Magnet systems are utilized throughout the NLC beamlines to form, switch, steer, preserve, and focus the electron and positron beams. The specific magnet requirements in each area of the machine are provided by computer codes that take the beam requirements from Accelerator Physics and convert them to a parameter set that is common to magnets (lengths, bore diameters, and integrated field). Other design codes convert these parameters to the actual mechanical designs of the magnets. In other words, there is no direct linkage (requirements flow-down) between accelerator requirements and the magnets selected for the machine. Many alternate designs are feasible, and the best cost/performance tradeoff is chosen.

The magnetic field of non-pulsed magnets must be stable over a period of a half-hour. The long-term stability of the field is also required, and on an electromagnet can be obtained by adjusting the current. Permanent magnets must also be stable over the long term, either by resistance to change or some adjustability.

The alignment of the beam through the magnets is produced through a process called beam-based alignment. This restricts the movement of the magnetic center of the magnet to less than one micron when the magnetic field is reduced by 20%.

**Area Complement:**
- Injector Systems (1.1) are either permanent or electromagnets based on a criteria generated by Ross Schlueter at LBNL. All permanent magnets in the Damping Rings must be ferrite due to the higher radiation backgrounds activating the samarium magnets and weakening the neodymium magnets. Many Damping Ring magnets are permanent in the current configuration.
- Main Linac (1.2) is all permanent magnets except for the diagnostic regions.
- Beam Delivery (1.3) magnets are all electromagnet to allow for center of mass energy flexibility.
- There are no magnet systems in Conventional Facilities (1.4).

**Technical Description:**

1. Layouts/Optics Decks
   - As discussed in the Requirements section, there are two places to look for magnet layout and optics deck information. The Accelerator Physics section contains pointers to the Optics Decks for each area of the machine. Accelerator Physics also parses this data into an Excel sheet that provides magnet parameters (e.g. bore diameter and length), and there are also pointers to this data. In most cases there is no other more detailed layout information available, although some magnets have been conceptually designed in order to understand the features, components, and costs that make up certain styles of magnets.

2. Technical issues
   - The main technical issues are beam-based alignment using permanent magnets, the radiation stability and activation of permanent magnets, and more accurate cost trade-off information between permanent and electromagnets. These issues are interconnected with the design assumptions used, making the overall permanent/electro evaluation process complex.
3. Magnet Design Features:

Electromagnets will be an enhanced SLAC typical design:
- Solid low-carbon steel cores
- Hollow copper conductors, vacuum-potted coils
- Quadrupole magnetic center stability satisfies beam-based alignment requirement
- Design for low cost and for high reliability (decision on redundant power supplies or other approach by Snowmass)
- Power supplies on strings wherever feasible

Permanent magnets will be a similar to FNAL recycler design with steel poles and integrated field strength adjustability obtained by rotating or sliding segments:
- Solid low-carbon steel cores
- NdFeB, SmCo$_5$/Sm2Co$_{17}$, or SrFe$_{12}$O$_{19}$ permanent magnet material in block form
- Rotating NdFeB elements for buck/boost adjustability. (BBA requirement not yet satisfied.)

4. By Type:

Magnet Type | Permanent | Electromagnet | Total
--- | --- | --- | ---
Dipoles 336 | 522 | 858
Quadrupoles 2610 | 799 | 3409
Sextupoles 270 | 82 | 352
Total 3216 | 1403 | 4619

These magnets are not candidates for permanent magnets:

<table>
<thead>
<tr>
<th>Magnet type</th>
<th>Quantity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctors</td>
<td>838</td>
<td>All air-cooled/solid wire</td>
</tr>
<tr>
<td>Pulsed magnets</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Solenoids</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>61</td>
<td>Wigglers, Septa, Spin Rotators</td>
</tr>
</tbody>
</table>

5. Changes from May, 1999
- Adjustable permanent magnets are replacing electromagnets in ~57% of the machine. (This percentage is currently fluid as lattices change; designs are judged for feasibility.)
- Electromagnets have been strung wherever feasible (no stringing in May, 1999)
- Power supply volt-amps have been reduced to the minimum required (small number of standard sizes, often oversized, used for CD-1)
- Controlling electronics are in TEE's.
- 2001 lattice changes, especially in Beam Delivery, will be included by Snowmass.
6. Notes:

- Most permanent magnet candidates are based on the simple Schlueter criteria at this point in time, engineering feasibility studies are on-going, will be mostly concluded by Snowmass.
- Trims are not included in these figures.
- Trims will disappear if an electromagnet with a trim is changed to a permanent magnet.
- Total magnet count: 5,653 of 123 styles (excluding new lattices/lines)
- Total power supply count: TBD by Snowmass
- Total cable lengths: TBD by Snowmass

**Discussion of Configuration Choices**

The magnet choices are highly constrained by the Optics Decks produced by Accelerator Physics. The main configuration choice at the present time is electromagnets versus permanent magnets. Permanent magnets may have a lower acquisition cost, are less expensive to install and operate, and should be much more reliable (no water and power connections). On the other hand, permanent magnets are not as radiation-resistant, not as adjustable, and may obsolete the current beam-based alignment approach.