A Few Things to Consider, Based on Experience from the Previous Snowmass and P5

Personal Perspectives

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This is a talk about the connections between Snowmass and P5 in 2013-14.

Snowmass is obviously about much more than just P5.

“It is very difficult to remember that events now in the past were once far in the future.”

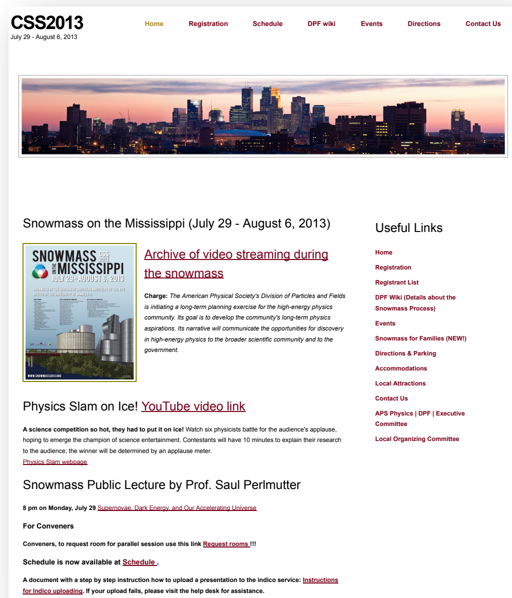
-Frederic William Maitland

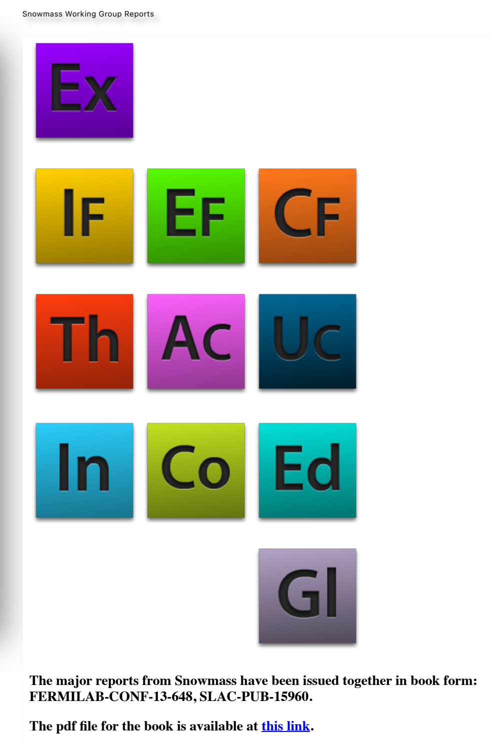
The Previous Snowmass Was Essential to P5

- A vast number of scientific opportunities were investigated, discussed, and summarized in the Snowmass reports.

http://www.slac.stanford.edu/econf/C1307292/

- The Snowmass documents enabled P5 to write a much shorter report.
  - A short report is more difficult to write than a long report, but a short report is usually **much more effective**.





https://www.usparticlephysics.org/wp-content/uploads/2018/03/FINAL_P5_Report_053014.pdf

