Report of the 2019 Committee of Visitors
Division of Materials Research
National Science Foundation

Meeting Dates
September 11-13, 2019

Submitted on behalf of the Committee by
Melissa A. Hines, Chair

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Executive Summary

The COV met in Arlington VA on September 11-13, 2019 to review all aspects of the Division of Materials Research over the time period FY 2015-2018 pursuant to the charge in Appendix C. In the following report, we outline our key recommendations in Section 1 and then provide program-specific reviews in Section 2.

Overall, the COV found that the integrity and efficacy of the processes used to solicit, review, recommend, and document proposal actions were of high quality. The COV specifically highlights the thorough documentation (eJackets) maintained by NSF staff on each proposal, which clearly document the data collected (typically peer reviews) on each proposal, the rationale for each funding decision, and all communications. The COV was also very impressed by the quality, dedication, and efficiency of the staff in the Division, from the Division Director to the program officers to the staff members.

The COV identified significant and impressive scientific accomplishments over the past four years in each program area, as documented in the program-specific reviews. The Division's portfolio also had many broader impacts, perhaps the most important being the education of the next generation of scientists and engineers who have the skills necessary for future advances in industry, academia, government, and other realms.

The COV also found that, in general, the Division was responsive to the prior COV report of 2015.

The COV considered the Division's balance, priorities, and future directions. This discussion was informed by the 2019 *Decadal Survey*[1] which was commissioned by NSF and the DOE at the urging of the 2015 COV, other published documents, as well as information provided by NSF. The *Decadal Survey* documents the importance of materials research to US global competitiveness, in part by citing estimates that *over 75% of economic growth in the coming decades (2030-2050) will be attributable to the development and application of advanced materials.* The *Decadal Survey* also benchmarks US competitiveness in materials research against many other countries, and the results are sobering. The DMR budget has increased, on average, by only 2.5% per year over the last 18 years, a factor that has barely kept pace with inflation. As a result, the COV found that many worthy and innovative proposals cannot be supported due to lack of funds and that necessary investments in infrastructure are being delayed. These funding decisions are negatively impacting workforce development and US competitiveness. This lack of investment contrasts that of many other countries, both established scientific powers and emerging competitors, that have invested heavily in materials research.

For this and other reasons, the COV is in agreement with the major conclusion of the *Decadal Survey*, namely that "materials research in the US is at a precipice" and that "if the US does not maintain its position as a world leader in materials research, it risks not being a significant player." In the following, the COV presents a number of high-level recommendations to help DMR begin to address this issue effectively.

The Committee of Visitors is part of a Federal advisory committee. The function of Federal advisory committees is advisory only. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the Advisory Committee, and do not necessarily reflect the views of the National Science Foundation.

Submitted on behalf of the 2019 Committee of Visitors,

Melissa A. Hines
2019 DMR COV Chair

[1] National Academies of Sciences, Engineering, and Medicine, *Frontiers of Materials Research: A Decadal Survey* (2019) Washington, DC: The National Academies Press. https://doi.org/10.17226/25244

1. Key Recommendations

One of the key recommendations of the 2015 DMR COV was the commissioning of a National Academies-level report to document the impact of materials research in a global context, to benchmark US competitiveness in this area, and to examine the return on investment in basic materials research. This stimulated the production of the recently published *Frontiers of Materials Research: A Decadal Survey (2019)*,[1] referred to as the *Decadal Survey* hereafter. The COV carefully studied this report, other published reports, and information provided by NSF in formulating the following recommendations.

The *Decadal Survey* documents the importance of materials research to US global competitiveness, in part by citing estimates[2] that *over 75% of economic growth in the coming decades (2030-2050) will be attributable to the development and application of advanced materials.* The report provides extensive documentation of advances over the past decade that are currently having significant societal impact — everything from ceramic composites that have enabled a new generation of highly efficient jet engines to advanced electronic materials used to produce super-dense, three-dimensional computer "chips" to the invention of self-healing polymers with improved recyclability and performance. In addition, new additive manufacturing technologies have enabled the design and production of fuel nozzles too complex for standard machining; these nozzles are five times as durable as standard nozzles, but only 75% of the weight. These advances and others span the gamut of materials: from traditional materials, such as metals and ceramics, to entirely new materials classes that could not have been imagined even two decades ago, such as topological insulators and atomically-thin materials. Importantly, the *Decadal Report* notes that breakthrough applications often require many advances, including new materials and new fabrication techniques.

The *Decadal Survey* benchmarked US competitiveness in materials research against many other countries, and the results are sobering.

The *Decadal Survey* notes that most established western countries and Japan are changing their investments in materials research as their share of the world's economy shrinks in comparison to that of emerging Asian economies. For example, Germany instituted their "High Tech Strategy" plan. As a result, the *Decadal Survey* noted that German R&D expenditures increased at an average rate of 4% over 2000-2013, and one of their current foci is investing in new instrumentation to drive innovation. Similarly, the EU Horizon 2020 plan, which includes materials research, is reported to be the largest EU program ever in R&D with a nearly €80 billion investment over 2014-2020. Finally, the UK has announced a specific goal of raising R&D investment to 2.4% of GDP by 2027. (US R&D investment is currently 0.8% of GDP.)

Investments in emerging Asian economies have also increased substantially. For example, China has been making strategic investments in R&D since 2006, which the *Decadal Survey* concludes have "the potential to change the world landscape of industrial and thus materials production and substantially increase competition with current leaders in manufacturing." As shown by Fig. 1, China's National Natural Science Foundation (*i.e.,* China's NSF) funding *for materials research alone* has increased almost five-fold since 2009,[3] reaching parity with the DMR budget in 2012.[4] In contrast, the dotted line in Fig. 1 shows that the DMR budget itself has increased, on average, by only 2.5% per year over the last 18 years, a factor that has barely kept pace with inflation.

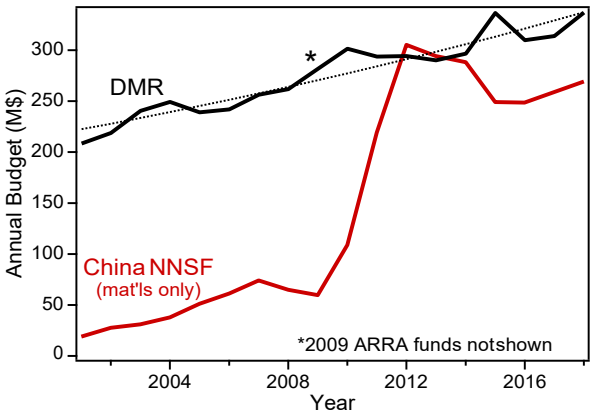

Figure 1: Annual budget for materials-related research by the national science foundations in the US (black, NSF DMR[4]) and China (red, materials program in China NNSF[3]). The dotted black line represents a 2.5% annual increase (best fit) in DMR funding.

In addition to increasing resources, China is investing heavily in research infrastructure, including the construction of three synchrotrons and two neutron sources in the past decade. China has also initiated its own well-funded materials genome initiative, modeled on the US Materials Genome Initiative,[5] which includes the DMREF program in DMR.

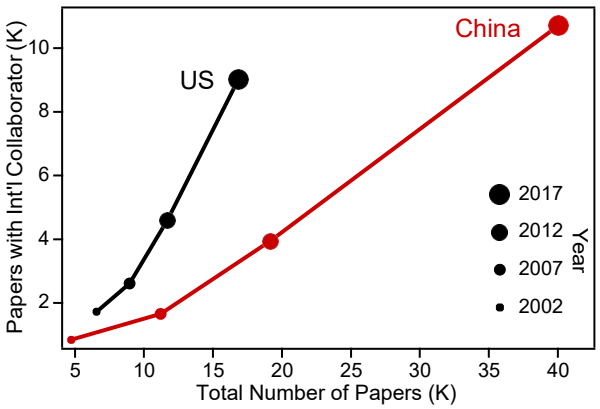

Figure 2: Comparison of materials research output in US and China. See Ref. 3.

