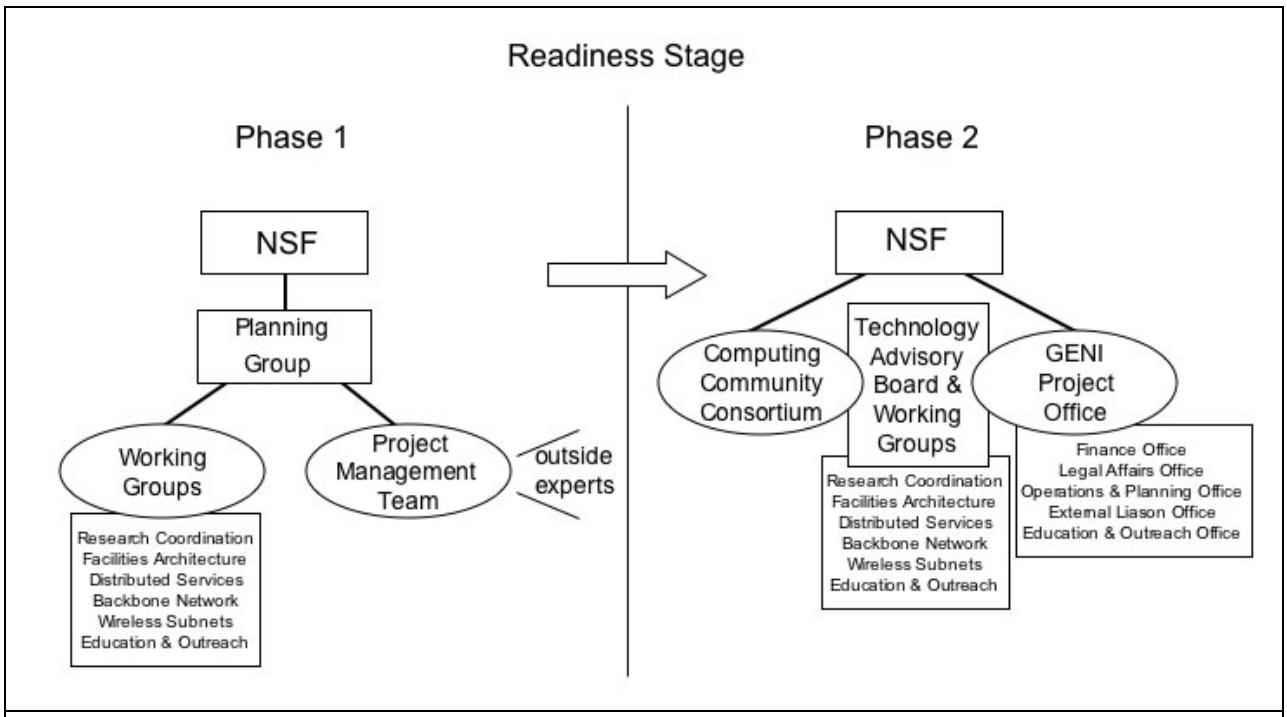

Figure 1.1 Team relationships and responsibilities during the Readiness Stage

Figure 1.1 portrays the transition in team relationships and responsibilities that will take place midway through the Readiness Stage. In phase 1, each WG includes one or more staff members

that are responsible for writing specifications, WBS, creating schedules, and interfacing with the PMT; in phase 2, these duties are subsumed by the PD and PM. The CCC and GPO in phase 2 are essentially peer organizations, with the TAB and WGs serving as links between them.

2 Execution of Readiness Stage Tasks

Several tasks make up the Readiness Stage work. Tasks relating to the technical design of the GENI facility will be assigned to one or more Working Groups (WG), with some groups still to be established during the Readiness Stage. The leader of each WG is responsible for its deliverables. During the first phase of the Readiness Stage, WG leaders will serve on the Planning Group. The Chair of the Planning Group will be responsible for directing progress on the development plan, and the Planning Group as a whole will internally review all designs, requirements, and specifications produced by the individual Working Groups to ensure that they are consistent and sufficiently detailed. During the second phase of the Readiness Stage—once the CCC, TAB, and EC have been established and a PD appointed—the Working Groups will report into the TAB, which will then internally review all documents.

Tasks relating to a management plan for GENI will be carried out by a *Project Management Team* (PMT) during the first phase of Readiness, and transitioned to the GPO once it is established. The PMT will consist of members of the current Planning Group, augmented by full-time staff with the necessary management expertise. The PMT will primarily define the requirements for project management, with the actual implementation left to the GPO during the second phase of the Readiness Stage.

The tasks are described in more detail in the following sections. Table 2.1 summarizes how tasks are associated with Working Groups, the Project Management Team, and the National Science Foundation. All of these tasks culminate in the Preliminary Design for GENI. A precise statement of the deliverables described in this section is presented in Section 3.2, and a corresponding timeline is given in Section 3.3.

Task	**Readiness Stage Sub-Tasks**	**Responsible Groups**
1	Research Requirements & Rationale Architecture Distributed Services Backbone Network Wireless Subnets	Research Coordination WG Facilities Architecture WG Distributed Services WG Backbone Network WG Wireless Subnets WG
2	Organizational Structure GENI Project Office Definition Management Processes & Procedures Transition to Operations Plan GENI Project Office Transition	Project Management Team
3	Computing Community Consortium GENI Project Office	National Science Foundation

4	Broad Community Engagement	Research Coordination WG
5	GENI for Education	Education & Outreach WG
6	Prototyping GENI Design Concepts	National Science Foundation & Selected Project Teams

Table 2.1 Working Groups associated with Readiness Stage Tasks

2.1 Facility Design

The GENI facility includes: (1) a backbone network and all of its network elements (e.g., programmable routers and dynamic optical switches), as well as connections to edge devices, the legacy Internet, and wireless subnets; (2) management software that provides an overall control structure for GENI; (3) a diverse collection of wireless subnets that connect to the GENI backbone; and (4) distributed services that facilitate the use of GENI for research and education. In addition to these components, there is an overall facility architecture that defines how the individual components connect to form a coherent whole.

During the conceptual design stage, the Planning Group developed the basic concepts for GENI, including its future use, what features and functions it had to have in order to be useful to the research community, and what fundamental technologies would be required for it to work.

In the Readiness Stage, the Planning Group—through the efforts of several Working Groups—will complete the Preliminary Design of the facility, including the development of specifications for all of the hardware and software components (including those that might be added during the Readiness Stage in order to fulfill facility use requirements). This information will be documented in a set of GDDs. The Working Groups will also provide detailed work breakdowns, budgeting information (including sensitivity analysis), risk analysis, and contingency plans for inclusion in project's overall management plan (see Section 2.2). Developing a sound risk management plan for the software development process will be a major focus of this effort.

2.1.1 Research Requirements & Rationale

The principal capabilities of the GENI facility were identified during the Conceptual Design stage by the GENI Planning Group, based on a synthesis of requirements that came out of a series of NSF-sponsored workshops. While this group tried to ensure that the architecture met the needs of the entire research community, one of the critical tasks during the Readiness Stage will be to further refine the requirements and corresponding facility capabilities based on community feedback. The *Research Coordination WG* will be primarily responsible for these tasks, where a precise list of deliverables corresponding to the following narrative is given in Section 3.2.3.

A series of town hall meetings, plus a community web page and mailing list have been established to provide a forum for collecting community feedback. These forums are important not only to ensure that a larger community has an opportunity to influence and contribute to GENI's design, but also to gain a better understanding of the projected needs of research on the GENI facility. A key role of the Research Coordination WG is to synthesize the community's feedback into a concrete set of required capabilities. The individual working groups will use the resulting set of requirements to refine the definition of the facility, as enumerated in following sections.

One specific requirement that we call out for attention is that of *instrumentation*. From the beginning of the project, it has been an architectural principle that a measurement capability be an integral part of the GENI design. *During the Readiness Stage, we will need to determine which measurements are most important to include in GENI, what physical components should incorporate this capability, and how will experimenters (or network operators) access and control the measurement sensors? We will also need to define a process for aggregating, archiving, and analyzing data that is collected.* Aspects of this problem fall across all of the working groups, although the Research Coordination WG has oversight responsibility to ensure that the right data is being collected and archived.

Finally, a critical aspect of defining the research community's requirements is to further refine the scientific rationale for GENI. This will involve identifying representative experiments that researchers want to run on GENI, articulating the broader research questions that the community hopes to address, and explaining how a large-scale experimental facility like GENI has the potential to qualitatively change the research modality of the networking systems community.

2.1.2 Facility Architecture

GENI is defined by a diverse and extensible collection of physical network resources, collectively called the *physical substrate*. A core set of software, called the *GENI Management Core* (GMC) knits these components together to form a coherent experimental facility. The GMC adheres to a well-defined *architecture* that specifies how physical components, user-level services, system-wide security, and a federation of similar facilities owned by organizations fit together.

To construct GENI, it will be necessary to *completely specify this architecture*, which corresponds to sets of principals, abstractions, software modules, and object interfaces. These specifications will be fully documented in a set of GDDs. The following summarizes the key requirements and specifications that must be completed during the Readiness Stage. In addition to these specifications, it will also be necessary to define a work breakdown structure, prepare a bottom-up budget (including sensitivity and contingency analysis), and complete a risk management plan for the software management framework that embodies this architecture. The *Facility Architecture Working Group* will be primarily responsible for these tasks, where a precise list of deliverables corresponding to the following narrative is given in Section 3.2.4.

Management Core: The GENI Management Core (GMC) defines name spaces for users, slices, and physical components. It is, in many respects, at the heart of the GENI architecture. The

interfaces by which the GMC interacts with individual components are therefore critical to the ability of the operations team to manage GENI, as well as the ability of researchers to create slices that span all of GENI's physical substrate. *During the Readiness Stage, the Facility Architecture WG is primarily responsible for defining these interfaces, and ensuring that they are sufficiently general to accommodate a wide range of component devices.*

Virtualization: Virtualization is a technique that allows a resource to be *sliced* into many parts, each one of which can then be assigned to a single (or group of) researcher(s) to use. *During the Readiness Stage, several issues regarding virtualization will be resolved: How deep does virtualization need to penetrate into the components, and what capabilities are lost if devices are virtualized at too high of a level? What are the implications for complexity, cost, performance, and interoperability of alternative levels of virtualization?* We plan to evaluate these and similar questions during the Readiness Stage to reach a preliminary architecture design. Answers to these and related questions will impact the complexity of the design, its cost, and the overall performance anticipated from the facility. This question will be addressed for each physical component by the working group responsible for that component, with the Facility Architecture WG responsible for the overall design.

