HEPAP Accelerator R&D Subpanel Report

Don Hartill on behalf of the Subpanel

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Background

- Subpanel was formed in response to a 2013 OHEP COV recommendation
- P5 also recommended formation of the Subpanel
- Summary of the Charge to the Subpanel
- Members of the Subpanel
- P5 Guidance
- Information gathering process
- Meetings
- Community input
- Workforce needs
- GARD thrust areas
- Challenges
- Fundamental Accelerator Research

Summary of the Charge to the Panel

National Goals: Appropriate goals in broad terms for medium ($\leq$ 10 years – bring new concepts to practice) and long term ($\leq$ 20 years – exploratory research developing new concepts) U. S. Accelerator R&D for a world leading future program in accelerator based particle physics aligned with the recommendations of P5

Current Effort: Examine the scope of the current effort and evaluate how well medium- and long-term R&D address the HEP mission as expressed by P5

Impediments: Describe any impediments that may exist in achieving these goals

Summary of the Charge to the Panel

Training: Accelerator R&D efforts play a major role in training future accelerator scientists and technologists. Are current programs adequate including local partnerships between laboratories and local universities?

Balance: How do we maintain a healthy and appropriately balanced national program? Provide further guidance for a plan based on the science and technology case for increased investment in HEP Accelerator R&D called for in P5's Scenario C

Current projects including PIP-II, HL-LHC, and the ILC were not part of the Subpanel considerations

Preliminary report by the end of November with a final report by March 2015

Members of the Subpanel

Bill Barletta	MIT	Young-Kee Kim	U of Chicago
Ilan Ben-Zvi	BNL & Stonybrook •	Tadashi Koseki	KEK/J-PARC
Marty Breidenbach•	SLAC	Geoff Kraft (NP Obs.)	JLAB
Oliver Bruning	CERN	Andy Lankford*•	(ex officio) UC Irvine
Bruce Carlsten*	Los Alamos	Lia Merminga•	Triumf
Roger Dixon	Fermilab	Jamie Rosenzweig	UCLA
Steve Gourlay	LBNL	Mike Syphers	MSU
Don Hartill (Chair)	Cornell	Bob Tschirhart*	Fermilab
Georg Hoffstaetter*	Cornell	Rik Yoshida	Argonne
Zhirong Huang (BES Obs.)	SLAC		

* Members of HEPAP • Members of P5

Guidance from P5

- Science Drivers
  - Use the Higgs boson as a new tool for discovery
  - Pursue the physics associated with neutrino mass
  - Identify the new physics of dark matter
  - Explore the unknown: new particles, interactions, and physical principles
  - (Cosmic Acceleration)
- Projected startup dates for existing projects

LHC: Phase 1 upgrade	~ 2020
HL-LHC	~ 2025
LBNF	~ mid 2020s
ILC	~ late 2020s

- Possible future projects (Next Steps and Further Future accelerators)
  - Multi-MW proton source, 1 TeV e+e- collider, and ~very high-energy pp collider
  - $\geq$ 3 TeV e^+e^- collider, Neutrino factory (physics case is yet to be made)
- Assuming ~ 10 years for the prime era for discovery of new physics for each of the "existing" projects sets the time scale for the construction start of future projects
- Assuming ~ 10 year R&D phase to develop the needed technologies to produce a credible conceptual design sets the start date of a significant R&D program

Information Gathering by the Subpanel

Meetings were held at BNL, Fermilab, Argonne, SLAC and LBNL on a road trip during the last week in August

Subpanel Website: http://www.usparticlephysics.org/p5/ards

The website has the agendas and the talks for the lab visits.

