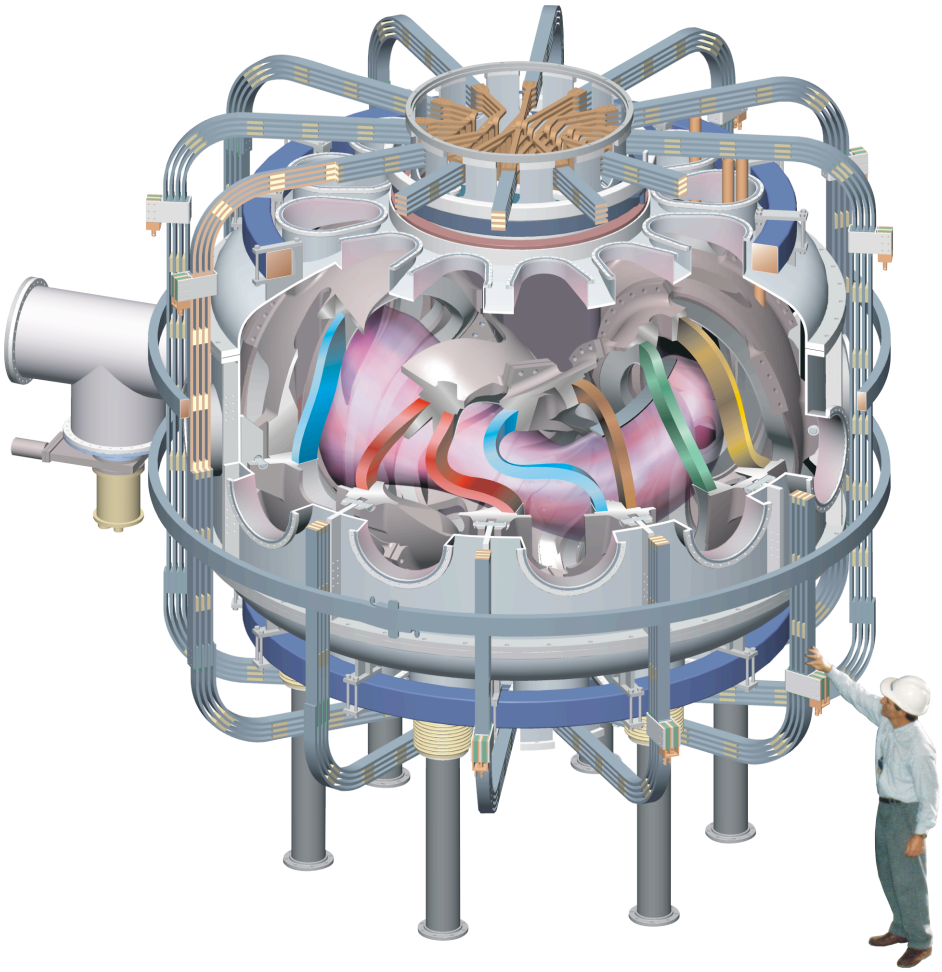
QUASI-POLOIDAL STELLARATOR (QPS)
PRELIMINARY PROJECT EXECUTION PLAN

January 2004



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1 INTRODUCTION AND SCOPE

The Quasi-Poloidal Stellarator Experiment (QPS) is an experimental research facility that is to be designed and constructed at the Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL). Its purpose is to develop the physics of compact stellarators, an innovative fusion confinement concept. The facility will include the stellarator device and ancillary support systems. The design and fabrication project will be led by ORNL in collaboration with the Princeton Plasma Physics Laboratory (PPPL) and the University of Tennessee (UT).

This Preliminary Project Execution Plan (PPEP) covers the design and fabrication phases of the QPS Fabrication Project, including integrated systems testing, field-line mapping, and first plasma production. The DOE has identified the QPS Project as a Major Item of Equipment (MIE) Project as opposed to a Line Item construction project. The differentiating factor between capital equipment and line item construction designation is that the equipment can be installed with little or no significant construction activities required. The device will be sited within a general purpose experimental facility that is being built (independently of QPS) as part of moving the ORNL Fusion Energy Division (FED) from the Oak Ridge Y-12 site to the ORNL X-10 site. This facility will have all of the necessary utilities and power systems, with only minor additional ancillary equipment needed. The overall cost objective that encompasses all project work scope is measured in terms of the Total Estimated Cost (TEC).

Although an MIE Project, the same overall management concepts applicable to line item projects will be applied to the degree appropriate for a project the size and cost of the QPS. DOE Order 413.3 will provide the basis for the overall management of the Project.

Key documents and plans that describe the QPS Project and how it will be managed are listed in the following sections. In some cases, documents that describe how the Project will be managed are presently being formulated and prepared and the discussion presented here is a statement of guidelines and principles. These documents are indicated by "To Be Provided" (TBP).

Documents for which DOE approval will be required:

- Acquisition Strategy (AS)—submitted as part of the Critical Decision 1 (CD-1) approval milestone.

  The DOE document that delineates the process by which DOE and the performing organizations (ORNL and PPPL) will acquire components and systems critical to completing and achieving the QPS Project goals and mission. For the QPS Project, the Acquisition Executive Officer (AE) will be the Associate Director for Fusion Energy Sciences, DOE Office of Science.

- Preliminary Project Execution Plan (PPEP) that will become the

Project Execution Plan (PEP) in support of Critical Decision 2 (CD-2).

This is the primary agreement on project planning and objectives among the Office of Fusion Energy Sciences (OFES), the Federal Project Director, and ORNL.

Institutional systems or plans for which DOE certification is required:

- ORNL Project Control System (PCS) (TBP). ORNL (in the Facilities Development Division) is presently developing and implementing a project control system that will implement the requirements of DOE Order 413.3. Elements of this system are in place and presently being used to manage several ORNL projects. DOE certification will be requested by June 30, 2004. QPS specific modifications will be developed and certified as appropriate.

  This set of procedures and tools will form the basis for planning, authorizing, and tracking QPS project work.

- ORNL Integrated Safety Management System (ISMS) Program Description. DOE verified the ORNL implementation of Integrated Safety Management (ISM) in September 2000. The ISMS was issued in April 2001 as an ORNL directive.

  This directive describes the structure and implementation of ISM at ORNL.

QPS Project approval required:

- General Requirements Document (GRD).

  Provides top-level (i.e., system-level) specification for the QPS project.

- Systems Engineering Management Plan (SEMP) (TBP).

  Describes systems engineering processes and management practices to be utilized by the QPS Project.

- Data Management Plan (TBP).

  Describes the processes to be utilized for document and drawing control.

- Document and Records Plan (TBP).

  Describes the purpose, content, format, approval level, records retention requirements, and file/document naming convention for each controlled document for the QPS Project (TBP).

- Configuration Management Plan (TBP).

  Describes the processes for proposing, approving, and implementing changes to the configuration, cost, and schedule baselines and controlled documents.

- Interface Control Management Plan (TBP).

  Describes the processes for generating and administering technical interface agreements between two or more technical activities.

- Test and Evaluation Plan (TBP).

  Describes the processes to transition from the design and fabrication activities to an operational experiment.

- Reliability, Availability, and Maintainability (RAM) Plan (TBP).

  Describes the processes for factoring reliability, availability, and maintainability considerations into the design. The GRD provides the overall top level RAM requirements for the Project.

- QPS Quality Assurance Plan (TBP).

  This project-specific plan integrates the ORNL FED and PPPL Quality Assurance Plans and implementing documents with specific plans and procedures to assure that an appropriate quality assurance program exists for QPS, consistent with DOE and ORNL policy, requirements, and guidance.

2 MISSION NEED STATEMENT AND PROJECT OBJECTIVES

2.1 Mission Need

The QPS mission need (Critical Decision 0) was approved by the Office of Fusion Energy Sciences in May 2001. The QPS mission is to contribute to the physics knowledge needed to evaluate compact stellarators as a fusion concept, and to advance the understanding of 3-D plasma physics for fusion and basic science. The QPS is an integral part of the Department's Office of Fusion Energy Sciences program. The recent report by the Burning Plasma Assessment Committee of the National Research Council (NRC) emphasized that one of the three main goals of the US fusion program is "to develop fusion science, technology, and plasma confinement innovations as the central theme of the domestic program." The NRC report additionally states: "Research in innovative and alternate magnetic fusion concepts is contributing to an understanding of how to design, implement and control future fusion devices."

The mission of the QPS supports two of the fusion program's goals (Report of the Integrated Program Planning Activity, December, 2000), namely:

> Goal 1: Advance understanding of plasma, the fourth state of matter, and enhance predictive capabilities through comparison of well-diagnosed experiments, theory, and simulation.
>
> Goal 2: Resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations.