Extensibility & Modularity: Extensibility is a feature of GENI that allows it to easily accommodate changes in technology as they emerge, before, during and after construction. This feature is very closely tied to the modularity of the architecture. The central question to be addressed is: *What modularization and interfaces make it possible for one component to be substituted for another as new technologies emerge?* This issue is at the heart of the architectural specification produced by the Facility Architecture WG.

Programmability: Programmability of network elements is an important architectural capability of GENI. Components must expose capabilities that researchers can program (control) in an experiment-specific way. Most commercial network elements are not yet fully programmable, or do not provide open interfaces, although there is a trend in this direction. *The question is, what level of programmability should a network element provide, and in what ways is the answer different for each component of the system.* Questions such as these will be reviewed and answered during the Readiness Stage in collaboration with Backbone and Wireless WGs responsible for defining the technology of the various network elements, with the Facility Architecture WG responsible for the overall design.

Controlled Interconnectivity: The concept of "controlled interconnectivity" has two parts: one refers to the ability of a researcher to determine the network topology and the selection of nodes that his or her experiment will span; the other refers to the interconnection between "slices" that run different network architectures or services. *The questions to be addressed during Readiness will focus on the degree of interconnectivity and to what extent connectivity should be in the hands of the user versus under some sort of centralized control.* All of the working groups must address these questions relative to their respective components, with the Facility Architecture WG responsible for the overall design.

Federation: GENI will support federation, meaning that it will be possible to "plug" other communities (and their resources) into a common, shared infrastructure. This feature helps to sustain GENI over time as new research communities "opt-in" to GENI and bring with them

new resources, and as international partners want to contribute resources to a world-wide effort. *The question that needs to be addressed in the Readiness Stage deals with the details of federation, including both mechanisms (i.e., interfaces) and policies (i.e., establishing peering agreements among partners).* The Facility Architecture WG group has overall responsibility for federation.

Security: The security of the GENI facility must be assured as part of the GENI Facility Design. This requires addressing a set of issues, starting from first principles. *What should GENI components and central management provide as building blocks for security? What is the GENI security architecture, and how far can we move this from current user practices?* The Facility Architecture WG, in collaboration with the Distributed Services WG will consider these questions. In addition, the National Science Foundation is well aware of its facilities being hacked (and the consequences thereof). The GENI working groups will work with the NSF security team during the Readiness Stage to ensure that the recommendations of this group are carefully considered in a secure design. Additional security experts will be added to the Working Groups to help specify security for the facility.

2.1.3 Distributed Services

GENI is expected to be used by a broad spectrum of researchers, educators, and students, many of whom will have had little experience using large shared network facilities for their work. It will be important, therefore, to make GENI as user-friendly as possible, so that new work is not stymied by the complexities of accessing the facility. To this end, developing a set of distributed (user) services is a critical part of GENI's design. In the Readiness Stage, the task is to completely describe—in terms of requirements and specifications—how these services provide value to the user (researcher, educator, student) communities. The task also includes defining a work breakdown structure, preparing a bottom-up budget (including sensitivity and contingency analysis), and completing a risk management plan for the set of distributed services. The *Distributed Services Working Group* will be charged to carry out this work. A precise list of deliverables corresponding to the following narrative is given in Section 3.2.5.

In GENI, distributed services serve two key roles. First, they include a set of *infrastructure service**s*** that researchers use as a portal to create and access slices of the GENI substrate, and network operators use to monitor, configure and diagnose the system. Second, they include a set of *underlay services* that serve as building blocks for researchers as they design and implement their experimental network architectures, allowing them to focus on new functionality rather than having to recreate a network architecture, service or application from scratch.

The key steps to more fully defining these services during the Readiness Stage include: (1) identifying the essential facilities that the GENI Management Core (GMC) must provide to enable the distributed services; (2) fully specifying the baseline set of distributed services to be constructed for the GENI facility; and (3) defining a timeline over which the distributed services will make new capabilities available. We also envision that the set of services will eventually be contracted to multiple teams (e.g., one per service area), and thus we will carefully define the specific requirements of each and the inter-relationship between each of those service areas. To the maximal extent possible, we will expect each development team to leverage the efforts of other development teams.

To date, we have identified eight broad focus areas for distributed services. Each of these will be considered in detail during the Readiness Stage and (assuming each survives this scrutiny) specifications will be written for its implementation, including cost, and related items as described above.

Provisioning Service: Used by researchers and students to create, initialize and manage a slice on a set of GENI resources;

Information Plane: Used by researchers and the GENI operations team to monitor the health of nodes and the slices running on them;

Resource Broker: Used by researchers and students to acquire and schedule GENI resources, and by the GENI governing board to set resource policy;

Development Tools: Used by researchers and students to develop and debug their experiments;

Security Service: Provides a set of security mechanisms to provide strong authentication and authorization;

Topology Service: Provides information about which neighbors exist in the network and the properties of the links that connect them;

File and Naming Service: Implements a core set of distributed storage and rendezvous services to enable experiments to load code onto the system and log output to a persistent "virtual disk"; and

Legacy Internet Service: Implements the data and control plane of today's Internet in a slice on top of the GENI substrate to allow GENI to bootstrap itself.

By the end of the Readiness Stage, we will compose a final list of focus areas, and for each focus area, a list of requirements, a design meeting those requirements, high-level interfaces between focus areas and the GENI Management Core, a Work Breakdown Structure and schedule, a construction budget (including a sensitivity analysis), and a risk analysis along with contingency plans. All these elements will address the dependencies between deliverables of individual implementation teams to be tasked with each focus area.

2.1.4 Backbone Network

The GENI backbone consists of a nation-wide fiber plant, a collection of customizable routers and dynamically controllable switches, peering connectivity to the commodity Internet, and tail circuits to edge sites around the world. During the Readiness Stage, the task is to bring the elements of the GENI backbone to Preliminary Design completion. The focus will be to create a complete set of design *requirements* and *specifications* for construction of the backbone, including its connections to edge devices, subnets (wired and wireless), and the legacy Internet. In addition to these specifications, it will also be necessary to define a work breakdown structure, prepare a bottom-up budget (including sensitivity and contingency analysis), and complete a

risk management plan related to backbone construction. The *Backbone Network WG* will be primarily responsible for these tasks, where a precise list of deliverables corresponding to the following narrative is given in Section 3.2.6.

To accomplish the Readiness Stage work, the Backbone Working Group has identified several issues that it will resolve, as discussed below. Completion of each of these work items is important to the development of requirements for the backbone, and for preparation of specifications that could be used to construct the backbone (e.g., by an external contractor).

Network Elements: During the Conceptual Design Stage, three main types of backbone equipment were identified for use in the GENI backbone: (1) high-speed programmable routers that can support multiple simultaneous experiments with new network architectures, (2) cross-connects to allow experiments to establish circuits with dedicated bandwidth between GENI nodes, and (3) reconfigurable optical add-drop multiplexers and dynamic optical switches to allow multiple experiments to share control of optical components. Each of these elements is expected to require performance at a level that is not expected to be available commercially and, therefore, will be designed and constructed as part of the overall backbone work. During the Readiness Stage, each of these network elements will be considered in detail, both in terms of the requirements for their individual performance and features, and in terms of their inter-working with other elements in the network. Thus, the WG will be required to develop specifications for the individual network elements and for the interfaces between / among them.

To accomplish this, the working group will assess the capabilities of existing commercial equipment and industry trends to determine which components might serve as hardware building blocks. For example, the group will investigate the availability and features of components (such as network processors and field-programmable gate arrays) that are compliant with the ATCA standard for telecommunications equipment. The group will study existing cross-connect equipment, and the associated element management systems, to determine the extra features necessary to provide each experiment with the abstraction of a virtual cross-connect for creating end-to-end circuits between sites. The group will also explore the unique capabilities needed from the optical components to make efficient use of the wide-area bandwidth and enable researchers to experiment with dynamic control over optical components. *During the Readiness Phase, the working group will assess the availability, functionality, and cost of these three classes of network elements to specify the hardware components needed in the more-advanced, customized GENI nodes.* The benefit of this work will be to identify those components, or classes of components, that will be available and suitable for the design of construction of the GENI custom network elements. Such conclusions will be incorporated in the specifications for the design of GENI network elements.

Timeline for Technology Insertion: Researchers will begin using GENI for experiments as the facility is being constructed and deployed. This is a unique feature of GENI. As such, GENI will start with a simplified node architecture, such as software routers built out of conventional computing platforms, and evolve toward a sophisticated design with hardware routers, cross-connects, and optical components. In addition, the GENI software running in the nodes will evolve over time to provide a finer granularity of control over the underlying equipment. During the Conceptual Design stage, we outlined a high-level timeline for adding new

hardware and software components to the node, motivated by the cost and availability of commercial hardware and the functionality required by the majority of potential research experiments. *During the Readiness Phase, the Backbone WG will construct a detailed timeline for technology insertion, based on component availability, cost and the complexity of the new functionality.* The results of this work will be important to the management of the GENI facility during construction, where both construction and operations will be taking place simultaneously (see Section 2.2.4).

