Introduction
A correct measurement of beam parameters depends on the effective combinations of a variety of beam monitors, control and data acquisitions (DAQ) and high level physics applications. Figure 1 shows the relationship between these systems.

The following beam parameters will be monitored during regular operations:
1) closed orbit (accuracy better than 10% of beam size);
2) working point (tune for both planes with 10^-4 resolution);
3) circulating current (0.1% accuracy) and beam lifetime (1% accuracy);
4) injection efficiency;
5) filling pattern (1% of maximal bunch charge);
6) emittance for both planes (10% relative accuracy);
7) energy spread;
8) individual bunch length (2 ps resolution);
9) position of the photon beam for the insertion devices;
10) coherent bunch instabilities;
11) distribution of beam losses around the ring;

Table 1: Diagnostics Controls Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Beam Monitor</th>
<th>Control Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPM</td>
<td>BPM Monitor</td>
<td>BPM height, position</td>
</tr>
<tr>
<td>Filling Pattern</td>
<td>Filling Pattern Monitor</td>
<td>Filling pattern, charge</td>
</tr>
<tr>
<td>Orbital Feedbacks</td>
<td>Orbital Feedbacks Monitor</td>
<td>Orbit feedbacks, lattice functions</td>
</tr>
<tr>
<td>BPM</td>
<td>BPM Monitor</td>
<td>BPM height, position</td>
</tr>
<tr>
<td>Filling Pattern</td>
<td>Filling Pattern Monitor</td>
<td>Filling pattern, charge</td>
</tr>
<tr>
<td>Electronic Controls</td>
<td>Electronic Controls Monitor</td>
<td>Electronic controls, lattice functions</td>
</tr>
<tr>
<td>Screen</td>
<td>Screen Monitor</td>
<td>Screen, position, charge</td>
</tr>
<tr>
<td>Loss Control and Monitoring</td>
<td>Loss Control Monitor</td>
<td>Loss control, injection efficiency, etc.</td>
</tr>
<tr>
<td>Orbit Feedbacks</td>
<td>Orbit Feedbacks Monitor</td>
<td>Orbit feedbacks, lattice functions</td>
</tr>
<tr>
<td>DC Current Transformer</td>
<td>DC Current Transformer Monitor</td>
<td>DC current, position</td>
</tr>
<tr>
<td>Beam Monitors</td>
<td>Beam Monitors</td>
<td>Beam parameters, etc.</td>
</tr>
</tbody>
</table>

Controls Requirements
To measure various beam parameters, a variety of diagnostic monitors will be deployed in NSLS-II. The Diagnostics Group and the Controls Group are working together on controls requirements for these beam monitors. These requirements are determined by accelerator physics. According to NSLS-II PDR, the following beam parameters will be monitored during storage ring regular operations. An attempt of analyzing and translating physics needs into controls requirements is made.

Closed Orbit
Requirement: accuracy better than 10% of beam size. The beam position and closed orbit is measured by BPM (Beam Position Monitor). The smallest beam size is expected to be 3.1 um at short ID (Insertion Device) location. So, the BPM pickup buttons and associated electronics should provide position measurement resolution (RMS noise) at 0.2 um (10% of beam size) for long term orbit drift which can be compensated by slow orbit feedback based on 10 Hz Slow Acquisition (SA) BPM data. Additionally, NSLS-II BPM system will provide 10 kHz Fast Acquisition (FA) data for fast orbit feedback (FOBF) as well as turn-by-turn (TBT) data and ADC raw data for physics studies and BPM system debugging. These applications require less position resolution, usually at tens of microns.

Working Points
Requirements: both planes with 10^-4 resolution. There’s several methods to measure tunes (the fractional part). Most of them need pick up BPM and extraction stripe. One common method is based on network or spectrum analyzer. NSLS-II revolution frequency is 378.7 KHz and the tunes a are expected to be 32.35/16.28. 10^-4 resolution frequency means ~10Hz (0.28 * 379 KHz ~100 KHz) scanning step for the analyzer. Another is to utilize (FFT) BPM to determine the tune from zero to full charge at 10Hz for Linac injection. At 1(Hz) to 2(Hz) for Booster injection, as well as 1 minute top-off cycle after filling up.

Circulating Current and Beam Lifetime
Requirement: 0.1% accuracy for circulating current and 1% accuracy for beam lifetime. This is measured by DCCT and associated electronics. Bergoz NPCT with its analog electronics can provide +/-0.1% accuracy. The NPCT has 10 KHz nominal bandwidth. Large bandwidth gives more noise in the measurement so that filtering it to 500 Hz is always a good practice. In this case, one digitizer with 1KS/s sampling rate should be sufficient. The required resolution for digitizer is determined by the requirement on accuracy of beam lifetime measurement: 2% for 20 mA with 60-hour lifetime and 1 minute measurement interval. 18-bit ADC seems adequate for all these applications.

Filling Pattern
Requirement: 20% bunch-to-bunch charge variation. Filling pattern is measured by high-bandwidth (>500MHz) diagnostics monitors such as WCM and FCT. The pulse width of the output signal from Bergoz FCT is about 1 ns. Required 20% means less than 8-bit. So, high-speed digitizer with 2GHz bandwidth, 5GS/s sampling rate and 8-bit resolution should be sufficient for fill pattern monitoring.

Emittance
Requirement: both planes with 10% relative accuracy. emittance is not directly measured by diagnostics. It’s calculated from β-function value (assumed to be a constant at the dispersion free location) and beam size (measured by one pinhole CCD camera at one diagnostics beamline). 10% relative accuracy should be achievable by well-designed pinhole optics and high-resolution (1620*1220) digital camera.

Functionalities and Applications
The basic functionalities of diagnostics controls can be summarized as:
1) Measurement of various beam parameters (-10) via a variety of beam monitors (-16).
2) Acquisition and processing of the signals from beam monitors via digital electronics and EPICS IOCs.
3) Provision of the processed data as EPICS PVs for high level physics applications.
4) Support of Top-off operation by providing filling pattern measurement to meet the requirements of initial filling storage ring from zero to full charge at 10Hz for Linac injection and at 1(0)Hz to 2(0)Hz for Booster injection, as well as 1 minute top-off cycle after filling up.

From the point of view of controls and applications, diagnostics and controls systems can be classified into the following groups, as shown in Figure 2:
1) BPM subsystem for orbit feedbacks, lattice measuring, etc;
2) Filling pattern measurements based on WCM, FCT, stripe/photograph light with photo-diode;
3) Loss Control and Monitoring subsystem as well as injection efficiency involving ICT, DCCT, SLM and separator;
4) Camera-based diagnostics such as screen/flag, pinhole system, streak camera, and synchrotron light monitor (SLM);
5) Network/Spectrum analyzer-based tune measurement and beam stability monitoring;