Town Hall meetings were held at most of the labs.
In addition, a virtual Town Hall meeting was held on Oct. 10

The subpanel met five times in addition to review the input and develop its conclusions. In addition to the face to face meetings there were weekly teleconference meetings with twice weekly meetings towards the end of the process

HEP General Accelerator R&D (GARD) Thrust Areas

Superconducting RF Cavities

Accelerator Beam Physics

Particle Sources

Beam Instrumentation and Controls

NC RF and High Gradient Accelerating Structures

New Accelerator Concepts

Super Conducting Magnets and Materials

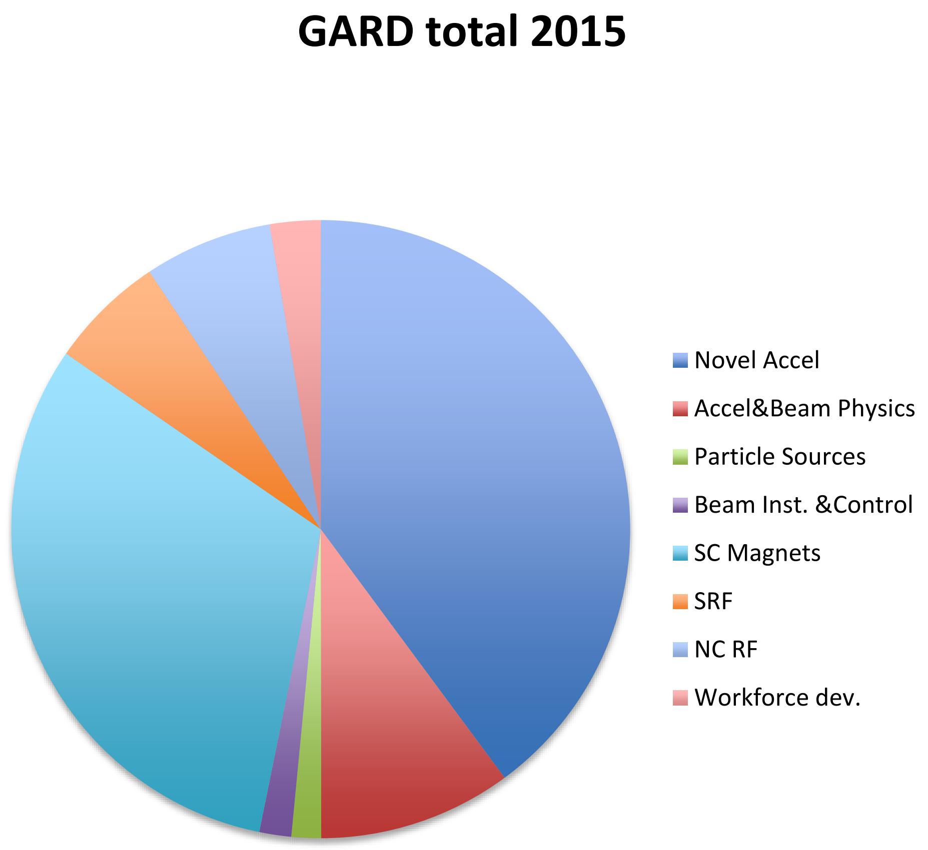
Current GARD Program (FY 2015)

For FY 15 (President's request) the current General Accelerator Research and Development budget is 68 M$.

This includes the facility operation costs at Argonne (AWA), Fermilab (SRF and SC Magnets), SLAC (FACET) and LBNL (BELLA) which total 28.6 M$. Both FACET and BELLA were constructed using ARRA funds which did not include operational support.

This leaves a net of ~ 39.4 M$ for the GARD base programs and is divided among the previously listed seven GARD thrusts areas. The following pie chart illustrates the current division:

Current GARD Program



The NSF Program in Accelerator Science

In addition to the DOE GARD program, NSF has started their new program in Accelerator Science with a total funding level of 9.8 M$ for this year.

Fourteen awards have been made covering a broad range of topics in Accelerator Science.

And, it is a very welcome addition to the NSF portfolio.

US GARD Opportunities

For the Intensity Frontier, the performance measure is MW•Ktons•beamtime/yr so producing higher beam power has significant leverage. Beam stability at synchrotron injection energies combined with higher power targets could have large benefits.

Future high energy colliders will be expensive and complex. Optimization studies will be key to lowering the construction cost and maximizing the operating efficiency. Optimized superconducting magnet design both in field intensity and manufacturability will require R&D for a very high-energy proton-proton collider. For e^+e^- colliders, more efficient RF sources as well as much higher accelerating gradients could lower operating costs.

Advanced acceleration technologies potentially have the promise of dramatically increasing the accelerating gradient and thereby significantly reducing the cost of a very high energy e^+e^- collider.