2.1.1 QPS Mission in Support of Program Goal 1

Within Goal 1, the Fusion Energy Science program aims to advance understanding and predictive capability in fusion plasma physics, including turbulence and transport, macroscopic stability, wave-particle interactions, plasma-wall interactions, and general plasma science. The QPS mission in support of Goal 1 is to understand 3-D plasma effects important to toroidal magnetic configurations at very small aspect ratio (less than three). Critical issues to be addressed using the QPS facility include:

1. 3-D equilibrium at low aspect ratio QPS can study equilibrium quality, magnetic islands and ergodic regions, through external coil variations that affect the plasma shaping, rotational transform profile, and magnetic shear at very low aspect ratio, less than half that of existing stellarators.
2. Physics of the bootstrap current QPS can extend the study of the configuration dependence of the bootstrap current to very low aspect ratio in stellarators. In QPS, the number of trapped particles in the toroidal ripples does not vanish near the magnetic axis, which mitigates the need for seed current and on-axis current drive. The direction of bootstrap current and the sign of shear should also decrease the size of magnetic islands as the plasma pressure increases.
3. Anomalous transport QPS can test the validity of transport scaling laws such as the 1995 International Stellarator Scaling (ISS95) and extend the database upon which such scalings are based to plasma aspect ratios less than five.
4. Neoclassical transport. QPS will extend the understanding of neoclassical transport and the role of quasi-symmetry in transport reduction to quasi-poloidal systems and to very low aspect ratio.
5. Poloidal flows and transport barrier formation. Damping in the poloidal (symmetry) direction is expected to be weak in QPS, thus allowing both self-generated and externally-driven poloidal flows. QPS can study the impact of poloidal flows on electric fields and enhanced confinement as well as the level of helical ripple than can be tolerated.

A program of experimental research will be carried out to accomplish this mission. The critical physics issues to be addressed—equilibrium robustness at low aspect ratio, improving anomalous and neoclassical confinement, and divertor operation—set minimum plasma performance requirements. These considerations define the scale and scope of facility that is needed and hence the requirements on plasma size, magnetic field strength, plasma control, plasma heating, diagnostic access, and flexibility that the facility must satisfy. The QPS design and fabrication project addressed by this plan will provide an operational facility that meets the physics requirements necessary to support the physics mission. The mission itself will be carried out in the operations phase of the QPS program.

2.1.2 QPS Mission in Support of Program Goal 2

The compact stellarator is one of the innovative magnetic confinement configurations being investigated by the Fusion Energy Sciences Program. The DOE Report of the Integrated Program Planning Activity states that critical scientific issues for the stellarator include the identification of optimal configurations for the magnetic field and the confinement and stability of stellarator plasmas. Within Goal 2, there is a ten-year objective to determine the attractiveness of a compact stellarator. A stellarator proof-of-principle (PoP) program consisting of theory, experiment, international collaboration, and design has been established for this purpose. The QPS will explore a new physics regime, using quasi-poloidal stellarator configurations at very low aspect ratio with very low damping for poloidal flows that can lead to improved confinement. In this regard it complements the larger quasi-axisymmetric National Compact Stellarator Experiment (NCSX), the largest element in the compact stellarator program.

2.2 Project Objectives

2.2.1 Technical Objective

The key technical objective of the QPS project is the fabrication and assembly of the QPS experimental facility. The facility will be capable of producing magnetized plasmas with a well-defined set of configuration properties, such as size, shape, magnetic field strength, and pressure, which in turn determine its physics properties. The QPS will provide the flexibility to vary the configuration parameters over a range.

The plasmas to be studied are three-dimensional toroids, that is, doughnut-shaped plasmas whose cross sectional shape varies depending on where it is sliced. The magnetic field coils, which control the plasma shape, must be accurately constructed to precise shape specifications. In order to meet the needs of the research program, the QPS will provide an initial set of plasma control, heating, diagnostic, and power and particle handling systems and will be able to accommodate later upgrades.

2.2.2 Schedule Objective

The DOE Critical Decision 4 (CD-4) project completion milestone of First Plasma is scheduled for January, 2009. The supporting milestones for this objective are presented in Table 3-3. This schedule is based on funding starting in FY 2005 and on the proposed funding profile.

2.2.3 Cost Objective

The DOE cost objective for the MIE project is a TEC of $24.3 M with an included contingency of $5.1 M. The supporting estimates by WBS (Work Breakdown Structure) Level 2 (Level 3 for WBS 1, the stellarator core) are presented in Table 3-2. The TEC of $24.3 M is the lower end of the project cost range of $24–29 M.

3 PERFORMANCE BASELINE

The QPS Performance Baseline is defined by performance, scope, cost, and schedule parameters. The performance and scope are defined in the GRD. This includes the

requirement for upgrades of additional plasma heating and diagnostics to meet the program needs for later phases of the QPS program. The detailed implementation of these upgrades will evolve as the needs of the research program are better defined as a result of the research program.

The QPS MIE project scope includes all of the equipment required for the start of operations (First Plasma). The scope includes Title I through Title III engineering, physics analyses in support of the design, manufacturing development for certain components, fabrication, assembly and installation, integrated systems testing, and project management associated with producing the in-scope equipment. It includes field-line mapping, achievement of First Plasma, and the diagnostics and heating equipment needed at the start of the QPS research program.

The QPS project resource-loaded schedule provides the schedule and cost details for the Project's performance measurement baseline. The Primavera Project Planner commercial scheduling module will be the standard software used for the QPS project. The schedule will be organized by level and will be developed to track work at the lowest required level required for effective management. The schedule will start with the Project Summary Schedule (Level 1). This summary level schedule will identify significant DOE and project milestones and summary logic for the entire project.

The cost and schedule estimates presented in this discussion of project baselines are appropriate for this phase of the QPS Project, but will be refined during the preliminary design.

3.1 Performance Parameters at Project Completion

The milestone marking the transition from a fabrication project to an operating facility is the DOE CD 4 milestone, also known as "First Plasma". The Operations phase will begin upon completion of the First Plasma milestone, which will demonstrate a level of system performance sufficient for the start of research operations. The performance objectives at Project Completion are tabulated at the end of this sub-section in Table 3-1. Project completion is determined by testing/verification that the coil systems will perform at the levels specified in the GRD, field line mapping, and First Plasma operation with a magnetic field strength of 0.5 T and plasma created with electron-cyclotron heating.

Performance projections for QPS have some uncertainty because of the developmental nature of the design. It is prudent to set a lower level of acceptable performance as a threshold in case the cost of meeting the objective performance proves to be prohibitive. At the threshold level of performance the scope of the physics mission that could be accomplished would be reduced to a degree, but the core mission to resolve issues bearing on the attractiveness of the compact stellarator concept would not be compromised. The performance thresholds at Project Completion are tabulated in Table 3-1. The design objective is provided in parentheses when it differs from the performance threshold.

As required by DOE, a Project Completion Report will be prepared and submitted to DOE/OFES within six months of completion of the Project. This report will provide the following information:

- The actual schedule on which the project will have been completed;
- The actual cost of the project;
- The technical performance of the systems at project completion; and
- Itemized changes in cost, schedule, and technical parameters as compared to the initial baseline.

Table 3-1 MIE Project Completion Performance

	Performance Objective
First Plasma	An electron-cyclotron-heated stellarator discharge will be produced with: • major radius 0.95 m. • magnetic field of ≥ 0.5 T (1.0 T) • at least 50% of the rotational transform provided by stellarator fields. The three-dimensional stellarator geometry will be confirmed by taking video images of the plasma.
Coils and Power Supply Performance.	The coils will be energized with the baseline power supplies to the following currents (one-turn equivalent per coil): • modular coils: 150 kA (380 kA) • TF Coils: 25 kA (56 kA) • inner Coils: 65 kA (130 kA) • mid Coils: 40 kA (180 kA)
Magnet System Rating	It will be demonstrated on the basis of component design verification data that the stellarator magnet system of modular coils, TF coils, and PF coils is rated for operation to support plasma conditions with: • magnetic field of 1 T (1.0 s) • full flexibility, per the GRD.
Vacuum Vessel System Rating	Vacuum vessel system rating: • base pressure less than or equal to 2×10^{-7} Torr (1×10^{-8} Torr) • global leak rate plus outgassing less than or equal to 2×10^{-4} Torr-L/s (2×10^{-5} Torr-L/s) • operable at room temperature (150°C)
Vacuum Pumping	A pumping speed of 1,400 L/s (2,400 L/s) at the vacuum vessel.
Controls	Integrated subsystem tests, to the level required for First Plasma, will be completed for the following systems: • safety interlocks. • timing and synchronization. • power supply real time control. • data acquisition.