Trade-offs between Flexibility and Complexity: To support a wide range of research experiments, GENI needs to provide researchers with programmable control over the operation of the underlying equipment and sub-divide physical resources (e.g., CPU, disk, bandwidth, and circuits) at a fine level of granularity. However, there is an inherent tension between the desire for such flexibility and the potential complexity of the underlying hardware and software in the infrastructure. *During the Readiness Phase, the Backbone WG will evaluate these trade-offs by means of a sensitivity analysis to help make an informed decision about how to strike the right balance, and how to increase the sophistication of the GENI node over time.*

Connecting Edge Sites and the Legacy Internet: A key feature of the GENI infrastructure is the ability to carry real user traffic and provide novel services to end-users. It will be important to evaluate a variety of options for high-bandwidth connectivity to end users and the legacy Internet. For example, direct tail circuits could provide high-bandwidth connections to the sites where flexible edge devices and wireless subnets are located. Existing regional exchange points and education-and-research backbone networks may provide a way to contain the costs of reaching these end-user sites. Connections to legacy Internet Service Providers, at major co-location sites and public exchange points, can provide a way to reach the legacy Internet and GENI-like facilities in other countries. *During the Readiness Phase, the Backbone WG will produce accurate cost estimates for the various options and explore ways to reduce the cost by exploiting existing network infrastructures and carefully identifying possible locations for GENI backbone nodes.*

2.1.5 Wireless Subnets

Wireless devices and networks are a critical part of any future global network. During the conceptual stage of planning for GENI a series of community workshops produced reports outlining the network architecture challenges related to wireless, mobile and sensor scenarios, and proposed a set of specific wireless subnet implementations for GENI. The workshops recommended the construction of five types of wireless subnets: (1) large-scale wireless emulators; (2) “Open API” urban deployment using short-range radios (such as 802.11x); (3) “Open API” suburban wide-area deployment using long-range radios (such as WiMax or 3G); (4) cognitive radio demonstrator networks for suburban wide-area scenarios; and (5) sensor networks for dense urban and vehicular scenarios. High-level wireless subnet architectures and hardware platforms were specified for each case. Critical path technology components for each of these projects were listed and, in many cases, existing NSF-supported results to mitigate technical risk and improve readiness were identified.

During the Readiness Stage, the main task is to identify the *requirements* for all subnet components and their connections, both within the subnet and to the GENI backbone, and to prepare *design specifications* for each of these components and their interfaces. It will also be

necessary to define a work breakdown structure, prepare a bottom-up budget (including sensitivity and contingency analysis), and complete a risk management plan for each major wireless subnet component. The *Wireless Subnet Working Group* will be charged to carry out this work. A precise list of deliverables corresponding to the following narrative is given in Section 3.2.7.

There are three overriding questions to be addressed to bring the wireless components of GENI to Preliminary Design. They include:

Platform Evaluation: This task involves aggregation of applicable experimental platform results from the wireless research community and conducting small incremental projects to extend features (such as soft MAC or virtualization) and validate feasibility for GENI. Incremental short-term projects for development of critical platform technologies and open interface radios may be proposed to NSF during the course of this task. *During the Readiness Stage, the Wireless WG will specify the wireless platforms and radio techniques to be deployed in GENI.*

Virtualization Evaluation: All wireless components planned for GENI are fully programmable, with capabilities for remote code downloading, reboot and remote monitoring and measurement. This makes it feasible to extend GENI's uniform *slice abstraction* (and management framework) across the wireless components of GENI. *The open question to be addressed by the Wireless WG during the Readiness Stage is how to implement slicing on different technologies.* Specifically, virtualizing the underlying hardware is one way to "slice" a resource, but other techniques—e.g., spatial sharing—can also be used to multiplex resources among multiple experiments. By choosing slicing strategies appropriate to experimenter requirements and technology capabilities, GENI will be able to integrate and unify an extremely heterogeneous physical resource base.

The current consensus is that virtualization suitable for certain long-term service experiments is indeed possible, but virtualization can interfere with the accuracy of protocol experiments that involve short-term performance. For these cases, alternative slicing techniques will be required. For example, since wireless deployments will have numerous radio nodes and sensors, it is feasible to use spatial sharing, in which physically disjoint nodes are used to connect to different long-running slices in the wired network. Also, for radios with a reasonable number of orthogonal channels in the band (for example, 802.11a in the 5 Ghz band), frequency domain slicing with multiple radio platforms is also an option.

Integration: An aspect for wired-wireless integration in GENI is the unification of the control protocols used to manage slices in a way that provides support for various radio specific requirements and multiple slicing techniques. *During the Readiness Stage, collaboration between the wired and wireless network communities will be needed to ensure a broad enough definition for the GENI Management Core, and to define the management protocols needed to unify all of GENI under the common slice abstraction.*

2.2 Management Plan

The management structure for GENI was developed during the Conceptual Design stage. The reader is referred to the PEP for a detailed discussion of GENI management.

In way of an overview, the management structure of GENI consists of the following elements. A Computing Community Consortium (CCC) provides broad community representation, and establishes an Executive Committee (EC) to provide oversight for the project. The EC appoints the Project Director and Project Manager, and establishes a Technical Advisory Board (TAB), the latter of which provides technical leadership for the project and has overall responsibility for the facility's design. A GENI Project Office (GPO)[1] oversees the construction of the facility, managing the sub-contractors, defining milestones, and ensuring that work is completed on schedule.

This section focuses on the GPO-related work items that must be completed during the Readiness Stage. These include developing the *requirements* for each function of the management organization and preparing *specifications* for these functions; developing a detailed *bottom-up budget* for the management functions that define the GPO; developing a *work breakdown structure* (WBS) for the management structure; developing an *implementation plan* for the GPO functions; carrying out a *sensitivity analysis* that explores alternative methods for implementing management functions; creating a *risk analysis* for the GENI project, and developing a *contingency plan* for the project budgeting process. As a permanent GPO does not yet exist, we will proceed through the Readiness Stage in two phases. In the first phase, we will assemble a *Project Management Team* (PMT) to develop *requirements* for each element of the management plan and to prepare *written specifications* for these elements. This PMT will complement the Working Group efforts outlined in Section 2.1. The PMT will consist of members of the current Planning Group, augmented by full-time staff with the necessary management expertise. In parallel with this effort, NSF will solicit bids to establish a permanent CCC and GPO, with both expected to come "on-line" at the midpoint of the Readiness Stage (approximately August 2006). At that time, responsibility for the management plan will transition from the PMT to the GPO. It is expected that the GPO will then implement the project management functions specified during the first phase.

This section focuses on the management-related tasks to be undertaken by the PMT/GPO during the Readiness Stage. Section 2.3 discusses the process of establishing the CCC and GPO.

2.2.1 Organizational Structure

The first major task is to more thoroughly define the organizational structure of GENI's management. This involves identifying the essential roles and defining the relationships among them. They include:

Computing Community Consortium: Planning for specification of a CCC will be undertaken starting soon after the Readiness Stage commences. There will be four focal points: (1) understanding of the role and responsibilities of the CCC; (2) developing of high-level job descriptions for future CCC members and committees; (3) defining the responsibilities of other components of the GENI management structure, including the Project Director, the Project

[1] We use the term GENI Project Office (GPO) in this document in place of Project Management Office (PMO) used in the Project Execution Plan.

Manager, and the Chief Architect; and (4) sorting out the details of setting up a 501(c)(3) corporation.

Executive Committee: At the same time that CCC planning is taking place, consideration will be given to the role and composition of the Executive Committee (EC). The EC should represent a broad spectrum of the computer science research areas, but also needs industry and government participation to guide certain management aspects of the project. *Work on this task will describe the roles and responsibilities of the EC in relationship to other organizational elements, and broadly outline the qualifications expected of future EC members.*

Technical Advisory Board: The role of the Technical Advisory Board (TAB) is central to how GENI is managed. The TAB is considered to be the technical heart of the project, with members of the TAB being the leaders of Working Groups assembled to address technical, educational and management issues related to GENI's design and operation. The chair of the TAB is also expected to play the role of *Chief Architect* for the project. *Planning during the Readiness Stage will evaluate the TAB composition; delineate the roles of the Working Groups as they relate to other GENI management areas (e.g., Systems Engineering in the GPO); define the responsibilities of the Chief Architect; and define the TAB's role related to direction of construction efforts.*

A precise list of deliverables corresponding to this narrative is given in Section 3.2.8.

2.2.2 GENI Project Office

The GENI Project Office (GPO) is a key part of the GENI management organization. This office has the full responsibility for delivering the GENI facility. During the Conceptual Design Stage, the GPO was defined at a high level; further detail is required in the Readiness Stage to bring the office to Preliminary Design completion, and to provide planning at the level of detail necessary to advise GPO implementation during the second half of the Readiness Stage.

The design of the GPO during the Conceptual Design phase is shown in Figure 2.2. The reader is also referred to Figure 1.1, which shows the relationship of the GPO to other components of the GENI management organization, and to the detailed description of the GPO in the Project Execution Plan.

Whatever its final organization, it is clear that the GPO must be able to offer several specific services, as shown in Figure 2.2. During the Readiness Stage, these services will be evaluated in detail with respect to the role that they play in GENI. This will lead to a set of requirements for each projected office of the GPO, which in turn will be developed into specifications for each office and incorporated into the *Management Requirements and Specifications* (MRS) Document, together with a budget and the other components of the document described above.

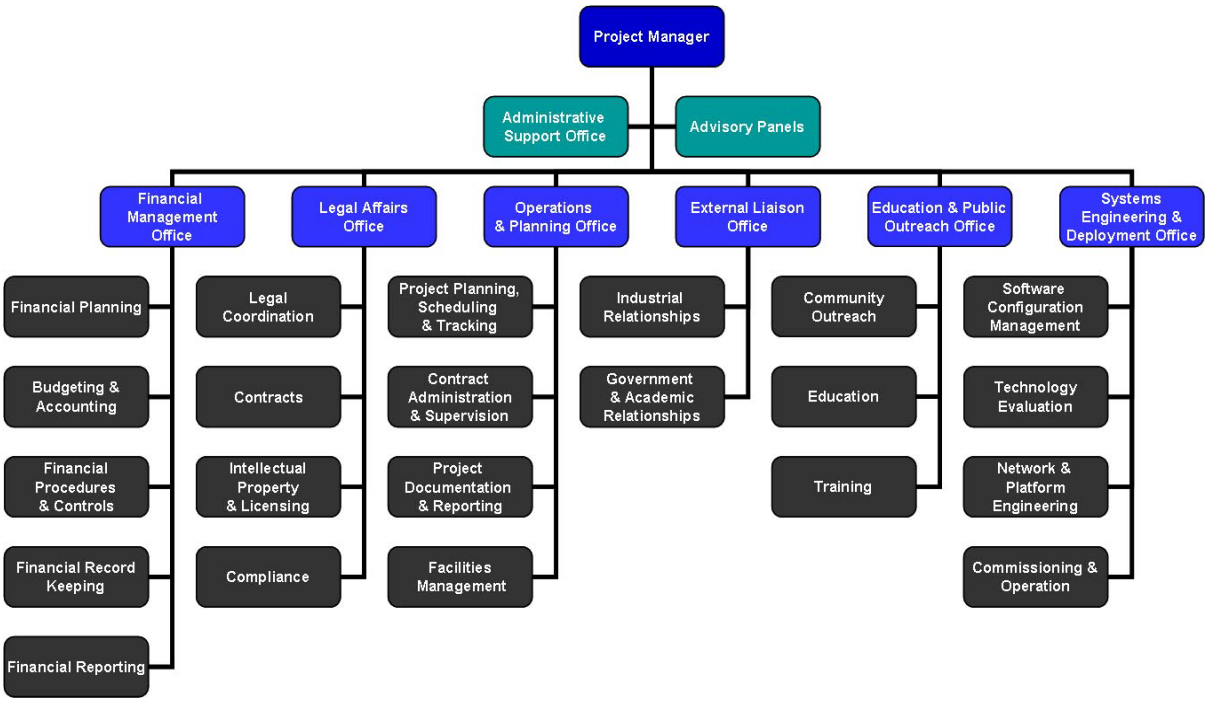

Figure 2.2 Framework and functional organization of the GPO as developed during the Conceptual Design Stage

In order to complete the MRS Document, the PMT will focus its attention of several topics of importance during the Readiness Stage. These tasks, which are principal functions in several of the GPO offices, are discussed in the following pages.

