Project Execution Plan

for the

STAR Heavy Flavor Tracker (HFT) Project

Project # MIE – 01VB

at the

Brookhaven National Laboratory
Upton, NY

Office of Nuclear Physics (SC – 26)
Office of Science
U.S. Department of Energy

Date Approved:
October 2011

Project Execution Plan
for the
STAR Heavy Flavor Tracker (HFT) Project
at the
Brookhaven National Laboratory

Submitted by:

______________________________ Date: 9/30/11
Flemming Videbæk, HFT Contractor Project Manager

______________________________ Date: 10/3/11
Thomas Ludlam, Chairman, Physics Department, Brookhaven National Laboratory

______________________________ Date: 9/30/11
Steven Vigdor, Associate Laboratory Director for Nuclear and Particle Physics, Brookhaven National Laboratory

______________________________ Date: 10/3/11
Lloyd Nelson, HFT Federal Project Director, DOE Brookhaven Site Office

______________________________ Date: 10/3/11
Michael D. Holland, Manager, DOE Brookhaven Site Office

Concurrence:
______________________________ Date: 10/11/11
Helmut Marsiske, Program Manager for Nuclear Physics Instrumentation
Office of Nuclear Physics, Office of Science, DOE

______________________________ Date: 10-11-11
Jehanne Gillo, Director for Facilities & Project Management Division
Office of Nuclear Physics, Office of Science, DOE

~~Concurrence:~~

______________________________ Date: 10/11/11
Daniel R. Lehman, Director
Office of Project Assessment, Office of Science, DOE

Approval:

______________________________ Date: 10/11/11
Timothy Hallman, Associate Director
Office of Nuclear Physics
Office of Science, DOE

Project Execution Plan
for the
STAR Heavy Flavor Tracker (HFT) Project
at the
Brookhaven National Laboratory

Change Log

Revision No.	Pages Affected	Effective Date
Revision 0	Entire Document	August 2010
Revision 1	Entire Document, at CD-2 Baseline	October 2011

Project Execution Plan
for the
STAR Heavy Flavor Tracker (HFT) Project
at the
Brookhaven National Laboratory

Table of Contents

1 INTRODUCTION

This Project Execution Plan (PEP) for the STAR Heavy Flavor Tracker (HFT), a Major Item of Equipment (MIE) project at the Brookhaven National Laboratory (BNL), 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 PEP defines the project scope and the organizational framework, identifies roles and responsibilities of contributors, and presents the work breakdown structure (WBS), cost and schedule. The PEP 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 Nuclear Physics. This PEP was prepared in accordance with DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*.

1.1 Project Background

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.

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

CD-1, *Approve Alternate Selection and Cost Range*: On August 31, 2010 Jehanne Gillo, Director of the Facilities and Project Management Division of the Office of Nuclear Physics approved the Alternate Selection and Cost Range of the STAR Heavy Flavor Tracker (HFT) with a Total Project Cost (TPC) range of $16.5 - $17.8M.

1.2 Justification of 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 the identification and characterization of the properties of the strongly-coupled quark gluon plasma (QGP) that is produced in RHIC collisions and is 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 project is to extend STAR's capability to measure heavy flavor production by the measurement of displaced vertices and to perform direct topological identification of open charm hadrons. These are key measurements for the heavy-ion program at RHIC. Heavy quark measurements will enhance the heavy-ion research program as it continues with the detailed systematic characterization of the dense partonic 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. The addition of the HFT will give STAR the capability to execute this physics program, which is a top priority in both the Nuclear Science Advisory Committee (NSAC) Long Range Plan for RHIC science as well as the RHIC Mid-Term Strategic Plan.

2 PROJECT BASELINE

This section describes the project Performance Measurement Baseline (PMB), which consists of the scope, cost, schedule, funding profile, and other information related to the PMB.

2.1 Scope Baseline

The STAR detector 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 that measures particles over the full azimuthal angle and over momenta 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 transverse momentum effects.

The addition of the HFT will extend STAR's unique capabilities even further by enabling the measurement of neutral and charged particles with displaced decay vertices 100 μm, or less, from the primary vertex. The fine spatial resolution of the HFT will allow direct topological identification of parent particles with very short lifetimes from decays of heavy quarks, such as the D^0 and D* meson and the Λ_c baryon. In addition, the HFT will allow exclusive and inclusive reconstruction of charm and bottom semi-leptonic decays.

2.1.1 Technical Scope

The HFT project scope comprises designing, building and assembling, testing, and installing into STAR the three sub-detectors that constitute the HFT system (see Figures 2-1 and 2-2). The technical performance requirements for achieving Critical Decision-4 (CD-4) are given in Table 2-1: Key performance parameters for the HFT instrument.

The three sub-detectors are: a Silicon Pixel Detector (PXL), 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 that will have its readout electronics upgraded to be fully compatible with the current STAR Data Acquisition System (DAQ). The primary purpose of the SSD-IST-PXL system 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.

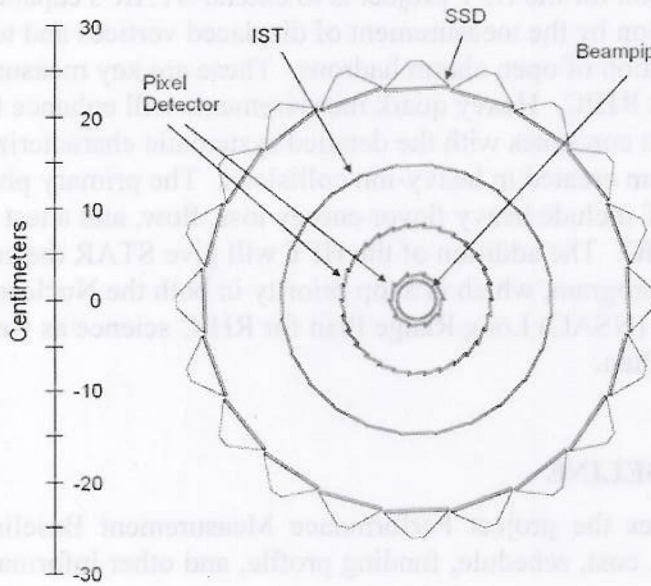

Figure 2-1: A schematic cross section view of the three HFT silicon sub-detectors that surround the beam pipe.

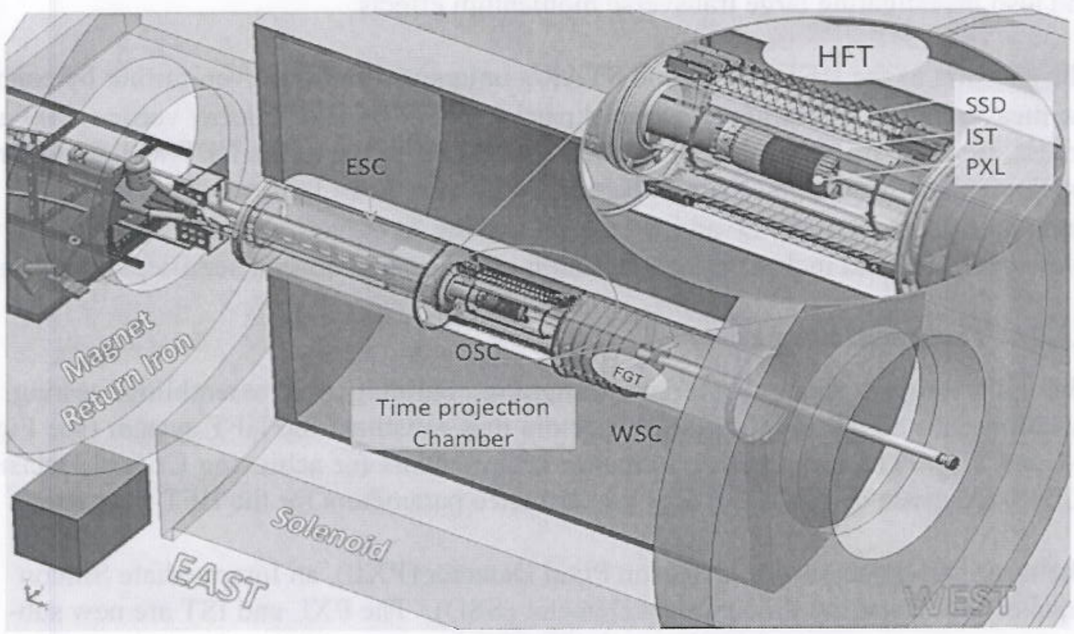

Figure 2-2: A cutout view of the geometry of the HFT. The HFT support structures (East (ESC), West (WSC), and Outer Support Cylinder (OSC)) and three sub-detectors are shown inside the STAR magnet and Time Projection Chamber.