3.2 Fabrication Project Cost Objective

The summary QPS cost estimate is shown in Table 3-2 (in as spent dollars). This estimate was derived from the QPS Conceptual Design Review (CDR). The changes include: the impact of a delay in project start; constrained project funding; the

incorporation of management and technical recommendations from the CDR; and the modification of the CD-4 project completion objectives.

Table 3-2 Preliminary QPS Summary Cost Estimate (as spent)

WBS	Cost element	$k
1	**Stellarator Core**	**13006**
12	Vacuum vessel	1085
13	Conventional coil systems	1228
14	Modular coil systems	8832
15	Coil structures	416
16	Coil services	422
17	Base structures	104
18	Core assembly	919
2	**Auxiliary Systems**	**904**
3	**Diagnostics**	**474**
4	**Power Systems**	**457**
5	**Central I&C and Data Acquisition**	**490**
6	**Utilities**	**85**
7	**Core and Facility Integration**	**805**
8	**Project Oversight and Support**	**2978**
	Project Estimate	**19198**
	Contingency (27% average)	**5095**
	Total including contingency	**24293**

3.3 Fabrication Project Schedule Objectives

Milestones for the QPS Project are presented in Table 3-3. This schedule is based on Project funding starting in FY 2005 and on the proposed funding profile.

Table 3-3 QPS Milestones

Milestone (“A” => Achieved)	**Schedule**	**DOE Acquisition Executive (Level 1)**	**DOE Federal Project Director (Level 2)**
Complete Physics Validation Review	**April 2001 A**		**X**
Complete CD-0 Milestone	**May 2001 A**	**X**	
Select Conceptual Design Configuration	**December 2002 A**		**X**
Complete Conceptual Design Review	**June 2003 A**		**X**
Submit NEPA Preliminary Hazards Analyses	**November 2003 A**		**X**
Complete CD-1 Milestone	February 2004	X	
Complete Design of Modular Coil Winding Form	March 2004		
Award Prototype Contract for Modular Coils Winding Form	June 2004		X
Start Preliminary Design (Title I)	October 2004		X
Produce First Prototype Modular Coil Winding Form Casting for Machining	November 2004		X
Complete DOE Preliminary Design Review	April 2005		X
Complete External Independent Review	April 2005		X
Complete Final Design Review for the Vacuum Vessel	May 2005		X
Complete CD-2 Milestone	July 2005	X	
Complete Final Design Review for Modular Coils Winding Forms	August 2005		X

Milestone ("A" => Achieved)	**Schedule**	**DOE Acquisition Executive (Level 1)**	**DOE Federal Project Director (Level 2)**
Complete Prerequisites for the CD-3 Milestone for Procurement and Fabrication of Components	October 2005		X
Complete CD-3 Milestone	November 2005	X	
Award Conductor Procurement for Production Modular Coils	December 2005		X
Award Production Contract for Modular Coils Winding Forms	December 2005		X
First Modular Coil Winding Forms Delivered	April 2006		X
Award Production Contract for Vacuum Vessel	June 2006		X
Award Production Contract for TF Coils	June 2006		X
Complete First Modular Coil Fabrication	October 2006		X
Last Modular Coil Winding Form Delivered	February 2007		
Vacuum Vessel Delivered	March 2007		X
Begin Assembly of First Field Period	August 2007		X
Last Field Period Assembled	February 2008		X
Complete Machine Assembly	August 2008		X
Complete Operational Readiness Assessment	December 2008		X
Complete CD-4 Milestone (First Plasma and Completion of MIE Project)	January 2009	X	

4 PROJECT DESCRIPTION

The QPS Project involves the design and fabrication of the QPS facility. The facility is principally a plasma confinement device: the stellarator core that is shown in a cutaway view in Figure 4-1. The central element of the stellarator core is a set of 20 nonplanar coils wound on cast, stainless steel coil forms. These coils surround the highly-shaped plasma. Both the coils and plasma are inside a cylindrical vacuum tank that produces a high-vacuum plasma environment with access for heating, pumping, diagnostics, and maintenance. Additional, simpler, coils outside the vacuum tank produce the magnetic fields needed for plasma positioning, shaping and driving plasma current. The shaped plasma (magenta) is produced by the modular coils (blue, red, brown, green, and tan). The twelve auxiliary toroidal field coils are shown outside of the vacuum vessel along with the purple coils for plasma shaping and control. These coils sets, combined with control of the nine independent currents in the coil sets, provide the configuration flexibility needed for the QPS mission. The large duct is for vacuum pumping.

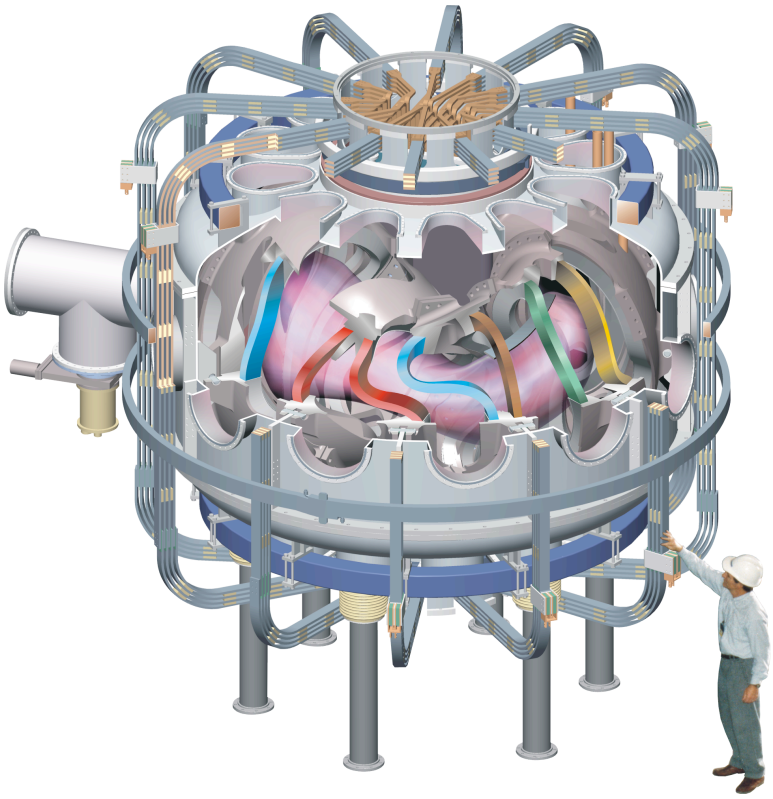

Figure 4-1 The QPS Device

The QPS project be located in a new multi-purpose building (7625) at ORNL. The building will be equipped with an electron cyclotron heating system, pumps, fueling system, diagnostics, control systems, and data acquisition systems. Site infrastructure such as high-current power supplies for the coils, high-voltage power supplies for the plasma heating systems, and utility services will be provided.

The design of the stellarator core will be accomplished by Laboratory (ORNL and PPPL) researchers and engineers. Development and manufacture of the major stellarator core components such as the coils and vacuum vessel will be done in

industry, under contract to PPPL, or by a combination of industry, UT, and ORNL/PPPL efforts. ORNL personnel will assemble the device. Ancillary systems will be assembled from a combination of new and existing equipment. Major site credits to be used are the radio-frequency heating systems, associated power supplies, a set of PF coils, and the coil power supplies originally used on the Advanced Toroidal Facility (ATF) at ORNL; the test cell and associated infrastructure; and the adjacent control and diagnostic rooms. In the final stages of the project, a program of integrated testing, field-line mapping, and plasma formation ("First Plasma") will be carried out on the device to make it ready for experimental operations.

5 ACQUISITION STRATEGY

The QPS Acquisition Strategy is being issued as part of the CD-1 approval process. The central feature of the QPS acquisition strategy and planning is the procurement of the critical components that comprise the stellarator core. The stellarator core includes the modular coils, vacuum vessel, and supplementary coil systems (e.g., toroidal field and poloidal field). In order to take advantage of similar procurements for the NCSX project, the major procurements for QPS will be the responsibility of PPPL. This approach will be used for the modular coil winding forms, the vacuum vessel, the center stack, and the toroidal field coils. The PPPL purchasing system provides a variety of source selection procedures geared to the cost and technical complexity of the product to be purchased. The major QPS procurements will be best-value procurements. For each such procurement, a subcontract procurement evaluation board (SPEB) will be appointed. The SPEB will typically include both ORNL and PPPL members and will be appointed by the PPPL source selection official (SSO) with the concurrence of the ORNL Fusion Energy Division Director. The SPEB is responsible for: developing a source selection plan for best-value procurement that meets the QPS requirements, developing the solicitation package including evaluation criteria, evaluating all proposals received, and preparing a report documenting its evaluation and recommendation to the PPPL SSO, who makes the ultimate selection decision with the concurrence of the ORNL Fusion Energy Division Director. Once the selection is made, the SPEB members work with the Procurement representative to debrief unsuccessful bidders.

