WBS Dictionary:

The WBS is divided into

* 1. Management
  2. PXL detector
  3. IST detector
  4. SSD detector upgrade
  5. Inner detector Support and Integration
  6. Software

**Revision History**

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| **Revision No.** | **Description / Pages Affected** | **Effective Date** |
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# 1.1 Management

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

# 1.2 Pixel

The Pixel System will provide as final deliverables, two copies of the production

### Sector Mount and Survey (Engineering)

After D-Tube assemblies are complete, Sectors are mounted to these detector halves, and using the tooling provided above, a survey of sufficient accuracy is performed.

Electrical testing of each sector after it is mounted and it’s cables dressed onto the D-Tube is required. The test equipment is provided by the Electronics effort. Labor to complete these QA tests is costed here. Tests are required after mounting and after survey to assure nothing was damaged (e.g. wire bonds) during survey. Auxiliary labor to replace damaged sectors is included here in contingency. As the installation is serial, if the first Sector is damaged, this represents complete replication of labor and test.

This will be the first qualification of the Survey method, as such, it is desired to have at least 5 sectors available, enough to populate ½ of the detector to verify the survey procedure for the Production Installation. There are currently 5 such electrically functional sectors costed in base, but argument for additional sectors is warranted. Should scope allow for only 5 sectors, disassembly will be required to populate the other half detector for the engineering run—and associated re-test, re-survey of the final version of the assembled halves.

Final deliverable is 2 surveyed half detectors, 1 with 2 sectors, the second with 1 sector. Each ready to mount onto the hinge structure of the cart and terminate their respective cables to the MTB. Note, Dummy Sectors (w/out functional ladders) may be required to establish proper boundary conditions for cooling air flow.

It is clear that this will at least first occur at LBNL. It is desirable to re-survey after shipment to BNL, thus requiring shipment of the ‘Survey Tool’ to BNL with the Pixel Engineering System.

Output of Survey is a primary input to ‘Alignment’ task in Software WBS

### Sector Mount and Survey

Two copies of the full detector are required (4 halves). Assembly of the first will use the D-Tube assemblies fabricated for production. The second copy will either use new D-Tubes, or the recovered D-Tubes from the Engineering Run. Advantage of using ‘new’ D-Tubes is earlier completion of production deliverables rather than waiting for recovery after opening in 2013.

As with the engineering run, all test equipment will have been developed in Electronics for production DAQ/Sensors. Labor here is to mount then test each sector. Survey of each completed half, and labor in contingency to rebuild should damage occur, perhaps for only 2 of the 4 required assemblies.

Deliverables are 1 complete detector for Production run sufficiently in advance to allow ~6mo system testing, and lagging a second copy. Note efficiency of completion of both copies simultaneously rather than waiting for recuperated structures from Engineering Run...

# *1.3 Intermediate Silicon Tracker (IST)*

Efforts related to construction on the IST, including sensors, readout electronics, cooling, and mounting structures.

# *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 are provided in this WBS.

# Global Supports and Integration

Primary deliverable is global support structure, and effort to maintain integrated design across all internal sub-detectors and with STAR and the FGT project.

Sub-systems of the HFT, e.g. 1.2, 1.3, and 1.4, will place requirements on the deliverables of this WBS. External deliverables, such as the FGT and Beampipe share support/environment with the HFT Project, but only with deliverables of this WBS. Definition and maintenance of all interface drawings and documents will

# *1.6 Software*

The Software deliverables contain all software modules necessary to produce physics results. The 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 sub-system.

## *1.6.2* Offline

The offline environment consists of the event reconstruction software packages. This starts with the raw data as input and through proper calibrations it proceeds with detector cluster/hit finding, integrated tracking, event vertex finding and event information writing on DSTs.

#### Hit Reconstruction

The Cluster/Hit finder is the first piece of code applied to the pedestal subtracted raw information from the IST and PXL detectors and its task is to deliver reconstructed space points to tracking software.

#### Tracking

The tracker module performs pattern recognition at hit level (spanning several detectors) and delivers reconstructed particle trajectories with momentum and directional information. Part of its job is to ‘match’ segments in different detectors.