2.1.2 Technical Performance Parameters

The HFT key performance parameters (KPPs) are given in Table 2-1. The capability of the HFT system to achieve the KPPs will be demonstrated through the measurement of subsystem functional parameters and detailed, realistic simulations using the full STAR detector simulation package and analysis software. The subsystem functional parameters will be obtained through bench tests, survey measurements, and the meeting of design specifications. The planned early finish schedule (see Section 2.3) has the HFT system ready for installation into STAR approximately two months prior to the RHIC Run-14 start date (approximately December 2013). As verification of the KPPs with beam is preferred, the project will attempt to demonstrate these using Run-14 Au-Au collision data. Appendix A provides further details on the KPPs and the underlying subsystem functional parameters.

Parameter	Threshold value	Optimal value
Pointing resolution of HFT system (750 MeV/c kaons)	≤60 μm in the r-phi plane and Z	~45 μm in r-phi plane and Z
Single-track efficiency for HFT system, requiring PXL hits on both layers. (1 GeV/c pions)	≥ 60%	≥ 75%
Compatible with STAR DAQ-1000 system	<20% dead time from HFT system at 1kHz	<15% dead time from HFT system at 1kHz.

Table 2-1 CD-4 key performance parameters

2.2 Cost Baseline

The cost baseline for the DOE TPC is $16.7M. Table 2-2 shows the cost summary at WBS Level 2 in At-Year (AY) dollars. Contingency is 34% of the funded estimate to complete.

WBS	Title	Cost ($M)
1.1	Project Management	1.9
1.2	Pixel	5.0
1.3	Intermediate Silicon Tracker	2.5
1.4	Silicon Strip Detector	1.0
1.5	Integration	2.4
1.6	Software	0
	Contingency	3.6
Total Estimated Cost (TEC)		16.4
OPC		0.3
Total Project Cost (TPC)		16.7

Table 2-2 HFT Cost Summary

Cost estimates were developed from a bottom-up analysis of each contribution to the scope of the HFT project and for contingency funds needed as an allowance for uncertainties, omissions, and risks. The total estimated cost (TEC) includes the cost of re-directed labor, which is already funded by operations funds at LBNL and BNL. Every institution employed a common method to develop their scope estimates and for calculating contingency within their scope at the lowest level of the WBS. The methodology to calculate contingency is based on technical, cost, schedule, and design weighting factors in combination with risk factors based on an assessment of the technical, cost and schedule risks of the labor and material components, and applying expert judgment. Further details can be found in the contingency analysis document maintained by the project. Contingency has also been estimated for certain manufactured items where past experience has shown that more than one fabrication attempt may be required. Finally, unassigned contingency (not associated with any identified risk) is held to cover "(un)known unknowns".

2.3 Schedule Baseline

2.3.1 Project Summary Schedule

The HFT subsystems are designed, fabricated, and assembled at various locations, shipped to the STAR detector hall at BNL, tested outside of the detector, and then assembled within the Inner Detector Support (IDS) and integrated into the STAR detector itself. The HFT will be installed and fully operational for RHIC Run 15 (approximate start date December 2014). Earlier installation is planned, and reflected in the early finish schedule, but depends on the RHIC run schedule in 2013-2014. The RHIC running schedule is not fixed from year to year, so additional time has been added to the planned early finish date such that assembly and installation in Q1FY14 has 18 months of schedule contingency to CD-4, planned for Q4FY15. This time will also be used to complete final project documentation (e.g., Project Closeout Report, Lessons Learned Report, Transition-to-Operations Plan), and a CD-4 Readiness Review.

Figure 2-3 shows the summary schedule and Figure 2-4 shows the Critical Path.