Budgeting and Contingency: During the Conceptual Design period, the Planning Group estimated the cost to build GENI. This estimate incorporated budgetary quotes for hardware and bandwidth components, but was based primarily on the prior experience of the various software and hardware components. These estimates were conservative, because experience dictates that software costs are often under-stated, but they did not include precise contingency calculations. The next stage of planning will develop, with the aid of experts who have significant prior experience costing large software-heavy projects, a process that will yield a more precise bottom-up budget for construction with calculable contingency costs based on the costs of alternative designs. Note that while the budget and contingencies will be calculated in a bottom-up fashion using information collected from the individual working groups, we expect the contingency budget will be consolidated and assigned to a centrally managed account (as opposed to distributed across the component-specific budgets).

This process will be developed very early in the Readiness Stage in order to provide working groups with the tools, forms, and instructions required to collect detailed budget information early in their design work. This will include the development of a process for contingency

budgeting. During the Readiness Stage, the bottom-up contingency calculation process will be linked to the Work Breakdown Schedule and incorporate each element of it. For example, the calculation of a contingency budget could be based upon changes in particular components of the WBS that are associated with specific strategies for components to be used in the facility design. This would lead to an alternative approach to a facility design that could cost more (or less) than the initial design (with corresponding changes in facility functions or features).

Work related to the deeper definition of the construction stage budget must also include *sensitivity analysis* of the budget. This involves dealing with the question of "what if the award is smaller than the predicted budget for GENI construction". Work in this area will be carried out in conjunction with the budget development so that the implications of a budget cut can be accurately assessed: Could the facility still be built? What would be left out of the facility? What would be the implications for the intended research? This sensitivity analysis extends beyond the initial funding cycle and will become a component of the design effort for each Working Group. For example, the hardware design efforts of the Backbone WG must carry out a sensitivity analysis to determine what the impact would be if a particular component were not to be developed on time, or were incompatible with the rest of a design. Would the design fail entirely, or might there be a delay, or could another component be substituted? Analyses such as these must be performed for each of GENI's major systems.

Scoping Legal Requirements: The Planning Group understands that GENI will have significant legal responsibilities: to contractors, to users, to its sponsors, and to others. These could include issues associated with conflicts of interest, protection of intellectual property, liability related to operation of the facility, environmental hazards, and much more. A Legal Affairs Office was identified during the Conceptual Design phase to address such issues. *During the Readiness Stage, the PMT will determine the scope of this responsibility and incorporate this as a requirement and specification in the MRS Document.*

Project Management Control System: GENI is a very large project that will involve more than two-dozen contractors at any given time, plus multiple Working Groups, and a multitude of reporting responsibilities. It is essential that an effective scheduling and tracking process be defined and an appropriate *Project Management Control System* (PMCS*)* put in place. The PMCS tool will be linked to the WBS and budget databases. It will show dependencies among tasks and implications of task slippage on construction schedule, personnel resources, facility deployment, and budget. It will permit reporting of financial status using the Earned Value Methodology. *In the Readiness Period, the PMT will identify and assess the tools and processes necessary to carry out these functions. This effort will include identification of the process by which Software Configuration Management will be implemented. The PMCS will be specified as part of completing the Preliminary Design stage for the GPO.* It is anticipated that the PMCS will become a part of the responsibility of the Operations & Planning Office of the GPO.

Risk Management: Risk management is an integral part of any large project. The management of risk is not a single task, but a process that must permeate the entire management structure, so that it includes the people involved in the project, the reputation of the project for the products and services it provides, the property owned or managed by the project, and the financial status of the project. In the Project Execution Plan, we highlighted some of the measures we would be

implementing during the construction of GENI to mitigate risk related to large-scale software development, and to the deployment of significant hardware systems. These included: starting with a well-crafted system architecture, building only what we know how to build, building in stages so that we can evaluate what we've already build before continuing, and leveraging existing software (and hardware) systems.

During the Readiness Stage, we will carry out a detailed analysis of the areas of risk, and evaluate tools that will assist in that analysis. We will primarily focus on risks involved in the engineering aspects of the project (e.g., those related to software and hardware development), but will also focus on areas involving finance, accounting, scheduling, liability and reputation, protection of property, and implications of significant changes in income (from grants, investors, etc.). We will establish processes and develop a plan that will become an integral part of the project management to mitigate risks in these areas and document these processes for review by the NSF. We will explore a variety of methods for reducing risk, including: (1) avoidance of some risks altogether, (2) modification of plans in some areas (both management and design) to reduce risk, and (3) risk sharing possibilities (e.g., through purchase of insurance, or developing collaborations where risk can be distributed). The risk assessment process will be carried out by a committee that includes members of the PMT as well as "outsiders" who have prior experience in the development of risk management processes and the management of risk in organizations similar to GENI. Project-wide risk management will also leverage risk analysis performed by individual Working Groups as they consider individual facility components.

Change Control: Because of the significant size of the software effort in this project, and because GENI will be used—even during its construction—for research, changes in construction and design plans are anticipated. Because such changes can have significant impacts on budget, schedule, or design, it is critical that the GPO have a well-defined Change Control Management process in place. An issue to consider other than the details of the process itself is where to position this function within the management organization. *The PMT will develop the change management process and specify how it will be incorporated in the overall management organization during Readiness Stage planning.*

Industry Participation: It is important that a broad community be made aware of GENI and the opportunities it has to offer. The Research Coordination Working Group was formed specifically to address this issue for the research community (see Section 2.4). The community impacted by GENI, however, is larger than the research community. An additional *informal* WG was formed during Conceptual Design planning to address the needs of other communities, particularly business and industry. *Work during the Readiness Stage will continue this effort, with a focus on questions such as: (1) how will industry participate in research using the GENI facility, (2) what policies related to the use of donated vendor products or services does GENI need, and (3) how will issues involving intellectual property, technology licenses, NDAs, and trade secrets be handled. This work will become part of the MRS Document.*

Systems Engineering Office: During Conceptual Design, the Planning Group recognized the need for a Systems Engineering Office within the GPO. Because the Working Groups under the TAB also play an important role in systems design, *Readiness Stage planning must address the issue of the relative roles of the SEO and the Working Groups of the TAB to ensure that the final design*

product for the GENI facility is very well integrated. The SEO and its responsibilities will be specified in the MRS Document.

A precise list of deliverables corresponding to this narrative is given in Section 3.2.9.

2.2.3 Management Processes and Procedures

In the Project Execution Plan, Figure 7.3 shows a schematic representation of the workflow and decision centers within the overall GENI management organization; the accompanying text describes the responsibilities and interactions of the parts of the organization. *During the Readiness Stage, the PMT, together with expert consultants from industry, government, and academia, will evaluate this workflow in greater depth than was possible during the Conceptual Design period.* This effort will focus on the following tasks:

- A review of each Working Group and GPO Office's responsibilities, with changes made as appropriate;
- A detailed analysis of the interactions among selected groups, such as the communications required between the Systems Engineering Office and the Working Groups. Particular attention will need to be paid to specifications and documentation, lines of authority, and responsibilities for signaling the need for changes in design, schedule, or processes;
- Formats for requirements and specifications documents and identification of the classes of such documents needed for good project management; and
- Formats and schedules for delivery of reports to the National Science Foundation

The output of this effort will be a draft guide to the workflow processes in the GENI organization. The document will not be a full specification in its initial form, since such workflow procedures change over time with use and experience. The document will establish a baseline for future policy definition by identifying specific areas for future policy development.

A precise list of deliverables corresponding to this narrative is given in Section 3.2.10.

2.2.4 Transitions to Operations and Commissioning

For the GENI project, transition from construction to operations will be a two-part process. The first part occurs during the construction itself, when the GENI facility will be used for research even as construction is taking place. The second part will occur at the end of construction when GENI is fully commissioned and transitioned to full-time operations. During the Readiness Stage, planning will take place for each of these transition stages. Requirements will be prepared for each and specified in the MRS document.

During Construction: The GENI facility will be used for research during the construction stage. This is one of the unique features of this project. In most cases, it is necessary to fully complete construction before a facility can be used; this is not the case for a facility that will evolve continuously throughout the construction stage as a result of the research that takes place on it. The point is to make the facility "available" for use as features and functionality are added to it,

then to use the results of the ensuing research to drive the development of new features and functionality. Although this is not the "final commissioning" process, these are steps along the way to ensure that the final commission is for a facility that is optimized for the communities that will use it.