The Previous Snowmass Was Essential to P5

Snowmass Questions

https://www.slac.stanford.edu/econf/C1307292/

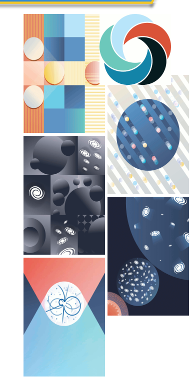
1. How do we understand the Higgs boson? What principle determines its couplings to quarks and leptons? Why does it condense and acquire a vacuum value throughout the Universe? Is there one Higgs particle or many? Is the Higgs particle elementary or composite?
2. What principle determines the masses and mixings of quarks and leptons? Why is the mixing pattern apparently different for quarks and leptons? Why is there CP violation in quark mixing? Do leptons violate CP?
3. Why are neutrinos so light compared to other matter particles? Are neutrinos their own antiparticles? Are their small masses connected to the presence of a very high mass scale? Are there new interactions that are invisible except through their role in neutrino physics?
4. What mechanism produced the excess of matter over anti-matter that we see in the Universe? Why are the interactions of particles and antiparticles not exactly mirror opposites?
5. Dark matter is the dominant component of mass in the Universe. What is the dark matter made of? Is it composed of one type of new particle or several? What principle determined the current density of dark matter in the Universe? Are the dark matter particles connected to the particles of the Standard Model, or are they part of an entirely new dark sector of particles?
6. What is dark energy? Is it a static energy per unit volume of the vacuum, or is it dynamical and evolving with the Universe? What principle determines its value?
7. What did the Universe look like in its earliest moments, and how did it evolve to contain the structures we observe today? The inflationary Universe model requires new fields active in the early Universe. Where did these come from, and how can we probe them today?
8. Are there additional forces that we have not yet observed? Are there additional quantum numbers associated with new fundamental symmetries? Are the four known forces unified at very short distances? What principles are involved in this unification?
9. Are there new particles at the TeV energy scale? Such particles are motivated by the problem of the Higgs boson, and by ideas about space-time symmetry such as supersymmetry and extra dimensions. If they exist, how do they acquire mass, and what is their mass spectrum? Do they provide new sources of quark and lepton mixing and CP violation?
10. Are there new particles that are light and extremely weakly interacting? Such particles are motivated by many issues, including the strong CP problem, dark matter, dark energy, inflation, and attempts to unify the microscopic forces with gravity. What experiments can be used to find evidence for these particles?
11. Are there extremely massive particles to which we can only couple indirectly at currently accessible energies? Examples of such particles are seesaw heavy neutrinos or grand unified scale particles mediating proton decay. How can we demonstrate that these particles exist?

March 2014

P5: Science Drivers of Particle Physics

P5 distilled the 11 groups of physics questions from Snowmass into 5 compelling lines of inquiry that show great promise for discovery over the next 10 to 20 years:

- Use the **Higgs boson** as a new tool for discovery.
- Pursue the physics associated with **neutrino mass.**
- Identify the new physics of **dark matter.**
- Understand **cosmic acceleration**: dark energy and inflation.
- **Explore the unknown**: new particles, interactions, and physical principles



- The Drivers are deliberately **not prioritized** because they are **intertwined**, probably more deeply than currently understood.
- A selected set of different experimental approaches that reinforce each other is required. **Projects are prioritized**.
- The vision for addressing each of the Drivers using a selected set of experiments is given in the report, along with their approximate timescales and how they fit together.