Challenges

- Limited funding for the GARD program
- Time scales for the possible construction starts for the next generation of accelerator facilities are long
- Next generation of multi-MW proton sources, very high-energy TeV pp colliders, 1 TeV e^+e^- colliders, and $\geq$ 3 TeV e^+e^- colliders will be complex machines
- The current sketch designs for these accelerators have a broad spectrum of maturity
- The very high stored energy of both the beams and the magnet systems of a ~ 100 TeV pp collider provide interesting design challenges
- Intense synchrotron radiation from the beams in a very high-energy TeV pp collider presents very significant challenges for both the vacuum system design and the needed cryogenic cooling capacity
- The cost of using known technologies for these machines is very high
- The applicability of the advanced acceleration technologies to HEP colliders is at an early stage of understanding
- Cost of R&D facilities (both construction and operating costs)
- A key driver for the GARD program is to understand and develop strategies to significantly reduce the costs of construction and operation for future facilities

Further Challenges

The Accelerator R&D Subpanel was not a project review panel. Our task was to recommend a balanced program in accelerator R&D to OHEP to provide the US with a world leading program in accelerator based particle physics. And, parenthetically developing a science and technology case for increased investment in accelerator R&D.

The current funding level (FY2015) for the entire GARD program is 68 M$ of which 28 M$ is operations.

A HEPAP subcommittee report presented last spring concluded that there was a shortage of accelerator scientists and technologists. Our observations and conversations with members of the accelerator community reaffirmed this.

Process towards the Report

After the Road Trip the Subpanel merged the seven GARD thrust areas into the following five accelerator R&D areas for study:

Accelerator physics and instrumentation:

Beam dynamics, simulation, computation, beam loss monitoring, etc

Particle Sources and Targets:

High power beams, horns, targets, and collimators

Beam dumps

Superconducting RF:

Superconducting Magnets and Materials:

Advanced Acceleration (see next slide):

Process towards the Report (cont.)

Advanced acceleration:

- Normal conducting RF structures and sources
- Dielectric wakefield accelerators
- Beam driven plasma wakefield acceleration
- Laser driven plasma wakefield acceleration
- Direct laser acceleration
- Fundamental aspects of muon acceleration

Accelerating Discovery

The report summarizes the Subpanel's findings from our analysis of the GARD program with the guidance from P5 firmly in mind.

The budget for the GARD program was assumed to be constant at the current FY 2015 level (Scenario A) for the future GARD program.

The GARD program is world leading in accelerator R&D, however, this position is at risk due to a large fraction of the total budget going to facility operations.

To limit this risk and to move forward more rapidly on the necessary R&D for the Next Steps and Further Future accelerators a Scenario B budget is proposed (a 10 – 20% increase).

To move forward more rapidly on the needed R&D for a very high-energy proton-proton collider and for a > 3 TeV e^+e^- collider a Scenario C budget as suggested by P5 is proposed.

Report

Executive Summary
Introduction
Recommendations in Scenario A, Scenario B, and Scenario C
Area Details:

- Accelerator Physics and Technology
- Particle Sources and Targetry
- RF Acceleration
- Superconducting Magnets and Materials
- Advanced Acceleration
- Facilities

Conclusion and Appendices

The final report is available at:

Science.energy.gov/~/media/hep/hepap/pdf/Reports/Accelerator_RD_Subpanel_Report.pdf

Recommendations

The focus of our analysis was to align GARD with P5's vision of the Next Steps and Further Future Accelerators.

The recommendations are organized in this fashion in Scenario A.

The Scenario B recommendation is for an overall funding increase to fund definite projects in each of the accelerator areas.

Scenario C is to fund two programs: a) increased R&D for superconducting magnets and materials along with other needed R&D aimed at a very high-energy proton-proton collider and b) R&D for a multi-TeV e^+e^- collider.