#### Event Vertex Reconstruction

The vertex finder module is responsible for using all available tracking and detector information to best estimate the collision point, i.e. the spatial point where the event occurred. Knowledge of the event vertex is a crucial piece of information in associating tracks to it and for secondary decay vertex searches. Several approaches might need to be deployed depending on the environment, e.g. a high multiplicity central Au+Au or a relatively low multiplicity p-p high luminosity event.

#### Secondary/Decay Vertex Reconstruction

The reconstruction of short-lived particles in a collider environment is an extremely challenging task and

The key measurements of HFT involve the reconstruction of D- and B-mesons with typical c in the range of 120 – 500 microns, and C with a c of 60 microns. These important software modules are to be developed, as they are a key piece of the new software. Their task is to discriminate (separate) the decay points from the primary vertex with good resolution so that the combinatorial background levels are manageable.

#### Databases – Calibration and Alignment

The accurate monitoring and recording of the state and the position of the detector inside the STAR apparatus is of outmost importance as it directly impacts its performance. Calibration is the online and offline task of monitoring the state of the detector as well as the set of tasks needed to correct for any disruptive action. The online part (often referred to a slow controls) gathers information of the detector in-situ, usually during running periods. Such information might be temperature or position of elements, pedestal files etc. This information is provided by the detector’s slow control system and it is stored in a Database with a timestamp. The offline part of the calibration includes software methods used to check e.g. the position of the detector elements using tracking information. The results of these procedures are stored as updated values in specific bank in the Database and are used in the massive offline physics production reconstruction passes.

Alignment is a special and very demanding task especially for the PXL detector where one would like to perform/know the positioning of the detector elements with offsets and tolerances to within a few microns. There are four distinct steps for the successful completion of this task:

1) **SURVEY** of detector elements: This is the task of determining the relative position of the various detector elements after they are assembled and before they are installed in the experiment. The sub-tasks associated with this problem are:

1.1 Develop software that analyzes the Coordinate Measuring Machine (CMM) data. The manpower needed is 0.5 FTE and the task can be completed in 6 (2) months.

1.2 Test/Certify software. 0.1 FTE is needed and the task duration is 1 (1) months.

1.3 CMM Data analysis. This task will take about 0.5 FTEs to complete and will take 6 (2) months to complete.

The deliverables are the following geometry matrices (for StarDb):

SSD: wafer-to-ladder geometry matrices (g.m.)

ladder-to-shell g.m.

IST: idem

PXL: [pixel-to-shell] geometry function [z=f(x,y)]

OR (depending on prototype test results)

chip-to-ladder g.m.

ladder-to-sector g.m.

sector-to-shell g.m.

Institutions responsible: SSD [BNL, KSU, other]

IST [MIT, BNL, KSU]

PXL [LBL, BNL, KSU]

The above tasks require skills at the graduate student and/or post-doc level.

Requirements/Pre-requisites:

a) Detector-element naming-scheme documentation.

b) CMM operator time to perform the data collection.

2) **GLOBAL** Alignment: This is the task of relative alignment of HFT complex to TPC (and thus the STAR coordinate system) using tracking information. The sub-tasks associated with this problem are:

2.1 Software development. The manpower needed is about 0.5 FTE and the task can be completed in about 3 (1) months (including testing).

2.2 Data analysis. This task takes about 0.5 FTE and about 1 (1) months to complete.

The deliverables are the following geometry matrices (for StarDb):

SSD: Shell-to-STAR (TPC) geometry matrices (6 param.)

IST: idem

PXL: idem

Note: This task needs to be repeated at the beginning of every RHIC run, except in the case of PXL detector where it needs to be repeated every time there is a shell replacement.

Institutions responsible: SSD [BNL, KSU, other]

IST [MIT, BNL, KSU]

PXL [LBL, BNL, KSU]

The above tasks require skills at the graduate student and/or post-doc level.

Requirements/Pre-requisites: Low luminosity data.

3) **SELF** Alignment: This is the task of determining the relative position of SSD, IST and PXL shells using tracking information. The sub-tasks associated with this problem are:

3.1 Software development. The manpower needed is about 1.0 FTE and the task can be completed in about 6 (2) months (including testing).