China's investments in research are paying off handsomely. As shown in Fig. 2, China's research output (as measured in publications) now dwarfs that of the US. Surprisingly, a recent *Nature* review[3] found that "China now publishes *more high impact research papers* than any other country in 23 fields with clear technological applications," including in batteries, semiconductors, and new materials. Importantly, much of this research funding includes investment in student education,[1] which will provide China with the trained workforce necessary for further advances in the coming decades.

As a result of this investment, institutions in China and other East Asian countries are increasingly recruiting established, highly successful materials researchers from US universities — something that would have been unheard of a decade ago.

To be sure, research is increasingly collaborative, and international collaborations play an important role. Nevertheless, US involvement in international collaborations is dependent on US investment and US capabilities.

For this and other reasons, the COV is in complete agreement with the major conclusion of the *Decadal Survey*, namely that "materials research in the US is at a precipice" and that "if the US does not maintain its position as a world leader in materials research, it risks not being a significant player." In the following, we present a number of high-level recommendations to help DMR begin to address this issue effectively.

Recommendation 1: DMR should take the lead in increasing funding for and awareness of materials research as this funding is essential to US global economic competitiveness and to the ability of the US to confront challenges ranging from national security and energy independence to climate change and waste management.

In contrast to investments by established western countries and emerging Asian economies, DMR funding has barely kept pace with inflation for the *past two decades* as shown by Fig. 1. The COV concludes that no amount of reshuffling of funds, reorganization of programs, or realization of efficiencies can remedy this fundamental issue. DMR must aggressively pursue additional funding at all levels.

To be clear, the COV is appreciative of the fact that many programs in DMR have worked over the past four years to increase the size of awards to individual investigators. Clearly, if grants are not large enough to support a graduate student, the proposed research cannot be accomplished. Nevertheless, increases in grant size cannot come at the cost of reduced funding rates, which will only serve to drive productive researchers out of the field or to other countries. In every grant cycle, there are more high-quality proposals than can be funded, and the program officers estimate that funding rates could be increased by 25-100% without a discernible decrease in the quality of science. Furthermore, increases in grant size or funding rates cannot come at the expense of investments in research infrastructure, as state-of-the-art experimental and computational tools are increasingly needed for impactful advances. Increases in grant size also cannot come at the expense of investments in undergraduates and diversity, as a highly trained workforce is vital to US global competitiveness. Finally, increases in grant size cannot come at the expense of the MRSEC

program, which remains the crown jewel in DMR, producing world-leading science with tremendous impact, as demonstrated in part by its 8-year-average citation rate of 24.5 citations/publication.

For this reason, the COV concludes that a "business as usual" approach will compromise the long term competitiveness of US innovation. Drastic changes are needed. We propose some in the following.

Recommendation 2: Given the breadth and importance of materials research across NSF and to the economic vitality of the US, the COV recommends that a separate directorate encompassing materials research, materials chemistry, materials engineering, and materials (condensed matter) physics be established in NSF.

Given the issues outlined in the introduction, NSF and the MPS Directorate must develop a strategy to increase funding for materials research and regain the pre-eminent position of the US *without cannibalizing support for fundamental science.* We suggest that one part of this strategy be structural.

The Division of Materials Research is distinct from other divisions in MPS in that, from the very beginning, it was designed to span disciplines by emulating successful industrial research labs, such as Bell Labs. The Interdisciplinary Laboratory (IDL) program was initiated by ARPA in 1960 to promote interdisciplinary research in materials at the intersection of physics, chemistry, and engineering. The goal of the program was to meet emerging national needs for both new technological materials and a highly skilled workforce in the post-Sputnik era. This approach was highly successful. With the advent of the Mansfield Amendment and its restrictions on Department of Defense investments in long-term research, the IDL program was transferred to NSF in 1970, which led directly to the establishment of DMR.

Consistent with its original goal, the DMR research portfolio remains highly interdisciplinary, with only 12% of current PIs being drawn from departments of materials science and engineering. Almost a third of current awardees come from departments of chemistry or chemical engineering, and more than 25% come from departments of physics or applied physics. The remaining PIs are drawn primarily from other fields of engineering as well as bioengineering, biochemistry, and biology.

One of the consequences of the current structure is that pockets of materials research can be found in numerous divisions of NSF, which leads to serious inefficiencies at all levels.

At the very highest level, the COV suggests that compartmentalizing materials research with four fundamental disciplines (mathematics, astronomy, chemistry, and physics) represents a missed opportunity for conveying the importance of NSF and science funding to everyday life. The public knows and appreciates the need for Gorilla glass for drop-proof cell phones, advanced aluminum alloy frames and carbon fiber wheels for faster racing bikes, and higher capacity batteries for increased-range electric cars. These applications sell themselves! But how many people think of NSF when it comes to solving these problems or educating the inventors of tomorrow?

Elevating materials research to a separate directorate would allow NSF to argue and justify more forcefully and more compellingly for the need for additional funding. We suggest using the urgent and immediate need to maintain global competitiveness against China and other emerging nations as one important rationale.

Elevating materials research to a separate directorate would also facilitate the review and funding of proposals that currently span divisions, such as fundamental chemistry and self-healing materials or biology and hierarchical materials. To be sure, cross-divisional (joint) funding of awards is possible within the current structure, and the COV commends the diligence of many program officers in seeking out such funding. Nevertheless, this places additional demands on already overstretched program officers. Additionally, cross-divisional funding relies on program officer's personal relationships and insights, which disadvantages programs overseen by temporary or rotating program officers.

Finally, elevating materials research to a separate directorate would, we believe, promote the funding of higher risk projects that may fall between the cracks in the current structure. There is a natural tendency for

reviewers in a tight funding climate to become both more conservative and more insular, favoring incremental advances in well studied areas over higher risk but potentially transformative ideas. The COV recognizes that the EAGER program was designed to meet this need and that many program officers are proactive in using this funding mechanism. Nevertheless, the EAGER program is, by design, small and at the program officer's discretion. A more aggressive and well-funded approach to high-risk research, especially in interdisciplinary materials research, is needed!

Recommendation 3: DMR should explore new mechanisms to promote the need for and impact of materials research on society and the economic well-being of the nation, potentially in partnership with other NSF divisions, NSF directorates and other Federal agencies. To this end, DMR should explore the feasibility of supporting an effort similar to the Computer Research Association, with a mission of uniting industries, academia and government to advance materials science to improve the lives and well-being of all.

DMR must become more agile in communicating the need for and impact of materials research at a national level and responding to emerging problems and opportunities. Other agencies, such as the Department of Energy, and consortia, such as the Computer Research Association, have developed highly effective models for this.

Advances in materials, either in the discovery of new materials or order-of-magnitude improvements in the properties of current material systems, are central to addressing key grand challenges and ensuring the vitality of the US economy. Examples of the impact of materials research are provided in the Decadal Study. However, it is the end product and its uses that are generally recognized with little to no appreciation for the enabler — the materials and the materials research needed to build the product. Consequently, the need for fundamental research in materials is often overlooked, not understood or appreciated.

The myriad of professional societies (*e.g.,* MRS, APS, ACS, ACERS, AVS, TMS, ASM) that represent the breadth of materials research has created a void in that there is no unified voice to advocate broadly for the importance and value of materials research or to connect academe with industry and government agencies.

Other disciplines, notably computer science, have recognized this as a challenge and have established "independent bodies to advocate for the discipline and to serve as a bridge between academia, industry, private Foundations, and federal agencies." DMR is uniquely positioned to spearhead the effort to establish such an organization that not only conveys the message about the impact of materials, but impacts workforce development through publishing position papers on materials education initiatives, emerging challenges and opportunities in materials research related to providing technological solutions to national, societal and global challenges, and connects academe with industry. This effort would complement the role program officers and topical workshops sponsored by DMR play in identifying emerging research funding opportunities, which are vital to maintaining the vibrancy of the research programs in DMR.

One highly successful model for achieving these goals is the Computer Research Association (CRA),[6] which was originally formed to increase R&D in computing, to promote awareness and excitement about the field of computer science and engineering, and to enable and improve the interactions between academe, industry, and government. A review of the CRA website shows impact reports on research issues, many of which also impact materials research; educational initiatives that have spurred a dramatic increase in interest in computer science in the past five years; and workforce development reports. One example of the impact of this group is that they stimulated the creation of the National Robotics Initiative in 2011, which is now jointly sponsored by NSF, USDA, NASA, and NIH, as well as national initiatives on big data and sustainability. The CRA also seeks to be a trusted source of information — formally and informally — for Congress, the White House, and the President's Council of Advisors for Science and Technology. This effort remains partially supported by NSF.

