Preliminary

Project Execution Plan

for the

**STAR Heavy Flavor Tracker Project**

**(HFT)**

**MIE – 01VB**

**at**

**Brookhaven National Laboratory**

**Upton, NY**

**For the U.S. Department of Energy**

**Office of Science**

**Office of Nuclear Physics (SC – 26)**

**June 2010**

**Project Execution Plan**

**for the**

**STAR Heavy Flavor Tracker (HFT) Project**

DEPARTMENT OF ENERGY BROOKHAVEN NATIONAL LABORATORY

Submitted by:

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**Preliminary Project Execution Plan**

**Heavy Flavor Tracker Project (HFT)**

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# Introduction

Brookhaven National Laboratory (BNL), located in Upton, NY, is owned by the U.S. Department of Energy (DOE) and operated by Brookhaven Science Associates (BSA) under the U.S. Department of Energy Contract No. DE-AC02-98CH10886. The flagship Nuclear Physics facility at BNL is the Relativistic Heavy Ion Collider (RHIC). Collisions at the intersection of RHIC’s two rings are studied by two detectors, STAR (Solenoidal Tracker at RHIC) and PHENIX (Pioneering High Energy Nuclear Interacting Experiment). The goal of STAR is to obtain a fundamental understanding of the interactions between quarks and gluons, and the Heavy Flavor Tracker (HFT) upgrade will extend STAR’s capabilities.

On February 18, 2009 Eugene A. Henry as the Associate Director of Science for Nuclear Physics (Acting) approved the statement of Mission Need (Critical Decision-0, CD-0) for the STAR Heavy Flavor Tracker (HFT) with a Total Project Cost (TPC) range of $11-$15 million.

This Preliminary Project Execution Plan (PPEP) describes the coordination of efforts of the project team, including the processes and procedures used by the HFT Contractor Project Manager (CPM) and Federal Project Director (FPD) to ensure that the project is completed on time and within budget. The PPEP defines the project scope and the organizational framework, identifies roles and responsibilities of contributors, and presents the work breakdown structure (WBS) and schedule. The PPEP also describes the formal change control process by which project cost, schedule, or scope may be revised in consultation with the FPD and the DOE Office of Science, Office of Nuclear Physics. This PPEP is in accordance with DOE O 413.3A Program and Project Management for the Acquisition of Capital Assets.

# MISSION NEED

The mission of the Nuclear Physics (NP) program is to understand the evolution and structure of nuclear matter from the smallest building blocks, quarks and gluons, to the elements in the universe created by stars. A main objective of this nuclear science field is searching for and characterizing the properties of the Quark-Gluon Plasma (QGP) that might occur in extremely hot, dense plasma of quarks and gluons believed to have filled the universe about a millionth of a second after the “Big Bang.” The program provides world-class peer-reviewed research results in the scientific disciplines encompassed by the Nuclear Physics mission areas under the mandate provided in Public Law 95-91 that established the Department.

The HFT project directly supports the NP mission and will allow U.S. researchers to explore fundamental questions into the nature of the QGP at RHIC.

The primary motivation for the HFT is to extend STAR’s capability to measure heavy flavor production by the measurement of displaced vertices and to do the direct topological identification of open charm hadrons. These are key measurements for the heavy-ion program at RHIC. Heavy quark measurements will facilitate the heavy-ion program as it moves from the discovery phase to the systematic characterization of the dense medium created in heavy-ion collisions. The primary physics topics to be addressed by the HFT include heavy flavor energy loss, flow, and a test of partonic thermalization at RHIC. Without the HFT upgrade the STAR experiment will not be able to execute the heavy flavor program proposed here. This program has been identified as a key goal for the RHIC program in the Long Range Plan RHIC-II science program and in the RHIC mid-term scientific plan.

# Project OVERVIEW

The technical objectives of the Heavy Flavor Tracker need to meet requirements of both the RHIC and STAR experimental long term programs. The corresponding technical scope and performance specifications required at Project Completion (CD-4) are described in this section.

## Technical Objective

STARD was designed to make measurements of hadron production over a large solid angle, and it features detector systems for high precision tracking, momentum analysis and particle identification. It is the only experiment at RHIC which measures the full azimuth in φ and tracks particles from 100 MeV/*c* to 20 GeV/*c*. Therefore, it is well suited for both characterizing heavy-ion collisions event-by-event and also investigating large Q2 effects.

By adding an HFT to STAR, we will be able to measure neutral and charged particles with displaced vertices that decay 100 m, or less, from the primary vertex. The high spatial resolution of the tracker will allow us to study parent particles with a very short lifetime from decay of heavy quarks, such as the D0 meson. The addition of the HFT will extend STAR’s unique capabilities even further by providing direct topological identification of mesons and baryons containing charm, such as Do and Λc  and for non-photonic electrons decaying from charm and bottom hadrons, and bottom by semi-leptonic decays. Thus, the HFT is the enabling technology for making direct charm and bottom measurements in STAR.

## Project Scope

The project activities within the MIE project are divided into several main areas in the WBS structure: (1) Management, (2) Pixel Detector (PXL) fabrication, integration and test, (3) Intermediate Silicon Tracker (IST) Detector fabrication, integration and test, (4) Silicon Strip Detector (SSD), (5) Integration, and (6) Software.

### R&D

A program of pre-conceptual R&D has been completed prior to CD-0 and R&D will continue through CD-1 (Approve Alternative Selection and Cost Range).

The objective of the R&D for the PXL detector is to explore silicon (Si) detector technology options and study detector performance for these technology alternatives. Prior to CD-0, several generations of active pixel sensors (APS) were designed and built at Institut Pluridisciplinaire Hubert Curien (IPHC), Strasbourg. Based on the experience gained with these early chips the final chip for the PXL detector is now in development. There are several short term R&D projects to explore the mechanical and thermal stability requirements for the PXL detector and to learn how to implement such a high-resolution detector.

The R&D items for the IST are to build a prototype ladder with sensors that can be integrated with STAR. These studies will show how to stabilize the proposed mechanical support structures, validate the quality of the readout system and then prove the effectiveness of the air cooling system for the chips. In addition the construction of a prototype ladder for the IST will exercise the assembly procedures and help us develop and refine the techniques to be used in the construction phase.

### CONSTRUCTION

In this section, the major systems and activities in the construction phase of the project is summarized.

The Heavy Flavor Tracker consists of three sub-detectors: a silicon pixel detector (PXL) and an intermediate silicon tracker (IST), and the Silicon Strip Detector (SSD). The PXL and IST are new sub-detector systems and the SSD is an existing detector. The primary purpose of the SSD-IST-PXL detector is to provide graded resolution from the Time Projection Chamber into the interaction point and to provide excellent pointing resolution at the interaction point for resolving secondary particles and displaced decay vertices.