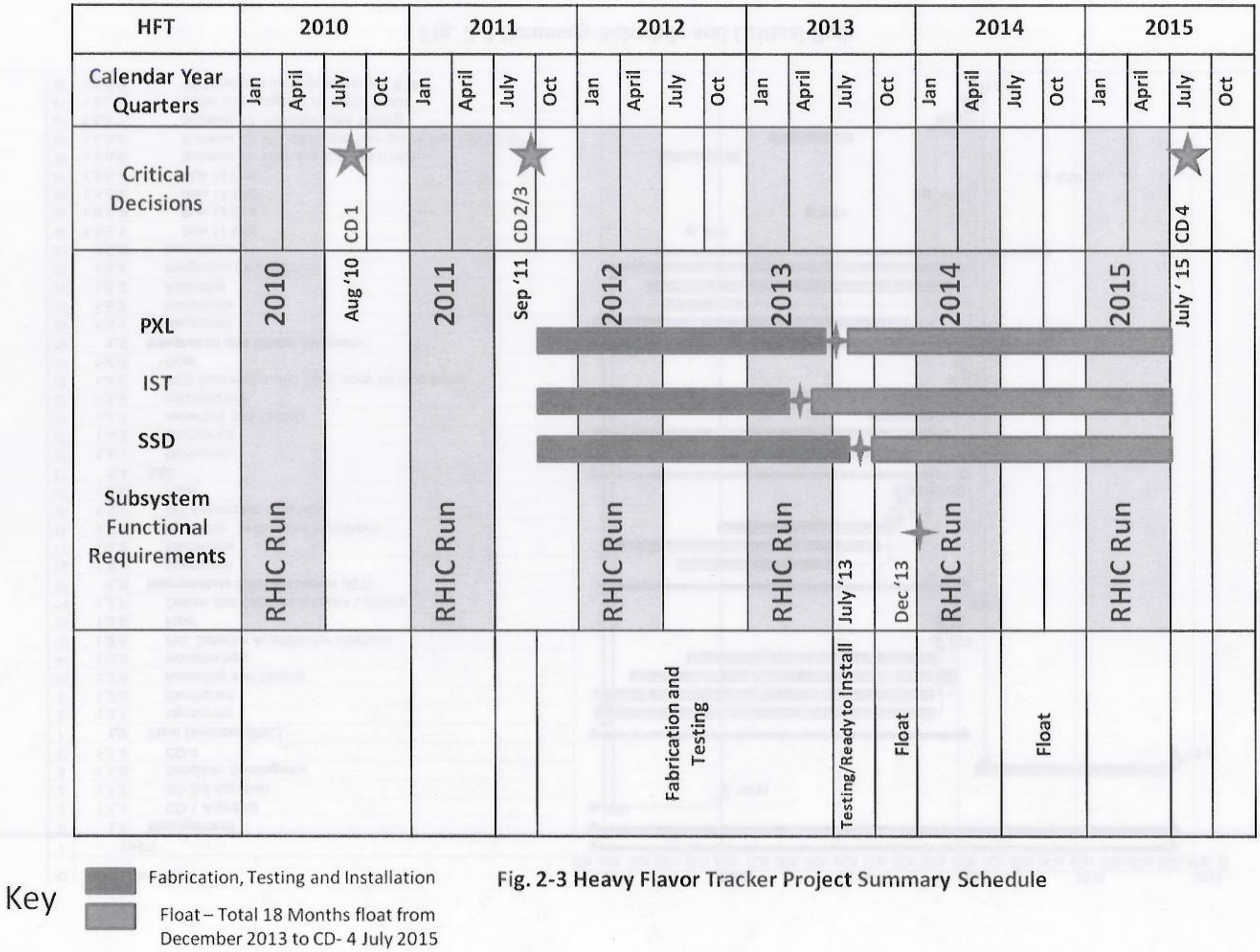

Fig. 2-3 Heavy Flavor Tracker Project Summary Schedule

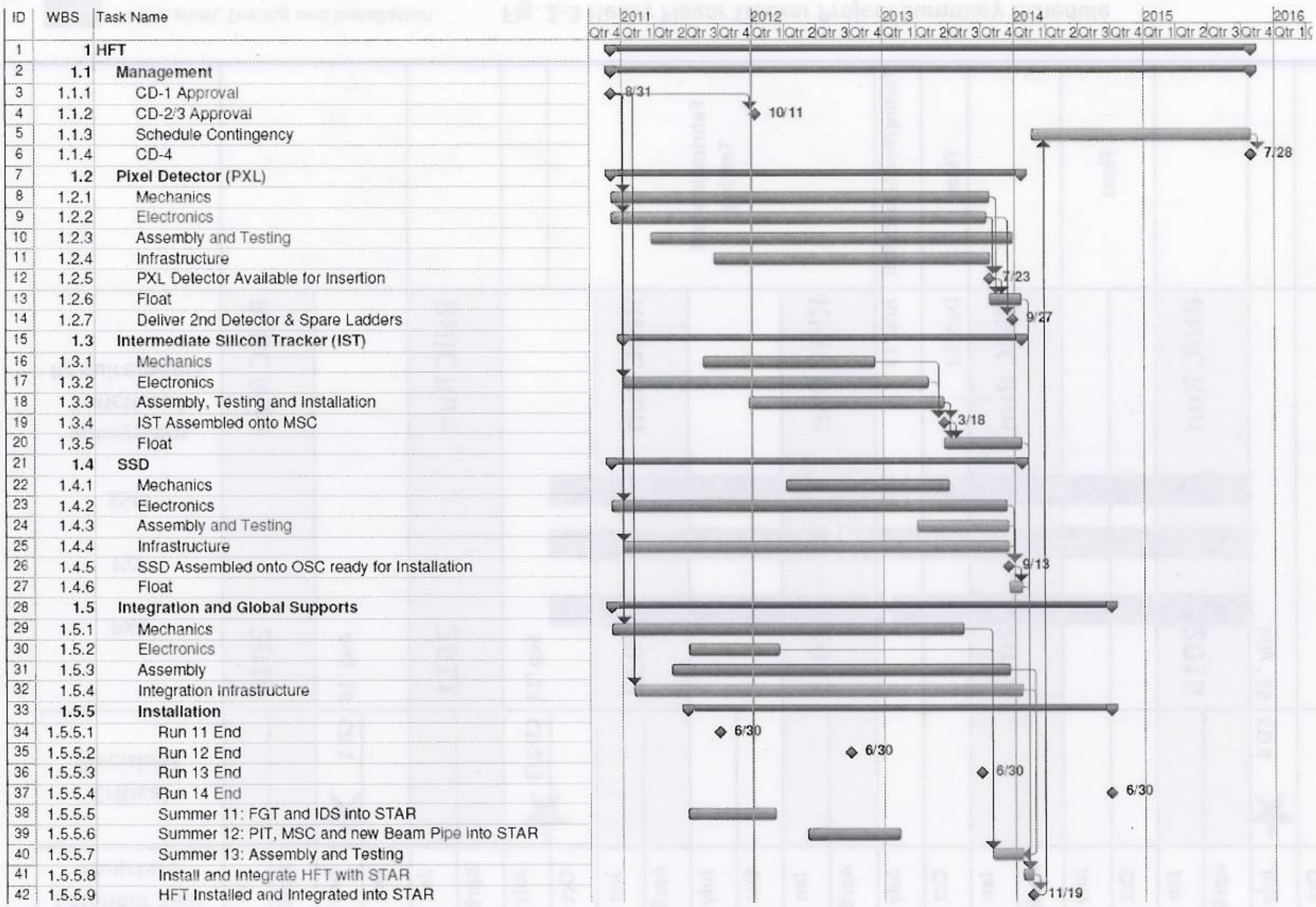

Fig. 2-4 Summary Schedule and Critical Path

2.3.2 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. The following tables detail the Level 1 and Level 2 milestones for the project. Additionally there are numerous Level 3 milestones in the project schedule.

Level 1 Milestones	Date
CD-0 Approve Mission Need	Feb. 18, 2009
CD-1 Approve Alternative Selection and Cost Range	Aug. 31, 2010
CD-2 Approve Performance Baseline	Q1FY12
CD-3 Approve Start of Construction	Q1FY12
CD-4 Approve Project Completion	Q4FY15

Table 2-3 Critical Decision Milestones

Table 2-4 shows the Level 2 milestones. All milestones are maintained in the HFT Microsoft Project cost and schedule database.

1.2	**PXL**	
	PXL Prototype Sector Design Complete	12/15/10
	PXL Receive Prototype sensors from IPHC	3/15/11
	PXL Prototype PXL Insertion mechanism Testing Complete	Q1FY12
	PXL Final PXL Sensors received	Q1FY13
	PXL Production Sector Assembly Start	Q2FY13
	PXL detector available for insertion	Q3FY13
1.3	**IST**	
	IST Sensor design finished	Q1FY12
	IST Prototype ladder tested	Q2FY12
	IST Flex hybrid produced	Q3FY12
	IST First staves produced	Q4FY12

	IST Staves finalized	Q2FY13
	IST assembled onto MSC ready for installation	Q3FY13
1.4	**SSD**	
	SSD Prototype Ladder Board design finished	10/15/10
	SSD QRDO Prototype Board design finished	7/20/11
	SSD Preproduction Design Review of RDO	Q3FY12
	SSD Production of Ladder Boards ready to begin	Q1FY13
	SSD Assembled onto OSC ready for installation	Q4FY13
1.5	**Integration & Global Supports (IGS)**	
	IGS Final MSC assembled at BNL	Q2FY13
	IGS Final OSC at BNL	Q4FY13
	IGS HFT assembled and integrated into STAR	Q1FY14

Table 2-4 Level 2 Milestones

2.4 Work Breakdown Structure (WBS)

The HFT has been organized into a 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.

Table 2-5 summarizes WBS definitions at Level 2. A complete WBS Dictionary is provided in Appendix B of this document, including more detailed descriptions of the tasks associated with each Level 2 WBS item, their deliverables and interfaces.

1.1	Project management	Level of effort tasks associated with the daily management, oversight, and assessment of the project. It includes the effort associated with the Project Office at BNL, LBNL and MIT-LNS. The effort includes CPM, Project Controls, financial oversight, documentation, and reporting.
1.2	Pixel Detector (PXL)	Fabrication, integration, and test of the PXL system. The PXL System will provide as final deliverables, two copies of the production PXL system with sufficient spare components to swap and refurbish elements of the two production units for the projected lifecycle of the project. As preamble to the Final PXL system, it is intended to install a prototype PXL system in an engineering run.

1.3	Intermediate Silicon Tracker (IST)	Contains deliverables and effort related to the fabrication of the IST, including sensors, readout electronics, cooling, and mounting structures. It also includes assembly and testing of prototypes and the final system.
1.4	Silicon Strip Detector (SSD)	The RDO boards of the existing Silicon Strip Detector (SSD) will be upgraded so its performance matches the requirement of the current STAR DAQ 1000. Upgraded cooling system, as well as mounting structures is provided in this WBS.
1.5	Integration and Global Supports (IGS)	Primary deliverable is global support structure, and the effort to maintain integrated design across all internal sub-detectors and with STAR and the FGT project. The infrastructure modifications necessary to support assembly, testing and installation of the detectors are part of this effort. Overall safety management for HFT and coordination with the BNL safety committees is provided.
1.6	Software	The Software tools contain two broad categories: Online and Offline. The modules needed will monitor, calibrate, reconstruct, analyze and evaluate the acquired data samples. The online software primarily ensures the data integrity during data acquisition via appropriate detector monitoring and sample event reconstruction. The offline environment consists of the event reconstruction software packages. It is not part of the project deliverables but monitored by the software subsystem manager

Table 2-5 Definitions of WBS at Level 2

2.5 Funding Profile

2.5.1 Planned DOE Funding

The HFT MIE project will be entirely funded by DOE-NP and the planned DOE funding profile by Fiscal Year (FY) is shown in Table 2-6.

Funding Profile ($M)						
	FY 10	FY 11	FY 12	FY 13	FY 14	Total
TEC	2.42	3.21	4.92	4.79	1.10	16.44
OPC/R&D	0.30	0.00	0.00	0.00	0.00	0.30
TPC	2.72	3.21	4.92	4.79	1.10	16.74
Redirect included in TEC	0.02	0.31	0.37	0.39	0.15	1.24
New Funds Required	2.70	2.90	4.55	4.40	0.95	15.50

Table 2-6 HFT Funding Profile in AY $M.

The total estimated cost (TEC) includes the cost for redirected labor, which refers to engineers, technicians and managers who are funded by DOE operations and research funds at BNL and

LBNL. The use of redirected labor helps decrease the amount of new funds required to implement the project.

3 LIFE CYCLE COST

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) Design, fabrication and testing as described in this document; (b) Operation; and (c) Decommissioning costs.

The cost of operation is estimated to be $100,000 annually and will be supported by the 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.

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 cost is likely less than $100,000. The estimated life-cycle cost is less than $19 million.

4 ACQUISITION APPROACH

The HFT project is being executed under an Acquisition Strategy (AS) approved previously by the Acquisition Executive (AE). There have been no significant changes in the acquisition approach since.

BNL, as the prime contractor, is responsible for the design, procurement, fabrication, assembly and integration of the HFT components. BNL has assigned the responsibility for design, procurements, and fabrication of the PXL system to LBNL, and the responsibility for the Intermediate Silicon Tracker has been assigned to MIT. The LBNL group has led the R&D effort for the thin complementary metal-oxide semiconductor (CMOS) detectors that is a key element for the inner detector. LBNL also has extensive knowledge and experience in carbon-fiber technology that is a crucial component of detector mounts and for the global support structures. The MIT group has extensive experience in conventional silicon detector technology from fabrication of the PHOBOS detector at RHIC, and has acquired expertise for the readout systems for the IST detector via the Forward GEM Tracker Project. BNL will be primarily responsible for the development of the SSD readout electronics upgrade, supporting the assembly, and testing of the individual subsystems.

Several activities related to this project, as indicated above, will be most efficiently and/or cost effectively performed by members at universities or at other national laboratories and as indicated earlier, such work will be carried out using MOUs which will specify deliverables and will include provisions for reports on progress and expenditures. They will be established in accordance with standard DOE and BNL procedures.

When appropriate, subcontracted equipment and material will be competitively procured through fixed-price contracts. Sole-source procurements of one-of-a-kind equipment will be supported by appropriate justification.