We note that the Engineering Directorate in conjunction with the ASEE and NAE have already held one workshop to explore options for establishing a group similar to the CRA that will connect academe,

industry, and government. As materials research is a component within the Engineering Directorate, DMR is encouraged to participate in these discussions and to help shape the conversation.

A second model is the Department of Energy's Basic Energy Science Advisory Committee (BESAC).[7] This committee provides advice in "establishing research and facilities priorities; determining proper program balance among disciplines; and identifying opportunities for interlaboratory collaboration, program integration, and industrial participation." BESAC is an active committee beyond the public meetings. BESAC forms subcommittees to prepare supporting documents about research activities, the latest being highlights of BES funded achievements over the last forty years.[8] Subcommittees also participate in and often lead basic research need workshops in energy-related areas — workshops that have shaped future funding investments. Finally, subcommittees serve on review committees for BES. The efforts of this committee provide community support for initiatives that often come with new funds, with the EFRC program, which received $100M in 2018,[9] being one high-profile example.

We recognize that the MPS directorate has an advisory committee; however, the membership is spread between the five divisions, making it challenging for this committee to function in a fashion similar to BESAC.

In conjunction with this, DMR must become more effective in communicating the impacts of previous funding to all constituents, including impacts on workforce development (discussed below). While NSF excels at the compilation of statistical data (*e.g.,* number of startups, number of students graduated), stories are much more compelling. These professionally written and illustrated "short stories" should be distributed to PIs and universities, made available at professional society meetings, and widely disseminated, including on a NSF website. These stories will provide constituents with the ammunition that they need to make a compelling case for materials research with their state and national representatives. Here again the "BES at 40" stories[10] produced by BESAC provide an example.

We emphasize that the goal of this effort is to ultimately stimulate new funding for materials research broadly, not to find exciting areas of research for the application of existing funds. We make this recommendation in full realization of the fact that NSF cannot participate in or fund any activities that can be construed as lobbying Congress. CRA and BESAC are two successful models that have a track record of stimulating new funding while not running afoul of this restriction.

Recommendation 4: DMR should take the lead in establishing partnerships with other government agencies (*e.g.,* DOE, DOD, NIH) to develop new initiatives aimed at connecting discovery to translation while also providing creative approaches to funding the underlying materials research and development.

The *Decadal Survey* makes a compelling case for a nationwide strategic response to the global challenges in materials research, which must include coordinated planning and funding across multiple government agencies. However, *this recommendation will have no impact without a champion to lead the charge.*

The COV recommends DMR take the lead in establishing partnerships with other NSF divisions and government agencies to respond to global challenges, national needs, and emerging opportunities, much as they have done with the Air Force. The NSF-AF partnership has already resulted in better coordination with DOD in the areas of materials for quantum information, extreme environments (*e.g.,* hypersonics), and AI/ML for materials discovery. There is also an opportunity for DMR to work with ONR and NASA on the development of advanced materials relevant to hypersonics. A second example would be the workgroup whose efforts resulted in the Materials Genome Initiative; this group was and remains comprised of leaders from NSF DMR, DOE BES, and the defense agencies. Opportunities may also exist in advanced manufacturing and critical materials.

The COV also recommends that DMR take the lead in organizing the response to the *Decadal Survey* recommendation that all US agencies supporting materials research "take coordinated steps beginning in 2020 to fully assess the threat of increased worldwide competition to its leadership in materials science and

in advanced and smart manufacturing." The *Decadal Survey* further recommended that this permanent assessment program "should also define a strategy by 2022 to combat this threat."

Recommendation 5: DMR should commission a study of the economic impact of the materials research workforce previously developed by the NSF and the future workforce needs in materials research, as this was not included in the *Decadal Study*.

DMR's most important contribution to the US economy is likely the training of highly skilled graduate students and postdocs who subsequently join the US R&D workforce; however, DMR is not making this case effectively in either statistical form or anecdotally. This is a missed opportunity. While the *Decadal Study* made a compelling case for the impact of materials research on US economic competitiveness, most of the examples, quite naturally, focused on commercialized products that were attributed to industrial labs. We suspect, but cannot prove, that many of these industrial labs were staffed with NSF-trained scientists and engineers. Quantifying the economic impact of DMR-supported trainees who have previously joined the US workforce would be a very valuable tool to measure DMR impact and to argue for increased national support.

While the *Decadal Study* estimated the economic impact of materials research worldwide, the impact of DMR funding on the US economy and the US workforce was not studied. Similarly, no estimate of US workforce needs in the coming decades was made.

The COV appreciates the efforts of individual program officers in reaching out to industry and collecting data on workforce needs. For example, CMP program officers held discussions with major US companies and found strong evidence of an urgent need for trained individuals in the area of quantum materials.

One model for this study might be the 2019 APS study *The Impact of Industrial Physics on the US Economy*.[11] This study documented the hiring of 70,000 degreed physicists by US industries over the 2003-2016 period and found that 11.5 million people (6% of total US employment!) are directly involved in US physics-based companies. In addition, $150 billion of internal R&D investments are made by US physics-based companies. Examples such as these focusing on the economic impact of the materials research workforce would be compelling in arguments for increased funding!

Recommendation 6: NSF should develop a data-driven understanding of how exposure to an environment of research excellence influences student persistence in STEM and assess how efforts to increase diversity are working.

The Partnership for Research and Education in Materials (PREM) program, first funded in 2004, is a unique and innovative program that seeks to improve the diversity of the STEM workforce by coupling the research strengths of DMR centers and facilities with the educational strengths of minority-serving institutions. The PREM mission is to increase recruitment, retention, and degree attainment by members of underrepresented groups, while at the same time advancing excellent research and education.

As the program completes its 15th year, the COV recommends that DMR look beyond simple statistics and develop measures of graduate student success post-graduation. These measures should be used to assess PREM program outcomes, particularly in comparison to traditional programs designed to increase diversity (*e.g.,* direct fellowships). A study of the role of research and research opportunities in improving graduate student persistence, which might be supported by NSF's Division of Educational Research, would also be valuable.

These studies are necessary to evaluate the efficacy of the PREM model, as effective means of increasing diversity in STEM are needed across NSF as well as in other agencies.

Recommendation 7: DMR should creatively find new mechanisms for funding much needed materials research infrastructure, both experimental and computational, for individual investigators.

The *Decadal Report* noted that over the past decade, "the ever-rising costs of acquiring and maintaining state-of-the-art research infrastructure combined with the dire lack of funding avenues for instrumentation have culminated in a situation that can only be described as a crisis" for all materials research. The importance of on-campus and PI-laboratory-based instrumentation was found to be critical to the tight feedback loop typical of many materials projects, which rely on rapid and iterative synthesis, structural characterization, and property measurements. The *Decadal Report* noted that for most materials research, "it is not feasible to carry out this research by relying on remote facilities." In short, the current mechanism of funding research infrastructure "is completely inadequate in sustaining forefront research in the long term." We agree.

For materials research, the importance of state-of-the-art materials characterization equipment, high-speed computer clusters for materials genome computations, and instruments to synthesize or characterize materials under extreme conditions cannot be overstated. This is true for the original acquisition, but applies equally to maintaining, operating and, at a reasonable time interval, replacing outdated equipment. A program that allows faculty to acquire new instruments for emerging research directions or to replace an outdated equipment in order to remain globally competitive is urgently needed. We suggest both a long-term (few year) and short-term (immediate) strategy.

Within the next few years, the COV recommends reinstitution of a funding program for PI-laboratory-based instrumentation (both experimental and computational) such as the Instrumentation for Materials Research (IMR) program, which last made awards in 2008. This program allowed individual investigators to obtain equipment too expensive for inclusion in a standard topical materials research program (TMRP) grant. Importantly, this program did not place a cap on the number of proposal submissions per institution. An institutional cap, such as that on the current MRI program, strongly disadvantages proposals from individual investigators in the institutional pre-selection competition (*e.g.,* at R1 universities).