PPPL will have lead responsibility for oversight of the large contracts required to execute this project. The technical representative on a contract may be an ORNL or a PPPL person, but QA oversight will be performed by PPPL. PPPL has project management, procurement management, and ES&H and QA management systems that are proven to be effective for oversight of procurements of this scale and type. While PPPL will oversee procurement of major components, ORNL's research staff is best suited to install the QPS components.

The modular coil winding forms are the highest risk components. During the NCSX conceptual design, manufacturing studies by industrial participants were conducted for NCSX to obtain feedback on planned manufacturing processes, input on feasibility issues and technical risks, and suggested manufacturing development activities to mitigate risks. In many instances, the studies carried out by the NCSX project are directly relevant to QPS and the results of these efforts will be incorporated into the

QPS project. The QPS Project will also use the results of the NCSX manufacturing development activities for the design and manufacturing of the modular coil forms. This NCSX activity is ongoing and will be used as a component in the QPS selection of vendor or vendors to fabricate the production units. For the remaining components, it is anticipated that simple build-to-print, fixed price procurements based on firm specifications are feasible.

6 LIFE-CYCLE COSTS

Although an accurate estimate of the total life-cycle cost cannot be made because it depends on the duration of the experimental program and precisely which of the equipment upgrades that are implemented, it is possible to identify the principal components. Fusion experiments like QPS typically operate for about 10 years or more. As is typical of fusion experiments, it is anticipated that additional upgrades to enhance the performance will be acquired during the project's lifetime. At this stage of the project the annual facility operating and upgrade expenses are estimated at approximately $7.5 M/year (in constant FY2003) dollars, similar to that for the University of Wisconsin, Madison Symmetric Torus, a facility comparable to QPS in size and scope. A more definitive estimate for QPS will be developed for the CD-2 project milestone.

At the end of the project's life, it is anticipated that the facility will be decommissioned and dismantled with much of the equipment likely to be re-used by other projects, as has been done with past fusion experiments at ORNL. The remaining equipment would be removed and it is expected that these activities would be routine and relatively inexpensive. Negligible amounts of radioactive activation or contamination of the structures are expected, and QPS itself is a relatively small experiment. As a result, we expect that the decommissioning costs will be relatively small. The ATF at ORNL, a somewhat larger experiment, had a decommissioning cost of $200 k (FY 1998). Based on this experience, costs in the $300–500 k (FY 2003 dollars) range are expected, but a more detailed estimate will be made for the CD-2 milestone.

In summary, the major components of the life cycle costs are:

Project MIE cost	$24-29 M (as spent)
Research preparations	$5.46 M (as spent)
Research operations	$7.5 million/year (FY 2003 dollars)
Decommissioning	$300–500 k (FY 2003 dollars)

7 ORGANIZATIONAL BREAKDOWN STRUCTURE

The QPS project will be led by ORNL with PPPL and UT as major collaborators. The parties have formed an integrated team to carry out the QPS project. Management responsibilities are clearly assigned, and ORNL has the overall responsibility for the project. The QPS project organization is shown in
Figure 7-1.

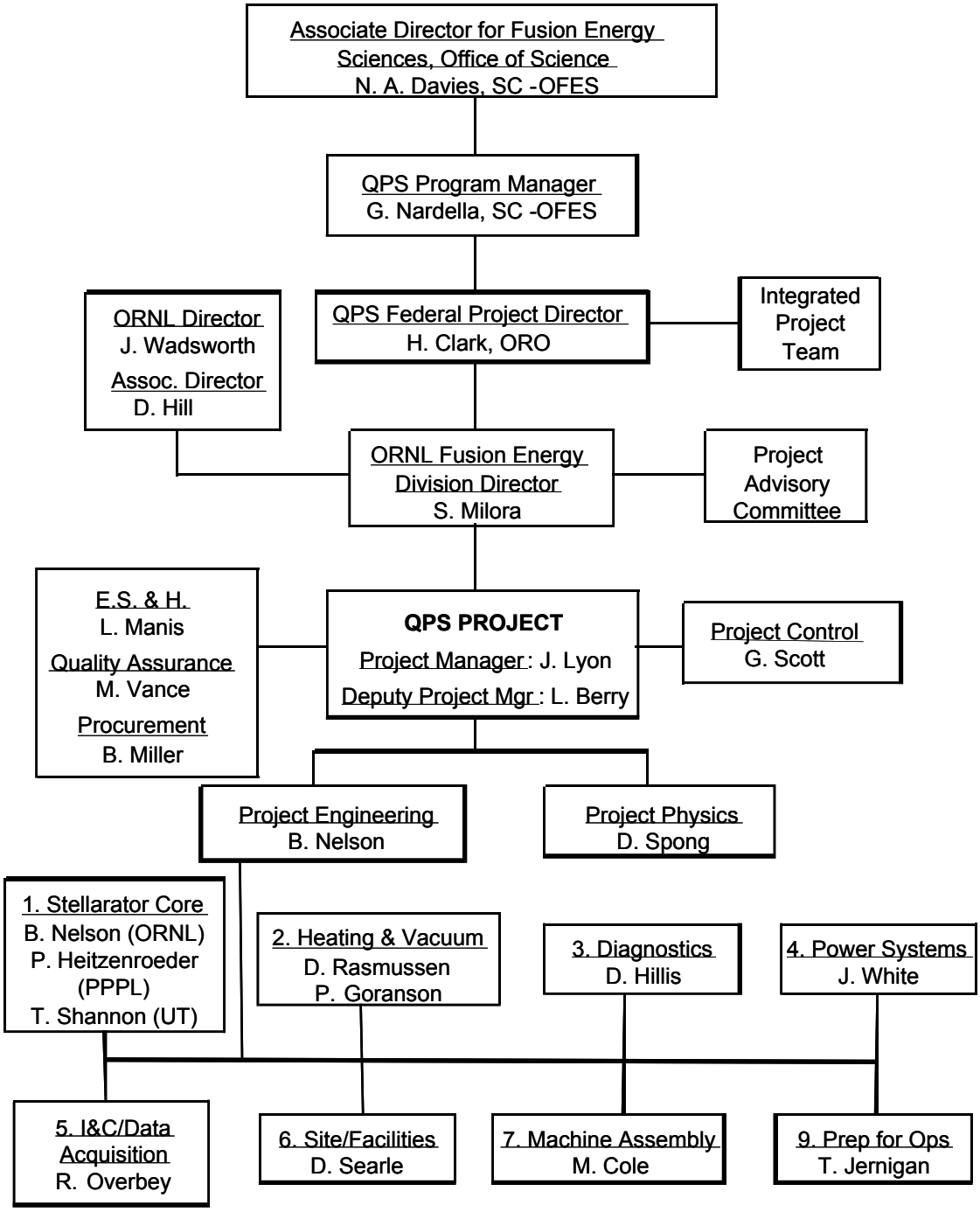

Figure 7-1 QPS Project Organization

The following paragraphs, presented by organization, describe the roles, responsibilities, and relationships among the elements of the project. More specific roles for managing contingency and management reserves are detailed in Section 18.

7.1 U.S. Department of Energy (DOE)

Within the DOE, the responsibility for the QPS Program resides in the OFES. The Associate Director for OFES has been designated as the AE for the QPS Project. However, approval of the Acquisition Strategy was not delegated, and this plan was approved by the Director of the Office of Science. OFES will also maintain executive level awareness of project progress, and an OFES QPS Program Manager has been assigned.

The OFES QPS Program Manager is:

- Responsible for programmatic guidance, including defining project objectives, scope, schedule and cost.
- Responsible for allocating project funding.
- Responsible for coordinating the organization and implementation of major project reviews (e.g. Physics Validation Review, Conceptual Design Review, etc.)
- Responsible for project oversight at an executive level.

The management responsibility, authority, and accountability for the day-to-day execution of the QPS Project within the DOE are the responsibility of the DOE ORNL Site Office Manager. Major authorities and responsibilities for the QPS project have been delegated to the QPS Federal Project Director.