The PXL detector is a low mass detector that will be located very close to the beam pipe. It will be built with two layers of silicon pixel detectors: one layer at 2.5 cm average radius and the other at 8.0 cm average radius.

The IST is a strip detector that is designed to match the high resolution of the PXL detector with the coarser resolution of the Time Projection Chamber and the SSD. The IST sits inside the SSD. In order to provide the required graded resolution between the SSD and the PXL layers, a cylindrical double layer of conventional silicon pad detectors will be installed at a radius of 14 cm. The IST provides space-points in the z and r-φ directions thereby reducing the number of possible candidate tracks that can be connected with hits in the outer layer of the PXL detector.

The SSD detector is an existing double-sided silicon strip detector that operated inside STAR during 2003-2007. The detector provides redundancy and increased efficiency for the overall HFT system. The detector electronics will be upgraded in this project to better match the requirements of the STAR Data acquisition System readout speed.

The three detector sub-systems PXL, IST and SSD, as well as a new thin-walled, and small-diameter beryllium beam pipe will be supported by the Inner Detector Support (IDS) structure.



Figure ‑1: A schematic cross section view of the Si detectors that surround the beam pipe. The SSD is an existing detector and it is the outmost detector shown in the diagram. The IST lies inside the SSD and the PXL layers are closest to the beam pipe.



Figure ‑2: An oblique view of the proposed geometry for the STAR mid-rapidity tracking upgrade. From the outer to the inner radius, the detectors are the SSD, the IST layer, the two PXL layers, and the beam pipe (red).

## Technical scope; key performance parameters

The HFT project scope compromises designing, building and assembling the 3 sub-detector systems that constitutes the system. The technical scope is defined in Table 3.1: Essential parameters for HFT instrument to achieve Critical Decision (CD-4) and in Section 3.4: Deliverable for CD-4. Although the high-level key performance parameters (KPP) cannot be directly measured without beam, the capability to achieve these parameters can be demonstrated (at CD-4) by demonstration that the low-level KPP has been achieved. These can be demonstrated (without beam) by building to design specifications, survey measurements, and bench tests. Appendix A provides further details on the KPP.

**High-level key performance parameters: instrument must be capable of**

|  |  |
| --- | --- |
| Pointing resolution of HFT system(750 MeV/c kaons) | < 50 μm |
| Single-track efficiency for HFT system (1 GeV/c pions) | > 60% |
| Compatible with STAR DAQ-1000 system |  |

**Low-level key performance parameters: experimentally demonstrated at Project Completion**

|  |  |  |
| --- | --- | --- |
| 1 | Thickness of first PXL layer | < 0.6% X0 |
| 2 | Internal alignment and stability PXL | < 30 μm |
| 3 | Internal alignment IST and SSD | < 300 μm |
| 4 | PXL integration time | < 200 μs |
| 5 | Detector hit efficiency PXL | > 95% sensor efficiency and noise from all sources < 10-4 |
| 6 | Detector hit efficiency IST | > 96% with 98% purity |
| 7 | Live channels for PXL and IST | > 95% |
| 8 | PXL and IST Readout speed and dead time | <5% additional dead time @ 500 Hz average trigger rate and simulated occupancy |
| 9 | SSD dead time | < 9% at 500 Hz |

Table 3-1 HFT Key Technical Performance Parameters

##  Technical Scope; Deliverables

The DOE deliverables for CD-4 associated with the STAR HFT project are described in this section. The HFT MIE project will be complete when all DOE deliverables have been received, assembled, surveyed tested, and either installed or ready for installation into the STAR detector at BNL.

The deliverables associated with the PXL detector are:

* the pixel insertion structure
* the pixel insertion tool
* a total of 10 sectors, with each sector containing:
	+ - one ladder at a radius of 2.5 cm
		- three ladders at a radius of 8.0 cm
		- with each ladder containing:
			* ten Si detector elements
			* one readout board
			* two DAQ receiver PCs
* two clam shells, with five sectors integrated and aligned on each clam shell
	+ the two clam shells will be installed around Pixel Insertion Tool, ready for insertion onto the New Cone Structure
* one additional complete detector and sufficient sector and populated ladder components to have the capability to fabricate one more complete detector assembly
* services including cabling and cooling
* a PC based control and monitoring system

The deliverables associated with the IST are:

* 27 ladders (24 + 3 spares) with six sensors per ladder
* readout system for 24 ladders
* silicon bias voltage system for 24 ladders
* 24 IST ladders installed on the Middle Support Cylinder.
* services including cabling and cooling

The deliverables associated with the SSD are:

* 20 of the existing SSD ladders instrumented with new readout electronics compatible with the readout requirements for the Time Projection Chamber
* SSD installed on the Outer Support Cylinder
* services including cabling and cooling compatible with the IDS structure and the Forward Gem Tracker (FGT)

The deliverables associated with the IDS structure are:

* the east support cone, and the middle support cylinders for the SSD, IST and the beam pipe support

# MANAGEMENT Structure and Responsibilites

## general

This document provides the management organization for the HFT project as needed for development, construction and final assembly of the apparatus. Agreements between BNL and collaborating institutions will be documented by signed Memoranda of Understanding (MOUs) after establishing the project baseline at CD-2. outlines the management structure for HFT.



 Figure ‑ HFT Management Organization Chart

## integrated project team

The responsibilities of the Integrated Project Team (IPT) are described in DOE G 413.3-18 and the Charter for the Team is in Appendix B. The DOE Federal Project Director chairs the IPT.

## Department of Energy

### Office of Nuclear Physics

Within the DOE Office of Science, the Office of Nuclear Physics (NP) has overall responsibility for the development of Nuclear Energy programs. NP is the lead program organization for the HFT Project. The Associate Director of Science for Nuclear Physics will serve as the Acquisition Executive for this project. This responsibility is currently delegated to the Director of the Facilities & Project Management Division. The prime headquarters point of contact for the project is the NP Program Manager for Instrumentation.

The NP responsibilities relating to the project include the following:

* Provides programmatic direction.
* Functions as DOE headquarters point of contact for the project.
* Oversees development of project scope, budget, schedule, and documentation.
* Prepares, defends, and provides project budget with support from the field organizations.
* Approves appropriate baseline changes.
* Organizes quarterly and other project reviews.
* Coordinates with HFT FPD.

### Brookhaven Site Office

The Brookhaven Site Office (BHSO) is the responsible DOE on-site office that provides day-to-day oversight of the laboratory. The HFT Federal Project Director, a BHSO employee, has the authority for day-to-day implementation and direction of the project. The HFT Federal Project Director is supported by the BHSO Site Manager and staff as needed.

###  HFT Federal Project Director

The management responsibility, authority, and accountability for execution of the project have been assigned to the HFT Federal Project Director. The HFT Federal Project Director receives guidance and direction from NP and serves as the principal point of contact for DOE headquarters on issues specific to the project.