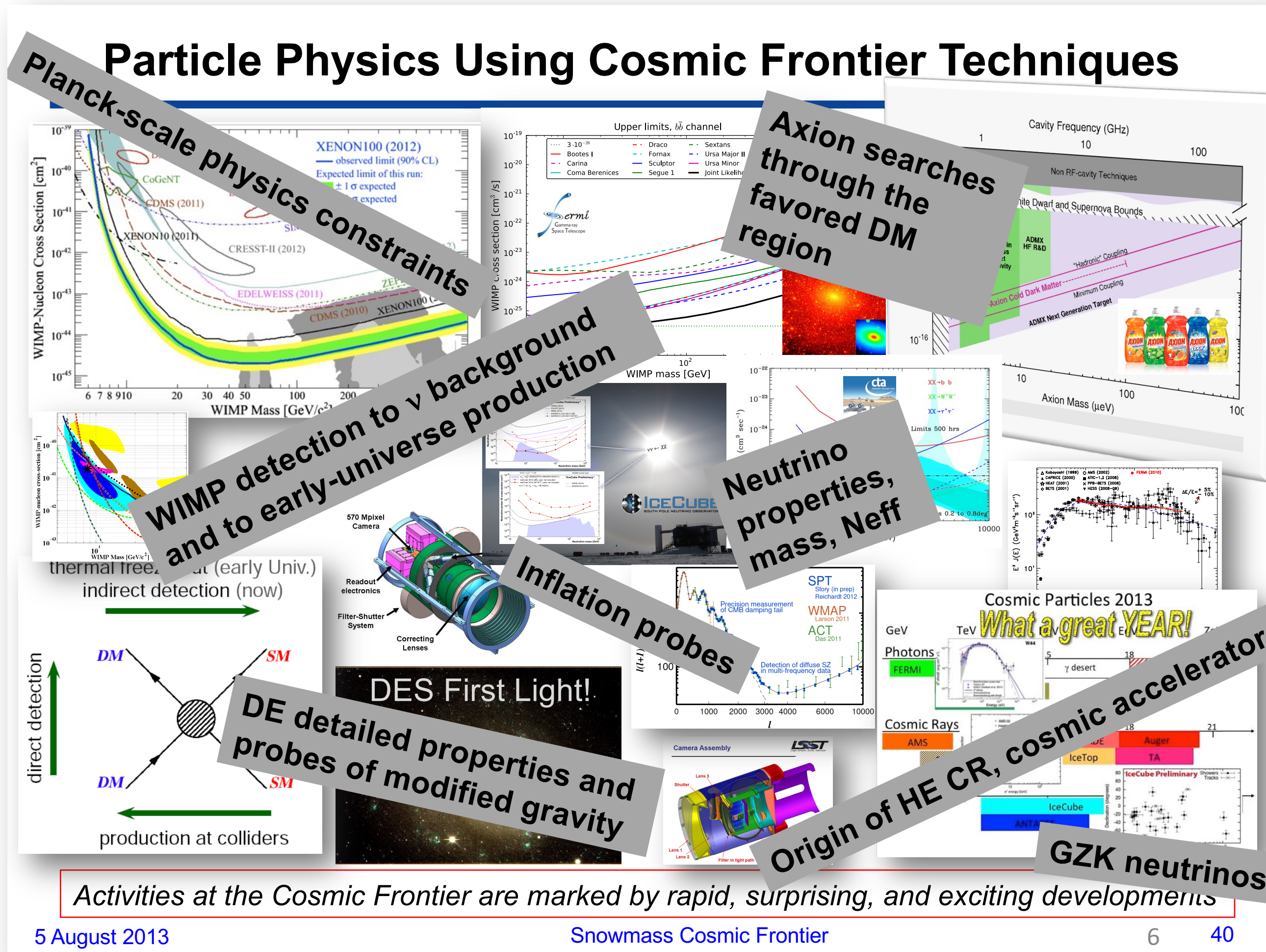
P5 Strategic Planning Process 8

P5 distilled the Snowmass questions (>30) into something more actionable and explainable to people outside the field: the 5 Science Drivers. **Could be done by Snowmass this time, pulling the field together.**

[Aside: All was not as orderly as it might seem in hindsight]

Sometimes, messy at Snowmass is good.

Indication of a vibrant field.



What else was essential from Snowmass?

…and some thoughts about what might be helpful this time.

Provide summaries of what has changed

- As before, P5 will likely need to articulate what has happened since the previous P5 report. It is helpful for Snowmass summaries to provide this.
- For reference, this is what we had last time

Significant Developments Since the 2008 P5 Report

- Physics!
  - Higgs boson discovered at a relatively low mass, pointing the way to the next steps and informing choices for long-term planning.
  - Three Nobel Prizes related to particle physics: Quark Mixing and Symmetries, Dark Energy, Higgs Boson.
  - A key neutrino mixing parameter, $\sin^2(2\theta_{13})$, was measured to be relatively large, enabling the next steps in a campaign to understand the implications of the tiny, but non-zero, neutrino masses.
- These successes demonstrate the deep value of diversity of topic and project scale.
- Programmatic changes
  - the Deep Underground Science and Engineering Laboratory (DUSEL) did not proceed, although the Sanford Underground Research Facility (SURF) laboratory continues to develop. The Joint Dark Energy Mission (JDEM) did not proceed.
  - Tevatron collider operations and PEP-II/B-factory operations ended.
  - Inflation-adjusted funding continued to decline.
- Snowmass

International Connections and Context

- The previous P5 was an outward-facing panel, with a large number of members from other countries, by design
  - thoughtful leaders of strategic planning and those familiar with U.S. program.
  - Report subtitle: **Strategic Plan for U.S. Particle Physics in the Global Context**
- Essential international cooperation in every subfield
- Therefore, thoughtful colleagues from other regions should feel fully welcome in the Snowmass process.