3.2 Data analysis. This task takes about 0.5 FTE and about 3 (2) months to complete.

The deliverables are the following geometry matrices (for StarDb):

SSD: Shell and/or Ladder-in-Shell (shift) geometry matrices

IST: idem

PXL: idem (but 2nd layer only since 1st defines the geometry)

Note: 1) Track info can be either collisions or cosmic rays with the detector in situ.

2) This task needs to be repeated at the beginning of every RHIC run, except in the case of PXL detector where it needs to be repeated every time there is a shell replacement.

Institutions responsible: SSD [BNL, KSU, other]

IST [MIT, BNL, KSU]

PXL [LBL, BNL, KSU]

The above tasks require skills at the graduate student and/or post-doc level.

Requirements/Pre-requisites: Low luminosity data.

4) Testing: Use DCA, pulls, physics quantities (like inv. mass resolution) to verify alignment.

4.1 Verification. The manpower needed is about 1.0 FTE and the intial (first time) task can be completed in about 3 (2) months.

Note: Needs to be repeated whenever item 2) or 3) above change, i.e. at least once per RHIC run and before major DST (offline) production.

### Simulation/Evaluation Framework

The tasks, and therefore software modules one needs to develop here are: a) the **detector geometry** definition, b) the **detector response** packages (fast and slow simulators), c) track **embedding** in real/raw events, d) a hit **pileup** handler, e) the Association Maker and structures for **evaluation** purposes, and f) Physics **analysis** code (performance, physics etc) capable of handling and evaluating the resulting information. Our group will have to contribute modules and effort in all these categories. It is worth mentioning here that besides this full and detailed simulation chain the group has developed very useful tools for quick estimates of various detector configurations, resolutions, layouts etc. These tools, sometimes referred to as ‘hand calculations’ or ‘fast Monte Carlo’ will keep playing an important role when either a quick turn around is needed or for cross checking purposes.

#### Detector Geometry Definition

This task is to include in the GEANT-simulated apparatus of the experiment the latest and most accurate/realistic geometry of HFT (IST and PXL), since this is the only way to ensure reliability of the resulting efficiency numbers. This task also includes the definition of the active areas of the detector, the hit information and the global positioning matrices of the detector

#### Detector Response Simulators

The detector response simulation packages in STAR reside outside the GEANT framework. They are actually invoked at the event reconstruction step. Typically there are two or three categories of response simulators: a) *Fast simulators*, which smear the hit position coordinates and assign hit uncertainties based on parameterized analytical functions. The fast simulators run extremely fast and are good for quick studies that do not need detailed implementation of the detector. They are also relatively easy to implement; we already have an HFT fast simulator in place for all syb-systems, b) *Slow simulators,* which simulates hits at the ADC level (usually obtained from sampling parameterized response functions. A slow simulator is a must when accurate acceptance and efficiency numbers are requested in physics analysis. A slow simulator is also used in embedding as discussed below, and c) *Very Slow simulators*, which track individual electrons through the detector body; from their generation to the readout. This is usually very time consuming and one utilizes this method only in small-scale productions in order to determine or verify the functions used in the first two methods.

#### Embedding and Pile-Up

The embedding of simulated tracks into the raw data stream (which provides the best ‘background environment’ for track/particle reconstruction and therefore the best way to estimate accurate efficiency numbers for physics analysis) has been around the heavy ion community for about fifteen years. It is the merging, at the raw ADC level, of a pedestal-subtracted event, for a given detector, with a few, slow-simulated hits. The resulting output is then passed through the reconstruction chain and the output is compared to MC input (this step is performed by the so-called Association Maker in STAR experiment). During the merging of real data with simulated hits and tracks one read the appropriate calibration tables so the dead areas of the detectors are properly excluded.

### Physics Analysis Framework

The physics analysis software is the most critical part in signal extraction. When it comes to physics analysis people use a diverse set of tools and methods to extract the physics signals, most of them developed by individuals. Here we will only indentify the broad areas of physics interests for the HFT mainly for the purposes of recording the institutional interests, responsibilities and commitments. These areas are: a) Charm-meson, b) Charm-baryon, c) B-meson reconstruction and d) possible spin-related signals.