5 TAILORING STRATEGY

DOE Order 413.3B allows for the development of a Tailoring Strategy for each project, based on the risk, complexity, visibility, cost, safety, security, and schedule. 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. At CD-1, the HFT project proposed as part of a tailored strategy to combine CD-2 and CD-3. The R&D was very advanced at CD-1 and upon approval of CD-1 the design was implemented quickly. At CD-2 the design is mature and the project is ready to begin fabrication, therefore concurrent approval of CD-2 and CD-3 is requested.

6 BASELINE CHANGE CONTROL

Changes to the approved technical, cost, and schedule baselines will be controlled using the thresholds described in Table 6-1 using the HFT Project Change Request (PCR) online system.

Project Controls is responsible for the PCR system. This begins with a request from any team member regarding a change to the cost, schedule, or technical baseline. A draft PCR is generated by Project Controls and pertinent data/documents are attached. Depending on the scope of the change, the draft document could be reviewed by safety and finance personnel before being forwarded to the CPM.

All Level 3 PCRs will be approved by the CPM. Level 1 and 2 PCRs will be submitted by the CPM to the FPD, after concurrence with the Physics Department Chair person. 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 for approval.

If the change is approved, Project Controls is responsible for implementing the approved cost, budget, schedule or milestone changes in the official HFT documents. If approval is denied, no changes are made to project documents. All PCRs, approved or rejected, are maintained in the database.

	DOE SC-2 Deputy Director for Sciences Program (Level 0)	DOE-SC-26 Acquisition Executive (Level 1)	DOE-BHSO Federal Project Director (Level 2)	HFT Contractor Project Manager (Level 3)
Scope (Table 2-1)	Any change affecting Mission Need	Any change affecting CD-4 deliverables as referenced in Tables 2-1 and 2-5	N/A	Any change not affecting CD-4 deliverables as referenced in Tables 2-1 and 2-5
Cost (Table 2-2)	Any increase in TPC	Any change to TEC or OPC, or cumulative allocation of ≥ $500k contingency as referenced in Table 2-2	A cumulative increase of ≥ $250k in WBS Level 2 elements, or cumulative allocation of ≥ $250k contingency as referenced in Table 2-2	Any increase of ≥ $50k in a WBS Level 2 element as referenced in Table 2-2
Schedule (Table 2-3, 2-4)	Any delay in CD-4 date	≥ 3 months delay of a Level 1 milestone date (other than CD-4), or ≥ 6-month delay of a Level 2 milestone date as referenced in Table 2-3 and 2-4	≥ 3-month delay of a Level 2 milestone date as referenced in Table 2-4.	≥ 1-month delay of a Level 2 milestone date, as referenced in Table 2-4, or ≥ 3-month delay of a Level 3 milestone date as maintained in the project schedule

Table 6-1 Summary of Baseline Change Control Thresholds

7 MANAGEMENT STRUCTURE AND INTEGRATED PROJECT TEAM

7.1 Management Structure and Team

This section provides the management organization for the HFT project as needed for development, fabrication and final assembly of the apparatus. Figure 7-1 outlines the HFT management structure.

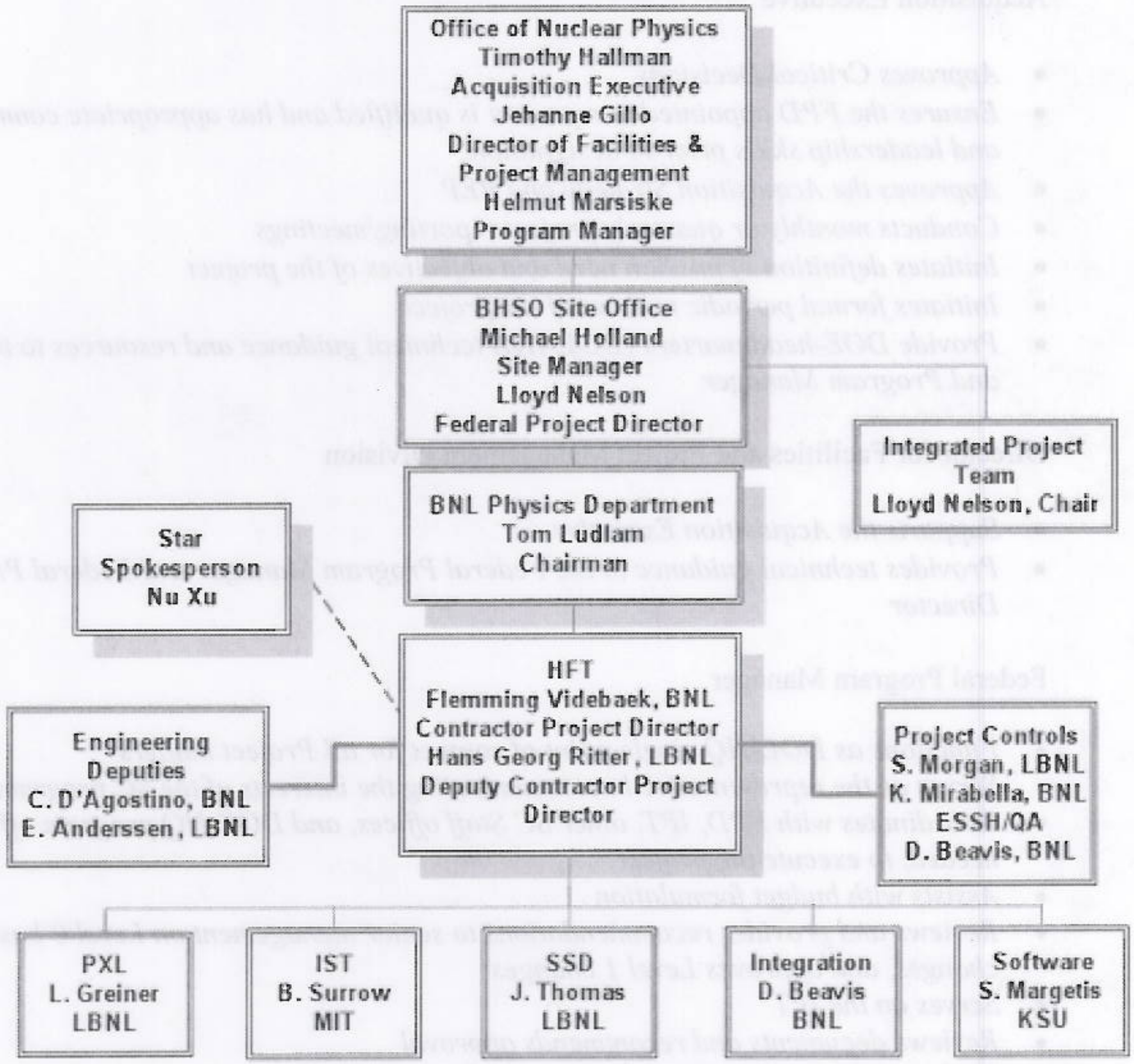

Figure 7-1 HFT Management Organization Chart

Acronyms used in the above chart:
BHSO – Brookhaven Site Office
ESSH/QA - Environmental Safety, Security, Health, and Quality Assurance
KSU – Kent State University
LBNL – Lawrence Berkeley National Laboratory
MIT – Massachusetts Institute of Technology

Within the DOE Office of Science (SC), the Office of Nuclear Physics (NP) has overall responsibility for the STAR HFT upgrade project. The Acquisition Executive (AE) is Timothy Hallman. Helmut Marsiske serves as the Federal Program Manager in the Office of Nuclear Physics and reports to Jehanne Gillo, the Director of the Facilities and Project Management Division, who supports the AE.

Acquisition Executive

- *Approves Critical Decisions*
- *Ensures the FPD appointed to a project is qualified and has appropriate communication and leadership skills prior to designation.*
- *Approves the Acquisition Strategy and PEP*
- *Conducts monthly or quarterly project reporting/meetings*
- *Initiates definition of mission need and objectives of the project*
- *Initiates formal periodic reviews of the project*
- *Provide DOE-headquarters (DOE-HQ) technical guidance and resources to the FPD and Program Manager*

Director for Facilities and Project Management Division

- *Supports the Acquisition Executive*
- *Provides technical guidance to the Federal Program Manager and Federal Project Director*

Federal Program Manager

- *Functions as DOE-HQ single point of contact for all Project matters*
- *Serves as the representative in communicating the interests of the SC program*
- *Coordinates with FPD, IPT, other SC Staff offices, and DOE-HQ program offices, as needed, to execute the project*
- *Assists with budget formulation*
- *Reviews and provides recommendations to senior management on Level 0 baseline changes, and approves Level 1 changes*
- *Serves on the IPT*
- *Reviews documents and recommends approval*
- *Reviews project progress reports and deliverables*
- *Supports formal periodic reviews of the Project including DOE Office of Project Assessment (DOE-OPA) Reviews and tracks issues to resolution*

Brookhaven Site Office Manager

- *Provides required Federal personnel resources at the site as necessary*
- *Approves site specific documents and permits*

HFT Federal Project Director (FPD)