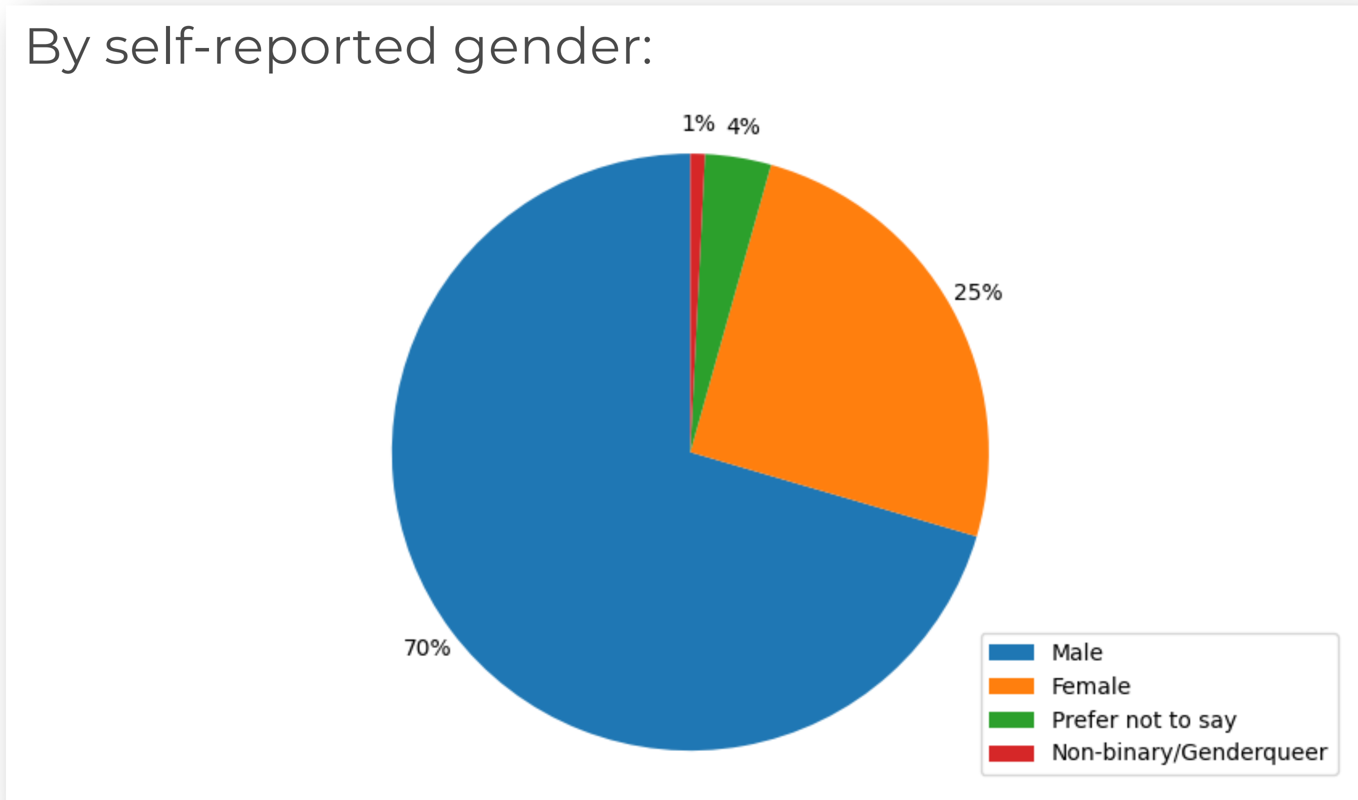
Significant changes in international context since 2014.

The essential importance of diversity, equity, inclusion, and climate in everything we do

- The persistent lack of diversity in our field won't be fixed just by individuals trying to be unbiased.
  - Systemic issues must be addressed, and we have work to do.
  - See, *e.g.*, https://www.particlesforjustice.org
- Yes, this is an important part of the Snowmass Process, and (IMO) could be part of every "Frontier" message – how is each "Frontier" doing, and how will it do better?
  - Not just for CommF3
- Real effort here will also help attract the best people to particle physics.
  - **Early career voices are especially important. Long-term choices most strongly affect our early career colleagues.**

Kudos to the organizers for posting this

http://seattlesnowmass2021.net/participantList/



The Importance of Program Balance

- A subfield (aka "Frontier") isn't defined by one large project. A facility isn't a vision.
- **What are the questions that can be answered, and how can they best be addressed with a mix of small, medium, and large experiments?**
- The 2014 P5 made a portfolio of smaller experiments a high priority
    - We can help the next P5 make a similar case
    - Again, the international context and connections to other subfields essential

The Importance of Theory

The following is obvious, but worth stating here:

- An essential focus in its own right:
  - Reveals important questions and issues
  - Provides the intellectual underpinning, new ways of thinking, and new frameworks for a deeper understanding of Nature

As well as…

- Necessary for success -- essential part of the ecosystem of projects in all stages.
- Gives meaning to the data
- Ties the field together
- Points in new directions