Specific responsibilities of the HFT Federal Project Director are to:

* Serve as Integrated Project Team (IPT) lead in drafting/coordinating the Acquisition Strategy (AS) and PEP. (The IPT Charter is provided as Appendix B to this document.);
* implement procedures for baseline management and control, approve baseline changes at Level 2 and recommend changes or corrective action to baselines above Level 2;
* Maintain close contact with the activities of the HFT project to assure that the goals and schedules are met in a timely and effective manner. Review project performance monthly and keep NP informed of cost, schedule, and technical progress and problems in a timely manner;
* Control the project contingency funds and authorize their use within levels established in this PEP;
* Coordinate with the Site Office Managers and Contracting Officers as needed regarding approval of subcontract procurement actions performed by Brookhaven National Laboratory in accordance with DOE thresholds;
* Oversee the preparation and review of the safety assessment documents;
* Direct the updating of the PEP;
* Coordinate updates of the budget;
* Participate in and provide support for the program peer reviews, reviews by oversight committees and validation of the project;
* Submit quarterly reports and other reports on the status of the project for DOE management as required in this PEP and applicable DOE requirements;
* Aid in the compliance by the HFT Project with appropriate DOE requirements, and contracting regulations;
* Update and maintain the monthly PARS reporting
* Responsible for ES&H implementation of the project

##  Brookhaven National Laboratory (BNL)

BNL is managed and operated by Brookhaven Science Associates (BSA), a contractor for DOE. The contractor has provided the Laboratory Director with the overall responsibility for all projects, programs, operations, and facilities at BNL. BNL will have the responsibility of completing the HFT Project within the technical, schedule, and cost baselines defined in this PEP.

### Chairman for the Physics Department at BNL

The Chairman for the Physics Department at BNL shall be administratively and fiscally responsible for the entire project. Specific responsibilities are:

* Provides overall management oversight for all aspects of the project.
* Appoints the Contractor Project Manager.
* Approves key personnel appointments made by the Contractor Project Manager.
* Approves major subcontracts recommended by the Contractor Project Manager.
* Ensures that adequate staff and resources are available to complete the HFT project in a timely and cost effective manner (within constraints of the budget provided by DOE).
* Ensures that the HFT project has demonstrated that it meets the CD-4 key performance parameters and deliverables.
* Ensures the work is performed safely and in compliance with the Integrated Safety Management (ISM) rules.
* Reports to the Associate Laboratory Director for Nuclear and Particle Physics regarding the operations of the Physics Department.

###  HFT Contractor Project Manager (CPM)

The HFT CPM reports to the BNL Chairman of the Physics Department and has the responsibility and authority for delivering the project scope on schedule and within budget.

Specific responsibilities of the HFT CPM are:

* Manage the technical progress on the HFT Project by appointing and maintaining close contact with the Level 2 managers and holding internal reviews prior to major procurements or design decisions.
* Manage the cost and schedule of the HFT Project and provide monthly cost and status reports using progress reports received from the Level 2 managers.
* Submits quarterly status reports to the BHSO Federal Project Director and participates in monthly and quarterly teleconferences with NP.
* Work with representatives of the divisions and sections at LBNL and BNL to obtain Laboratory resources for the project as authorized by the LBNL and BNL Directorates, and participate in the development of Memoranda of Understanding (MOUs) and Statements of Work (SOW) as required for all collaborating and contributing institutions, manage change control, and make annual updates to those documents if needed.
* Approves level 3 PCRs and submits higher level PCR to FPD.

### HFT Deputy Contractor Project Manager (DCPM)

The Deputy Contractor Project Manager assists the HFT CPM in all matters relating to the HFT Project, including the planning, procurement, disposition and accounting of resources, progress reports on project activities, ES&H issues, and Risk Management. In the absence of the CPM, the DCPM assumes the project management responsibilities.

The DCPM also reviews Memoranda of Understanding and other project documentation, advising the Project Manager on risk management, ES&H, or other relevant issues.

###  HFT Engineering Deputy

The HFT Engineering Deputy is responsible for overall engineering coordination of the design and fabrication phases of the project and works directly with the Level 2 Managers to achieve this. The Engineering Deputy is directly responsible to the HFT CPM. In cooperation with them the Engineering Deputy works with the HFT ES&H Coordinators to implement BNL policies of Integrated Safety Management (ISM) in the project and resolve any ES&H issues that may arise. The Engineering Deputy is also responsible for implementing quality assurance procedures.

###  HFT Subsystem Managers

The HFT Project contains three major subsystems: PXL detector, IST detector, and SSD detector. In addition there are subsystem managers for Software and for Integration. The HFT CPM has appointed managers for each of the subsystems. They will be responsible for the design, construction, installation, and testing of their subsystem, in accordance with the performance requirements, and providing a monthly status on progress, schedule, and budget.

### HFT Project Integrator(s)

The Project Integrator(s) represents STAR and are responsible for coordinating data produced by the HFT team and confirming that the output from the various systems and scientists aligns with the STAR detector. While not responsible for creating the information, the integrator maintains an overview of all scope requirements, including parameters, energy, power; footprints, quantities and planned locations of equipment; and is responsible for calling meetings as required whenever data from one area appears to be in conflict with expected outcomes and/or project scope and direction.

## Participating Institutions

BNL will have overall responsibility for the fabrication of this MIE instrument. Institutional responsibilities for the major subsystems comprising the HFT are: LBNL for the PXL detector; MIT for the IST detector; LBNL and BNL for the SSD upgrade, Kent State University for the software; and BNL for integration. These institutions have expertise and past experience in designing / fabricating / implementing similar subsystems. A number of other institutions have responsibilities within these sub-systems (UCLA, PU, NPU with software, and UT with PXL). Memoranda of Understanding (MOUs) will define the relationship between the institutions and BNL and will be in place following CD-2.

The sensor development is taking place at the IPHC in Strasbourg, France, and the LBNL group is working in close collaboration with Marc Winter and his group there. The development path for the PXL detector sensors is tailored to follow the development path of the technology as it was set by the IPHC group. This work and collaboration will be covered by an MOU that is expected to be signed by CD-2.

The electronics upgrade of the SSD is the responsibility of the STAR BNL group in collaboration with electrical engineers from the SUBATECH group that will provide engineering for layout and initial testing of the new boards. The work of this collaboration institute is covered by an MOU that was signed in January 2010.

The following is a list of all participating institutions:

|  |  |
| --- | --- |
| Brookhaven National Laboratory | BNL |
| Czech Technical University, Prague, Czech Republic  | CTU |
| University of California, Los Angeles | UCLA |
| Kent State University, Kent | KSU |
| Nuclear Physics Institute, Prague, Czech Republic | NPU |
| Institut Pluridisciplinaire Hubert Curien, Strasbourg, France | IPHC |
| Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge | MIT |
| Lawrence Berkeley National Laboratory, Berkeley | LBNL |
| Purdue University, West Lafayette | PU |
| SUBATECH, Ecole des Mines, Nantes, France | SUB |
| University of Texas, Austin | UT |

## operation Phase

The estimated yearly cost of operation is less than $20,000 and will be supported by existing BNL experimental support funds. It does not include support for the U.S. scientific research program under the conditions set by HFT management and the required annual replacement costs for computing resources which will be covered with existing operating and capital equipment funds from RHIC.