The COV further recommends that DMR develop a fair and creative process to make needed infrastructure investments to current awardees using, for example, end-of-year funds. Delays in federal appropriation bills have become more common in recent years, and it is not uncommon for program officers to have a small amount of unobligated end-of-year funds that must be allocated in a window too short for a RFP. Under government rules, these funds can be used without competition to give small increases to current awardees, which we recommend be used for instrumentation.

Recommendation 8: The current division of program areas along specific classes of materials — the topical materials research programs (TMRP) — is working well, and the COV does not recommend a restructuring of the topical areas.

The *Decadal Survey* considered different means of classifying and evaluating materials research opportunities and found that an organization around specific types or classes of materials, such as currently used to delineate DMR program areas, "strongly leverages current state-of-the-art knowledge and has a proven track record of successful materials research advances." The *Decadal Survey* also emphasized, repeatedly, that "paradigm-changing advances often come from unexpected lines of work" and that fundamental, exploratory research leads to very important — but inherently unpredictable — advances that feed technology, often years in the future. As a result, one of the key recommendations of the *Decadal Survey* was that NSF and other federal funding agencies "maintain robust programs to support, and in some cases expand, fundamental research in long-established areas such as metals, alloys, and ceramics."

The COV concurs with these assessments and recommends DMR maintain the current division of program areas (*i.e.,* TMRPs). In its review, the COV documented evidence showing that these programs are not static; they are all highly evolutionary and reactive to emerging opportunities. (Examples are provided in the program-specific reports that follow.) This structure allows NSF to maintain a balanced portfolio of

research that is both reactive to unexpected advances and supportive of the short-, medium-, and long-term research necessary for both idea-driven and purpose-driven advances at the frontiers of materials research. This distribution is also critical for the education of a balanced US workforce, which must support a wide range of industries and technological needs.

The current topical division of program areas also allows DMR to capitalize on one of its most important assets: its highly trained and deeply knowledgeable cadre of program officers who individually have decades of experience in their topical areas. This deep experience allows program officers to recognize and prioritize potentially transformative ideas over incremental advances. The program officers' decades-long knowledge of both US and international researchers and their research enables the identification of reviewers with the breadth of experience necessary to provide balanced evaluations, particularly of new ideas and approaches.

Recommendation 9: Every DMR program should have at least one permanent (non-rotating, non-temporary assignment) program officer to maintain institutional memory and to enable long-term, reasoned evolution of the program.

As mentioned in the previous recommendation, the COV was deeply impressed by DMR program officers and their dedication to the DMR mission. Nevertheless, some programs have been deleteriously impacted by high turnover in both rotating program officers and permanent staff, which has made it difficult to maintain a high quality review process and to enable long-term evolution of the portfolio. Program officers are particularly important for maintaining continuity in panel reviews, as the membership of successive panels is not constant. Program officer turnover also negatively impacts institutional memory and impedes long-term evolution of the program. As a result, the COV recommends that every DMR program have at least one permanent program officer.

Recommendation 10: DMR, MPS, and NSF should work to stabilize the US supply of helium at a national level and the efficient use of helium by researchers, as an uninterrupted supply of helium is crucial to scientific research, economic advances, and health infrastructure.

Many sources have documented the significant deleterious impact of recent disruptions and price fluctuations in the US helium supply, which we will not repeat. The COV recommends that DMR, MPS, and NSF work at all levels to address this critical issue.

The COV commends the creative and proactive action of DMR program officers, particularly a MRSEC PO, in providing the support necessary to retrofit existing infrastructure to enable He capture and reliquefaction from end-of-year funds.

Recommendation 11: The MRSEC program should not introduce a sunsetting provision but should introduce a network model, in which several institutions can collaborate to support two or more IRGs, as a separate track within the MRSEC program.

The COV recommends strongly against the proposed mandatory sunsetting of MRSECs after a defined period of time (*e.g.,* one six-year funding cycle). The MRSEC program is the crown jewel in DMR programming as demonstrated by many metrics, including an exceptionally high citation rate (24.5 citations/paper over 2011-2019), the nucleation of many start-up companies (32 since 2015), and a large portfolio of patents (1500 since 1985). In addition to quantitative metrics, the program-specific MRSEC review which follows gives many examples of world-leading research results in just the last four years. One is hard-pressed to think of an NSF program that has had a bigger positive impact on scientific innovation as well as US economic vitality.

The success of the MRSEC program has been driven by its unrelenting focus on high-quality research demanding a collaborative, team-based approach. Unlike many other NSF center awards (*e.g.,* STCs, ERCs), existing centers are *always reviewed competitively* against all comers. As a result, long-lived

MRSECs have repeatedly reinvented themselves by proposing entirely new research thrusts (IRGs) and including many new researchers. The 2017 MRSEC competition is illustrative of this process. Four of nine previously-existing MRSECs were unsuccessful in the competition, and three new MRSECs were funded. The program officer estimated that only two unfunded MRSEC proposals in this competition were "above the bar" and denied due to funding limitations. This implies that there were only 3-5 competitive proposals from new MRSECs. Thus, a sunsetting clause in 2017 would have reduced the number of funded MRSECs by 40-60% for no reason.

In the next round, DMR anticipates the competition shrinking from 12 recompeting MRSECs to 8 or 9 funded MRSECs. The COV finds that this highly competitive process for funding provides an effective mechanism for turnover and worries that imposing artificial, non-scientific constraints on MRSEC selection will significantly lower the quality of the program, to the ultimate detriment of DMR.

Nevertheless, the COV recognizes the importance of lowering the barrier for new institutions to successfully compete in the MRSEC program, as there is no longer a mechanism to support single-IRG MRSECs. The introduction of a network track in which several institutions can collaborate to support two or more IRGs would be beneficial. A network track would require separate review criteria, additional support to administer the program, and additional funds. Although "network MRSECs" are not disallowed in the current program (as evidenced by the previously funded Research Triangle MRSEC), they are also not specifically encouraged.

Recommendation 12: The centers programs are exemplars within DMR and MPS; however, the time from pre-proposal to proposal to site review to decision has lengthened over the years. It is taxing for PIs and institutions to sustain efforts for well over 12 months from pre-proposal to decision. The COV recommends that efforts be made to either shrink the evaluation time or to possibly provide development support as ENG does for the ERCs.

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[1] National Academies of Sciences, Engineering, and Medicine, *Frontiers of Materials Research: A Decadal Survey* (2019) Washington, DC: The National Academies Press. https://doi.org/10.17226/25244

[2] S. L. Moskowitz, *Advanced Materials Innovation: Managing Global Technology in the 21st Century* (Wiley, Hoboken, NJ, 2016). http://dx.doi.org/10.1002/9781118986073

[3] S. O'Meara, "The materials reality of China," *Nature* **567,** S1-S5 (2019).

http://dx.doi.org/10.1038/d41586-019-00885-5

[4] Data on the DMR budget were compiled from "Directorate for Mathematical and Physical Sciences," *NSF 17-115* (2017), https://www.nsf.gov/pubs/2017/nsf17115/nsf17115.pdf, and Linda Sapochak's presentation to the COV. The conversion of Chinese yuan in Ref. 3 to US dollars was made using Sept 2019 conversion factors.