- *Serves as the single point of contact between Federal and contractor staff for all matters relating to a project and its performance.*
- *Prepares and maintain the IPT Charter and operating guidance with IPT support and ensure IPT is properly staffed. Defines and oversees the roles and responsibilities of each IPT member.*
- *Reviews and provides recommendations to senior management for Level 0 and Level 1 baseline changes; approves Level 2 changes*

- *Leads the IPT and provides broad program guidance. Delegates appropriate decision-making authority to the IPT members.*
- *Ensures development and implementation of key project documentation*
- *Defines project cost, schedule, performance, and scope baselines.*
- *Ensures design, construction, environmental, safety, security, health and quality efforts performed comply with the contract, public law, regulations and Executive Orders.*
- *Ensures timely, reliable, and accurate integration of contractor performance data into the project's scheduling, accounting, and performance measurement systems, to include PARS II.*
- *Evaluates and verifies reported progress; makes projections of progress and identifies trends.*
- *Approves (in coordination with the Contracting Officer) changes in compliance with the approved change control process documented or referenced in the PEP.*

Brookhaven National Laboratory

- *Ultimately responsible and accountable to DOE for executing the Project within scope, cost and schedule in a safe and responsible manner.*
- *Provides access to laboratory/contractor resources, systems, and capabilities required to execute the Project.*

HFT Contractor Project Manager (CPM)

- *Reports to the Chairman of the BNL Physics Department and has the responsibility and authority for delivering the project scope on schedule and within budget.*
- *Manages the execution of the project to ensure that the project is completed within approved cost, schedule and technical scope,*
- *Ensures that effective project management systems, cost controls and milestone schedules are developed, documented and implemented to assess project performance,*
- *Ensures that project activities are conducted in a safe and environmentally sound manner.*
- *Ensures ES&H responsibilities and requirements are integrated into the project.*
- *Oversees R&D program, design, fabrication, installation, and construction. Represents the project in interactions with the DOE. Participates in management meetings with DOE and communicates project status and issues.*
- *Requests and coordinates internal and external peer reviews of project.*
- *Evaluates change control thresholds.*
- *Responsible for risk evaluation and management in accordance with the risk management plan.*
- *Approves Level 3 change control proposals. Prepares and provides recommendations to the Federal Project Director for Level 0, 1, and 2 changes. Identifies and manages project risks.*
- *Manages the interface and coordination of requirements with other projects*
- *Primary point of contact with the Federal Project Director*

HFT Deputy Contractor Project Manager (DCPM)

- *Assists the CPM in all matters relating to the HFT Project, including the planning, procurement, disposition and accounting of resources, progress reports on project activities, ESSH/QA issues, and Risk Management. In the absence of the CPM, the DCPM assumes the project management responsibilities.*
- *Reviews Memoranda of Understanding and other project documentation, advising the Project Manager on risk management, ESSH/QA, or other relevant issues.*

HFT Engineering Deputies

- *Report directly to the CPM*
- *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.*
- *Responsible for reviewing data produced by the HFT team to confirm it will support the HFT key performance parameters and is consistent with the STAR detector requirements.*
- *Maintains an overview of all scope requirements, including parameters, energy, power; footprints, quantities and planned locations of equipment*
- *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.*

HFT Subsystem Managers

- *Responsible for the design, fabrication, assembly, and testing of their subsystem in accordance with the performance requirements.*
- *Provide a monthly status on both technical progress and schedule.*

HFT Project Controls

The Project Controls personnel assist the project in developing the required documentation, reports, project plan, and control of cost and schedule.

HFT ESSH/QA

The ESSH/QA lead is responsible for ESSH/QA coordination between the HFT project and the ESSH/QA organization at BNL and other participating institutions.

HFT Integrated Project Team (IPT)

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

7.2 Participating Institutions

The following is a list of the institutions that participate in the fabrication of the deliverables of the HFT project.

Brookhaven National Laboratory	BNL
Kent State University	KSU

Institut Pluridisciplinaire Hubert Curien, Strasbourg, France	IPHC
Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge	MIT
Lawrence Berkeley National Laboratory	LBNL
SUBATECH, Ecole des Mines, Nantes, France	SUB
University of Texas, Austin	UT

Table 7-1 Participating Institutions

BNL has overall responsibility for the fabrication of this MIE. 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 online software; and BNL for integration. These institutions have expertise and past experience in designing / fabricating / implementing similar subsystems. UT is responsible for components of the PXL system. MOUs define the relationship between the institutions and BNL.

Sensor development is taking place at the IPHC in Strasbourg, France, in close collaboration with the LBNL group. The SUBATECH, Ecole des Mines, Nantes group provides engineering for the electronics upgrade of the SSD, in close collaboration with the BNL group. MOUs define the relationship between BNL and IPHC and SUBATECH, respectively.

A number of additional institutions have responsibilities for offline software (see Appendix D) as part of the software coordination with STAR.

Czech Technical University, Prague, Check Republic	CTU
University of California, Los Angeles	UCLA
Nuclear Physics Institute, Prague, Check Republic	NPU
Purdue University, West Lafayette	PU

Table 7-2 Institutions participating solely in offline software

8 PROJECT MANAGEMENT/OVERSIGHT

8.1 Risk Management

Risk management is based on a graded approach in which levels of risk are assessed for project activities and elements and assessments of technical, cost and schedule risks are conducted throughout the project lifecycle.

The HFT risk management approach consists of a five-step process:

1. Identifying potential project risk – any member of HFT may suggest a potential risk. The subproject (WBS level 2) managers are responsible for addressing the potential risk with the DCPM or CPM concurrence.

2. Analyzing project risk - the probability of the risk occurring together with the potential impact to the project's technical performance, cost and/or schedule baseline. Probability is assessed qualitatively (Low, Moderate, and High).

3. Planning risk abatement strategies.

4. Executing risk abatement strategies - abatement strategies differ according to the potential risk and its timing. A table of abatement strategies is included in the Risk Management plan.

5. Monitoring and tracking the results and revising risk abatement strategies risk assignments are associated to specific WBS entries down to Level 3. The WBS number will also serve as the Risk Index. This serves to emphasize the role of the Level 2 WBS manager in risk management. Risk information, including the probability and impact assessments and brief summaries of mitigation strategies, are stored in the HFT document repository.

In addition to the task-based risks at the sub-system level there are broader risks to the project to be considered:

- Delays in funding, e.g., due to an extended continuing resolution:
    - The HFT project plan assumes funding for each new FY arrives no later than the beginning of 2QFY of that year. Any additional delays may result in schedule disruptions due to, e.g., procurement delays or reassignments of planned-for engineering/technician effort.
- RHIC run schedule and off-project contributions:
    - The RHIC schedule for shutdown periods constrains periods where installation of IDS, IST and SSD can take place;
    - The HFT requires a new beryllium beam pipe, which is considered part of the accelerator structure and as such is a responsibility of the BNL Nuclear and Particle Physics Directorate;
    - Redirected contributions or scientific effort could be insufficient;
        - supplement by on-project labor using contingency funds;
    - The innovative sensor development at IPHC, Strasbourg, though well underway and strongly committed to, could run into problems; the same applies to the SSD electronics design work by the group at SUBATECH, Nantes;
        - supplement by on-project labor using contingency funds.

Mitigation strategies are as indicated, but cannot completely remove some of the risks that originate from outside the project.

8.2 Project Reporting and Communication

The HFT project has been entered into PARS II and its status is updated monthly by the FPD.

The CPM leads monthly cost and schedule reviews and reports the results 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. It is anticipated that ONP will have progress reviews as required.

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, Engineering and Design, Fabrication) 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.

8.3 Earned Value Management System (EVMS)

The Brookhaven National Laboratory has a certified EVMS that complies with the ANSI/EIA-748 Standard. The HFT TPC is below the threshold for requiring EVMS Reporting. The health of the project will be assessed using milestone status, weekly/monthly teleconferences, and face-to-face meetings as necessary.

8.4 Project Reviews

Independent Project Reviews of the project status and management may be conducted by the Office of Science, Office of Project Assessment if needed prior to each CD. Additional external and independent technical and design reviews, as applicable may be performed.

8.5 Engineering and Technology Readiness

The project will assess engineering and technology readiness through design reviews, IPRs, and other independent technical reviews as required (see Project Reviews).

8.6 Alternatives Analysis and Selection

At present there is no other known technology that can achieve the thin Si sensors required for the proposed innermost layers of the PXL detector. Some other known Si sensors would be less risky, but would not be able to fulfill the requirements for low-mass detectors, and thus would reduce physics capabilities.

As discussed in detail in the HFT Conceptual Design Report (CDR) four other technologies were considered for this task: hybrid pixels as used in LHC detectors, CCDs as were successfully used in the SLD experiment at SLAC, Monolithic Active Pixel Sensors (MAPS) and Depleted P-Channel Field Effect Transistors (DEPFET), and conventional Silicon technology detectors. They were rejected due to: i) Hybrid pixels result in thick layers >1% X_0; ii) CCDs do not fulfill the requirements of readout speed; and iii) the DEPFET is a very aggressive unproven technology.