The QPS Federal Project Director (DOE-ORO) is:

- Responsible and accountable for planning and implementing, and completing the project using a systems approach.
- Organizing and directing the Integrated Project Team (IPT) that is comprised of both DOE and QPS Project team personnel to implement and achieve the overall project objectives and goals.
- Responsible for overseeing implementation of the project objectives, scope, schedule, and cost, including:

- Overseeing the design, fabrication, environmental, safety, and health efforts, including risk management, performed by the ORNL and PPPL team and their subcontractors, and other functions enumerated in the Project Execution Plan, in accordance with public law, regulations, and Executive orders.
- Serving as the point of contact between federal and contractor staff for all matters relating to the QPS Project and its execution.
- Performing all required project status reporting to both DOE ORO and DOE Headquarters (HQ) organizations.
- Adding additional DOE-ORO personnel as appropriate to ensure the project's success.

7.2 DOE Contractor Organizations

7.2.1 Oak Ridge National Laboratory

ORNL has overall responsibility for QPS project execution, reporting to DOE through the Director of the ORNL Fusion Energy Division. Project support in the areas of Quality Assurance and Environment, Safety and Health (ES&H) are provided by ORNL. Major hardware procurements will be placed through the ORNL and PPPL procurement organizations.

7.2.2 Princeton Plasma Physics Laboratory

PPPL is a collaborator in the QPS project with key responsibilities. In order to take advantage of similar procurements for the NCSX project, PPPL will be responsible for the modular coil winding forms, the vacuum vessel, the center stack, and the toroidal field coils. Within the PPPL organizational structure, the QPS Project activities are accomplished within the Advanced Projects Department.

7.2.3 Other Organizations

All other participants (i.e., industrial or university organizations, including UT) are subcontractors to either ORNL or PPPL.

7.3 QPS Management Team

The responsibility for QPS is assigned to the ORNL's Fusion Energy Division. The FED Division Director reports to the ORNL Director through the ORNL Associate Director for Energy and Engineering Sciences.

7.3.1 QPS Project Management Team

<u>QPS Laboratory Project Manager</u>

The QPS Project Manager is responsible for the day-to-day execution of the QPS project in a cost-effective manner, in accordance with requirements, procedures and standards, as set forth in the ORNL contract with DOE. This includes executing the technical, cost, schedule, project control, risk management, ES&H, and quality assurance aspects of the project within approved cost, schedule, and scope baselines, as defined in the Project Execution Plan and the contract. He is the project's primary point of contact with DOE and with the Project Advisory Committee. He reports to the Director of the ORNL Fusion Energy Division.

<u>Deputy Project Manager</u>

The QPS Deputy Project Manager supports the Project, especially on programmatic issues. He reports to the Project Manager.

<u>Project Manager for Engineering</u>

The QPS Project Manager for Engineering supports the Project Manager, especially on manufacturing and overall engineering issues. He reports to the Project Manager.

<u>QPS Project Physics Head</u>

The QPS Project Physics Head is responsible for the physics requirements and supporting physics analyses as necessary. He reports to the Project Manager.

The QPS Project Control Manager

The Project Control Manager reports to the QPS Project Manager and is responsible for all project control and administrative functions necessary to support QPS Project activities.

The QPS Project Control Manager's support responsibilities include:

- Coordinating the development of project plans and administering the centralized Work Authorization system;
- Maintaining up-to-date QPS cost and schedule baselines that are consistent with the technical baseline;
- Coordinating the preparation of statements of work, sole source justifications (as appropriate), the processing of requisitions, and tracking of procurements and subcontracts supporting the project;
- Establishing, maintaining, and monitoring project budgets and schedules to ensure consistency with project control milestones and funding;
- Operating the ORNL PCS as the Project Control System for the QPS Project.
- Assisting the Project Engineering Manager in administering the operation of the QPS documentation, configuration management, requirements definition, and design description systems;
- Serving as the primary point-of-contact to ORNL Business and Information Systems functions; and
- Performing administrative functions such as space planning, facility maintenance coordination, travel approvals and vouchers, and overall personnel planning.

Control Account Managers

The project organization for carrying out tasks is structured according to the WBS. A Control Account Manager is assigned to a task or group of tasks at the optimal WBS level according to a risk-based, graded approach. In some instances, this "optimal" level may be at WBS Level 2 and sometimes at a lower level. Because of the importance (cost and criticality) and complexity of the Stellarator Core (WBS 1), Control Account Managers have been assigned to lower level WBS 1 elements (e.g., WBS 11, WBS 12 .). Each Control Account Manager is responsible for the execution of the work scope in the WBS element. The Control Account managers report to the Project Engineering Manager.

Quality Assurance (QA) and Environment Safety & Health (ES&H)

A QPS QA Specialist and a QPS ES&H Health and Safety Specialist are assigned to support the QPS Project Manager. A brief description of their responsibilities follows.

The QPS QA Specialist, with the support of the entire QA Division, will assist the project in meeting quality assurance/control objectives. Support tasks include:

- Preparing a project QA plan;

- Assisting in the development of project procedures, policies, and other plans, as requested by project management;
- Providing quality related services such as inspections and support of procurements; and
- Performing both compliance-based and performance-based audits of the project and its associated plans and procedures

The QPS Health and Safety Specialist will assist the project in meeting ES&H objectives. These include safe execution of the project and producing a facility that will be safe to operate. He will assist in implementing ORNL ES&H policies and procedures. The QPS Health and Safety Specialist will prepare any required National Environmental Policy Act (NEPA) documentation and a Safety Assessment Document (SAD).

While their normal reporting relationship is to the QPS Project Manager, both individuals have a direct line of reporting to the ORNL Head of ES&H and Quality for items involving overall QA and ES&H impact.

7.3.2 Project Advisory Committee

The QPS project is advised by a Project Advisory Committee (PAC) that reports to the ORNL Fusion Energy Division Director and provides broad-based input to the project from the fusion research community. The committee is composed of senior U.S. and foreign fusion scientists with broad expertise. The membership was selected to give an overlap with the NCSX Program Advisory Committee and to have knowledgeable NCSX team members from PPPL to ensure that the committee would be knowledgeable about compact stellarator issues and to have better interaction between the NCSX and QPS projects. The PAC meets about once a year. As the experimental program nears, a Program Advisory Committee will be formed with representation from the institutions collaborating on QPS and senior U.S. and foreign fusion scientists. This committee would meet about twice a year to give advice on the development of the QPS experimental program.

7.3.3 Integrated Project Team (IPT)

The QPS IPT is made up of key DOE and QPS Project Team personnel and is led by the QPS Federal Project Director. The IPT holds teleconference meetings approximately monthly, plans the major project reviews, and guides preparation of documentation for all critical decisions. All members of the team participated in the development of the Acquisition Strategy and the Preliminary Project Execution Plan. Consistent with DOE Order 413.3 and DOE Manual 413.3-1, there is an appropriate mix of skills among the team members to successfully execute the QPS MIE project. While the makeup of the IPT will evolve as the project matures, the initial makeup of this cross-functional team includes the following personnel:

- The QPS Federal Project Director;
- The OFES QPS Program Manager;
- The QPS Laboratory Project Manager;

- The QPS Deputy Project Manager;
- The QPS Project Control Manager;
- The QPS Engineering Manager; and
- The NCSX Laboratory Project Manager

Other DOE, QPS Project Team, and ORNL, PPPL, and UT personnel may be added as the need arises in order to accomplish the QPS Project objectives.

7.4 Funds Management

7.4.1 Project Funding Mechanisms

ORNL and PPPL will each be funded directly via DOE Budget and Reporting (B&R) lines. The exact split between ORNL and PPPL will be negotiated each year using the resource-loaded schedule as the guide. Participation of other organizations other than other DOE National Laboratories will be funded by either ORNL or PPPL through subcontracts. Transfer of funds from ORNL to PPPL or vice versa will be accomplished by Financial Plan transfer requests to DOE. All project work and expenditure of project funds will be centrally authorized and controlled by the project office via the PCS. The annual QPS funding requirements will be updated each year by ORNL and PPPL through their respective DOE Field Work Proposal (FWP) processes.

7.4.2 Management Reserve Funds

All funds authorized for the Project by the DOE Financial Plan will be disbursed to the Project (ORNL and PPPL). Management reserve funds are a portion of each year's approved funding allowance that are set aside at the beginning of each fiscal year instead of being immediately used to authorize work. Management reserve funds will be held in a unique management reserve account controlled by the QPS Project Manager. As needs arise, the Project Manager will authorize disbursement of the management reserve funds to authorize as yet unfunded work scheduled for the current year or future years, or resolve approved changes arising within the current year's authorized scope of work. When such changes require the application of contingency, they will be handled via the change control process defined in Section 18 and will, as stated there, require DOE approval. As part of the reporting process, the QPS Project Manager will report on management reserve disbursements regularly and as part of the cost and schedule project review meetings with DOE.