## Life cycle costs

The elements of the HFT could have a useful life of up to ten years. The components of a total life-cycle cost include: (a) Fabrication, as described in this document; (b) Operation; and (c) Decommissioning costs. The estimated yearly cost of operation is addressed in section .

The decommissioning of HFT covers the disposal of standard electronic, computer, and experimental lab equipment, which must follow accepted standard procedures for disposal of these items. The decommissioning activities are not anticipated to be complex or cost prohibitive, and would likely be carried out by U.S. researchers and the STAR operations group, as is commonly done for pieces of scientific instrumentation. Although a detailed analysis has not been carried out, it is estimated that the decommissioning is likely less than $100,000. The estimated life-cycle cost is less than $18 million.

## Acquisition Strategy

The HFT project will be executed under an Acquisition Strategy (AS) approved by the Acquisition Executive (AE). The AS will be reviewed by the DOE SC Office of Project Assessment (OPA) as a prerequisite for CD-1, and will be approved by the AE in support of CD-1.

# work Breakdown structure, COst range and SCHEDULE.

## work breakdown structure

The HFT has been organized into a Work Breakdown Structure (WBS) for purposes of planning, managing and reporting project activities. Work elements are defined to be consistent with discrete increments of project work. Project Management efforts are distributed throughout the project, including conceptual design and R&D. The HFT has 6WBS Level 2 components as shown below:



Table ‑ HFT Preliminary WBS Structure

All WBS elements below Level 2 will be finalized at CD-2.

## cost range

The estimated cost range for the DOE TPC at CD-1 is $14.6M to $17.8M. Table 5-2 shows the estimated DOE cost summary for the HFT project in AY $M.

|  |  |  |  |
| --- | --- | --- | --- |
| WBS | Title | Cost (Low range)($M) | Cost (High range)($M) |
| 1.1 | Project Management | 0.8 | 1.0 |
| 1.2 | PIXEL | 3.8 | 5.2 |
| 1.3 | Intermediate Silicon Tracker(IST) | 2.1 | 2.9 |
| 1.4 | Silicon Strip Detector | 0.5 | 0.9 |
| 1.5 | Integration | 1.1 | 1.5 |
| Contingency |  | 3.7 | 3.7 |
| Total Estimated Cost (TEC) |  | 12.0 | 15.2 |
| OPC |  | 0.3 | 0.3 |
| Redirected Labor |  | 2.3 | 2.3 |
| Total Project Cost(TPC) |  | 14.6 | 17.8 |

Table ‑ HFT Preliminary DOE cost summary.

Add words on how cost range was achieved--

### Funding

The HFT MIE project will be entirely funded by DOE-NP. Workforce contributed at no cost to DOE by the Institut Pluridisciplinaire Hubert Curien, Strasbourg, France, is committed to develop the final version of the MIMOSTAR 4 chip to be used for the patch pixel detector in 2009 – 2011, and the final version of the ultimate chip to be used in the final version of the full PXL detector for the second phase of the project leading to CD-4. Engineering labor at a level of 0.6 FTE in 2010-2011 contributed at no cost to DOE by SUBATECH Ecole des Mines, Nantes, is developing parts of the layout for the SSD electronics upgrade.

The planned DOE funding profile is shown in Table 5-3.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Funding Profile ($M) |  |  |  |
|  | FY 10 | FY 11 | FY 12 | FY 13 | FY 14 | Total |
| TEC | 2.4 | 2.9 | 5.3 | 4.4 | 0.2 | 15.2 |
| OPC/R&D | 0.3 |  |  |  |  | 0.3 |
| Planned Redirect | 0.3 | 0.5 | 0.6 | 0.7 | 0.2 | 2.3 |
| TPC | 3.0 | 3.4 | 5.9 | 5.1 | 0.4 | 17.8 |
| New Funds Required | 2.4 | 2.9 | 5.3 | 4.4 | 0.2 | 15.2 |

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Table ‑ HFT DOE Project Funding Profile in AY $M

### Planned Labor Resources

Project labor is defined as the technical and engineering effort associated with R&D, preliminary/final design and engineering, construction, assembly, and project management. The scope is included in the work breakdown structure; the cost is included in the HFT TPC and is funded by the DOE. Redirected labor is also associated with design, engineering, construction, and assembly efforts and refers to engineers and technicians already funded by DOE. The scope is included in the work breakdown structure; the cost is included in the HFT TPC and is planned as a redirection of base DOE funding at LBNL, BNL and MIT, decreasing the amount of new funds needed to implement the project.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Planned redirect | **FY10** | **FY11** | **FY12** | **FY13** | **FY14** | **Total** |
| BNL | 0.08 | 0.23 | 0.24 | 0.17 | 0.08 | 0.8 |
| LBNL | 0.22 | 0.27 | 0.28 | 0.28 | 0.07 | 1.12 |
| MIT | 0 | 0.04 | 0.12 | 0.23 | 0 | 0.39 |

Scientific labor is scientific effort supporting the overall development and operational capability of the HFT detector within the STAR experiment, including software and physics analysis models.  Scientific labor cost is not included in the HFT TPC, but tasks and milestone dates related to this scope are integrated with the HFT project schedule. Funding sources include the DOE Heavy Ion physics research program and research support from the French funding agency IN2P3.

MOUs between BNL and the collaborating institutions will describe the expected efforts of both redirected and scientific labor; summarizing people (names/category) and their anticipated FTE fraction (%) of activity related to tasks at the WBS level 3. Draft MOUs which summarize the full scope and detail the first year’s expected effort and milestones will be prepared for CD-2 and signed thereafter. The MOUs will then be updated annually to assert the task efforts for each institution for the next 12 month period.

Redirected labor will be tracked by each institution on a monthly basis and will be appropriately included in the Total Project Cost.

Contributed labor will be tracked from reports by institutions, which will reflect the overall fractional time spent by individuals on the HFT project. This information will be reported at DOE NP annual progress reviews.

Progress on all tasks will be monitored by sub-system managers by having sufficiently frequent milestones at level 4, such that task completions are noted, and changes to the schedule float can be evaluated as soon as possible.

Non-DOE contributed labor will be tracked by monitoring milestones set forth in the MOUs.

Scope funded as redirected labor will be assigned risk and contingency in the WBS. Scientific efforts will be assigned risk. n case an institutional commitment cannot be met, HFT and STAR management will jointly seek solutions to identify and commit resources.