This process raises several issues, such as: (1) how will the project (practically speaking) support simultaneous research and construction, (2) will the project need an operations team defined before construction is completed (we believe the answer is yes), and (3) how would such an operations team interact with the construction team? These, and similar issues, are all important. *We expect to complete a requirements document during Readiness and then to prepare a specification document that could be used in open bidding to establish such an operations team.*

Full-Time Operations: The transition to operations after construction is described at a high level in the Project Execution Plan, and the reader is referred to that document. This transition period will incorporate several important steps, such as: (1) developing *Acceptance Criteria* for the facility, (2) developing a *Facility Test Plan*, (3) completing facilities testing for acceptance, and (4) preparing a *Test Exit Report* that reports results of testing and is part of the contract with facilities builders. *During the Readiness Stage, the Project Management Team will begin the study of these issues and prepare a draft Post-Construction Transition Plan that will be carried forward into the next stage of planning for completion.*

A precise list of deliverables corresponding to this narrative is given in Section 3.2.11.

2.3 CCC and GPO Establishment

As outlined earlier in this report, one of the major tasks during the Readiness Stage is to formally establish a community consortium and a project office to oversee and manage the construction of GENI. This section describes the two main aspects of this task.

2.3.1 NSF Solicitations

Early in the Readiness Stage, the National Science Foundation will release two solicitations, one for competitive bids for the formation of a Computing Community Consortium (CCC) and the other for the establishment of a GENI Project Office (GPO). It is expected that awards will be made approximately midway through the Readiness Stage. The contracted CCC provider will establish an Executive Committee, hire a Project Director and a Project Manager, and create a Technical Advisory Board to coordinate the working group activities.

2.3.2 Transition

The GPO will be established under the direction of the CCC in concert with the National Science Foundation. Once established, it will be necessary to transition responsibility for defining GENI from the existing Planning Group to the CCC and GPO. Specifically, responsibility for directing the Working Groups will move from the Planning Group to the TAB, and responsibility for developing and executing the management plan will transition from the PMT to the GPO.

As a tangible demonstration that they are on-line, the CCC and GPO will conduct a "Conceptual Design Review Prime" (CDR') once they have been established. This is expected to take place in September.

2.4 Community Engagement

Outreach to the various communities that will make use of GENI is one of the most important activities that will be continued into the Readiness Stage. Work started during the Conceptual Design Stage (e.g., workshops, mailing lists, seminars, web site) will be continued and be broadened to ensure that the broadest possible community is engaged in the definition and objectives of GENI, and that the broad community of researchers, educators, and future users fully understand that they are an integral part of the design and development of GENI.

To address this task, the Research Coordination Working Group will review and prioritize proposals for the use of the GENI facility. *The WG will also ensure that there will be a voice for the various CS research communities that will use GENI and that GENI is designed and operated in such a way that it meets the needs of its users.* It is not clear if issues of priority-setting will arise in this first year, but there may be issues where the needs of different potential user communities must be balanced as the GENI design is made final.

As a first step in community outreach, NSF is commissioning a series of GENI Town Meetings to be held in 2006. Since these are being organized in parallel with the preparation and review of this proposal, NSF has separately arranged for their planning. *The WG will be responsible for the timely review and summary of the information gathered in these meetings, and for ensuring that meeting results are appropriately conveyed to Working Groups assigned to complete Preliminary Design of the GENI facility. It will also arrange for the review and summary of the supplemental information requested in all proposals to the FIND[2] solicitation: descriptions of the infrastructure that would be required to support each such proposal.*

Early in its work, this WG will identify the relevant research communities likely to have a strong interest in GENI. Three of the most important of these include: the networking community that will propose work under FIND; the network security community that will propose work under the relevant section of the CyberTrust solicitation; and the distributed systems community. Suitable representatives will be identified in each such community and they will be asked to join the Working Group. The WG will then identify conferences and other venues at which it can arrange panel sessions, breakout sessions, or associated workshops to discuss the relevance of GENI to the work of that community.

The next task will be to identify other government agencies that may have interests in GENI, and research communities in other countries that may have interest in launching an interoperable research support infrastructure, as well as funding related research. The WG will

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[2] FIND, which stands for "Future Internet Design," is a current NSF solicitation calling for proposals on clean-slate network architectures. Proposers are asked to submit supplemental information identifying their experimental facility needs.

establish liaisons (initially informal), as appropriate, with these other agencies, researchers, and funding agencies.

Once FIND and related programs are funded and launched, there will be working meetings that facilitate community-building among the researchers of these programs. With respect to FIND in particular, the WG will work with the FIND Coordination and Planning Committee to make sure that the FIND working meetings are a venue to link the research objectives of FIND to the infrastructure capabilities of GENI.

The principal outputs of this effort are: (1) timely input to the completion of Preliminary Design of the GENI facility from the larger research community, and (2) engagement of this larger community to participate broadly in the use of GENI as its construction proceeds.

A precise list of deliverables corresponding to this narrative is given in Section 3.2.13.

2.5 GENI for Education

Much of GENI planning to date has focused on research. GENI planners also recognize the great importance of GENI in education. To address education issues in the Readiness Period, the Planning Group will establish an *Education and Outreach Working Group* to focus specifically on education. General areas for study will include: (1) the use of GENI to boost educational opportunities in America's school systems (including K-12 as well as university and postgraduate), (2) education of the general public on the complex issues that will surround research on GENI, and (3) the need for training on the use of GENI.

Although this effort is quite different from defining a Facility, or a Project Office, it will still be necessary to define the *educational needs* that GENI should address, and then to define the *requirements* on the GENI facility so that such educational needs can be met. The process, therefore, is quite similar to that for the GENI facility or the GPO. Requirements will first be identified (both types), and then *specifications* written that will drive GENI enhancements to meet educational needs. All of this will be incorporated into the budgeting and related processes to reach Preliminary Design completion. *This task will be under the direction of the new Education and Outreach WG when it is formed.*

A precise list of deliverables corresponding to the following narrative is given in Section 3.2.14.

2.5.1 GENI in the Classroom

Classroom education has changed enormously over the past 10 years as computers and electronic networks—both local and wide-area—have become more integrated into the teaching environment. There is no expectation that this trend will diminish in any way in the future; in fact, we expect it to grow rapidly as progress is made on projects like GENI, where special network features, such as virtualization, programmability, or federation make the project particularly well suited to education.

There have been several pedagogically oriented programming environments developed for teaching computer science concepts at various educational levels. Most of these, however, run

on a single computer. And students are isolated from one another. GENI would provide a platform to support a system in which programs of multiple students could be run in parallel in some sort of multi-agent activity. The programming goal could be a cooperative or competitive activity, such as controlling a number of independently programmed virtual robots toward some goal, or activities similar to some of the popular "sim" games. For example, students could try to create a virtual ant that then enters a virtual ant nest and tries to interact with virtual ants programmed by other students. The pedagogical objective would be to expose students to the complexity of highly parallel systems with independent agents, and to such concepts as self-organization and emergent behavior. With proper design, versions of such a system could be accessible to students from high school (or even lower grades) up through college.

2.5.2 Education of the General Public

The general public is largely familiar with the Internet, and is familiar as well with some of its problems, such as poor security and configuration difficulties. However, the internals of the Internet are not at all visible to its users—just as modern automobile users do not expect to be able to comprehend the innards of their cars (even though they depend on them). The objectives of FIND – to give the world a better Internet—make GENI even more relevant (in principle) to the normal citizen than other sorts of scientific infrastructure. With creative thought, it may be possible to make the workings of GENI visible in a way that gives a non-technical Internet user a hint of what is going on "under the hood". This sort of visualization might be combined with public visibility of some of the programming activities described in section 2.5.1. Some programming games, such as the RoboCup soccer-playing robot dogs, attract audiences that number in the hundreds of thousands. Perhaps virtual activities running on GENI might attract a similar "viewing audience" if properly designed.

2.5.3 Training for GENI Users

As the GENI facility comes on line, we anticipate that hundreds (even thousands) of researchers, students, and educators will want to use it. This has been an important part of our planning and we have specifically included the development of Distributed Services (see Section 2.1.3) in the GENI Facility Construction stage. This so-called "underlay software" is meant to greatly facilitate access to GENI by researchers and others. The existence of this software will not, however, eliminate the need for training on the use of GENI. Starting in the Readiness Stage, the *Education and Outreach Working Group* will explore the range of methods by which the user community will be trained to make the best use of GENI. These methods could include: (1) tutorials at major technical and educational conferences; (2) reference implementations of working slices that students can build on; (3) additions to the infrastructure that will further reduce the user learning curve; and (4) development of pointers on the GENI web site to courseware developed for use on GENI.

2.6 Prototyping GENI Design Concepts

The GENI facility is a complex technical system, dependent on the operation and integration of a number of functionalities and components. To increase confidence in the final GENI design, and to aggressively *mitigate the risks* inherent in any large engineering project, a series of

carefully chosen prototyping and development exercises will be undertaken prior to completion of the GENI facility's detailed design. These prototyping efforts will serve as inputs, guides, and critical validation in support of the GENI engineering effort. *The National Science Foundation will define the process for selecting prototyping efforts to be performed and then select the groups to perform these efforts.*

To meet these goals, each GENI prototyping effort will focus on a narrow, carefully identified objective. Benefits of this model are that individual projects can be undertaken by groups of reasonable size, and that prototyping projects can proceed in parallel, drastically shortening the time needed to obtain useful results. We identify three classes of work, and describe them below. Within each class, objectives of highest concern will be identified and appropriate prototyping projects defined within the first phase of the Readiness Stage. In the second phase of the Readiness Stage, these projects will be carried out.

2.6.1 Defining and Validating Core Capabilities

GENI depends for its success on a number of key core capabilities, integrated to form a coherent whole. Among these capabilities are: virtualization and slicing; management heterogeneity; controllable experiment isolation and interconnection; and federation.

Prototyping efforts within this class have the objectives of: (1) understanding the current state of the art in each of these areas, drawing from existing testbeds and research tools; (2) identifying gaps and limitations of the current state of the art with respect to the requirements of GENI, and (3) identifying and validating approaches to bridge or mitigate any such gaps or limitations.

2.6.2 Validating Critical System Components

GENI depends on a number of different system components, such as routers, switches, optical and wireless devices. These components are distinguished from others of their type by the GENI requirement that they be capable of being virtualized, programmable, and sliceable to the extent possible. The objective of this class of prototyping effort is to identify and validate options for the critical system components of GENI, and to provide guidance about the extent to which each of these capabilities can be provided within each component in the initial GENI construction phase.