[5] Office of Science and Technology Policy, *Materials Genome Initiative for Global Competitiveness,* (Washington, DC, June 2011).

https://www.mgi.gov/sites/default/files/documents/materials_genome_initiative-final.pdf

[6] https://cra.org/about/

[7] https://www.energy.gov/science/bes/basic-energy-sciences-advisory-committee-besac

[8] https://science.osti.gov/bes/Community-Resources/Overview-Brochures

[9] https://www.energy.gov/articles/doe-awards-100-million-energy-frontier-research-centers

[10] See the "individual story summaries" in the "BES at 40" section at https://science.osti.gov/bes/Community-Resources/Overview-Brochures

[11] https://www.aps.org/programs/industrial/upload/APS-Report-Economic-Impact-of-Industrial-Physics.pdf

2.1 National Facilities and Instrumentation (NaFI)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

The National Facilities and Infrastructure section was partitioned into four sections and assessed as follows:

Center for High Resolution Neutron Scattering (CHRNS) – Michael Lilly

Cornell High Energy Synchrotron Source (CHESS and CHEXS) – Margaret Murnane

High Magnetic Field Laboratory – Nancy Washton

Materials Innovation Platforms (MIPs) – Luigi Colombo

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? For the National Facilities and Instrumentation, the higher cost of the programs leads to a review process with higher complexity. In addition to individual *ad hoc* reviews, site visits (or reverse site visits), PI responses to site visits, a thorough internal review and frequent communications between the NSF program director and the PI also occur. The higher cost, higher visibility, and longer time commitments make this more involved process appropriate for the facilities that NSF/DMR stewards or partners with. These multiple review methods are appropriate given the size of the awards. After the award, annual site visits, regularly scheduled calls, and quarterly reports are used to monitor progress. This process also enables NSF to recommend changes or for the Center to suggest changes in the event of major discoveries or if there is a need to sunset less successful activities. The review process for the High Magnetic Field Laboratory is extensive and comprehensive, including on-site panels coupled to *ad hoc* reviews. Reviewers were chosen from a variety of scientific disciplines relevant to magnetic resonance and encompassed a diverse group demographically. The reviews were thorough on scientific	Yes

merit (*e.g.,* Chemical Dark Matter, Quantum Materials, Materials for Magnets, etc.), technical merit (*e.g.,* hardware infrastructure and development), and broader impact. For large facilities such as the Cornell High Energy Synchrotron Source, a combination of individual reviews, site visits and reverse site visits, site visit reports and responses are implemented that are extremely thorough and detailed. In addition, there is a multi-step internal NSF review that involves the Division Director, the Action Review Board of MPS, the National Science Board, an NSF budget review process as well as an independent cost accounting review.	
1. Are both merit review criteria addressed **In individual reviews?** Yes - the in-depth and comprehensive reviews of the Cornell High Energy Synchrotron Source addressed both merit review criteria very well. In the case of MIPS, the reviewers also addressed the two review criteria, although in a few cases the reviewers could have expanded more on their comments. **In panel summaries?** Note that because of the site visits and reverse site visit, panel summaries are not used for the larger facilities. The panel summaries for MIP adequately addressed the review criteria. **In Program Officer review analyses?** The program officers have done a great job in capturing the essence of the National Facilities and Instrumentation proposals and the reviewer's comments. A comprehensive 38-page review analysis of the Cornell High Energy Synchrotron Source renewal addressed strengths and weaknesses of the proposal, strategic needs for the facility for research and education, as well as including the need to enhance broadening participation. For National Facilities, NSF uses additional criteria beyond intellectual merit and broader impacts. For partnerships such as the Center for High Resolution Neutron Scattering, ChemMatCARS and the National Nanotechnology Coordinated Infrastructure, user statistics, education, and outreach are additional criteria included in the review process. The program officer review analysis for the HMFL captured the salient points concisely and effectively. The COV found the reading to be informative and reflective of the overall review from the onsite visit (20 panel members); the information was also interesting to read. The individual reviews were typically thorough, although based on background and personal interest they varied in composition and foci.	Yes

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? For the National Facilities and Instrumentation, overall the reviewers have done a good job in the evaluation of the proposals. The individual reviews for the High Magnetic Field Laboratory provided clear justifications for their assessments and suggestions. This was especially true for areas of concern such as the semantics surrounding the term *Chemical Dark Matter* and the lack of diversity in senior personnel. In several instances, the MIPS reviewers were in fields peripheral to the primary field under review. We recognize the difficulty in finding technically sophisticated reviewers in each field, particularly in view of COI's and the finite size of scientific communities. During the previous review for CHRNS the reviewers took the opportunity to highlight the broad impacts of the projects, the attention to education and outreach, and the	Yes

strengths of the program. The 17 reviews for the Cornell High Energy Synchrotron Source were very insightful, pointing out where it can be a leader and be unique – for example in accelerator and detector technologies, or in being able to innovate quickly. They also pointed out some weaknesses – which were related to the lack of uniqueness compared to other national synchrotron facilities, and in broadening participation.	
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? As explained above, panel summaries are not used in many of the National Facilities and Instrumentation grants, because of the large scale nature of these facilities. For MIPS, panel summaries tended to have less information for the awarded MIPS proposals than the declined proposals. Overall, the summaries had sufficient information for the reader to understand the rationale for disagreement. For large facilities such as the High Magnetic Field Laboratory and the Cornell High Energy Synchrotron Source, more in-depth Site Visits and reports serve instead of panel summaries. The site visit reports were extensive and clear.	Yes
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The documentation provided in the eJackets was extensive and upon ingestion of all the material afforded a holistic and global perspective on the proposal and review process. The COV was impressed by the amount of effort put in by the program officers in their diligent oversight of the review process, including in many cases choosing appropriate and diverse reviewers. For the Cornell High Energy Synchrotron Source transition proposal for example, the combination of the 17 individual reviews, the 7 site visit reports, the Director Review Board (DRB) and the National Science Board (NSB) reports, and the 38-page program officer review analysis provide a very clear rationale for the award decision.	Yes

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The documentation given to the PI(s) provide thorough justification and explanation for the award(s) as evidenced by the reviews and the review analysis.	Yes
7. Additional comments on the quality and effectiveness of the program's use of merit review process: For the large-scale facilities associated with National Facilities and Instrumentation Program, such as the High Magnetic Field Laboratory and the Cornell High Energy	

Synchrotron Source, the merit review process is designed and implemented very well. A multi-step external and internal reviews and site visits ensure a strong merit review process. We applaud the rigor of the NSF review process and especially the diversity of reviewers, both scientific and demographic.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? Reviewers were chosen both for expertise and breadth of knowledge in the given fields. It appears that effort was also expended to diversify the reviewers in terms of professional life stage (*e.g.,* early, mid, and late career). For the Cornell High Energy Synchrotron Source renewal, the written reviews and the site visit reviewers were area experts, who articulated very well the strengths of the facility (*e.g.,* an increasing demand for techniques that can uniquely probe samples under extreme conditions, or interrogation of "real" components, devices, and systems that frequently require high-energy x-rays). They also pointed out areas that could be strengthened. In a few cases, some of the programs under review would have benefited from additional expertise. The COV recommends engaging a few experts on each panel who have experience in the private and non-profit sectors, and who are familiar with the academic landscape.	Yes

2. Did the program recognize and resolve conflicts of interest when appropriate? From the information provided in the e-jackets it appears the reviewers selected did not have a conflict of interest, and the COV could see that reviewers with a COI were removed.	Yes
3. Additional comments on reviewer selection: Excellent efforts in choosing reviewers from a broad technical and demographic pool. For the more complicated review process with individual reviews, panels and site visits, eJackets clearly link to the individual and panel reviews.	Yes

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW

1. Management of the program.

National Facilities and Instrumentation manages several partnerships (Center for High Resolution Neutron Scattering, ChemMatCARS and National Nanotechnology Coordinated Infrastructure). For the funds contributed (CHRNS: $2.7 M/year, ChemMatCARS at the Advanced Photon Source: $0.33M/year and NNCI: $2.58M/year), these programs are extremely productive in user numbers, publications, and outreach opportunities. These partnerships all serve a very broad scientific community. Oversite and management of the NaFI program within DMR is comprehensive and it is clear that the program officers and DMR are committed to quality research and operational excellence. In addition, they have an excellent knowledge base of the funded programs and the professors doing the research. This effort is supported by extensive community input in the form of workshops that function as advisory groups to assist in determining future directions and ongoing activities.

