## Chapter 6. Beyond the ILC and the LHC

The Steering Group examined the steps necessary to explore higher-energy colliders at Fermilab that might follow the ILC or that might be needed should the results from LHC point toward a higher energy than that planned for the ILC. Steps to explore higher-energy hadron and e+e- colliders are currently underway at other laboratories, with results expected within five years. The exploration of a muon collider is a far different matter and will require considerable attention and significantly increased resources.

### LHC energy upgrade

Magnet technology needed to upgrade the LHC to 21 TeV center-of-mass energy is currently under development as part of the LHC Accelerator Research Program, or LARP, and of the DOE base funding for magnet technology development. This technology should be ready for application in about five years.

[](http://www.fnal.gov/pub/directorate/steering/images/photos/ch6_01.jpg)

**Muon Collider R&D RF cavity being prepared for tests at Fermilab.**  
Credit: Yagmur Torun

### Very Large Hadron Collider

Likewise, the basic technology that could support construction of a VLHC will be in hand on a five-year time scale should it be needed. Detailed magnet development would need to follow a reanalysis of the energy and optimum size of the collider once the physics objectives clarify. Luminosity will be a challenge if it is to increase beyond that planned for the LHC as required to follow the energy dependence of the physics cross section.

### Compact Linear Collider

The current CERN midterm plan includes efforts to demonstrate by 2010 the CLIC two-beam accelerator concept using X-band technology for an e+e- collider up to 3 TeV. The U.S. High-Gradient Collaboration is studying technologies that may provide an alternative approach to a multi-TeV e+e- collider.

### Muon collider

In contrast to the situation for electron and hadron colliders, demonstrating the viability of a muon collider will require many steps:

* exploration of various end-to-end conceptual designs,
* a specialized proton driver,
* various targeting, capture and phase-rotation schemes,
* various possible six-dimensional (6D) ionization cooling configurations,
* various methods of acceleration to high energy of the cooled muons,
* storage ring designs,
* detector configurations.

Each of these steps (see Appendix H for details) may involve development of more than one technology. Given the many unknowns, especially in mastering 6D ionization cooling, it is not possible to state even a technically limited schedule with any precision. However, a significant evaluation of cooling and other feasibility items might be carried out in approximately five to seven years. A rough comparison with the U.S. ILC development intensity prior to the International Technology Recommendation Panel decision would indicate the need for a minimum of $20M annually and 100 FTE of appropriate skills in the U.S.

## Summary

The Steering Group recommends a strengthening of the R&D program for future accelerators such as a muon collider over the next five years independent of the ILC timeline. A construction start for the ILC early in the next decade would dictate reevaluation and adjustment of the effort as appropriate. If the ILC were built offshore, and if a satisfactory cooling method and a concept design for the collider system have emerged, the muon collider effort could rapidly ramp up.