Examples of system components to be considered include: (1) programmable and FPGA-based high-performance routers; (2) software radio platforms; (3) emulation facilities; and (4) campus area programmable wireless infrastructures

2.6.3 Integration and Leveraging of Existing Research Facilities

A number of currently deployed research testbeds and infrastructures (e.g., PlanetLab, ORBIT, Emulab, DETER, and others) bring to the GENI development process both technical contributions and access to existing, active research communities. For example, the well-known and widely used PlanetLab has already demonstrated the value of virtualization, although in the environment of relatively homogeneous facilities and an overlay interconnection network. Similarly, Rutgers' ORBIT testbed has focused on the creation of a large-scale wireless network testbed to facilitate a broad range of experimental research in this area.

Prototyping efforts of the third class build on these existing testbeds and infrastructures by integrating additional GENI concepts and technologies into their facilities. The benefits of this activity are twofold. First, the existing testbeds provides an active, large-scale environment for evaluating and validating new GENI technology. Second, the user community of the existing facility is exposed to GENI concepts at an early stage, serving both to motivate and build community interest, and to provide valuable early feedback to the designers of the full GENI facility. As such, this class of prototyping effort provides both technical and community-building benefit to the GENI project.

Example activities of this class include:

- Initial prototype of a virtual network infrastructure in the National Lambda Rail and Abilene backbones, with the goal of investigating network virtualization, support for experimentation with new network architectures, and interfacing with end users and commercial Internet providers in an assured bandwidth environment;
- Integration of PlanetLab and ORBIT facilities, with the objective of providing a coupled wireline / wireless testbed environment.

In each case, activities of this third class are expected to both build on and inform activities of the first and second classes, strengthening those efforts as well as achieving the objectives listed in this section.

3 Deliverables

This section identifies the specific deliverables for each part of the Readiness Stage. It also gives a deliverable schedule, identifies the dependencies among tasks, and outlines the corresponding budget.

3.1 Definitions of Deliverable Types

The deliverables are of the following types. Note that document-related deliverables that are appropriate for community review and feedback (e.g., design requirements and specifications), and not otherwise required to conform to a prescribed format, will be released as GENI Design Documents (GDDs) and made available on the GENI web site (*www.geni.net*).

3.1.1 Preliminary Design Document

The MREFC Readiness Stage Preliminary Design Document for the GENI will be a compilation of the following five documents:

- Facility Design Requirements & Specifications
- Management Requirements & Specifications
- Work Breakdown Structure
- Bottom-up Construction Budget

- Management Plans

These documents are described in the following subsections. The composite Preliminary Design will be put together by the Project Director and Project Manager, advised by the Technical Advisory Board and the GPO.

3.1.2 Facility Design Requirements & Specification Documents

Facility requirements documents will be based on the architecture, service and component definitions for the facility. The format will be in the form of short, descriptive "bullets" that state the requirements for the particular function. In particular, the requirements documentation will not state how the requirements are to be achieved. It is expected that the requirements documentation will be "living" documents, updated throughout the Readiness Stage as new needs are identified. Initial statements of requirements will be made as early as feasible in the Readiness Stage.

Facility specification documentation will delineate: (1) how a particular requirement can be met, (2) standards that must be incorporated, (3) specific performance requirements, and (4) internal and external interfaces required in order to meet interoperability with related systems. The specifications (in terms of how requirements may be met) developed by working groups are intended to be advisory. The Planning Group recognizes that technology will change over the course of the project and that later implementations of requirements may be better served by a newer technology than the working groups consider during the Readiness Stage. Also, while we want to leave room for creativity on the part of the vendor—provided requirements related to performance, cost, and risk are met—these specifications will include reference designs illustrating how the corresponding component might be realized, as well as high-level descriptions (e.g., schematic depictions, organizational charts, process flows) describing how the various components fit in the larger picture.

Technical requirements and specifications for the GENI facility will be rolled up in a *Facility Design Requirements & Specifications* document.

3.1.3 Management Requirements & Specifications Documents

Management requirements documents will be associated with specific offices of the GPO (e.g., Financial, Legal, Systems Engineering, etc.) and will be in the same form as requirements documents for technical aspects of the project. The format will be in the form of short, descriptive "bullets" that state the requirements for the particular function. In particular, the requirements documentation will not state how the requirements are to be achieved. It is expected that the requirements documentation will be "living" documents, updated throughout the Readiness Stage as new needs are identified. Initial statements of requirements will be made as early as feasible in the Readiness Stage.

Management specifications documentation will delineate: (1) how a particular requirement can be met, (2) standards that must be incorporated, (3) specific performance requirements, and (4) internal and external interfaces required in order to meet interoperability with related offices and processes.

Requirements and specifications for the various offices of the GPO will be incorporated in the *Management Requirements & Specifications* document.

3.1.4 Work Breakdown Structure (WBS)

A *Work Breakdown Structure* (WBS) will be created for each major component of the GENI project (e.g., management software, backbone network, and principal platforms). These WBS documents will be built around sub-tasks and work packages that have minimum completion times of 1-3 months. Each WBS will include approximately three levels of detail (e.g., task, sub-task, and work package). Earlier draft versions of the WBS may only included 1-2 levels of detail, but these will be filled out as planning progresses during the Readiness Stage.

Individual WBS documents will be rolled up and integrated into a project-wide *Work Breakdown Structure for Construction,* which will include all cross-component dependencies.

3.1.5 Bottom-up Construction Budget

The *Bottom-up Construction Budget* will be based on data received directly from potential suppliers of facility and GPO systems and platforms. These are expected to be based on "catalog pricing" and not negotiated final pricing. Where possible, pricing information will be obtained from multiple sources in order to estimate a most likely price at the start of GENI construction. An appropriate model will be used for *forward pricing* to the start of construction, and a contingency budget calculated to address price variations.

3.1.6 Management Plans

A set of *Management Plans* will describe the processes by which the GENI management teams and offices will address several critical issues, including risk management, contingency management, change management, PCMS and critical path analysis, office transitions, and so on. The format of these deliverables will depend on the models and tools used to create the plan.

3.1.7 Meetings and Reports

Quarterly Meetings: Meetings with the NSF and MREFC (as appropriate) will be scheduled quarterly by the GENI Planning Group in collaboration with the National Science Foundation. Meetings will consist of presentations made by Working Group leaders and staff. Slide materials from these meetings will be made available to the NSF prior to the meeting. Formal notes from the Quarterly Meeting will be provided within one week following the end of the meeting – to be submitted by the GENI Planning Group leader.

Monthly Reports: Brief monthly reports will be provided to the NSF, MREFC, and others, as appropriate. These reports will describe progress against objectives during the Readiness Stage by each Working Group. An overall executive summary will highlight significant events during the reporting period.

Conference Calls: The Planning Group and NSF representatives have held weekly conference calls to discuss both technical and management aspects of the GENI project. This practice will continue until responsibility for GENI is passed to the CCC and GPO.

GENI Design Documents: GDDs will be published regularly on the GENI website to inform the community of progress on the facility design. They include official Requirements and Specifications documents produced by the Working Groups (as described in this PDP), but may also include discussions, analysis, and commentary produced to members of the broader community.

3.2 Deliverables Components

We now outline specific deliverables for the Readiness Stage.

3.2.1 Reporting and Meetings

- Weekly Phone Conference Calls: Phone meetings of NSF and the GENI Planning Group, held on a weekly basis and chaired by the chairman of the Planning Group or his designate.
- Monthly Progress Reports: Project reports prepared by the leaders of the Working Groups, assembled by the GENI Planning Group manager and distributed electronically to the NSF and Planning Group members.
- Monthly Prototyping Status Reports: Progress reports summarizing the results of experimental prototyping work. Prepared and distributed electronically to the NSF and the Planning Group by the Principal Investigator for the experimental project.
- Town Hall Meeting Minutes: Notes on results of Town Hall Meets, prepared and delivered electronically by the RCWG leader to NSF and the GENI Planning Group members.
- Collaboration with NSF Cyber Security Working Group: Periodic meetings as required to stay connected to work of this NSF team.
- Quarterly Project Reviews: Face-to-face meetings between the GENI Planning Group and NSF to report progress during Readiness Stage planning. Organized by the chairman of the Planning Group with the participation of each Working Group.
- Preliminary Design Review (PDR): End-of-Readiness Stage face-to-face review with NSF (and others, as determined by NSF) that details results of Readiness Stage planning and completion of Preliminary Design for the GENI facility and management plan.

3.2.2 Preliminary Design Compilation

- Facility Design Requirements & Specifications: Compilation of requirements and specification documents for all components of the GENI facility (see deliverables in 3.2.3 – 3.2.7).

- Management Requirements & Specifications: Compilation of requirements and specifications documents for the GENI management-related processes and procedures for the CCC, EC, TAB, and GPO (see deliverables in 3.2.8 – 3.2.11).

- Bottom-up Construction Budget: Compilation of budgets for all components of the GENI facility (see deliverables in 3.2.4 – 3.2.7) and GENI management (see deliverables in 3.2.9).

- Work Breakdown Structure for Construction: Compilation and integration of work breakdown structures for all components of the GENI facility (see deliverables in 3.2.4 – 3.2.7) and GENI management (see deliverables in 3.2.9).

- Management Plans: Compilation of all documents describing management processes and procedures, including functions to be carried out by the GPO (see deliverables in 3.2.9).

3.2.3 Facility Design – Research

- Research Requirements Document: Defines overall facility functions and capabilities required by the research community, including instrumentation. Also makes the overall scientific case for GENI, including intellectual merit and broader impacts, and ties this case to specific facility functions and capabilities.

- Town Hall Meeting Minutes: Timely reporting of results of Town Hall Meetings, to NSF, GENI Planning Group, and GENI Working Groups.

3.2.4 Facility Design – Architecture

- Architecture Requirements Document: Defines the overall facility architecture, including all functional requirements, unique features, and interactions of facility components.

- Architecture Specifications Document: Defines modules, interfaces, and name spaces that collectively specify the GENI architecture. Includes a reference design for the GENI Management Core (GMC), which serves as the central component of this architecture, and defines the "logical backplane" by which the other components of GENI plug into a coherent experimental facility.

- Management Core Budget: Develops budget for management core "builds" by external teams, including contingency budget that goes beyond simple percentage. This budget becomes embedded into the GENI Construction Budget by end of Readiness.