Before Unity, Vigorous Discussion

- Snowmass ideally a process in which ideas are discussed, debated, and refined by everyone together.
- We should not hesitate to ask the tough questions -- in good faith.
- Feedback and **tough questions** from other subfields are gold.
    - They help us develop viable options that can realistically work. Look skeptically at your own subfield's messages to strengthen them.
- Debate at Snowmass can be enormously helpful to P5:
    - Basis for making, and articulating, well-reasoned choices
    - "*In our deliberations, no topic or option was off the table. Every alternative we could imagine was considered. We worked by consensus—even when just one or two individuals voiced concerns, we worked through the issues.*" – 2014 P5 Report

The Opportunity of Cross-roads

- The science drivers in the 2014 P5 report, which grew out of Snowmass, are inherently intertwined.
- Snowmass is an excellent chance to broaden our own research, to reassess directions, and to make connections.
  - **How can we expect others to become interested in our own subfields if we don't become interested in theirs?**
  - **Breakthroughs happen when we move beyond inviting "them" to "our" meetings**
  - **Cross-cutting activities are essential.** Great to see the Liaisons.
- **Will the "Frontier" messages connect to each other?** This would likely help the next P5.
  - For example, some obvious and important connections for Neutrino "Frontier" with Cosmic, Energy, Instrumentation and Accelerator R&D "Frontiers"
    - Neutrinos also don't care if people call some aspects Nuclear Physics

Beyond particle physics, too:

"More generally, we strongly affirm the essential importance of fundamental research in all areas of science."
-2014 P5 Report Executive Summary

And then, after P5, it’s important to work together for the whole program in a unified manner.

- https://www.usparticlephysics.org
- https://www.usparticlephysics.org/wp-content/uploads/2022/03/Particle-Physics-Progress-and-Priorities-2022.pdf
- Every year, working with DPF, and Users Groups, and others, materials about the whole field are developed and updated for interactions with decision makers in Washington and elsewhere.

Building for Discovery

Strategic Plan for
U.S. Particle Physics
in the Global Context

usparticlephysics.org

The P5 Report provides the strategy and priorities for U.S. investments in particle physics for the coming decade.

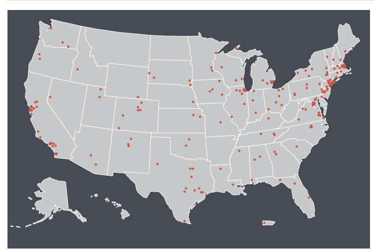
The top three priorities in 2022

Strengthen support for particle physics research at universities and national laboratories, which includes data analysis, R&D, design of new experiments, and a vibrant theory program. As emphasized in the P5 Report, these activities are essential for the success of the field. They are crucial for extracting scientific knowledge from all the great new data, developing new methods and ideas, maintaining U.S. leadership, and training the next generation of scientists and innovators.

Advance the High-Luminosity Large Hadron Collider (HL-LHC) accelerator and ATLAS and CMS detector upgrade projects on schedule, continuing the highly successful LHC program and bilateral partnership with CERN.

Advance the Long-Baseline Neutrino Facility (LBNF), Deep Underground Neutrino Experiment (DUNE), and Proton Improvement Plan-II (PIP-II), working with international partners on the design, prototypes, initial site construction, and long-lead procurements.

These carefully chosen investments will enable a steady stream of exciting new results for many years to come and will maintain U.S. leadership in key areas.



Particle physics is both global and local. Scientists, engineers, and technicians at more than 180 universities, institutes, and laboratories throughout the U.S. are working in partnership with their international colleagues to build high-tech tools and components, conduct scientific research, and train and educate the next generation of innovators. Valuing equity, diversity, and inclusion, the field is committed to increasing participation of underrepresented groups. Particle physics activities in the U.S. attract some of the best scientists from around the world.

The P5 strategy has been very successful. Even with extraordinary challenges due to COVID-19, there was great progress.

Recent results

The LHC experiments reported many important and precise results. The remarkably productive ATLAS and CMS experiments have each produced more than 1,000 refereed publications. The advances in precision are represented well by the new measurement of fundamental symmetry properties of **Higgs boson** decays that test the foundations of the underlying theory. The LHCb experiment also published many new results that are sensitive to **new physics**.

The **Muon g-2** fundamental parameter was measured to much greater precision, which represents another success in the program recommended in the P5 report. Remarkably, the value differs significantly from the theoretical prediction, pointing the way to more scientific progress.