The excellence in management is evidenced by the smooth transition of the Cornell High Energy Synchrotron Source from a stewardship model to a partnership model, which was based on community input and review of the facility. This transition was catalyzed by review in 2014, as well as the previous COV report, where concerns over the lack of uniqueness and cutting-edge capabilities were brought to the attention of DMR. A full assessment of the capabilities at the Cornell High Energy Synchrotron Source was undertaken as a result, and a determination was made by DMR that a more focused support model would enable higher impact science. We applaud DMR for actively managing their resources and for working with Cornell University to transition from a DMR fully supported facility to a partner model, with no negative impact to the user community. Cornell was also able to work with the State of New York to secure significant funds to upgrade the facility (~$15M). We believe this strategy allows for the highest impact science to be generated through the use of the Cornell High Energy Synchrotron Source. This partnership reduces DMR support by $8M for FY19 and 20, with additional savings generated as CHESS increases the number of supporting partners over the next 5 years. Current management of the Cornell High Energy Synchrotron Source is very pro-active, involving regular calls with the PIs 1-2 times a month, quarterly reports, annual site visits, and other interactions. In addition, several internal NSF management meetings are also regularly convened with the DMR leadership, with MPS and NSF Large Facilities Office. Moreover, for the Cornell High Energy Synchrotron Source transition, comprehensive reports are also prepared annually for the National Science Board, the Action Review Board (ARB), and the Director Review Board (DRB).

2. Responsiveness of the program to emerging research and education opportunities.

The National Facilities and Instrumentation program is responsive to emerging research and educational/workforce needs. Based on community input related to the need for additional infrastructure funding in the area of magnetic resonance, DMR chose to increase the budget for the HMFL to support an advanced high field magnet. This investment will allow for interrogations that cannot be conducted with current instruments. Educational opportunities abound at the HMFL and all the other NaFI facilities in the form of postdoctoral scholarships, internships, and an extensive outreach component (*e.g.,* MagLab open house).

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

The National Facilities and Instrumentation program portfolio is planned and prioritized based on science drivers which are identified by the scientific communities that utilize these resources through NSF, NRC, and other reports. The DMR program officers interact with communities both within and outside of NSF, and are informed by these interactions and through reports and other means.

Unfortunately, the size and breadth of the portfolio of the National Facilities and Instrumentation Program is limited by available funds — more capacity for discovery research and innovation exists in the US than can be currently funded. Since the last COV, there have been significant enhancements to this program, with the introduction of the Materials Innovation Platforms (MIP) program and with the strategic transition of the Cornell High Energy Synchrotron Source from stewardship to partnership. We commend DMR for pursuing a truly innovative mid-scale program (MIPS) to address the needs of the materials community, as stated for example in the National Academy study from 2009, *Frontiers in Crystalline Matter*. The approach to MIPS was based on the Materials Genome Initiative, and seeks to foster an environment that encourages a holistic scientific ecosystem comprised of participants from multiple disciplines to accelerate discovery. With continued community input and NSF stewardship, we anticipate that the MIPS program will become an example of future agile investment strategies. We strongly support continuing and expanding the MIPS program to address mid-scale infrastructure needs of the materials community.

4. Responsiveness of program to previous COV comments and recommendations.

The DMR has made significant efforts in addressing the previous COV comments and recommendations — all of the previous COV comments related to the National Facilities and Instrumentation were addressed. In some cases, such as a comment that the portfolio had not changed significantly, major changes were made, *e.g.,* the strategic transition of the Cornell High Energy Synchrotron Source from stewardship to partner (selecting 4 beamlines to fund, CHEXS), which addressed the uniqueness issues for some of the beamlines. The addition of the MIP program (with two competitions to date) also served to enhance and evolve the NaFI program. DMR and the HMFL were also responsive to COV recommendations that resulted in 1) adoption of a new safety oversight strategy, 2) prioritization of high impact and unique capabilities, and 3) continued development of new magnet materials and capabilities.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? This is a particularly important question due to heightened international competition arising from increasing science investment abroad. Without proportional increases in funding in the U.S., this situation can result in loss of science competitiveness, subsequent brain drain, and decreased economic activity in the United States. The five-year award for the High Magnetic Field Laboratory is a compromise between the scientific opportunities of the facility and the available resources from DMR. Given flat DMR budgets over the last decade and only incremental increases at best anticipated for the near term, the funding allocation is understandable For large national facilities like the Cornell High Energy Synchrotron Source, the award size and duration support cutting-edge science through access to unique capabilities. These require long term funding, and also transitions as new science requirements, facilities, and opportunities emerge. As noted above, in response to the 2015 Committee of Visitors and other input, the National Facilities and Instrumentation Program is transitioning the Cornell High Energy Synchrotron Source from a stewardship model of ~$20M per year, to a partnership model at ~$10M per year (similar to the successful management approach used for the NIST Neutron facility (CHRNS)). The portion of the Cornell synchrotron facility that NSF will support going forward is called CHEXS, which will provide community access to 4 upgraded beamlines for Materials Research, Biology, and Engineering Science. Funding for the four CHEXS beamlines will be provided by NSF DMR and the BIO and ENG directorates, and DoD, NIH and other affiliates (*e.g.,* the private sector) will provide support for the remaining seven beamlines. The NaFI partnerships support shared larger resources in neutron scattering, nanotechnology infrastructure, and x-ray scattering for the DMR community. For the funds invested in these projects, there is an excellent return on number of users, number of publications, and education outreach efforts. The award of nearly $43M over five years for two Materials Innovation Platforms (MIPs) is adequate for the objectives of this program.	
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. The DMR National Facilities and Instrumentation program portfolio contains a mix of moderate and high-risk programs, which is balanced. This indicates diligence on the part of DMR to support programs that span traditional materials characterization and support of existing facilities (lower risk), mid-scale infrastructure ecosystems	

that represent some mid- and high-risk activities (MIPS), and large scale infrastructure upgrades (NHMFL) that are higher risk endeavors. The Materials Innovation Platforms (MIPS) programs are developing and studying a wide range of existing and new materials, from oxides to chalcogenides to carbon based to nitrides. Any one of these materials systems could consume the full budget to develop it to an industrial level; thus, industrial partners will be key to help bring the discoveries from MIPS to broad impact. Another concern is that for the research to have high value, the materials properties must be reproducible. This means that the defect chemistry will have to be either well understood and controlled, or easily reproduced or controlled. Finally, a related question is what goals are appropriate for the MIPs program compared with individual PI efforts. One possibility would be for MIPS to study the most scientifically important materials that may potentially lead to transformative applications and impact.	
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? For the National Facilities and Instrumentation program portfolio, we will address this question using the facility and user distributions. The High Magnetic Field Laboratory and the Cornell High Energy Synchrotron Source have extensive national and international user bases that appear to be geographically diffuse (although a moderate eastern U.S. concentration is evident and understandable). For example, the Cornell High Energy Synchrotron Source had 1043 unique users in 2018, with 854 from within the US, 81 from national labs, and 45 from industry. Moreover, 37% of these users are early career scientists (students, postdoctoral scientists, or young faculty/scientists); and include ~11% female and ~2% under-represented groups. Users come from many states all over the US, from a map provided in the proposal. The Cornell High Energy Synchrotron Source also partners with Hispanic-serving institutions (*e.g.,* teachers from NY and Puerto Rico). User distributions from the CHRNS project report show a good distribution across the US and internationally. There is a higher concentration of local users, but many of the users are from all over the country. The two Materials Innovation Platform programs have PIs predominantly in the Northeast US with one of the centers having PIs from across the country. Given the goal of these centers, the COV feels that this is not a major problem at this time.	

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. New users are documented for the Cornell High Energy Synchrotron Source (34%) and the High Magnetic Field Laboratory (average of 25% per year). In addition, at the Cornell High Energy Synchrotron Source, 37% of the users are early career	

scientists (students, postdoctoral scientists, or young faculty/scientists); and include ~11% female and ~2% under-represented groups. The Center for High Resolution Neutron Scattering has no information on new users in the project report. However, it is stated that users span a range of experience from undergraduate students through senior scientists. According to the MIPs proposals, there are only a few cases where the PIs can be considered early-career. Given the primary goals of these centers, this is not unexpected.	
5. Does the program portfolio have appropriate participation of underrepresented groups[2]? Although the demographic user data cannot be comprehensive due to legal constraints, based on the information available, we believe that outreach efforts to under-represented groups continue to be a priority for NaFI and the program PIs. Specific demographic data was provided by the High Magnetic Field Laboratory and the Cornell High Energy Synchrotron Source. Averaged over a 4-5 year period based on data contained in the renewal proposals, the percentage of under-represented groups is as follows: • HMFL: approximately 18% female and 5.5% minority • Cornell High Energy Synchrotron Source: approximately 11% female and 2% minority • CHRNS: approximately 20% female and 5% minority • MIPs: PARADIM 10% female and 5% minority; 2DCC 33% female and 18% minority Students represent 30% of users, and ~35% of those are female; 22% of the postdoc users are female, and 1 of three postdocs supported by the grant are female. The Cornell High Energy Synchrotron Source supported 23 students: 11 female, 5 African-American, 3 Hispanic and 1 with a disability. In addition, one of the five co-PIs is female. Finally, the diversity recruiter brought 7 minority and 7 female graduate students to Cornell. For the Center for High Resolution Neutron Scattering for 2016, 89 of 476 users were female, and 25 of 476 users were minority. Compared to 2015, 124 of 567 users were female, and 23 of 567 were minority. The Materials Innovation Platform programs have participation of underrepresented groups in their PI teams and plans to maintain or achieve higher participation.	