### Contingency

At CD-1 (Approve Alternate Selection and Cost Range) the total contingency is $3.7 M. Contingency percentages vary from a low 25% for well-understood and well defined tasks to 50% for tasks with high associated risks. These contingency percentages were based on expert judgment and were applied at the appropriate WBS level. Contingency dollars and percentages by WBS are shown in Table 5-2.

The FPD will manage the contingency funds according to DOE Order 413.3A and the procedures described in the Baseline Change Control section with thresholds as specified in

Table 6‑1.

## Schedule

The HFT project is proposing a tailored strategy by having a combined CD-2, CD-3 review.

The HFT project has several phases:

The first phase consists of the assembly of PXL ladders using either phase-1 or ultimate sensors, the mechanical insertion mechanism, and the mechanical integration with the small-diameter beam pipe and the STAR detector. This is required for an engineering run scheduled for Q1FY13 in time for RHIC run-13.

The second phase pf the PXL system consist of construction and assembly of the ladders with the final sensors and readout system ready for installation in Q1FY14 ahead of RHIC run-14. Note that the PXL detector, due to the rapid insertion mechanism will be installed into STAR when detector is in place for beam. The SSD will be installed at this same time.

The IST will be assembled and tested ready for installation in Q2FY14, and will be assembled with IDS and SSD in Q3FY14.

Confirmation of the CD-4 key performance parameters will be done by Q2FY14.

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The HFT project has two phases: the first phase consists of the assembly of PXL ladders using either phase-1 or ultimate sensors, the mechanical insertion mechanism, and the mechanical integration with the small-diameter beam pipe and the STAR detector. This is required for an engineering run scheduled for Q1FY13 in time for RHIC run-13. The second phase consists of the assembly of final ladders for the PXL, and the IST and SSD detectors, and is scheduled for Q2FY14. However, this funding driven schedule does not allow the full system, i.e., PXL, IST and SSD to be installed inside the STAR detector during the second quarter of FY14, since this time of year is usually during a RHIC run. Under such normal running conditions the full HFT will be installed in STAR ahead of run-15 for Project Completion in Q1FY15. The PXL detector, due to the rapid insertion mechanism, could be ready and inserted into beam opportunistically already during run-14. The SSD detector upgrade schedule would also allow it to be installed ahead of run-14. The collaboration will revisit the schedule of the IST before CD-2 with the goal of accelerating it for a Q1FY14 installation (i.e., ahead of run-14).

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With a preliminary CD-4 date of Q1FY15 and a planned early finish date of Q3FY14 for the final task of assembling the IST and SSD on the support cone and verification of functionality, 12 weeks have been allocated for Performance Validation and Document development, Project Closeout, and Lessons Learned. This allows approximately 30 weeks of float after the end of the early finish schedule.

The critical path for Early Finish is determined by the production of the sensors, bonding and assembly and testing of the ladders for the IST detector, as shown in the following figure:

Preliminary Critical Path for STAR Heavy Flavor Tracker



## Milestones

Milestones will be used as schedule events to mark the due date for accomplishment of a specified effort or objective. A milestone may mark the start, an interim step, or the end of one or more activities as needed to provide insight into the project’s progress. Milestones will be assigned to different levels depending on their importance and criticality to other milestones and the overall project schedule.

|  |  |
| --- | --- |
| Milestone | Date |
| CD-0 | Q2 FY09 (A) |
| CD-1 | Q4 FY10 |
| CD-2 | Q1 FY11 |
| CD-3 | Q1 FY11 |
| CD-4 | Q1 FY15 |

Table ‑ Critical Decision Milestones (Level 1)

Table 5-5 shows the preliminary performance milestones. All milestones will be maintained in the HFT Microsoft Project cost and schedule database. Milestone levels will be assigned prior to CD-2.All milestones at and below Level 2 will be approved at CD-2.

|  |  |  |
| --- | --- | --- |
| 1.2 | **PXL** |  |
|  |  |  |
|  | Pixel Prototype Sector Design Complete | Q4FY10 |
|  | Receive Prototype sensors from IPHC | Q2FY11 |
|  | Prototype Insertion mechanism Testing Complete | Q2FY11 |
|  | Receive final Ultimate Sensors from IPHC | Q1FY13 |
|  | Sector assembly start | Q1FY13 |
|  | PXL detector available for insertion | Q3FY14 |
| 1.3 | **IST** |  |
|  | Sensor, Module and ladder design complete | Q3FY10 |
|  | Prototype Module tested | Q1FY12 |
|  | First 3 modules produced | Q3FY12 |
|  | Staves finalized | Q3FY13 |
|  | Installed on MSC, ready for installation in STAR | Q1FY14 |
| 1.3 | **SSD** |  |
|  | Prototype Board Layout Review | Q3FY10 |
|  | Prototype test on bench | Q2FY11 |
|  | Final Design Complete | Q4FY11 |
|  | Move Full System to STAR for test | Q4FY12 |
|  | Ready for installation | Q3FY13 |
| 1.5 | **Integration** |  |
|  | Beam pipe delivered and accepted at BNL | Q1FY12 |
|  | Inner detector support assembled with FGT | Q1FY13 |
|  | Production OSC/MSC at BNL for integration | Q2FY13 |
|  | Inner detector support assembled with SSD/IST/FGT | Q4FY14 |
| 1.6 | **Software** |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  | IST online software commissioned | Q2FY13 |

Table ‑ Preliminary Technical Milestones (Level 2)

#

# CHANGE CONTROL

As part of the CD-0 approval, the Associate Director (AD) of the Office of Nuclear Physics within the Office of Science is delegated as the Acquisition Executive (AE) responsible for all subsequent Critical Decision approvals for the project. The Associate Director has delegated the Director of the Facilities and Project Management Division to be the acting AE for this project.

Changes to the technical, cost and schedule baselines established at CD-2, will be controlled using the thresholds described in

Table 6‑1.

All Level 3 PCRs will be approved by the CPM. Level 1 and 2 PCRs will be submitted by the CPM to the FPD. All Level 2 PCRs will be reviewed and approved by the FPD. For PCRs exceeding the thresholds of Level 2, the FPD will forward them to the NP Program Manager with a recommendation.