Using the high-temperature superconductor, YBCO, researchers at **Fermilab set a new record for a fast-cycling accelerator magnet**.

The **Dark Energy Survey (DES)** announced many results using data from its first three years of operation.

Theoretical physicists have discovered new connections between particle production at **colliders** and fundamental concepts in **quantum field theory**, offering new, more incisive tests. They have also discovered new ways to search for candidate **dark matter** particles.

Intriguing first results from the **MicroBooNE** neutrino experiment, which is a proof-of-principle application of liquid argon for neutrino detectors, tested hypotheses about anomalies from previous neutrino experiments.

Program advances in 2021

Building upon the historic 2015 and 2017 bilateral U.S.-CERN agreements, U.S. and CERN scientists successfully continued their cooperative partnership at the LHC and the international neutrino program hosted by Fermilab. So far, government-to-government agreements with 10 countries have been signed for LBNF/DUNE, PIP-II, and the Short Baseline Neutrino program at Fermilab, with more in progress.

The **Vera C. Rubin/LSST Camera** successfully passed its CD-4 construction completion milestone. The **Dark Energy Spectroscopic Instrument (DESI)**, the world’s premiere multi-object spectrometer, began its 5-year survey in May 2021, enabling major advances in the study of the nature of **dark energy** using methods complementary to those of Rubin Observatory’s upcoming imaging survey.

The next-generation cosmic microwave background facility, CMB-S4, was ranked highly in the NAS Decadal Survey of Astronomy & Astrophysics, opening the path for a partnership in this interdisciplinary science that was also a priority in the P5 report. CMB measurements uniquely probe **physics of the inflationary era in the early Universe** at energies well beyond those of earth-bound accelerators and can also reveal **neutrino properties**.

Looking forward

All eyes are on the LHC, as its sensitivity to new physics will continue to improve through vastly greater data volumes and new deep-learning data analysis methods. The experiments will extend their discovery reach and probe the Higgs boson’s properties with ever greater precision for many years to come. Despite COVID and funding constraints, the HL-LHC upgrade projects are progressing.

Eagerly anticipated new data from operating experiments will advance the understanding of the intertwined Science Drivers identified in the P5 Report. At the LHC, the accelerator is on track to resume operations this spring for data-taking by the successfully upgraded experiments.

Particle physicists are expanding efforts to develop and apply artificial intelligence (AI) techniques to the operation of accelerators and experiments, data analysis, and simulations, opening new avenues for scientific discovery.

Theoretical and experimental particle physicists are advancing Quantum Information Science (QIS), providing solutions to problems in computation, data analysis, sensors, and simulations.

The particle physics theory community will continue to play key roles in interpreting results from current experiments, motivating future experiments, and pursuing answers to the deepest questions.

Looking beyond the current P5 horizon, and guided by new results, the U.S. is currently engaged in the Snowmass community planning process, in which opportunities in all areas of the field are discussed in depth. To inform choices, the U.S. is also working with partners worldwide on the development of concepts for facilities that could be hosted in the U.S. and abroad.

U.S. researchers are pursuing R&D on advanced technologies to enable future generations of accelerators and detectors with a wide variety of applications in science, medicine, and industry.

Building for Discovery

Strategic Plan for
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in the Global Context

usparticlephysics.org

Finally, the Importance of Positive, Clear, and Actionable Messages

- Snowmass can provide clear questions and viable options. Nothing should be off the table for consideration.
- Realism is important, but so are well-motivated, big aspirations. Snowmass can provide these, too. From the 2014 P5 Report:
  - *As work proceeds worldwide on long-term future-generation accelerator concepts, the U.S. should be counted among the potential host nations.*
  - *We had the responsibility to make the tough choices for a world-class program under each of these scenarios, which we have done. At the same time, we felt the responsibility to aspire to an even bolder future. These are not contradictory responsibilities: an annual budget is a balance sheet, but investment in fundamental research is a powerful expression that our culture and economy have greater potential in the long run. Our society's capacity to grow is limited only by our collective imagination and resolve to make long-term investments that can lead to fundamental, game-changing discoveries, even in the context of constrained budgets.*
- Diversity, Equity, and Inclusion are also areas of necessary attention and different thinking.
- Cutting across "Frontiers" is important
  - Suggest how to think about activities in a given area and how they connect to everything else.
- The evolving international context remains essential.

Thank you