Excerpt from
Mission Need Statement for

COORDINATED SECOND-GENERATION DARK MATTER EXPERIMENTS (DM-G2)

Office of High Energy Physics
Office of Science

1. Statement of Mission Need

The mission of the High Energy Physics (HEP) program is to understand how the universe works at its most fundamental level by discovering the elementary constituents of matter and energy, probing the interactions between them, and exploring the basic nature of space and time. Determining the nature and identity of dark matter is a key component of HEP's mission. Dark matter particles constitute the dominant form of matter in the Universe and in particular are the primary constituent of our Galactic halo, yet what they are is still not known. They are not contained within the Standard Model of particle physics, so their detection and characterization would profoundly impact our understanding of physics.

Federal advisory committees that report to the DOE, as well as the National Research Council, have ranked the identification of dark matter as one of today's most important goals in physics. In particular they have emphasized the need for multiple, independent experiments for dark matter detection. In response to this advice, the Mission Need Statement for Coordinated Second-Generation Dark Matter (DM-G2) Experiments calls for a set of independent, "second-generation" ground-based experiments that will perform direct searches for dark matter particles. This set of experiments will have significantly increased sensitivity compared to current dark matter experiments.

2. Capability Gap

Current Capability Gap

There are many experiments world-wide that are currently searching for dark matter. They all fall into one of three categories: accelerator searches for dark matter particle production; indirect searches for dark matter annihilation or decay within our Galaxy; and searches for cosmic dark matter particles that directly interact with detectors in terrestrial laboratories. This mission need statement is for experiments of the last type, the "direct detection" of dark matter.

As the sizes of detector targets increase, so does the sensitivity for dark matter detection. At the current time, "first-generation" experiments world-wide are all competing with comparable levels of sensitivity. These experiments use differing technologies and target media (e.g., liquid xenon, liquid argon, germanium crystals, bubble chamber fluids, magnetized resonant cavities and others). Learning about the capability and cost-effectiveness of these various technologies is one of the goals of the first-generation dark matter program. Over the next year most of these experiments will have set interaction cross section limits not far from their ultimate reach (in the absence of detection). It is therefore time to initiate R&D for a set of second-generation experiments and to fabricate two or more detectors whose dark matter sensitivity will be larger by one or more orders of magnitude.

To this end, a recent DOE solicitation[1] has been issued that provides one year of Research and Development (R&D) support for potential second-generation dark matter experiments. This R&D effort, whose goal is to identify the leading detection technologies, will be followed by the selection of the second-generation dark matter experiments.

In the second-generation dark matter program, the detector sizes will increase by at least an order of magnitude. This will bring sensitivities to the point where detection of dark matter particles will be substantially more probable than at the present time. Design and fabrication of second-generation experiments will require significantly more resources than those for current, first-generation experiments. The capability gap is the order of magnitude difference in performance between current first generation dark matter experiments and the proposed second generation dark matter experiments.

Strategic Risk

The two DOE/HEP FACA committees, HEPAP and AAAC, have placed a high priority on maintaining US leadership in the search for dark matter. Failure to proceed with a set of second-generation dark matter experiments would negatively impact the DOE/HEP

[1] DOE-FOA-0000597

science goal of "understanding…the mysterious forms of unseen energy and matter that dominate the universe."

In addition, because the mystery of dark matter is so prominent in the eye of the general public there continues to be a plethora of media presentations on the dark matter saga. A discovery by a non-U.S. lead experimental group would negatively impact public U.S. scientific prestige. Given that much of the technology employed in current experiments has been supported and developed in the U.S., it would be unfortunate if the first direct detection of dark matter were not made by U.S. scientists. This is real possibility; European and Asian-led second generation dark matter experiments are being planned that threaten current U.S. leadership in this field. To remain competitive, U.S. second-generation dark matter experiments need a project start no later than FY2014.

Priority of Mission Need

Both the National Research Council and the Federal Advisory Committees for the DOE Office of High Energy Physics have emphasized the importance of searches for dark matter, and have consistently recommended a vigorous program for their detection as a high priority. The need for this effort is documented in the 2002 report of the National Research Council, "Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century", which identified *"What is dark matter?"* as one of the eleven most fundamental questions of our time.