7.5 Cost and Schedule Reviews

Quarterly the QPS Federal Project Director will provide a project status report to OFES Management. Annually, the QPS Project will perform a bottoms-up cost estimate to ensure that the current cost and schedule baseline remains up-to-date and self-consistent with the technical baseline. Based on these inputs the project will recommend to DOE changes to the Project Baseline. This recommendation will be documented in the form of a formal change. In addition, independent reviews will be requested by OFES and organized by the Office of Science Office of Construction Management Support (the "Lehman" Review).

8 WORK BREAKDOWN STRUCTURE

The WBS organizes the QPS project work scope and provides the logical structure that will be used to control the project. The WBS is developed in an outline format with the number of levels determined by the need for efficient work definition and control. The first digit in the WBS is designated "level 2," the second digit "level 3," etc. (Level 1 is implicitly the QPS Project itself.) The Level 2 WBS matrix is provided in

Table 8-1, with the Stellarator Core (WBS 1) expanded to level 3 due to its importance. All the WBS elements are expanded and more completely defined in a series of separately-issued and approved set of WBS dictionaries. The WBS Dictionary for each WBS element contains a brief description of the work scope for each element. As specified in the GRD, this work scope includes design work necessary to assure that required future upgrades can be accommodated.

Table 8-1 QPS Work Breakdown Summary

Level 2 WBS Number	Level 2 WBS Title (Level 3 expansion)
WBS 1	Stellarator Core Systems—
WBS 1	In-Vessel Components (WBS 11) Vacuum Vessel Systems (WBS 12) Conventional Coils (WBS 13) Modular Coils (WBS 14) Coil Supports (WBS 15), Coil Services (WBS 16), Machine Base (WBS 17) Stellarator Core Assembly (WBS 18)
WBS 2	Auxiliary Systems
WBS 3	Diagnostics
WBS 4	Power Systems
WBS 5	Central I&C and Data Acquisition
WBS 6	Utilities
WBS 7	Core and Facility Integration
WBS 8	Project Oversight and Support

9 RISK ANALYSIS AND RISK MANAGEMENT

The QPS project will analyze and manage risks, where “risk” refers to factors within the project’s control that threaten project performance, namely:

- Technical risk—the possibility that the product might not meet requirements.
- Cost risk—the possibility that the cost might exceed the target value.
- Schedule risk—the possibility that the project might take longer to complete than planned.

Although risk management is everyone’s business and will be factored into every project decision throughout the life of the project, the responsibility for risk

management rests with the QPS line management. The Systems Integration Team will facilitate the identification of areas of risk; coordinate the development of risk mitigation plans; and monitor performance against those plans. The design engineers, with the appropriate management oversight, establish the specific approaches to addressing the individual risk elements. The QPS project design process is structured to identify risks. These risks are addressed through design improvements, manufacturing studies, prototypes, schedule contingency and cost contingency. In many cases the risk mitigation comprises several of the above listed mitigation elements. A risk listing and tracking approach is applied to avoid overlooking important risks and to assure that the risk mitigation has adequate management oversight. The QPS Risk Management Plan (ORNL/CF-03/31) provides more details on the QPS Project approaches to minimizing and mitigating risk. Control of environment, safety, and health hazards, while part of risk management in a broader sense, is covered in other sections.

10 SYSTEMS ENGINEERING AND VALUE MANAGEMENT PLANNING

10.1 Systems Engineering

Project Engineering has responsibility for implementing a systems engineering program on QPS. The systems engineering program includes the development and allocation of requirements; system design and verification; risk management; value engineering; configuration management; interface management; data management; and technical reviews. The systems engineering program is described in the QPS Systems Engineering Management Plan.

10.2 Value Management Planning

Value Engineering (VE) is the systematic application of recognized techniques by a multidisciplinary team to identify the function of a product or service, establish a worth for that function, generate alternatives through the use of creative thinking, and provide the needed functions to accomplish the original purpose of the project at the lowest life-cycle cost without sacrificing safety, necessary quality, and or environmental attributes of the project. The QPS Project will apply VE methodologies following a tailored approach to the formal elements of VE. The QPS approach includes:

- Using a multi-disciplinary team to identify and assess alternates;
- Following a systematic job plan;
- Identifying and evaluating function, cost and worth;
- Developing and evaluating new alternatives for required functions; and
- Developing and implementing recommendations.

The QPS Project has applied value engineering methods early in the design process, starting with the pre-conceptual design. Examples include examining the tradeoffs between performance and cost for: two field periods versus three field periods; reusing poloidal coils from previous fusion facilities; an internal vacuum vessel versus an external vacuum vessel; combining two modular coil winding packs into one winding

form; reducing the number of different winding forms from four to three; reducing the number of winding packs from 32 to 20; increasing the space in the middle for the central legs of the TF coils and an Ohmic-current solenoid; increasing the space between the plasma and the coils and between coils in different winding forms; and the height of the center stack solenoid coils.

The project will continue to apply a Value Engineering philosophy at the day-to-day level and will continue to conduct formal Value Engineering studies as we enter the Preliminary Design phase. During the work planning process it will be determined what design areas would benefit from additional value engineering assessments. These assessments will be conducted and documented.

10.3 Quality Assurance

The QPS Project QA Plan will demonstrate how the existing ORNL-FED and PPPL QA Plans and implementing policies and procedures, in conjunction with additional QPS specific plans, policies, and procedures will satisfy the requirements of the DOE Order on Quality Assurance, 414.1A, and provide an appropriate level of quality on the project.

11 RESOURCE REQUIREMENTS

11.1 Budget

The lower end of the range for estimated budget requirements for the QPS project is shown in Table 11-1. This estimate is derived from the QPS Conceptual Design estimate (see discussion in Section 3.2) and is the basis for the lower end of the project cost-range objective of $24-29 M.

Table 11-1 Estimated Budget QPS Budget Requirements

	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	Total
Project Estimate	$4.50M	$5.79M	$4.72M	$3.94M	$0.25M	$19.20M
Contingency	$0.51M	$0.51M	$1.53M	$1.78M	$0.76M	$5.09M
Total B/A needed for MIE project	$5.01M	$6.30M	$6.25M	$5.72M	$1.01M	$24.29M

It should be noted that, in addition to the MIE project, there are non-project activities in preparation for the QPS program that are budgeted in the "Research Preparations" category. These activities include, as examples, diagnostics and heating systems work for phases of the QPS Program after First Plasma.

11.2 Staffing

The QPS estimate presented in Table 11-1 is based on a on a bottoms-up estimate of costs, including staffing. The staffing levels derived from this estimate for the MIE portion of the project are presented in Table 11-2. Additional staff to support the research preparations component of the QPS program is planned.

Table 11-2 QPS MIE Project Staffing Estimates in Person-Years (PY)

	FY2005	FY2006	FY2007	FY2008	FY2009
ORNL Engineering and Design	6.9	4.2	3.4	3.5	1.0
ORNL Staff	0.7	0.7	0.8	0.8	0.2
ORNL Operators and Craft	0.3	1.3	2.9	6.0	0.4
PPPL Engineering and Procurement	1.0	2.5	1.1	0.8	0.2
PPPL Staff	0.1	0.1	0.1	0.1	0.0
Total MIE project	9.1	8.7	8.3	11.3	1.9

11.3 Support Contracts

No support contractors are planned for the QPS project.

12 PLANNED MAJOR PROCUREMENTS

Major procurements for the QPS project include the modular coils; modular coil structure; external vacuum vessel; auxiliary toroidal coils; and poloidal coils for plasma shaping, positioning, and for driving a plasma current. The poloidal coil-pairs will have been salvaged from the ATF at ORNL and the Princeton Beta Experiment at PPPL. The acquisition strategy for these components was addressed in Section 5.

13 PROJECT CONTROL AND REPORTING SYSTEMS

13.1 Project Management Systems Approach

The QPS Project Manager will ensure that all project activities are properly controlled using ORNL's Project Control System (PCS). This system will be used as a management aid in planning and executing the project work scope and evaluation of schedule and budget performance. The status of progress and variance in the WBS elements will be reported monthly to the QPS Project Manager. The QPS Project Manager will work to ensure early detection of technical, schedule or cost problems through regular meetings with the Systems Integration Team (SIT) and regular evaluation of project earned value metrics. As areas of concern are identified, they will be proactively managed for early correction and remediation. The functions of the SIT are described in the SEMP (TBP).