- Work Breakdown Structure for Management Core: Develops a WBS for the GENI management core. Includes a schedule for each WBS element. Becomes integrated into WBS for the overall GENI facility, where dependencies with other tasks are defined and conflicts resolved.

3.2.5 Facility Design – Distributed Services

- Distributed Services Requirements Document: Identifies baseline set of distributed services. Describes essential facilities that must be provided by the architecture to enable the services built on top of GENI to be secure, reliable, and flexible.
- Distributed Services Specification Document: Defines specific interfaces for each service and inter-relationship between each of these services. Must be done at a level needed to contract "build" of these services to external teams, including a timeline for rollout of service capabilities.
- Distributed Services Budget: Develops budget for service "builds" by external teams, including contingency budget that goes beyond simple percentage. This budget becomes embedded into the GENI Construction Budget by end of Readiness.
- Work Breakdown Structure for Services: Develops a WBS for the Distributed Services component of the GENI facility construction. Includes a schedule for each WBS element. Becomes integrated into WBS for the overall GENI facility, where dependencies with other tasks are defined and conflicts resolved.

3.2.6 Facility Design – Backbone Network

- Backbone Requirements Document: Defines the functional, performance, interface, and other related requirements for each of the major components of the GENI backbone (e.g., programmable routers, dynamical optical switches, element management systems, ROADMs, etc.).
- GENI Backbone Specifications Document: Develops specifications for all major components of the backbone, including connections within the backbone, to edge devices and subnets, and to other networks. Sensitivity analysis is not part of first draft, but must be included in final draft.
- Backbone Construction Budget: Bottom-up budget for construction of the backbone, including all components, connections, etc. Includes results of sensitivity analysis and a contingency budget based on that sensitivity analysis.
- Backbone Work Breakdown Structure: Specifies tasks, subtasks, work packages required to construct backbone. Indicates dependencies within backbone work structure and defines schedule for completion of each component to work package level. Includes a projected schedule for insertion of new technologies into the backbone.

3.2.7 Facility Design – Wireless Subnets

- Wireless Subnet Requirements Document: Documents requirements for all wireless subnets and their connections, both within the subnet and between the wired and wireless networks. Includes a description of various wireless networking platforms and radios.
- Wireless Subnets Specifications Document: Develops details specifications for each subnet component and its interfaces to other parts of the network (within and external to

the subnet). Includes high-level designs for individual subnet, showing major components and their interconnection.

- Wireless Subnet Construction Budgets: Bottom-up budget for each of the wireless subnets, including sensitivity analysis on individual components and calculated contingency budget based on the sensitivity analysis.

- Work Breakdown Structure for Subnets: Describes work breakdown at least three levels deep for construction of each wireless subnet. Shows schedule and dependencies for completion of tasks to the work package level.

3.2.8 Management Organization – CCC

- CCC Requirements & Specifications: Defines roles and responsibilities for the Computing Community Council and the Executive Committee. Develops high-level descriptions for future staff recruitment, defines responsibilities of key management positions, and establishes methodology for setting up of 501(c)(3).

- TAB Requirements & Specifications: Defines function, roles and responsibilities for the Technical Advisory Board, particularly for its leader, the GENI Chief Architect. Specifies relationships and joint processes with other parts of the GENI management organization, particularly the GPO. Describes reporting relationships of the Working Groups within the TAB and throughout the GENI management organization, and defines role of the TAB in direction of GENI construction (interaction with vendors).

3.2.9 Management Organization – GPO

- Construction Budget Process: This document specifies the processes to be followed, the tools to be used, and the format for the development of a bottom-up budget by all components of the GENI management organization. It will include guidelines for sensitivity analyses in the development of the budget. This is an early deliverable that is intended to provide guidance to working groups as they proceed with the GENI facility design.

- Contingency Plan Design Document: This document describes the approach to contingency planning, primarily for budgeting purposes. The plan will focus on alternatives to simple percentage-based budget contingencies that represent a more realistic strategy for contingency planning. [This approach will then be used in the development of a contingency budget for GENI construction]

- GPO Requirements Document: This document summarizes the functional requirements for each major office of the GPO, including finance, legal, operations, liaison, education, and systems engineering. In particular, addresses requirements for the legal function and for systems engineering.

- GPO Specifications Document: Based on requirements defined for the GPO in the GPO Requirements Document, the GPO Specifications Document will describe how requirements will be met in each office of the GPO. This document will include details of the Project Management Control System (PMCS).

- GPO Construction Budget: This bottom-up budget for the GPO will include projected costs associated with operation of the GPO during construction. It will incorporate the methodologies described in documents on bottom-up budgeting, sensitivity analysis, and contingency budgeting.

- Transition to GPO Support Plan: This document describes the support plan to be implemented by the GENI Planning Group during the formation of the GPO.

- Risk Management Plan: Description of a plan developed by the PMT and external experts to manage risk in the construction of the GENI facility and in the operation of the project during all of its stages. Rolls up risk management strategies developed by individual Working Groups for individual components.

- Change Control Management Plan: This plan will detail the processes and procedures that must be used by the management organization when significant changes to the original schedule, technology, staffing, cost, etc., occur during the construction stage.

- PMCS and Critical Path Plan: This report will show dependencies among tasks and implications of task slippage on construction schedule, personnel resources, facility deployment, and budget.

- Industry Participation Plan: This plan describes the results of a WG to determine how business and industry should participate in GENI. It develops policy recommendations related to this participation and to the use of equipment and services provided by business/industry users. It also specifies under what conditions participation in research can occur.

3.2.10 Management Organization – Processes and Procedures

- Workflow Plan: Documents several workflow process issues, including group responsibilities, interactions among various groups in the TAB and GPO, formats for requirements and specifications documents, and formats and schedules for reports to NSF. [This is a "living" document with frequent updates expected.]

3.2.11 Management Organization – Transitioning to Operations

- Operations During Construction: Establishes the requirements and specifications for operations of the GENI facility for research during construction of the facility. Answers questions related to how the facility must be managed to support both research and construction, keeping funds separated, the need for a separate operations management team, and similar issues.

- Commissioning and Post-Construction Transition Plan: This document describes processes required during commissioning, including the development of facility test plans, acceptance criteria, text exit reports, and similar.

3.2.12 CCC and GPO Implementation

- CCC and GPO Established (CDR'): These deliverables are the responsibility of the National Science Foundation and are entered here for completeness. However, as a

tangible demonstration that they are on-line, the CCC and GPO will conduct a "Conceptual Design Review Prime" (CDR') once they have been established.

3.2.13 Community Engagement

- Workshop Reports: The reports document proceedings of workshops to be sponsored by the NSF in 2006 to inform the broad CS research community of GENI and to obtain feedback from that community related to GENI design and use. Reports to advise GENI facility design by several WGs under the direction of the Project Director or Chief Architect (TAB Chair).
- Community Engagement Plan: Documents plans for engagement of the broad CS research community. Goes beyond the NSF-sponsored workshops. Incorporates engagement of government and industry where appropriate.
- Periodic Reports of FIND and Related Meetings: Reports of meetings organized to get the word out concerning GENI, its use and its design for research.

3.2.14 GENI for Education

- Education Requirements Document: Develops the requirements for the role of GENI in education, including each of the areas of classroom, general education for the public, and the training of facility users
- Education Specifications Document: Takes the requirements previously defined and develops specifications for their implementation. Also, develops and action plan for implementation.

3.2.15 GENI Prototyping

- This activity will be under the direction of the National Science Foundation. Specific experiments to be executed will be determined during the course of the Readiness Stage. The purpose is to reduce risk in the design and deployment of the GENI facility.

3.3 Summary of Deliverables

The following table summarizes the work tasks, a due date for deliverables, and the responsible Work Group (or NSF). Each item references the section of this document that describes the task in more detail.

Section	DELIVERABLES	Due	Responsible
	Administration: Reporting & Scheduled Meetings		
1.3	Phone Conferences on Project Progress w / NSF	Weekly	Director
1.3	Written Project Progress Reports to NSF	Weekly	PM / WGs
1.3	Prototyping Status Reports	Monthly	WG Leaders
1.3	Minutes of Town Hall Meetings	TBD	RCWG
1.3	NSF Cyber Security Working Group collaboration	TBD	TBD

1.3	Quarterly Project Progress Reviews (face-to-face meetings between NSF and the GENI Planning Group)	6/06, 9/06, 12/06	Director & WG Leaders
1.3	Preliminary Design Review (PDR)	1/07	Director
	Preliminary Design Compilation		
1.3	Facility Design Requirements & Specifications	12/06	PD/PM
1.3	Management Requirements & Specifications	12/06	PD/PM
1.3	Bottom-up Construction Budget	12/06	PD/PM
1.3	Work Breakdown Structure for Construction	12/06	PD/PM
1.3	Management Plans	12/06	PD/PM
	Facility Design – Research		
2.1.1	GENI Requirements Document	5/06	RCWG
2.1.1	Town Hall Meetings Minutes	6/06	RCWG
	Facility Design - Architecture		
2.1.2	Facility Architecture Requirements Document	5/06	FAWG
2.1.2	Facility Architecture Specifications Document – Draft	8/06	FAWG
2.1.2	Management Core Development Budget – Draft	11/06	FAWG
2.1.2	Management Core Specifications Document – Final	8/06	FAWG
2.1.2	Management Core Development Budget – Final	12/06	FAWG
2.1.2	Work Breakdown Structure for Management Core	11/06	FAWG
	Facility Design - Services		
2.1.3	Distributed Services Requirements Document	5/06	DSWG
2.1.3	Distributed Services Specifications Document – Draft	8/06	DSWG
2.1.3	Distributed Services Development Budget – Draft	11/06	DSWG
2.1.3	Distributed Services Specifications Document – Final	8/06	DSWG
2.1.3	Distributed Services Development Budget – Final	12/06	DSWG
2.1.3	Work Breakdown Structure for Distributed Services	11/06	DSWG
	Facility Design - Backbone		
2.1.4	Backbone Network Requirements Document	5/06	BNWG
2.1.4	Backbone Network Specifications Document – Draft	8/06	BNWG
2.1.4	Backbone Network Development Budget – Draft	11/06	BNWG