The alternative selected for the intermediate and outer tracker, i.e., the IST and SSD, was chosen following a BNL-led STAR review in 2007, where a hybrid technology was compared to the selected alternative but deemed to be considerably more expensive and required more resources than the more conventional technology employed by the IST.

8.7 Environment, Safety and Health

8.7.1 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.

8.7.2 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 Environmental Policy Act (NEPA), State, and local requirements will be addressed and completed in advance of CD-2.

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. It is anticipated that the proposed fabrication and (off-project) 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.

8.7.3 ESSH Plans for Fabrication

The HFT upgrade for STAR will use the BNL 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 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.

8.7.4 DOE ESSH Oversight

The FPD has the overall responsibility for the ESSH implementation to ensure that the project is constructed safely. He will maintain cognizance of all project activities, including the final ESSH plan and subsequent updates. The FPD is assisted in these responsibilities by the DOE Facility Representative from BHSO. The Operations Management Division 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 as needed. BHSO personnel will monitor the HFT fabrication activities on a regular basis to ensure that planned BNL oversight is being performed and that applicable BNL plans are being followed.

At BNL, BNL management is 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 BNL, and field operation awareness activities to ensure that BNL oversight is functioning properly. Applicable ESSH 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.

8.8 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.

8.9 Value Engineering

As part of the Peer Review process, the design and fabrication will be reviewed and evaluated with Value Engineering principles in mind. The review teams will evaluate alternative design approaches and evaluate the flexibility of the design for present and future research as appropriate. The VE approach will determine the impacts on cost (both project and life cycle) of any suggested changes to the design.

8.10 Quality Assurance and Configuration/Document Management

The project shall adopt in its entirety the BNL Quality Assurance Program maintained in the SBMS. 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 414.1C, 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.

8.11 Transition to Operations

Prior to CD-4 a Transition to Operations Plan (TOP) will be prepared by the HFT IPT in accordance with DOE Guide 413.3-16, *Project Transition/Closeout (CD-4)*. The TOP will be approved by the DOE Office of Nuclear Physics, the DOE Federal Project Director, and the Contractor Project Manager, and concurred by the BNL Associate Director for Nuclear and Particle Physics and the STAR spokesperson. The plan will describe the management of, and resource requirements for, the transition phase steps that need to be undertaken to operate and maintain the HFT, as well as the scientific efforts to achieve optimal performance suitable to attain the science goals of the instrument. Part of the TOP will be a detailed Checkout, Testing, and Commissioning Plan which identifies all tasks with associated deliverables and milestones.

8.12 Project Closeout

Project closeout will begin when all equipment is ready for installation in the STAR detector and subsystem measurements to verify the KPPs have begun. A Draft Closeout report will be developed prior to CD-4 and is expected to address demonstration of KPPs, Lessons Learned, the closure status of purchase orders, the expected total cost of the Project and the value of remaining contingency, and when the Project is expected to close the control accounts and complete the financial closeout.

9 GLOSSARY

AE	Acquisition Executive
APS	Active PXL Sensor
AS	Acquisition Strategy
AY	At-Year
BER	Bit error rate
BHSO	Brookhaven Site Office
BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates
C-AD	Collider Accelerator Department (at BNL)
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
ES&H	Environmental, Safety and Health
ESC	East Support Cylinder
ESR	Experimental Safety Review
ESRC	Experimental Safety Review Committee
ESSH/QA	Environmental Safety, Security, Health, and Quality
EVMS	Earned Value Management System
FGT	Forward GEM Tracker
FPD	Federal Project Director
FTE	Full Time equivalent
FY	Fiscal Year
HAD	Hazard Assessment Document
HFT	Heavy Flavor Tracker
IDS	Inner Detector Support
IGS	Integration & Global Support
IN2P3	Institut National de Physique Nucléaire et de Physique de Particules
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
MIE	Major Item of Equipment
MIT	Massachusetts Institute of Technology
MSC	Middle Support Cylinder
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NP	Nuclear Physics

NPU	Nuclear Physics Institute
NSAC	Nuclear Science Advisory Board
OPA	Office of Project Assessment
OPC	Other Project Costs
OPM	Operational Procedures Manual
OSC	Outer Support Cylinder
OSHA	Occupational Safety and Health Act
PARS	Project Assessment and Reporting System
PMB	Performance Measurement Baseline
PC	Personal Computer
PCR	Project Change Request
PHENIX	Pioneering High Energy Nuclear Interacting Experiment
PEP	Project Execution Plan
PU	Purdue University
PXL	Silicon Pixel Detector
QA	Quality Assurance
QGP	Quark-Gluon Plasma
QRDO	Quick Read out
R&D	Research & Development
RDO	Read out
RHIC	Relativistic Heavy Ion Collider
SAD	Safety-Assessment Document
SBMS	Standards Based Management System
SC	Office of Science
Si	Silicon
SOW	Statement of Work
SSD	Silicon Strip Detector
STAR	Solenoidal Tracker at RHIC
SUB	SUBATECH
SVAR	Security Vulnerability Assessment report
TEC	Total Estimated Cost
TPC	Total Project Cost
UCLA	University of California, Los Angeles
UT	University of Texas
VE	Value Engineering
WBS	Work Breakdown Structure
WSC	West Support Cylinder

APPENDIX A HFT CD-4 KEY PERFORMANCE PARAMETERS

This appendix explains in detail the CD-4 key performance parameters, their justification and verification methods, and the underlying subsystem functional parameters.

CD-4 Key Performance Parameters

The instrument must be capable of a pointing resolution in r-phi of better than 60 µm for kaons of 750 MeV/c. 750 MeV/c is the mean momentum of the decay kaons from D^0 mesons of 1 GeV/c transverse momentum, the expected mean of the D meson distribution. The pointing resolution is defined as the width of a Gaussian fit (in sigma) to the distribution of distance of closest approach vectors (DCA) in the X-Y plane to the primary event vertex in 0-5% central Au-Au collisions. The pointing resolution in z will be similar. The resolution in z is defined as the square root of the difference between the squared 3D DCA and the squared r-phi DCA. The pointing resolution in r-phi and Z directions can be calculated with the full STAR detector simulation based on the design parameters, as-built dimensions, and from the results of surveys of the sensor ladders.

The instrument must be capable of a single-track reconstruction efficiency in a Au+Au collision environment of better than 60% for pions at 1 GeV/c that are emitted from the center of the detector within a rapidity window of ± 1 unit. This efficiency is defined as the fraction of TPC tracks that have a correct association to PIXEL hits on both layers and that has at least one hit in the IST and/or SSD layers. The single-track efficiency will be calculated using the full STAR simulations package with input taken from the design parameters and as-built dimensions of the detector.

The STAR DAQ1000 system allows reading out events that include the TPC with a dead time of no less than 4% at 1 kHz. The HFT should not add significant dead time to this value. The threshold value is completely driven by the existing non-replaceable components on the sensor modules on the ladders of the SSD.

The capability of the HFT system to achieve the KPPs will be demonstrated through the measurement of subsystem functional parameters (see below) and detailed, realistic simulations using the full STAR detector simulation package and analysis software. The simulation will reflect the as-built detector geometry, noise, and efficiency and response, and will employ proper signal and background event multiplicities. The subsystem functional parameters will be obtained through bench tests, survey measurements, and the meeting of design specifications. The planned early finish schedule (see Section 2.3) has the HFT system ready for installation into STAR approximately two months prior to the RHIC Run-14 start date (approximately December 2013). As verification of the KPPs with beam is preferred, the project will attempt to demonstrate these using Run-14 Au-Au collision data.

Subsystem Functional Parameters

Subsystem functional parameters 1-11 in Table A-1 support the key performance parameters. It will be shown by detailed measurements that fulfilling these parameters results in the anticipated performance given above.

The required pointing resolution can be achieved if performance requirements 1-4 in Table A-1 are fulfilled.

The required single-track efficiency can be achieved if in addition to requirements 1-4, the performance requirements 5-9 are fulfilled.

The requirements 10-11 will allow the HFT system to acquire data in excess of 500M Au+Au collisions for a typical RHIC running period (10 weeks).

Detailed explanations and justifications are given in the text following the table with the requirement number given in the heading.