Recommendations Summary

For the multi-MW proton beam:

High power components, IOTA (space charge), simulations, and SRF (Recommendations 1-4, 14, 15)

For a very high-energy proton-proton collider:

Design effort, simulation, high field magnets, Nb_3Sn, HTS, and industrialization for cost reduction (Recommendations 5, 5a-5f, 14, 15)

For a 1 TeV ILC:

Higher Gradient SRF (Recommendation 6)

For a >3 TeV e^+e^- collider:

Facility to continue particle-driven wakefield acceleration, continue laser-driven wakefield acceleration, develop a roadmap, efficient RF sources, component test facilities, and a next step plan for normal conducting RF technology (Recommendations 7-13, 14, 15)

One Recommendation in Scenario A

Further Future Accelerators (Particle Driven Wakefield Accelerator)

FACET-II would allow significant progress on much lower emittance and energy spread electron beams in the context of very high acceleration gradients. It would eventually have a new small damping ring for positrons that would utilize the existing positron source and a “sailboat” chicane, which would allow adjustable separation of the drive electron and witness positron beams. FACET-II would enable beam matching and transport at the entrance/exit of a single module, but does not permit independent stages with drive beams. Initial staging experiments can be performed at the ATF and AWA facilities.

The cost of this project is substantial and cannot be accommodated within the current GARD budget.

Recommendations in Scenario A

Support for Next Steps and Further Future Accelerators

Recommendation 14. Continue accelerator and beam physics activities and beam instrumentation and control R&D aimed at developing the accelerators defined in the Next Steps and the Further Future Goals. Develop coordination strategies, both nationally and internationally, to carry out these studies in an efficient manner.

Recommendation 15. To ensure a healthy, broad program in accelerator research, allocate a fraction of the budget of the Accelerator Physics and Technology thrust to pursue fundamental accelerator research outside of the specific goals of the Next Steps and Further Future Goals. Research activities at universities should play a particularly important role.

Scenario B

Whereas the current GARD budget (Scenario A) is insufficient to satisfy the expectations of P5, a modest rise in base funding for GARD research (Scenario B: an increase of ~10-20% of GARD research, ~1-2% of HEP) would open numerous critical R&D opportunities that do not fit in the current base, as well as invigorate fundamental accelerator science research.

Recommendation B1. Increase base GARD funding modestly in order to open numerous critical R&D opportunities that do not fit in the current base, as well as to invigorate fundamental accelerator science research, and to step up development of the national accelerator workforce.

Opportunities include ambitious computational accelerator science, R&D on NCRF, higher gradient SRF using new materials, expanding use of the BELLA facility, more robust superconducting magnet R&D, and radiation damage in candidate target materials for neutrino beams.

Scenario C

The P5 report called for a roadmap for the U.S. to "move boldly toward development of transformational accelerator R&D […] with an aggressive, sustained, and imaginative R&D program […] changing the capability-cost curve of accelerators" in Scenario C. Motivated by the P5 science drivers, the goal is to "make these further-future accelerators technically and financially feasible on much shorter timescales."

Recommendation C1. Hasten the realization of the accelerator of P5's medium-term vision for discovery: a very high-energy proton-proton collider and the realization of the accelerators of P5's long-term vision for discovery: a multi-TeV e^+e^- collider.

Scenario C

For the very high-energy proton-proton collider:

Recommendation C1a. Ramp up research and development of superconducting magnets, targeted primarily for a very high-energy proton-proton collider, to a level that permits a multi-faceted program to explore possible avenues of breakthrough in parallel. Investigate additional magnet configurations, fabricate multi-meter prototypes, and explore low cost manufacturing techniques and industrial scale-up of conductors. Increase support for high-temperature superconducting (HTS) materials and magnet development to demonstrate the viability of accelerator-quality HTS magnets for a very high-energy collider.

Scenario C

For the multi-TeV e^+e^- collider:

Recommendation C1b. Develop, construct, and operate a next-generation facility for particle-driven plasma wakefield acceleration research and development, targeting a multi-TeV *e^+e^-* collider, in order to sustain this promising and synergistic line of research after the closure of the FACET facility.

Conclusions

A healthy program in accelerator R&D is key to ensuring that the US accelerator based high energy particle physics program is world leading.

Training of the next generation of accelerator scientists and technologists is a very important element of the GARD R&D program. See the HEPAP Subcommittee on Workforce Development report published in early 2014.

Need to provide continued support for fundamental accelerator R&D that is not directed towards the possible projects presently under discussion. This has provided us with our current suite of accelerator capabilities.

Our hope is that our report will provide useful guidance to DOE OHEP in charting the future of accelerator R&D in the US.