13.2 Project Control System Overview

The QPS Project will use the ORNL PCS as described in the ORNL Project Control System Description, which is available as a separate ORNL document. The system described in this document will be submitted to DOE for validation by June 30, 2004. The ORNL PCS satisfies the principles of project management and control systems outlined in this PPEP and DOE Order 413.3 ("Program and Project Management for the Acquisition of Capital Assets"). ORNL, PPPL and other participants will utilize the ORNL PCS to ensure that the entire project cost and schedule performance is measured. The ORNL Engineering Business Management function of the PCS includes the application of sound management principles to provide an integrated, systematic approach used to facilitate efficient planning, organization, budgeting, and control of programs, projects and tasks applied in a graded approach. The assessment

provides visibility of all key decisions based on an analysis of scope, schedule, estimated cost, actual cost, available funding, manpower resources, and performance measurement.

The PCS is an integrated earned value management control and reporting system that establishes the documentation, data requirements, information flow, and system disciplines necessary to operate and maintain a system for control of the QPS Project work, costs, and schedules. The overall objective of the PCS is to provide ORNL and DOE with timely and auditable cost and schedule performance information in order to effectively manage Project scope and progress.. To accomplish this objective, the PCS provides a formal process for:

- Organizing the project work scope via the WBS;
- Planning and estimating the work scope via the project resource loaded schedule;
- Authorizing work and forecasting resource requirements via work authorizations;
- Controlling management reserve and authorized allocated contingency via the change control process;
- Monitoring progress relative to schedule status and completion estimates and reporting cost and schedule performance against established cost and schedule baselines using the Level III schedules;
- Documenting approved changes to the performance measurement technical, cost, and schedule baselines via the change control process; and analyzing variances to the cost and schedule baselines, including critical path analyses resulting from status results of the Level III schedules.
- Monitoring project scope and progress against the Risk Management Plan on a regular basis and taking corrective action, as needed.

The key planning and measurement metric for the project is the Level III schedule, but the ORNL and PPPL work authorization processes form the basis for development of these schedules. Through the work authorization process, details of work scope, schedule, budget, and responsibility will be integrated, documented, reviewed, and agreed to by both project management and the performing organization. The cognizant job manager will be responsible and accountable for accomplishing the scope of the work, as defined, with established schedule and cost targets. The vehicle for documenting and authorizing work is the Work Authorization Form which formally documents the work scope to be performed, establishes a schedule, provides a cost estimate, identifies a responsible person for accomplishing the work, and provides time-phased cost and manpower profiles.

13.3 Project Reporting

Quarterly project reports will be prepared for the QPS Federal Project Director and OFES Program Manager. However, to foster and facilitate visibility into project status

all monthly PCS status will be provided to the QPS Federal Project Director and assessed at monthly meetings of the Integrated Project Team (chaired by the Federal Project Director). The DOE QPS Federal Director is responsible for entering monthly performance data into the DOE Project Assessment and Reporting System (PARS) database.

13.4 Data Management System

A system for controlling documents and drawings, adapted from existing ORNL document and drawing control systems using hard copy and electronic media, will be developed to ensure the organized and consistent treatment and format of QPS documents including procedures, plans, memos, drawings, calculations, requirement documents, design documents, and procurement documents. This system will utilize web-based file servers for rapid review, authorization, updating, and retrieval of documents and drawings. The majority of project documents (other than drawings) can presently be retrieved from the QPS web page located at http://qps.fed.ornl.gov. Drawings in electronic format can be accessed via the Pro/INTRALINK database. Legacy drawings only in hard copy can be obtained from the ORNL Engineering File Storage System. The QPS project will develop a separate Document and Records Plan that identifies documents to be controlled on the project, including the document's purpose, approval level, format, naming convention, and records retention requirements. A Data Management Plan that describes the processes to be used for document and drawing control will be developed. Processes for effecting changes to controlled documents will be described in the Configuration Management Plan. All participants are encouraged to use the project standards for documents of either the Macintosh or PC versions of Microsoft Word, Microsoft Excel, or Microsoft PowerPoint.

14 SITE DEVELOPMENT, PERMITS, AND LICENSING

The QPS experiment will be located in the 7600 area at the Oak Ridge National Laboratory. A new, multipurpose building (7625) is being built as part of the Fusion Energy Division move from the Y-12 site to the X-10 site. This building would be constructed independent of the QPS project. In addition to QPS, the new building will house a range of plasma physics and related technology programs in support of DOE programs both inside of and outside of the Office of Science. The DC and radio-frequency power systems that are required for QPS and these other programs will be moved from Y-12 and integrated with the new utility systems. All site development will be accomplished as part of the building fabrication effort. The 7600 area has been the site of ongoing ORNL science and technology programs, and existing permits are expected to cover the additional research efforts. A NEPA Action Review Documentation Form has been submitted to support the needed decisions.

15 INTEGRATED SAFETY MANAGEMENT

In September 2000, the DOE formally verified the implementation of ISM at ORNL. Since that time, the ORNL has built on the ISM through deployment of an integrated set of Standards-Based Management Systems (SBMS). The ISMS Program Description was issued in April 2001 as an ORNL Directive under the Worker Safety

and Health Management System to provide the institutional framework for ISM deployment and to define other ORNL management systems that would serve as contributing inputs to the ORNL ISMS approach. The QPS Project intends to follow that implementation for ISM for the conduct of QPS work performed at ORNL. PPPL, UT, and other subcontractors, vendors and collaborators are responsible for safety at their respective sites. ISM at ORNL is comprised of both a set of policies and procedures and the over arching principle that safety be integrated into work management and work practices at all levels.

The "core functions" of ISM include the following five-step process:

- Defining the scope of work;
- Analyzing the hazard;
- Developing and implement hazard controls;
- Performing the work within these controls;
- Providing feedback and continuous improvement to this process.

The QPS project will incorporate these ISM core functions of folding safety into the work planning, establishing appropriate controls, operating within established parameters, and feedback. More specifically, the QPS project will incorporate ISM into its management approach as follows:

- By accepting responsibility for safety as a line management responsibility. The QPS Project Manager is responsible for safe execution of the project.
- By following applicable procedures for work planning. The SBMS provides a current reference to relevant federal, state, and contractual requirements and implementing procedures.

Where project-specific procedures must be developed, ISM principles will be incorporated into them.

16 RESEARCH AND DEVELOPMENT, ALTERNATIVE STUDIES, TRADE STUDIES

16.1 Research and Development

The modular coils and modular coil forms are the most significant components requiring research and development (R&D). With few exceptions, the design approach closely follows that of NCSX and the QPS Project will utilize the results of that R&D. The NCSX modular coil R&D plans are documented in the NCSX Preliminary Design Review. Because ORNL has the responsibility for the NCSX Stellarator Core WBS, including the modular coils, the NCSX experience is closely coupled to QPS.

The QPS coils differ from those for NCSX in that the coils must be closed to vacuum because of the external vacuum vessel that houses the modular coils. Thus, R&D to test the coil form closure design is planned. In addition, because the coil winding forms are exposed to the plasma, baking is a requirement. The bakeout temperature is presently under study, and, if the bakeout temperature is above 120 °C, a different

potting compound must be employed and at least some of the NCSX R&D repeated for the QPS material.

Measurement techniques for verifying coil dimensions and for the stellarator core assembly are a second area of common R&D for NCSX and QPS. QPS will employ instruments and techniques similar to those that are developed for NCSX.

16.2 Alternative Studies

Two types of alternatives were considered for the QPS mission. First, the use of planned or existing facilities was evaluated as potential sources of the required data. The mission need for both low aspect ratio and quasipoloidal symmetry do not exist in any one facility, thus precluding that alternative. The planned QPS will be, by a significant margin, the lowest-aspect ratio stellarator in the international magnetic fusion effort.

The second class of alternatives involved the size and magnetic field capability needed to address the QPS mission. The size of ~2 m^3 and average magnetic field of 1 T were derived at as a tradeoff between lower risk (higher fields and larger magnetic volumes) and higher cost. Input and review by stellarator experts in the U. S. Magnetic Fusion program have validated these global choices.

16.3 Trade Studies

The starting point for the QPS design was, in essence, a trade study based on a computer based optimization model. This model, Stellopt, employed a range of physics and engineering objectives and constraints ("targets") to arrive at an optimum design. With regard to specific issues, as cited in the discussion of Value Engineering, Section 10.2, specific trade studies have been a continuing activity in development of the QPS design. Examples include internal versus external vacuum vessel, number and symmetry of modular coils, winding form concept, and center stack height.

Future trade studies will be conducted with in the framework of QPS Value Engineering task, Section 10.2.