	Functional parameter	**Threshold value**	**Optimal value**
1	Transverse thickness of first PXL layer	< 0.65% X_0	~ 0.37% X_0
2	Measured Internal alignment of sensors on a ladder of PXL.	< 30 μm	< 25 μm
3	Internal stability of PXL sector	< 30 μm	< 20 μm
4	Relative Stability of ISD and SSD relative to PXL layer	< 300 μm	< 100 μm
5	PXL integration time	< 200 μs	~187 μs
6	PXL hit efficiency and noise	> 95% sensor efficiency and noise level < 10-4	> 98% sensor efficiency and noise level < 10-4
7	IST hit efficiency and noise	> 90% from Signal: Noise better than 10:1	>97% from Signal: Noise better than 15:1
8	Live channels for PXL and IST	> 85%	> 95%
9	Functioning ladder cards for SSD	> 95%	100%
10	PXL and IST Readout speed and dead time	< 5% additional dead time at 1 kHz average trigger rate and simulated occupancy	~2% additional dead time at 1kHz average trigger rate and simulated occupancy
11	SSD dead time	< 20% at 1k Hz	~ 14% at 1kHz

Table A-1 Subsystem Functional Parameters

Multiple Scattering in the Inner Layers (1)

The precision with which the detector 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 which the particles have to traverse. The beam pipe and the first PXL layer are the two elements that have the most profound effect upon the pointing resolution. The new beam pipe has a radius of 2 cm 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 transverse thickness of the first PXL layer must be smaller than 0.65% of a radiation length. In a small solid angle area the walls of the sectors will contribute a considerably longer radiation length; this area is of the order of a few percent and can be excluded in the final physics analysis. 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, 4)

The PXL sensor positions need to be known and need to be stable over the course of a run in order not to have a negative effect on the pointing resolution. The measured alignment between PXL layers and within one sector needs to be better than 30 μm. The stability for a sector needs to be better than 30 μm (envelope).

The relative positions of the pixels within a sector will be measured with a coordinate measuring machine (CMM) with an anticipated envelope accuracy of < 30 microns. Stability against thermal expansion induced changes will be measured with TV holography and a capacitive probe. Stability against cooling air-induced vibration will be measured in the final PXL assembly with a capacitive probe.

The internal placement and stability of the IST and SSD relative to PXL should be determined to better than 300 μm (envelope). This refers to hardware limitations and requirements and not e.g. to off-line software relative alignment efforts. Those parameters can be determined from system parameters and cosmic ray measurements. Relative internal alignment of IST components and internal alignment of SSD components will be mapped with a CMM with typical errors of a couple of tens of microns. Final alignment of detector system to detector system will be determined from cosmic ray measurements and off-line alignment analysis. The relative stability of SSD and IST to pixel is verifiable by mechanical modeling of the Inner Detector Support structure. The mechanical construction will be built to specifications that guarantee the SSD and IST ladder position will be known to this initial accuracy.

PXL Integration Time (5)

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 (6)

High hit efficiency for the PXL detectors is essential for good detection efficiency. In the case of secondary decay reconstruction, the hit inefficiency of each detector layer enters into the total inefficiency with the power of the number of reconstructed decay particles. 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 for the active area and live columns. A MIP signal in the Ultimate sensors will typically have a signal to noise of

35:1 and intrinsic resolution of ~4 microns, as observed in beam tests. This can be verified by measurements of complete readout chain on bench and with test beam.

IST Detector Hit Efficiency (7)

High hit efficiency for the IST detector is essential for good detection efficiency for tracks. In order to keep the efficiency high, we require that the active strips of each of the detector ladders has a hit efficiency of better than 95% with a purity of > 95%. The hit efficiency of each detector layer can be determined on the bench before installation by signal to noise measurements. 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%.

Live Channels (8)

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 small and will only affect the overall acceptance, not pointing resolution. If more than 85% of all channels are alive at any time, the impact of dead channels will be minimal. The number of dead channels can be determined immediately after installation of the detectors on the mounting cone structures. The value is set to reflect typical performance of newly installed detector system as evaluated from historical data.

Functioning Ladder Cards for SSD (9)

To fully utilize the existing SSD sensors and ladders in the instrument the new ladder cards should be fully functional. It is outside the project scope and expertise to replace the existing ladders silicon modules should they be damaged during shipping, and handling in assembly.

Readout Speed and Dead Time (10, 11)

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. In order not to add significant dead-time to DAQ, the PXL and IST readout speed need to be compatible with that of DAQ-1000. This implies that the dead-time, with the Time Projection Chamber readout at a rate of 1 kHz, should be no more than 5% for PXL and IST, and less than 20% for the SSD. The SSD dead time varies linearly with rate and is constrained by the existing non-replaceable components on the detector ladders. For reference, the TPC dead time is ~4% at 1kHz. 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	$|\eta| < 1.15$
D	PXL RDO data path integrity	BER $< 10^{-10}$

Table A-2 Other functional requirements

The active sensors length requirements for PXL and IST are to ensure rapidity coverage in $-1 < \eta < +1$ 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 $-1 < \eta < +1$.

The length of the SSD ladders is fixed because it is an existing detector. The requirement C, listed in the table, 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 WBS DICTIONARY

1.1 MANAGEMENT

Level of effort tasks associated with the daily management, oversight, and assessment of the project.

This WBS contains the effort associated with the Project Office at BNL, LBNL and MIT-LNS. The effort includes STAR, Project Controls, financial oversight, documentation, and reporting.

1.2 PXL

The PXL System will provide as final deliverables, two copies of the production PXL system with sufficient spare components to swap and refurbish elements of the two production units for the projected lifecycle of the project. As preamble to the Final PXL system, it is intended to install a prototype PXL system in an engineering run.

Each of the WBS items described below defines unique deliverables with clearly defined interfaces. These have been defined to minimize interface interaction with deliverables from external WBS items within the PXL WBS and the HFT project. Where this interaction is required by tight interfaces, responsibilities are clearly defined across the shared interface.

All internal interfaces to the HFT project are mechanical, and directly to the HFT 'Global Support' deliverables, e.g. MSC. Installation and Infrastructure deliverables will contain all interfaces to STAR (i.e. external to HFT). Infrastructure includes service route and rack space allocation, as well as any permanent modification to the STAR Assembly Hall and clean room. Installation interfaces directly with STAR opening operations and installed configuration.

PXL internal interfaces and deliverables will be described below.

1.2.1 MECHANICS

Deliverables of this WBS are all mechanical elements required to assemble the insertable PXL system. Moderate mechanical assembly for various dry runs of later assembly and installation steps will be accounted for here, for design verification purposes—major tooling for these assembly steps are in the Assembly WBS. 'Dry' implies without electronics.

1.2.2 PXL ELECTRONICS

Deliverables of this WBS is the PXL sensors. The Ladder cable is the readout cable that is located beneath the sensor and brings the hit data, clocks, configuration and other digital signals to and from the sensors. It also distributes power and ground. Deliverables include the production RDO boards, mass termination boards, LU-protected power boards, RDO PCs, fiber optic communication modules, all testing electronics, firmware and software for the entire production detector RDO and testing. Also included is a control PC and interface boards that also serves as slow control system hardware.

1.2.3 DETECTOR ASSEMBLY

Assembly is mostly mechanical mounting of Electronics or Infrastructure deliverables onto Mechanical Structures. To minimize overlap with Mechanics Deliverables, all effort to develop assembly tooling and procedures, even for mechanical assemblies, is included here. Where appropriate, tooling iterations will be included

1.2.4 INFRASTRUCTURE

Deliverables for 'Infrastructure' are primary interfaces to STAR—these are all considered 'services'. Effort to integrate these deliverables into STAR, both the Detector, and the Assembly Hall is explicitly included here. 'Internal' services have explicit interface with HFT Project deliverables, which are external to the PXL WBS, primarily with the Global Support WBS Deliverables.

1.2.5 READY FOR INSTALLATION

PXL Installation has a primary interface with STAR configurations, e.g. STAR on beam line with or without pole-tip installed on east side, and STAR in the assembly hall. Some installation interfaces and activities will be shared with the 'Global Supports' i.e. final dry fit into the MSC.

It is required to be able to install/remove any installed PXL detector regardless of STAR configuration/schedule. Platforms and tooling will be consistent with STARs various configurations.

The Half Detector Enclosures are integral to all tooling proposed as they are the primary delivery platforms for any installation (and removal) scenarios.

Once a subsystem has been delivered, assembled and tested such that the individual subsystem parameters have been confirmed, it will be declared ready for installation.

1.3 INTERMEDIATE SILICON TRACKER (IST)

This WBS contains deliverables and effort related to the fabrication of the IST, including sensors, readout electronics, cooling, and mounting structures.

1.3.1 MECHANICAL

This WBS contains design, production and procurement of all mechanical items necessary to successfully mount the silicon sensor modules in a cylindrical layer at 14 cm radius. These are ladders, support of ladders and cooling systems.

1.3.2 ELECTRIC

This WBS contains design, production and procurement of all electrical items necessary to successfully operate the IST detector. Electric items include silicon sensors, readout chips, cable hybrids, and the complete readout system.

1.3.3 ASSEMBLY AND TESTING

This WBS covers assembly and testing of prototypes and the final system. Integration of 24 certified staves into a layer at 14 cm radius on the Middle Support Cylinder is included here. Includes final system testing.

1.4 SILICON STRIP DETECTOR (SSD)

The RDO boards of the existing Silicon Strip detector (SSD) will be upgraded so its performance matches the requirement of the current STAR DAQ 1000. Upgraded cooling system, as well as mounting structures is provided in this WBS.

1.4.1 ELECTRONICS

Deliverable of this WBS are the RDO boards, ladder boards, mounting the ladder boards on the existing ladders, fiber cables, and DAQ computers with DDL interfaces. SUBATECH collaborators will do the ladder board layout.