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports.

The National Facilities and Instrumentation program portfolio is highly relevant to both fundamental and applied national needs. The estimated economic impact of an improved Materials Innovation Infrastructure to the private sector is $123-270B per year as noted in the NIST report entitled *Economic Analysis of National Needs for Technology Infrastructure to Support the Materials Genome Initiative* (2018).

The National Facilities and Instrumentation program is especially critical for the competitiveness of US science, particularly at this time when the national and international landscape are changing.

1) The numbers of new faculty hires in materials science is increasing in the US, in departments ranging from chemistry, physics, materials, energy, quantum and engineering sciences. This is evidenced at NSF by an increasing number of career proposals being received by DMR. This is also part of a general move towards transdisciplinary science in the 21st century – materials science is impacting more disciplines, and universities are also starting new materials science programs.

2) There is very strong investment internationally in materials science and infrastructure - in China, Singapore, Korea, Europe and elsewhere. *e.g.,* https://www.nature.com/articles/d41586-019-00885-5

3) Materials science also represents a rapidly growing area of discovery science, with particular importance for industry and future technologies (quantum, data, electronics, energy, storage, etc.).

These national and international trends make a case for increased DMR funding of programs, as well as the associated small scale instrumentation (*e.g.,* <$1M), in addition to the existing NSF Major Research Equipment (MRI) and Mid-Scale programs. These recommendations for enhanced investment into university laboratory infrastructure were also given by the *NSF Report on Instrumentation for Quantum Materials*, and the *NRC Decadal Study on Materials*. Students conduct their Ph.D. research projects within US universities and need to have access to the same instrumentation and computing capabilities as their counterparts abroad.

Each program within the National Facilities and Instrumentation addresses facilities and infrastructure needs that have been noted in a variety of national reports. The Materials Innovation Platforms program is substantiated through addressing the knowledge gaps and grand challenges stated in the National Academy of Sciences report *Frontiers in Crystalline Matter: From Discovery to Technology* and the *Materials Genome Initiative Strategic Plan.* The High Magnetic Field Laboratory program has the potential to answer the needs outlined in the NSF workshop entitled *Ultrahigh Field NMR and MRI: Science at the Crossroads*. Specifically, the urgent need for ultra-high field magnetic resonance technology is being actively pursued by the HMFL, and to our knowledge no other facility/institution has the technical expertise to address this need. Additionally, many DMR National Facilities and Instrumentation science areas link to the NSF Ten Big Ideas — Understanding the Rules of Life, Mid-scale Research Infrastructure, Harnessing Data for 21st Century Science and Engineering, the Quantum Leap: Leading the Next Quantum Revolution and Growing Convergent Research at NSF. They also address recommendations from other reports and priorities related to the National Quantum Initiative, as well as

NSF and DOE reports on Quantum Materials, and the *NRC Decadal Study on Materials*. In the MIP program, approaches for designing new materials are being developed. The National High Magnetic Field Laboratory has a variety of high field capabilities that are used to modify change the spin, modify important length scales, probe the energy scales in a material and change the states of matter.	

7. Are any emerging research areas missing from the program's portfolio? We note that countries abroad are providing an ever increasing number of new opportunities for high risk and/or longer term (*e.g.,* 5 to 10 years) project funding that better enable breakthrough discoveries.	
8. Additional comments on the quality of the projects or the balance of the portfolio:	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

The COV reiterates the critical need for re-investment in instrumentation at universities (where students are trained), with more advanced capabilities located at regional centers.

The COV believes that in the case of the Materials Innovation Platforms, the program should try to identify materials that have high potential for broad adoption by developing long-term collaborative relationships with applications experts and working with equipment or materials suppliers to optimize growth processes. In some cases, this might lead to very beneficial outcomes such as cost sharing of projects, or enhancement (acceleration) of the science.

Many worthy research endeavors will not progress due to funding constraints, which creates a gap in scientific discovery. The COV recognizes that difficult choices must be made and encourages DMR to continue to assess the research portfolio on a continuing basis to identify opportunity cost.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

The COV recommends that the National Facilities and Instrumentation program considers a network of user facilities, where any user could request any material to be deposited or grown by the center.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

Given the increased research footprint and hiring of faculty working in materials science, the need for increased funding in the U.S. in this DMR area is urgent.

4. Please provide comments on any other issues the COV feels are relevant.

NSF DMR is supporting significant and important programs for the development of materials and materials science in the US that are extremely critical to the continued health and success of the US economy.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

Overall this COV process was extremely well run by NSF/DMR.

2.2 Materials Research Science and Engineering Centers (MRSEC)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The MRSEC program uses an extensive set of review methods, resulting in a thorough and deep evaluation at all steps of the review process. At the preliminary proposal stage, each IRG receives an average of 4.3 reviews through a combination of mail and panel reviews. This seems an adequate number. The reverse site visit provides an opportunity for assessing the ability of the proposed MRSEC leadership to work together as a team and the extent to which the leadership is deeply familiar with all aspects of the proposed center. Although we understand the desire to cut down on the work and time commitment of the panelists and the difficulties associated with putting together a panel with no COIs, some of us feel that the model where a given panel reviews a larger number (3-4) of proposed centers may be preferable to the current one where each panel reviews only two. On the other hand, reviewing fewer proposals provides the opportunity for more extensive discussion among the panelists. There is also a good mechanism in place for providing some continuity of the review process by having a subset of panelists or mail reviewers serve on reverse site visits and site visits. Finally, site visits are a very useful mechanism for providing feedback by experts in the field.	Yes

2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? Individual reviews address both merit criteria, although the comments on broader impacts are often briefer and less substantive. The panel summaries address both merit criteria in a satisfactory way. The Program Officer (PO) review analyses are extremely detailed and well thought out and address all aspects of the merit review. The PO analyses are meticulously even-handed in reporting the reviewers' comments, and go well beyond a mere summary of the reviews by including substantive comments on the science and careful justification of difficult decisions, supported by data.	Yes

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? Overall the majority of individual reviewers provided substantive comments. Only a few of the reviews were rather short and occasionally lacking in meaningful content. In a few instances, the overall score seemed a bit at odds with the text. On the other hand, the PO pays attention to the substance of the report over the rating.	Yes
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The whole panel summary generally provides an adequate description of the panelists' assessment and the rationale for the recommendation. The connection between individual reviews and the panel summary is usually clear.	Yes
5. Does the documentation in the jacket provide the rationale for the award/decline decision? As stated above, the PO review analyses and especially the context statement do an excellent job of describing the various stages of the review process and providing a rationale for the decisions. In these documents the PO demonstrates an impressive ability to assess a very broad range of scientific topics and put them in the context of current research.	Yes