2.1.4	Backbone Network Specifications Document – Final	8/06	BNWG
2.1.4	Backbone Network Development Budget – Final	12/06	BNWG
2.1.4	Work Breakdown Structure for Backbone Network	11/06	BNWG
	Facility Design – Wireless		
2.1.5	Wireless Subnet Requirements Document	5/06	WSWG
2.1.5	Wireless Subnet Specifications Document – Draft	8/06	WSWG
2.1.5	Wireless Subnet Development Budget – Draft	11/06	WSWG
2.1.5	Wireless Subnet Specifications Document – Final	8/06	WSWG
2.1.5	Wireless Subnet Development Budget – Final	12/06	WSWG
2.1.5	Work Breakdown Structure for Wireless Subnet	11/06	WSWG
	Management Organization CCC		
2.2.1	CCC Requirements Document	5/06	PMT
2.2.1	CCC Specifications Document	8/06	PMT
2.2.1	TAB Requirements Document	5/06	PMT
2.2.1	TAB Specifications Document	8/06	PMT
	Management Organization GPO		
2.2.2	Construction Budget Process	4/06	PMT
2.2.2	Contingency Plan Design Document	5/06	PMT
2.2.2	GPO Requirements Document	5/06	PMT
2.2.2	GPO Specifications Document	8/06	PMT
2.2.2	GPO Construction Budget – Draft	11/06	PMT
2.2.2	GPO Construction Budget – Final	12/06	PMT
2.2.2	GENI Management Requirements & Specifications	8/06	PMT
2.2.2	Transition to GPO Support Plan	8/06	PMT
2.2.2	GENI Risk Management Plan	11/06	PMT
2.2.2	PMCS & Critical Path Plan	11/06	PMT
2.2.2	Change Control Management Plan	11/06	PMT
2.2.2	Industry Participation Plan	11/06	PMT
	Management Organization Processes & Procedures		
2.2.3	Draft Guide to Workflow Processes	5/06	PMT
	Management Organization Transitions to Operations		
2.2.4	Operations during Construction	10/06	PMT
2.2.4	Commissioning & Post-Construction Transition Plan – Draft	11/06	PMT
	CCC & GPO Implementation		
2.3	Solicitations for CCC and GPO published	4/06	NSF

2.3	Successful CCC Bidder Selected	7/06	NSF
2.3	Successful GPO Bidder Selected	7/06	NSF
2.3	Project Director and Project Manager Hired	9/06	NSF
2.3	CCC and GPO Implemented (CDR' held)	10/06	CCC/GPO
	Community Engagement		
2.4	Workshop Reports to NSF/Planning Group	TBD	RCWG
2.4	Community Engagement Plan	6/06	RCWG
2.4	Periodic Reports on FIND and Related Meetings	TBD	RCWG
	GENI for Education		
2.5	Education Requirements	5/06	EOWG
2.5	Education Specifications	8/06	EOWG
	GENI Prototyping		
2.6	GENI Prototyping Processes Established	4/06	NSF
2.6	GENI Prototyping Experiments Defined	6/06	WGs
2.6	Call for GENI Prototyping Experiments	7/06	NSF
2.6	GENI Prototyping Experiments Selected	8/06	NSF
2.6	GENI Prototyping Experiments Started	9/06	TBD
2.6	GENI Prototyping Experiments Completed	11/06	TBD

3.4 Budget Breakdown

The Budget for the Readiness Stage is built around the requirements of the tasks and their associated deliverables, the costs of which have been calculated individually. The budget also includes costs for: (1) administrative tasks associated with the operation of the project; (2) expenses associated with consultants; (3) travel to attend NSF meetings and meetings of the GENI Planning Group; (4) purchase of capital equipment, such as software tools for management and similar; (5) prototyping facilities (staff expenses not included); and (6) contingency capital equipment for prototyping.

PROJECT TASKS	Staff (MY)	Faculty (MY)	Total MY	Rate (K$)	Consults (K$)	Total (K$)
Administrative (Readiness Stage)	0	1.05	1.05	250	0	262.5
Facility Design (1H Readiness Stage)	6.55	TBD	6.55	250	250	1,887.5
Management & GPO Definition (1H Readiness Stage)	1.8	TBD	1.8	250	250	700
Comm. Engagement (Readiness Stage)	0	0.25	0.25	250	400	462.5
Education Planning (1H Readiness Stage)	0.15	TBD	0.15	250	TBD	37.5

CCC/GPO: FY06 2H Readiness Stage	NSF	---	---	---	---	1,000
Prototyping Facilities	NSF	---	---	---	---	3,000
Travel: 100 Trips		9 + 1	---	0.75	---	75
Capital	---	---	---	---	---	500
TOTALS	**8.5**	**1.3+**	**---**	**250**	**900+**	**7,925**

Table 3.1: GENI Readiness Stage Budget. The 1H rows show budget prior to establishment of the CCC and GPO. Row 2H shows the budget for the CY06 period after the CCC and GPO are established.

3.5 Schedule Chart

The following Gantt chart shows the schedule and highlights the dependencies between the deliverables and tasks described in this section. For readability, the chart does not show the dependency between the CCC and GPO being established, and the tasks assigned to them.

Project Development Plan: Readiness Stage ***February 15, 2006***

ID	Task Name	Start	Finish
1	**GENI Readiness Stage**	**2/1/06**	**1/31/07**
2	**Facility Design Requirement & Specifications**	**2/1/06**	**12/31/06**
3	Research Requirements	2/1/06	5/1/06
4	Architecture Requirements	2/1/06	5/1/06
5	Architecture Specifications	5/2/06	8/1/06
6	Services Requirements	2/1/06	5/1/06
7	Services Specifications	5/2/06	8/1/06
8	Backbone Requirements	2/1/06	5/1/06
9	Backbone Specifications	5/2/06	8/1/06
10	Wireless Requirements	2/1/06	5/1/06
11	Wireless Specifications	5/2/06	8/1/06
12	Education Requirements	2/1/06	5/1/06
13	Education Specifications	5/2/06	8/1/06
14	Facility Design - Preliminary Design Compilation	12/1/06	12/31/06
15	**Management Requirements & Specifications**	**2/1/06**	**12/31/06**
16	CCC Requirements	2/1/06	5/1/06
17	CCC Specifications	5/2/06	8/1/06
18	TAB Requirements	2/1/06	5/1/06
19	TAB Specifications	5/2/06	8/1/06
20	GPO Requirements	2/1/06	5/1/06
21	GPO Specifications	5/2/06	8/1/06
22	Management - Preliminary Design Compilation	12/1/06	12/31/06
23	**Bottom-Up Construction Budget**	**2/1/06**	**12/31/06**
24	Construction Budget Process	2/1/06	4/1/06
25	Management Core Budget - Draft	8/1/06	11/1/06
26	Management Core Budget - Final	11/2/06	11/30/06
27	Services Budget - Draft	8/1/06	11/1/06
28	Services Budget - Final	11/2/06	11/30/06
29	Backbone Budget - Draft	8/1/06	11/1/06
30	Backbone Budget - Final	11/2/06	11/30/06
31	Wireless Budget - Draft	8/1/06	11/1/06
32	Wireless Budget - Final	11/2/06	11/30/06
33	GPO Budget - Draft	8/1/06	11/1/06
34	GPO Budget - Final	11/2/06	11/30/06
35	Budget - Preliminary Design Compilation	12/1/06	12/31/06
36	**Work Breakdown Structure (WBS)**	**8/1/06**	**12/31/06**
37	Management Core WBS	8/1/06	11/1/06
38	Services WBS	8/1/06	11/1/06
39	Backbone WBS	8/1/06	11/1/06
40	Wireless WBS	8/1/06	11/1/06
41	WBS - Preliminary Design Compilation	12/1/06	12/31/06
42	**Management Plans**	**2/1/06**	**12/31/06**
43	Contingency Management Plan	2/1/06	5/1/06
44	Transition Plan	2/1/06	8/1/06
45	Risk Management Plan	2/1/06	11/1/06
46	PMCS & Critical Path Plan	2/1/06	11/1/06
47	Industry Participation Plan	2/1/06	11/1/06
48	Change Control Management Plan	2/1/06	11/1/06
49	Draft Guide to Workflow Processes	2/1/06	5/1/06
50	Operations during Construction	2/2/06	10/1/06
51	Commissioning & Post-Construction Transition Plan - Draft	2/1/06	11/1/06
52	Community Engagement Plan	2/1/06	6/1/06
53	Management Plans - Preliminary Design Compilation	12/1/06	12/31/06
54	**Reporting & Scheduled Meetings**	**2/1/06**	**1/31/07**
55	Weekly Phone Conferences on Project Progress w/NSF	2/3/06	12/31/06
56	Monthly Project Progress Reports to NSF	2/3/06	12/31/06
57	Monthly Prototyping Status Reports	2/3/06	12/31/06
58	Quarterly Project Progress Reviews	2/1/06	11/29/06
59	Minutes of Town Hall Meetings	3/1/06	6/1/06
60	NSF Cyber Security Working Group Collaboration	3/1/06	6/1/06
61	Workshop Reports to NSF/Planning Group	2/1/06	11/1/06
62	Periodic Reports on FIND and Related Meetings	2/1/06	11/1/06
63	Preliminary Design Review	1/1/07	1/31/07
64	**CCC & GPO Implementation**	**2/1/06**	**10/1/06**
65	Solicitations for CCC and GPO published	2/1/06	4/1/06
66	Successful CCC Bidder Selected	6/1/06	7/31/06
67	Successful GPO Bidder Selected	6/1/06	7/31/06
68	Project Director and Project Manager Hired	8/1/06	9/1/06
69	CCC and GPO Implemented (CDR')	9/4/06	10/1/06
70	**GENI Prototyping**	**2/1/06**	**11/16/06**
71	GENI Prototyping Processes Established	2/1/06	4/1/06
72	GENI Prototyping Experiments Defined	4/3/06	6/1/06
73	Call for GENI Prototyping Experiments	6/2/06	7/1/06
74	GENI Prototyping Experiments Selected	7/3/06	8/1/06
75	GENI Prototyping Experiments In Progress	8/2/06	11/1/06
76	GENI Prototyping Experiments Completed	11/2/06	11/16/06