If the change is approved, a copy of the approved PCR, together with any qualifications or further analysis or documentation generated in considering the request is returned to the requestor, and copies are sent to the official at the next higher control level and to the HFT CPM for filing. If approval is denied, a copy of the PCR, together with the reasons for denial, is returned to the requestor, and a copy is filed. The official at the next higher control level may review the granted change to ensure proper application of the procedure and consistency of the change with the goals and boundary conditions of the project.

|  |  |  |  |
| --- | --- | --- | --- |
| **Change Level** | **Cost**(Table 5-2) | **Schedule**(Tables 5-4 and 5-5) | **Technical Scope**(Table 3-1) |
| DOE-SC-26 Associate Director(Level 0) | Any increase in TPC | Any delay in CD-4 date | Any change affecting Mission Need |
| DOE-SC-26 Program Manager(Level 1) | Any change to TEC or OPC, or cumulative allocation of ≥ $500k contingency | ≥ 3 months delay of a Level 1 milestone date (other than CD-4), or ≥ 6-month delay of a Level 2 milestone date | Any change affecting CD-4 deliverables |
| DOE-BHSOFederal Project Director(Level 2) | A cumulative increase of ≥ $250k in WBS Level 2 elements, or cumulative allocation of ≥ $250k contingency | ≥ 3-month delay of a Level 2 milestone date | Any change in technical scope deliverables (section 3.4) |
| HFT Contractor Project Manager(Level 3) | Any increase of ≥ $50k in a WBS Level 2 element | ≥ 1-month delay of a Level 2 milestone date, or ≥ 3-month delay of a Level 3 milestone date | Any change not affecting CD-4 deliverables |

Table ‑: Summary of Baseline Change Control Thresholds

# Environment, Safety, Security, Health and quality

## Environment, Safety and Health

### Integrated Safety Management

The Integrated Safety Management (ISM) policy for this project requires full commitment to safety by the project management team. Principles of ISM are incorporated into project planning and execution, following the guidelines described in the LBNL Health and Safety Manual (PUB-3000) and Integrated Environment, Health and Safety Management Plan (PUB-3140) and the BNL Standards Based Management System (SBMS). All phases of the project at other locations will be carried out in compliance with those institutions’ ES&H policies and procedures, and the HFT Contractor Project Manager will work collaboratively with those institutions to help ensure US researchers are working in an appropriately safe manner.

### Environmental and Regulatory Compliance

It is expected that there will be no significant environmental, regulatory or political sensitivities that impact the project, and appropriate National Environment Protection Agency (NEPA), State, and local requirements will be addressed and completed in advance of the CD-2 review.

BNL will submit design documentation to its Environmental Protection department as required by 10 CFR 1021, DOE’s Rules for Implementing the National Environmental Policy Act (NEPA). It is anticipated that the proposed construction and installation of the HFT within existing structures falls within the scope of the RHIC Environmental Assessment (DOE EA #0508). Work at LBNL will be covered for California Environmental Quality Act (CEQA) purposes under existing CEQA documentation.

### ESSH Plans for Construction

The HFT upgrade for STAR will use the BNL Standards Based Management System (SBMS) to identify and control hazards for all equipment and work at BNL for the HFT. The Physics Department and the C-AD have review processes that comply with the BNL SBMS. The project will prepare designs and work procedures and have them reviewed by the appropriate laboratory or department review committees. Testing of equipment in Physics Department will go through the Experimental Safety Review (ESR) process (see <http://www.phy.bnl.gov/~safety/ESRs/>). The equipment and work practices used at STAR will be reviewed by the C-AD Experimental Safety Review Committee (ESRC). The reviews of the ESRC are covered in C-AD Operations procedures manual (OPM) chapter 9 section 2. The installation will be covered under the rules and safeguards in place for work in the RHIC experimental halls and assembly area.

The risk analysis in the Preliminary Hazard Analysis Document (HAD) addresses the hazards of the HFT detector system. It also addresses hazards, controls and risks for experimental halls, experiments and their associated targets and detectors. The Safety Assessment Document (SAD) follows the generally accepted principles identified in DOE Order 420.2B.

### DOE ES&H Oversight

The FPD is responsible for the ES&H implementation of the project. He will maintain cognizance of all project activities, and will approve the final ES&H plan and subsequent updates. The FPD is assisted in these responsibilities by the DOE Facility Representative from BHSO. The Operations Management Division (OMD) at BHSO will coordinate ES&H oversight with the DOE Facility Representative. The DOE Facility Representative will coordinate with other subject matter experts (e.g., health physics) in the Operations Management Division (OMD) as needed. BHSO personnel will monitor the HFT construction activities on a regular basis to ensure that planned BSA oversight is being performed and that applicable BSA plans are being followed.

At BNL, both BSA and Lab management are responsible for ensuring the safety (including meeting all requirements) of the project. BHSO oversight is planned to monitor BNL’s activities and to assess BNL’s systems for ensuring safety and environmental compliance. This will include review of the various plans and procedures developed by BSA, and field operation awareness activities to ensure that BNL oversight is functioning properly. Applicable ES&H disciplines, such as construction safety, industrial hygiene, and waste management, will be identified for the project. Oversight activities under each applicable discipline will be performed as needed to monitor BNL performance.

## Safeguards and security

Identification of potential security risks was begun early in project planning as part of implementing the Integrated Safeguards and Security Management systems required by DOE P 470.1. A Security Vulnerability Assessment Report (SVAR) was completed indicating that the proposed work is not security sensitive and does not warrant changes to the standing Vulnerability Assessment Reports at BNL. A copy of the determination will remain in the project’s database.

## Quality Assurance Program

The project shall adopt in its entirety the [BNL Quality Assurance (QA) Program](https://sbms.bnl.gov/program/pd04/pd04d011.htm). This QA Program describes how the various BNL management system processes and functions provide a management approach that conforms to the basic requirements defined in DOE Order 414.1B, Quality Assurance. These requirements will include:

* management criteria related to organizational structure, responsibilities, planning, scheduling, and cost control;
* training and qualifications of personnel;
* quality improvement;
* documentation and records;
* work processes;
* engineering and design;
* procurement;
* inspection and acceptance testing; and
* assessment

The quality program embodies the concept of the “graded approach” i.e., the selection and application of appropriate technical and administrative controls to work activities, equipment and items commensurate with the associated environment, safety and health risks and programmatic impact. The graded approach does not allow internal or external requirements to be ignored or waived, but does allow the degree of controls, verification, and documentation to be varied in meeting requirements based on environment, safety and health risks and programmatic issues.

Quality Board Representatives have been assigned to serve as focal points to assist management in implementing QA program requirements. The Quality Board has the authority to assist sub-system managers in identifying potential and actual problems that could degrade the quality of a process/item or work performance, recommend corrective actions, and verify implementation of approved solutions.

# PROJECT CONTROLS AND REPORTING SYSTEMS

The HFT project has been entered into the DOE Project Assessment and Reporting System (PARS) and is updated on a monthly basis by the FPD.

The CPM leads monthly cost and schedule reviews and reports the result to the FPD. In addition, he leads quarterly overall cost, schedule and technical performance reviews and reports the results to the BHSO-DOE office. The FPD reports progress to the DOE Program Manager on a quarterly basis. The FPD and CPM participate in monthly teleconference calls with the DOE Office of Nuclear Physics. The Office of Nuclear Physics conducts annual progress reviews with a panel of experts.

The standard BNL accounting system is the basis for collecting cost data, and the Control Account structure for HFT will separate costs according to funded phase (R&D, PED, Construction, Pre-Ops), and WBS. A direct one-to-one relationship will be established between each WBS element of Level 2 or lower and a separate control account in the BNL accounting system.