Other recommendations from Federal Advisory Committees include:

The Report of the Dark Matter Scientific Assessment Group, a joint sub-panel of the High Energy Physics Advisory Panel (HEPAP) and the Astronomy and Astrophysics Advisory Committee (AAAC), states (July 2007):

> *The existence of dark matter is at present one of the strongest pieces of evidence that the current theory of fundamental particles and forces, summarized in the standard model of particle physics, is incomplete. At the same time, because dark matter is the dominant form of matter in the Universe, an understanding of its properties is essential to determine how galaxies formed and how the Universe evolved. Dark matter therefore plays a central role in both particle physics and cosmology, and the discovery of the identity of dark matter is among the most important goals in science today.*

The Report of the Particle Physics Project Prioritization Panel (P5), constituted by HEPAP for the purpose of developing a plan for US particle physics for the upcoming decade, states (May 2008):

> *…The panel recommends support for the study of dark matter and dark energy as an integral part of the US particle physics program.*

High Level Interdependencies

HEP is coordinating its program with NSF to optimize the national dark matter effort within the context of the second-generation dark matter program. The NSF has effectively partnered in the past with DOE on dark matter experiments, and has received the same federal advisory committee advice on the conduct of this program.

Several of the collaborations proposing second generation experiments plan to install their detectors in deep underground facilities outside the U.S. This in large measure is due to the fact that there is a shortage of such facilities in the U.S. Such U.S.-led collaborations would have a substantial fraction of international members, and their experiments would likely receive significant amounts of in-kind foreign support. By Critical Decision (CD)-2 these foreign contributions would be well defined.

3. Potential Approach

Our plan is to competitively select several experiments for one year of R&D support in FY 2013 through a current Funding Opportunity Announcement. These selected experiments will cover a range of detection methods and target media. R&D activities during this year will include conceptual experiment design and work that reduces scientific, technical or cost risk to the experiment.

Near the end of the one year R&D period, a “down-selection” of up to four experiments will be made as part of CD-1. The down-selection will be based in part upon the accomplishments of the supported experiments during the R&D period in FY 2013. No further support will be given to those experiments that are not selected.

The selected experiments will implement a tailored CD process beginning in FY 2014 in accordance with DOE 413.3b project management requirements. At this point these experiments become individual projects within an overarching Second-Generation Dark Matter Experiment Mission Need. The project phase extends from the beginning of FY 2014 to the end of FY 2016.

The R&D funds expended for those experiments that enter project phase will count towards the total OPC. MIE funds will be available for fabrication beginning in FY 2014 and continuing through to the end of FY 2016.

Location Constraints:

Most experiments will need to be located in caverns that are deep underground to shield them from cosmic ray particles which are sources of background events. Potential underground sites include the Sanford Underground Research Facility in South Dakota, the SNO Laboratory in Canada, and the Gran Sasso National Laboratory in Italy. U.S. experiments are currently operating in all these locations; international cooperation between DOE and these foreign laboratories to date has been positive and mutually rewarding.

Environmental, Safety and Health

All work at DOE sites will be conducted under DOE-approved Integrated Safety Management System (ISMS). All facilities will comply with the requirements of the National Environmental Policy Act (NEPA). Based on the nature of the projects, and their planned locations at an existing laboratory, impacts to the environment are anticipated to be minimal. For locations in foreign countries, the ES&H policies of the host country will be observed.

Cost Risks

The cost risks are mitigated by the fact that most of the proposed projects are very similar to existing experiments with proven technologies, only scaled up in size and target mass. The cost risks associated with remaining technical and schedule challenges will be reduced through the application of appropriate contingency.

Schedule Risk

Schedule risks are mitigated by the fact that most of the proposed projects are very similar to existing experiments with proven technologies, only scaled up in size and target mass.

Safeguards and Security

All projects will be managed by DOE laboratories, which will follow existing safeguards and security policies and procedures.

There may be International Traffic in Arms Regulations (ITAR) controlled parts of the scientific instrumentation. DOE laboratories have extensive experience in dealing with the ITAR regulations and no issues are foreseen. A majority of the scientific and technical work is expected to fall under the fundamental research exemption of ITAR.