The board layout for the RDO card will be done by BNL using pinouts supplied by SUBATECH (master Field Programmable Gate Array (FPGA) and VME FPGA) and BNL (slave FPGAs).

Fabrication of both boards will be the responsibility of BNL.

1.4.2 MECHANICS

The SSD ladders need to be mounted on the cone. In addition, the cable need appropriate support. Deliverables include mounting hardware on the SSD with the appropriate mounting on the cone, cable supports so that cables can be routed, patch panel for the cables, so that the cables from the platform can be attached.

1.4.3 DETECTOR ASSEMBLY

The Analogue Digital Converter boards needed to be attached to the existing ladders. Once they are physically attached, the full system needs to be assembled and tested. The assembly needs to be shipped to the installation area.

1.4.4 INFRASTRUCTURE

Cables
There are three categories of cables that have to be produced. Thin aluminum clad power and HV cables, and fiber cables are routed on the cone to a patch panel. These cables then go the South Platform Racks. Optical fiber cables then go from the South Platform to the PCs in the DAQ room. In, addition some miscellaneous cables, connect trigger and slow controls to the SSD.

Cooling
The SSD needs to be operated at a constant temperature. The SSD will pull air from the TPC inner field cage. Deliverables include a vacuum source, the tubing needed to direct the flow

to the SSD and handle the input air from the TPC inner field cage. In addition, appropriate monitoring hardware and software is needed to monitor the air.

1.4.5 INSTALLATION/ASSEMBLY

The completed ladders are mounted on the cone system. When this is done, there needs to be an alignment effort to determine the location of the ladders. Effort needs to be done to install the cables on the new cone. Finally, the cables from the cone to the South Platform and the South Platform to the DAQ room need to be installed. At each stage of the assembly there needs to be sufficient infrastructure to test that the assembly is done correctly.

1.5 INTEGRATION & GLOBAL SUPPORTS

Primary deliverable is global support structure, and the effort to maintain integrated design across all internal sub-detectors and with STAR and the FGT project. The scope also includes the infrastructure modifications necessary to ensure that the subsystems are ready for installation as well as supporting the assembly and testing of the individual subsystems. Overall safety management for HFT and coordination with the BNL safety committees is provided.

Subsystems of the HFT, e.g. 1.2, 1.3, and 1.4, will determine the requirements on the deliverables for the global supports. Deliverables external to the HFT Project such as the FGT and beam pipe share support/environment with the HFT Project, but only within deliverables of this WBS. Definition and maintenance of all interface drawings and documents are part of this scope, and associated with the design effort of each specific deliverable.

Each subsystem is responsible for delivery and installation of detector and services, including all test and assembly tooling required. The Inner Detector Support (IDS) is one such system.

1.5.1 MECHANICS

The IDS replaces the current 'Cone' support system of STAR. The Cone system supported the SVT, SSD, and beam pipe in the past but currently supports only the beam pipe. The IDS is a carbon fiber composite designed to provide low mass support of all detectors inside the TPC inner field cage. The IDS shares structures with the FGT and directly supports the SSD, and indirectly supports the IST, PXL, and small diameter beam pipe via the MSC (Middle Support Cylinder). The IDS is directly supported by STAR via the east and west Time Projection Chamber Wheels.

The deliverables in this WBS also provide environmental volumes to each of the subsystems. As such, design work for each of these deliverables will also include at appropriate levels, work to establish and maintain 'Integration' and 'Requirements' documents over-arching HFT deliverables, and all external interfaces to STAR, FGT, and the beam pipe.

The beam pipe (not an HFT deliverable) is highly integrated with the HFT design and several HFT deliverables impact the design of the beam pipe.

1.5.2 ELECTRONICS

Grounding/EMI, environmental monitoring and electrical shrouds are deliverables for this task.

1.5.3 ASSEMBLY

Assembly of the IDS and MSC eventually includes the SSD and IST detectors, and integrates structurally the HFT with the FGT. The assembly of the beam pipe into the IDS is provided. PXL assembly and insertion are included in the PXL mechanics WBS (1.2.1)

1.5.4 INFRASTRUCTURE

Services independent of the detector subsystems, specific to the IDS/MSC are included here. Any significant modifications to the existing assembly hall infrastructure, not specific to a subsystem's needs are also included here.

Preparation of the space in the STAR assembly hall for the assembly and testing of the HFT detectors are the deliverables. Two areas will be prepared for assembly and testing. The existing "clean room" will be modified to provide appropriate conditions for assembly and testing of individual detectors. Assembly of multiple systems will occur inside another assembly area. Auxiliary equipment, and hardware required is included here.

1.5.5 INSTALLATION

Installation of the IDS is analogous to the current installation process for the cone system. Work is defined to be installation of the IDS into STAR, and any removal and re-installation required for project completion. This includes the installation of equipment on the STAR platforms including cables, power supplies, cooling systems. Termination of services specific to the IDS/Inner Field Cage is also included here.

1.5.6 ENGINEERING PRIOR TO CD3

The engineering efforts for the mechanical structures prior to CD3 are totaled here.

1.5.7 ENGINEERING AFTER CD3

The engineering efforts for the mechanical structures after CD3 are totaled here. The deliverables are an early IDS to be used with the FGT and the final IDS. Other deliverables include the MDS, PIT, internal beam pipe support and other mechanical structures.

1.5.8 SAFETY

Deliverables are the safety documentation and reviews.

1.6 SOFTWARE

The Software tools are divided into two broad categories: Online and Offline. The modules needed will monitor, calibrate, reconstruct, analyze and evaluate the acquired data samples.

1.6.1 ONLINE

The online software primarily ensures the data integrity during data acquisition via appropriate detector monitoring and sample event reconstruction. Online software is detector specific and is a deliverable of the corresponding subsystem.

1.6.2 OFFLINE

Offline software is not a project deliverable, but is being directed by the software subsystem manager. The offline environment consists of the event reconstruction software packages. This starts with the raw data as input and through proper calibration and alignment it proceeds with detector cluster/hit finding, integrated tracking, event vertex finding and event information writing to DSTs.

APPENDIX C 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

As applicable, the responsibilities of the IPT members include:

- *Support the Federal Project Director (who chairs the committee).*
- *Work with the Contracting Officer to develop a project Acquisition Strategy and Acquisition Plan, as applicable.*
- *Ensure project interfaces are identified and defined*
- *Assist with completion of the project environmental, safety, health, security, risk and quality assurance requirements.*
- *Identify and define appropriate and adequate project technical scope, schedule and cost parameters.*
- *Perform periodic reviews and assessments 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 and comment on project documents and deliverables (e.g., drawings, specifications, procurement, and construction packages).*
- *Review change requests (as appropriate).*
- *Participate, as required, in Operational Readiness Reviews or Readiness Assessments.*

Members

The following are members of the HFT Integrated Project Team. As the project progresses, membership of the IPT will change as needed.

DOE Program Manager for HFT	Helmut Marsiske
DOE Science Program Manager	Gulshan Rai
DOE Federal Project Director (Chair)	Lloyd Nelson
DOE Site Contracting Officer	Evelyn Landini
BNL Contractor Project Director for HFT	Flemming Videbaek
LBNL Project Controls	Sarah Morgan
BNL Project Controls	Kerry Mirabella
LBNL Deputy Project Director	Hans Georg Ritter
BNL ESSH/QA Lead	Dana Beavis
Physics Assistant Chair for Administration	Robert Ernst
BHSO Facility Representative	Patrick Sullivan

Roles and responsibilities of most members of the IPT are described in Section 7. The DOE Site Contracting Officer supports the HFT FPD to review contracts and ensure that procurements and MOUs for the HFT project are developed and executed in accordance with federal procurement regulations; the Physics Assistant Chair for Administration is responsible for the subcontract procurements and laboratory-to-laboratory contracts for work for the HFT project, facilitates budget and project accounting, and assists the CPM in providing cost information for monthly and quarterly reports; the BHSO Facility Representative reviews risk management plans for safety oversight of the implementation, fabrication and installation of HFT components in the STAR detector in accordance with BNL Standards Based Management Systems requirements and national safety consensus standards.

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 BNL Management and other affected personnel. The HFT Deputy Project Director will be the IPT point of contact for similar issues at LBNL.

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 D HFT OFFLINE SOFTWARE

In addition to the project deliverables it is important that the offline software is developed for the HFT detector so it is ready for physics analysis when the detector system is installed. The project works in close collaboration with STAR on this, lead by the subsystem manager for software. The work is all done by scientific labor at institutions within STAR at no cost to the project.

A number of other institutions have only responsibilities for the software (KU, UCLA, PU, and NPU).

The offline software consists of: analysis, alignment, and calibration procedures and software is necessary for the ability to analyze data and to extract physics information.

The components needed include:

- 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; and
- Physics analysis software fully integrated with the STAR software framework.

The associated tasks will be described in a software WBS with milestone to track the progress, and an associated dictionary.