Technical performance is monitored throughout the project to insure conformance to approved functional requirements. Design reviews and performance testing of the completed systems are used to ensure that the equipment meets the functional requirements.

## Risk management

Risk management is based on a graded approach in which levels of risk are assessed for project activities and elements. Risk assessments are conducted throughout the project lifecycle. Risks included technical, cost and schedule risks. The draft Risk Management plans detailing the process for identifying, evaluating, mitigating, and managing risks in compliance with DOE order 413.3A was reviewed at the CD-1 Readiness Review in November 2009.

A preliminary risk list was determined by sub-sys manager as per WBS level.

- major identified risk: Technical schedule

-

- low risk for IPHC work involved in sensor development (albeit time risks)

## Value Engineering

A Value Engineering (VE) study will be performed before the HFT project seeks approval for CD-2/CD-3. The study will follow the traditional approach to VE, according to applicable procedures. A review team formed by members of the IPT and representatives of the HFT management and technical teams will evaluate alternative design approaches and evaluate the flexibility of the design for present and future research. The VE approach will determine the impacts on cost (both project and life-cycle) of any suggested changes to the design. Additionally, the project team will perform informal VE evaluations throughout the duration of this MIE.

##  Tailoring Strategy Plan

DOE Order 413.3A allows for the development of a Tailoring Strategy for each project. Based on the risk, complexity, visibility, cost, safety, security, and schedule of the project. The requirements of the Order are to be applied on a tailored basis as appropriate to the project. Tailoring is subject to the Acquisition Executive’s approval and is identified prior to the impacted Critical Decision and approved as early as possible. The Tailoring Strategy will be prepared to support approval of CD-2. The HFT project is proposing as part of a tailored strategy to combine CD-2 and CD-3.

# Glossary

AE Acquisition Executive

APS Active Pixel Sensor

BER Bit error rate

BHSO Brookhaven Site Office

BNL Brookhaven National Laboratory

BSA Brookhaven Science Associates

C-A Collider Accelerator (BNL department)

CD Critical Decision

CDR Conceptual Design Report

CEQA California Environmental Quality Act

CMOS Complementary metal–oxide–semiconductor

CPM Contractor Project Manager

CTU Czech Technical University

DAQ Data Acquisition

DOE Department of Energy

DCPM Deputy Contractor Project Manager

EDIA

EF Early Finish

ES&H Environment, Safety and Health

ESAAB Energy Systems Acquisition Advisory Board

ESRC Experimental Safety Review Committee

ESSH Environmental Safety, Security, Health, and Quality

FGT Forward GEM Tracker

FPD Federal Project Director

FTE Full Time equivalent

FY Fiscal Year

HFT Heavy Flavor Tracker

IDS Inner Detector Support

IPHC Institut Pluridisciplinaire Hubert Curien

IPT Integrated Project Team

ISM Integrated Safety Management

IST Intermediate Silicon Tracker

KPP Key Performance Parameter

KSU Kent State University

LBNL Lawrence Berkeley National Laboratory

M&O Management and Operations

MCS Multiple Coulomb Scattering

MIE Major Item of Equipment

MSC Middle Support Cylinder

MOU Memorandum of Understanding

NEPA National Environmental Policy Act

NP Nuclear Physics

OECM Office of Engineering and Construction Management

OPM Operational Procedures Manual

OSC Outside Support Cylinder

OSHA Occupational Safety and Health Act

PARS Project Assessment and Reporting System

PCR Project Change Request

PED Project Engineering and Design

PEP Project Execution Plan

PU Purdue University

PXL Silicon Pixel Detector

QA Quality Assurance

QAB Quality Assurance Board

QAM Quality Assurance Manager

QGP Quark-Gluon Plasma

R&D Research & Development

RHIC Relativistic Heavy Ion Collider

SAD Safety-Assessment Document

SBMS Standards Based Management System

SC Office of Science

SOW Statement of Work

SSD Silicon Strip Detector

STAR Solenoidal Tracker at RHIC

TDR Technical Design Report

TPC Total Project Cost

TPC Time Project Chamber

UCLA University of California, Los Angeles

UT University of Texas

VE Value Engineering

WBS Work Breakdown Structure

# Appendix A - HFT Key Performance Parameters

This appendix describes in detail the CD-4 key performance parameters, justification and verification methods.

## High-Level Parameters

**High-level parameter justifications**

We require the instrument to be capable of a pointing resolution of better than 50 μm for kaons of 750 MeV/c. 750 MeV/c is the mean momentum of the decay kaons from D mesons of 1 GeV/c transverse momentum, the peak of the D meson distribution. The pointing resolution can be calculated from the design parameters and from the results of surveys of the sensor ladders. The pointing resolution can also be measured in tests with cosmic rays or in beam tests.

We require the instrument to be capable of a single-track efficiency of better than 60% for pions at 1 GeV/c in an Au+Au environment that are emitted from the center of the detector within a rapidity of ± 1. The 1 GeV/c pion is representative of the momentum distribution. This efficiency does not include the TPC tracking efficiency. The single-track efficiency can be calculated from the design parameters. It can also be measured with cosmic rays or in beam tests.

## Low-level parameters

**Low-level parameter justifications**

Low-level parameters 1-9 in table 3.1 support the high-level key performance parameters. It is known from detailed simulations that fulfilling these parameters results in the anticipated performance given above.

The required pointing resolution can be achieved if performance requirements 1-3 in table 3.1 are fulfilled.

The required single-track efficiency can be achieved if additionally performance requirements 4-7 are fulfilled.

The requirements 8-9 will allow the HFT system to acquire data in excess of 500M Au+Au collisions for a typical RHIC running period (10 weeks). The requirement of software will ensure that that analysis of data will be ready to be included in the STAR production chain after being collected.

Specific justifications are given in the following with the requirement number given in the heading.

### Multiple Scattering in the Inner Layers (1)

The precision with which we can point to the interaction vertex is determined by the position resolution of the PXL detector layers and by the effects of multiple scattering in the material the particles have to traverse. The beam pipe and the first PXL layer are the two elements that have the most adverse effect on pointing resolution. We have chosen a radius of 2 cm for a new beam pipe with a wall thickness of 750 μm, equivalent to 0.21% of a radiation length. The two PXL layers will be at a radius of 2.5 cm and 8 cm, respectively. The total thickness of the first PXL layer must be smaller than 0.6% of a radiation length. The radiation lengths of the two innermost structures, the beam pipe and the first PXL layer, are verifiable design parameters.

### Internal Alignment and Stability (2, 3)

The PXL sensor positions need to be known and need to be stable over a long time period in order not to have a negative effect on the pointing resolution. The alignment and stability need to be better than 30 μm for the PXL. The internal alignment of IST and SSD should be determined to better than 300 μm. Those parameters can be determined from surveys, and bench measurements.