17 PLANNED DESIGN REVIEWS

Planned major design reviews include the External Independent Review and "Lehman" reviews needed for the CD-2 project milestone. In addition, technical design reviews will be held for critical procurement packages. These packages include the modular coil winding forms; modular coil winding, vacuum impregnation and closure; and the external vacuum vessel (particularly with regards to the center stack assembly). In addition, all components will be continuously monitored with respect to risk, and specialized reviews will be held as required.

18 CHANGE CONTROL AND MANAGEMENT

18.1 Control of Project Baselines

18.1.1 Configuration Management Approach

Changes to the QPS configuration, cost, and schedule baselines will be controlled using a disciplined, yet flexible configuration management approach. This approach will ensure that the configuration, cost, and schedule baselines are controlled at the appropriate level for the respective stages of the Project as defined in Office of Science ESAAB equivalent procedures dated January 2001. Changes to the baseline will be carefully considered and evaluated for impact before proceeding. Processes for effecting changes to the configuration, cost, and schedule baselines are described in the QPS Configuration Management Plan.

18.1.2 QPS Change Control

The QPS change control process ensures that changes to the design and requirements are properly identified, screened, evaluated, implemented, and documented. A formal procedure will be established to implement the process of change classification and submittal of supporting documentation at the beginning of Preliminary Design. Once an Engineering Change Proposal (ECP) has been prepared and the impacts fully documented, the ECP will come before a project Change Control Board (CCB) that is comprised of senior members of the QPS management team. The QPS Project Manager or his designee will chair the CCB. The QPS Systems Engineering Support Manager will serve as the CCB Secretary. Other members of the CCB will be assigned as appropriate, but may include the following:

- QPS Project Control Manager;
- QPS Engineering Manager;
- QPS Physics Head;
- WBS Managers;
- ES&H representative;
- QA representative;
- Other cognizant job managers impacted by the proposed change.

The chairperson shall have the ultimate authority to recommend changes for the final approval; other board members act solely as advisors. Once a proposed change is approved, the project will implement the change in a timely manner. An updated list of approved, disapproved, and pending changes will be maintained electronically by Project Engineering on the QPS File Share System.

18.2 Change Control Levels

Changes to the QPS configuration, cost, or schedule baselines will be classified according to their impact on the project. The change approval levels are established consistent with the technical, cost, and schedule risk and are intended to feed into the higher level DOE configuration change system. The following tables summarize the

performance baseline change authority for the Director of the Office of Science (Table 18-1), the Associate Director of OFES (
Table 18-2), the QPS Federal Project Director (Table 18-3), and the QPS Project Manager (Table 18-4).

Table 18-1 Performance Baseline Change Authority
Director of the Office of Science

Type of Change	Approval Authority
Technical	Any change in scope and/or performance that affects mission need requirements or is not in conformance with the currently approved OMB 300.
Schedule	Six month or greater increase (cumulative) in the original project completion date.
Cost	Increase in excess of 25% (cumulative) of the original cost baseline.

Table 18-2 Performance Baseline Change Authority
Associate Director for Fusion Energy Sciences, Office of Science

Type of Change	Approval Authority
Technical	Changes to technical requirements and parameters that affect safety basis and operation function, but do not affect mission need objectives.
Schedule	Three to six month increase (cumulative) in the original project completion date.
Cost	Increase of the original cost baseline.

Table 18-3 Performance Baseline Change Authority
QPS Federal Project Director

Type of Change	Approval Authority
Technical	Technical Changes with ES&H impacts significant enough to affect the approved NEPA/EA documentation.
Schedule	Less than three month increase (cumulative) in the original project completion date. Change in DOE level 2 milestone.
Cost	Cost Changes requiring the use of contingency funds.

Table 18-4 Performance Baseline Change Authority
QPS Project Manager

Type of Change	Approval Authority
Technical	Technical Changes to the GRD and all other changes not requiring DOE approval.
Schedule	All other changes to the performance measurement baseline schedules not requiring DOE approval.
Cost	All other changes to the performance measurement baseline costs not requiring DOE approval.

18.3 Contingency Management Plan

The amount of contingency is established at the beginning of the project based on a risk assessment performed as part of the cost estimating process. A formal risk-assessment methodology that considers technical, cost, and schedule risks at the subsystem level, is performed, using a high-medium-low risk classification. This methodology is outlined in Annex I to this plan. The initial project contingency level will be approved by the Associate Director for Fusion Energy Sciences as the Acquisition Executive for QPS at CD-2 as part of establishing the overall cost and schedule performance baselines. Based on experience with similar projects, changes in scope of work and schedule, requiring the application of contingency, typically arise as a project proceeds. Changes involving the application of contingency must be approved by the QPS DOE Federal Project Director via the configuration control process. Cost and schedule performance measurement baselines and remaining contingency will be adjusted upon approval of change proposals.

Each fiscal year the QPS Project Manager will assess the status of authorized work, achieved milestones, and current and future risks, to determine how to apply remaining management reserve (Section 7.4.2) funds under his control. They can be used to authorize as yet un-funded work planned for the current or future years, to fund approved changes, or a combination of these. This decision will occur early enough in the fiscal year to permit effective use of these funds.

19 INSPECTION, TESTING, TEST EVALUATION, TURNOVER, AND STARTUP

Testing and inspections that are needed for development, fabrication, and procurement activities will be specified on a case-by-case basis as required. The level and rigor of these activities will be sufficient to ensure the required functionality and level of risk for that component or process. Assembly will have specific inspection and test plans because of the need for maintaining the required tolerances for acceptable field errors and because of the need for acceptable vacuum leak rates. Turnover and startup planning and tasks will be addressed in the QPS Test, Evaluation, and Operational Readiness Plan as indicated below.

20 TRAINING AND OPERATIONAL READINESS PLANS

Operator training and the steps required to bring the QPS to the start of operations will be developed in the QPS Test, Evaluation, and Operational Readiness Plan (TBP)

ANNEX 1 QPS CONTINGENCY GUIDELINES

Cost Contingency Overview

Contingency is the amount of additional money, above and beyond the base cost, that is required to ensure the project's success from a cost perspective.

Contingency Estimating Procedure

Each WBS Manager develops a contingency estimate by assessing risk and weighting factors in three areas: technical, schedule, and cost. Although the Manager has the option to modify the following procedure as appropriate to reach a more appropriate level of contingency for his sub-system, it should be utilized as a starting point.

The contingency is based on a risk level (1–15) times a weighting factor in percent (1-4%) in each of three areas: technical, schedule, and cost. The risk factors are obtained by comparing the conceptual state of the subsystem design with the descriptions contained in Table Annex 1-1. The weighting factors are obtained from Table Annex 1-1. Once the Risk Factor and Weighting Factor is determined for each of the three areas multiply the individual risk factors by the appropriate weighting factors and then summed to determine the contingency percentage for each area. The contingency percentages for each area are then summed to arrive at a composite contingency percentage. The dollar amount of contingency will be determined by multiplying the base estimate (MIE + OPEX) by the calculated composite contingency percentage.

Table Annex 1-1 Technical, Schedule, & Cost Risk Factors

Risk Factor	*Technical*	*Schedule*	*Cost*
1	Existing Design and Off-the-Shelf H/W	*Not Used*	Off-the-Shelf or Catalog Item
2	Minor Modifications to an Existing design	No Schedule Impact on Any Other Subsystem	Vendor Quote from Established Drawings
3	Extensive Modification to an Existing Design	*Not Used*	Vendor Quote with Some Sketches
4	New Design, but Nothing Exotic	Delays Completion of Non-Critical Path Subsystem Activity	In-House Estimate Based on Previous Similar Experience
6	New Design, Different from Established Design Or Existing Technology	*Not Used*	In-House Estimate with Minimal Experience, but Related to Existing Capabilities
8	New Design that Requires Some R&D, but Does Not Advance the State-of-the Art	Delays Completion of Critical Subsystem Activity	In-House Estimate with Minimal Experience and In-House Capabilities
10	New Design Development of New Technology that Advances the State-of-the Art	*Not Used*	Top-down Estimate Based on Experience from Analogous Programs
15	New Design, Way Beyond the Current State-of-the-Art	*Not Used*	Engineering Judgment

Table Annex 1-2 Technical, Schedule & Cost Weighting Factors

Area	Condition	Risk %
Technical	Design OR Manufacturing Uncertainties	2%
	Design AND Manufacturing Uncertainties	4%
Schedule	Same for All Cases	1%
Cost	Material Cost OR Labor Rate Uncertainties	1%
	Material Cost AND Labor Rate Uncertainties	2%