### PXL Integration Time (4)

The PXL is a “slow” device with a long integration time. All events that occur during the integration or lifetime of the PXL will be recorded and may contribute to pile-up. Pile-up will not limit the physics capability of the HFT if the integration time of the PXL detector is smaller than 200 μs. The PXL integration time is a verifiable design parameter.

### PXL efficiency and noise (5)

The hit efficiency of PXL detectors is essential for good detection efficiency. In the case of secondary decay reconstruction, the hit inefficiency of each detector layer enters with the power of the number of reconstructed decay particles into the total inefficiency.

The PXL detector sensors are designed to have an operating threshold point such that they will be more than 95% efficient for Minimum Ionizing Particles with a sensor noise hit rate of < 10-4.

This can be verified by measurements of complete readout chain on bench and with testbeam.

### Detector Hit Efficiency (6)

The hit efficiency for the IST detector is essential for good detection efficiency for tracks. In order to keep inefficiency low, we require that each the detector layer has a hit efficiency of better than 96% with a purity of > 98%. The hit efficiency of each detector layer can be measured on the bench before installation. A signal to noise ratio of 10:1 is known from experience with Si-sensors to ensure a hit purity of 97% or better with an efficiency of 99%. The IST is a triggered detector.

### Live Channels (7)

Dead channels in the PXL and IST will cause missing hits on tracks and thus lead to inefficiencies in the reconstruction of decay tracks. Therefore, the number of dead channels needs to be as low as possible. The impact of dead channels on the overall performance will be minimal if more than 95% of all channels are alive at any time. The number of dead channels can be determined immediately after installation of the detectors on the mounting cone structures.

### Readout Speed and Dead Time (8, 9)

In the absence of a good trigger for D mesons it is imperative for the measurement of rare processes to record as many events as possible and as required by the physics processes. In order not to add significant dead-time to DAQ, the PXL and IST readout speed needs to be compatible with that of DAQ-1000 and the dead-time such that at a readout rate with the Time Projection Chamber at 500 Hz additional dead time is no more than 5% for PXL, IST and 9% for SSD. The SSD dead time varies linear with rate constrained by the existing non-replaceable components on the detector ladders.

Readout speed and dead time are verifiable design parameters.

## Other functional requirements

|  |  |  |
| --- | --- | --- |
| A | Active sensor length of PXL layer 1 & 2 |  ≥ 20 cm |
| B | Active sensor length for IST | ≥ 46 cm |
| C | Pseudo-rapidity coverage for SSD | |η| < 1.15 |
| D | PXL RDO data path integrity  | BER < 10-10 |

The active sensors length requirements for PXL and IST are to ensure rapidity coverage in -1<η< 1 for all detector systems in the vertex range from -5 cm to +5 cm.

The total length of the PXL detector silicon sensors is designed to be 21.7 cm. The active tracking silicon in this length is 21.19 cm.

The total active silicon length of the IST should be 46 cm or greater at a maximum radius of 15cm to be able to cover -1< η <+1.

The length of the SSD ladders is fixed. The requirement C is consistent with a radius of 22 cm and 2π azimuthal coverage.

The PXL readout data path is expected to have a data transfer rate of ~ 200 MB/s (with a trigger rate of 1 kHz). In order to preserve the data integrity we will validate the data path to have a bit error rate (BER) of < 10-10.

# Appendix B - Integrated Project Team Charter

Mission Statement

The mission of the HFT IPT is to provide planning, coordination, and communication for the HFT Project that will ensure the completion of the HFT Project scope on schedule and within budget, while complying with all applicable laws and standards. The IPT will ensure that project management is carried out with integrity and that quality assurance principles are applied to processes within the project.

Purpose and Goals

The roles and responsibilities of the IPT include:

* Support the HFT Federal Project Director;
* Develop a project contracting strategy;
* Ensure project interfaces are identified, defined, and managed to completion;
* Identify and define appropriate and adequate project technical scope, schedule, and cost parameters;
* Perform monthly reviews and assessment of project performance and status against established performance parameters, baselines, milestones, and deliverables;
* Plan and participate in project reviews, audits, and appraisals as necessary;
* Review all CD packages and recommend approval/disapproval;
* Review and comment on project deliverables, e.g., drawings, specifications, procurement, and construction packages;
* Review change requests, as appropriate, and support Change Control Boards as requested;
* Plan and participate in Operational Readiness Reviews or Readiness Assessments; and
* Support the preparation, review, and approval of project completion and closeout documentation.

Members

The following are members of the initial HFT Integrated Project Team.



As the project progresses, membership of the IPT will change as needed.

Primary Team Interfaces

Multiple interfaces are necessary for the HFT IPT to ensure well-coordinated timely project performance. These include DOE NP, BHSO, BNL and LBNL HFT Project Management Offices, the HFT subproject managers, and personnel from the various collaborating and contributing institutions.

The HFT Federal Project Director will be the primary point of contact with the HFT Program Manager for coordination and submission of CD documentation. The HFT Federal Project Director and the HFT Program Manager will be in routine contact to communicate project status and discuss issues or concerns. Input will also be solicited from the HFT Program Manager on institutional developments that may impact project performance.

Interface with Brookhaven Management and affected personnel will be necessary for coordination with site activities that may impact project performance or where project activities may have broader site impacts. These interfaces will also be necessary for planning and implementing the assembly and testing of HFT components. The HFT Contractor Project Manager will be the IPT point of contact for day-to-day interfaces with LBNL Management and other affected personnel. The HFT Deputy Project Manager will be the IPT point of contact for similar issues at Brookhaven.

For CD approvals and project reviews it will be necessary for the HFT Federal Project Director to interface with other DOE Headquarters program and project management organizations. The HFT Program Manager will be the IPT point of contact for day-to-day interfaces with these organizations.

The HFT subproject managers will be responsible for implementation of project elements of work. The HFT Contractor Project Manager and/or IPT team members directly associated with the elements of work being performed will be the primary points of contact with the subproject managers.

Meetings

The IPT will meet as necessary to accomplish the stated goals and mission. Team members will meet with each other and external interfaces as necessary to resolve specific issues.

# Appendix C – HFT SOFTWARE

Analysis, Alignment, and Calibration procedures and software are necessary for the ability to analyze data and to extract physics information. The detector performance can only be realized if software and procedures are in place and fully functional. Software and procedures are ready when test data or simulated data can be processed through the official STAR analysis chain.

The deliverables for the software are:

* Calibration and Monitoring software including Alignment and Distortions correction packages plus proper Databases of the detector state during data taking.
* Event reconstruction software fully integrated with the STAR software framework. This includes Hit and Track reconstruction software, Event and secondary vertex finder software
* Simulation and Evaluation software. This includes proper geometry databases, detector response packages, track embedding, association and evaluation.
* Physics analysis software fully integrated with the STAR software framework.