6. Does the documentation to the PI provide the rationale for the award/decline decision? The reviews, panel summaries (particularly the reverse site visit panel summaries) provide excellent feedback and explain clearly the rationale for the decision. The rationale is articulated fully in the PO review analysis. This document is not shared with the PIs, but its essence is communicated informally, especially when a proposal is declined. In all cases, the PO offers individual feedback via phone calls. The site review reports do an excellent job of articulating strengths and weaknesses of the ongoing center and provide valuable input for redirecting and strengthening ongoing activities.	Yes
7. Additional comments on the quality and effectiveness of the program's use of merit review process:	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The program makes good use of qualified reviewers with the right expertise, as evidenced by the usually very substantive reviews. The panels also have good balance in terms of diversity, disciplinary expertise, experience, institutions, and geographical representations.	Yes
2. Did the program recognize and resolve conflicts of interest when appropriate? The program is meticulous in addressing the COI issues and is effective in resolving them when they arise. This is a particularly important and sometimes demanding issue given the large number of PIs involved in each center proposal.	Yes
3. Additional comments on reviewer selection:	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. The COV panel feels the program is extremely well managed. The program is large and complex with a great many elements that need to be dealt with. The Program Officers charged with its management do a wonderful job in balancing all the competing aspects of the program along with dealing with the PIs who are in a high stress situation.
2. Responsiveness of the program to emerging research and education opportunities. The COV panel believes that the program appropriately evolves to deal with emerging, exciting new opportunities and phase out older, less impactful research areas. One cannot stay with the old forever or jump from one hot new topic to another without the time to make genuine, deep progress in the field. The COV feels that the program evolves at a well-considered rate and carefully avoids either of these two non-optimal limits. For example, new topics such as the use of data science tools and architected materials and metamaterials (which have structures designed to provide specific functionalities), identified as emerging in the National Academies *Decadal Survey*, are indeed covered by the span of IRGs funded in the last competition.
3. Program planning and prioritization process (internal and external) that guided the development of the portfolio. The planning and prioritization process seems appropriately responsive to emerging areas. The call for the 2019 competition explicitly suggested a number of strategic research directions aligned with the NSF Big Ideas, following up on an earlier call for iSuperSeeds. The program also fairly balances competing interests in a strongly resource-limited environment, but often has to turn down highly worthy proposals. For instance, in the last competition (2017) there were at least two additional highly worthy proposals that were turned down due to a lack of funds. Given 8 awards were made, this implies that 25% more proposal should have been funded. The COV strongly feels that in view of its success and impact as well as its superb management, the MRSEC program should be given more resources.
4. Responsiveness of program to previous COV comments and recommendations. The previous COV comments were largely minor. The responses of the program to those comments were exemplary. For example, in response to the comment on leveling the “playing field’’ for recompeting and new proposals, the 2017 MRSEC solicitation eliminated a proposal section on Publications and patents under prior NSF support, which was only applicable to recompeting centers. In the actual 2017 competition, out of 80 submitted preproposals, 18 were invited for full proposals (including 61% new proposals), 10 proposals were invited to the reverse site visit (including 50% new proposals). At the end, 8 centers were funded, including 3 new centers (38%). Notably, 4 out of 9 recompeting centers were not funded. Overall, new proposals appeared to be competing on a leveled playing field.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? The MRSEC program is one of the NSF's oldest, highest impact (see item IV.8 below) and most important programs. Many of us in the room at the COV review were trained as students under the auspices of a MRSEC. Unfortunately, the number of awards and the size of the awards relative to scientific inflation have not kept up. The largely flat-funded program has been forced to shrink the effective funding level as well as the number of awards. This extracts a real scientific cost upon the materials community and negatively impacts US industrial competitiveness. The COV panel strongly endorses an increase in the level of support for the MRSEC program. With almost 1000 publications out of the MRSEC program just in 2018 (and an additional 950 acknowledging the use of MRSEC facilities), and 172 startups in 22 states spun from MRSEC research since 1985, one is hard-pressed to think of an NSF program that has had a bigger positive impact on scientific innovation as well as US economic vitality.	Appropriate
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. The MRSEC awards have been highly innovative and transformative. Many of them are aligned with major achievements and future opportunities identified in the 2019 National Academies Decadal Survey on *Frontiers of Materials Research*. Some specific examples are listed in Section IV.8. The level of risk in a majority of the projects is moderate. However, the MRSEC does have an effective mechanism to foster promising but high-risk projects through its Seed and iSuperSeed programs. Some of these programs indeed matured into regular IRGs or transformed into separate successful programs.	Appropriate
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The COV commends the Program Officer for achieving a reasonable distribution in the affiliation of the PIs in terms of geography and type of institution with the limited resources at his disposal (given the current MRSEC budget, only 12 awards could be made in 2014 and 8 in 2017). MRSEC Centers are currently hosted at a range of public (*e.g.,* University of Colorado-Boulder, Ohio State, University of Texas at Austin, University of Nebraska) and private (*e.g.,* Brandeis University, Northwestern University, Columbia University) institutions. To increase both geographic and institutional diversity, the COV recommends the creation of a new MRSEC track supporting a network model, as described below in Other Topics.1.	Appropriate

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? The MRSEC program acts as an important leadership incubator for young scientific talent. Successful teams have a healthy mix of senior, well-established and well-regarded scientists and more junior researchers at an early stage of their careers. The MRSEC gives these young scientists an opportunity to lead, grow, and learn within a nurturing environment. The research environment in a typical university is designed to create strong, world-class scientists. Opportunities to learn how to lead are, however, less common. The MRSEC program addresses this issue by providing a learning environment for leadership. MRSECs play an important role in training the next generation of scientific leaders.	Appropriate
5. Does the program portfolio have appropriate participation of underrepresented groups[3]? The MRSEC program has appropriate participation of underrepresented groups. For example, about 25% of the MRSEC-supported faculty participants and 30% of the IRG leaders are women. Amongst MRSEC-supported junior researchers, ~25% of the postdocs, ~30% of the graduate students, and 40% of the undergraduate students are women. URMs account for about 7% of the faculty participants, 6% of the postdocs, 8% of the graduate students, and 18% of the undergraduate students.	Appropriate
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The MRSEC program is central to essentially every other science and technology program in the US today. Advanced materials are a basic ingredient to all the cutting-edge science and engineering projects currently underway. These include advanced semiconductor materials used in computation, large band gap semiconductors for use in solid state lighting and electric vehicles, single crystal turbine blades used in high efficiency jet engines, drug development and delivery for human health, strong and lightweight materials for construction including the new generation of cable-stayed bridges that lower costs, speed construction time and reduce the total amount of material needed, organic displays that reduce power needs, and superconductors that enabled the discovery of the Higgs Boson and also make routine MRI measurements possible and accessible. The world that would exist today in the absence of the breakthroughs made by this program would be poorer, sicker, and less prosperous than the one we do have. Essentially everything we touch and work with has been improved by the materials research supported by this program. It is hard to overestimate its impact. A detailed description of the vast impact and future needs of advanced materials can be found in the recent *Decadal Report f*rom the National Academies.	Appropriate

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

7. Are any emerging research areas missing from the program's portfolio? The MRSEC program spans the breadth of areas of materials research highlighted in the recent Decadal Studies of the National Academies and has a long history of responding quickly to new developments through its established Seed program, as well as the recent iSuperSeed calls. Materials research provides critical underpinning to the country's economic growth and competitiveness, as well as to national defense, areas in which the US has traditionally been a worldwide leader. This leadership position is currently under serious threat due to the stagnant level of investment in programs like the MRSEC. The COV strongly urges a substantial increase of federal investment in materials research.	
8. Additional comments on the quality of the projects or the balance of the portfolio: The MRSEC program has been highly successful in producing striking new science. Examples include: • Biomimetic 4D printing: the ability to 3D-print composite hydrogels was combined with a theoretical framework for solving the inverse problem of designing the printed structure to produce prescribed target shapes. This allows programmable fabrication of architectures that change their complex three-dimensional shapes on immersion in water. • Plasticity in disordered solids: All solids flow under stress—this is plasticity—but a crystalline aluminum spoon can flow (bend) much more than a glass rod. In one of the first examples of the use of data science to make conceptual progress in materials science and engineering, machine learning was used to discover universal signatures of plasticity in disordered packings of objects ranging from atoms to grains, spanning seven orders of magnitude in diameter. • The joint experimental and theoretical discovery of exotic quasi-particles known as Majorana zero modes. These occur at the end of a chain of magnetic atoms placed on a superconducting surface. These "particles" can drive the "on-off switch" of small magnetic memory bits and have the potential of being used as the fundamental bits in a quantum computer. • The control of active flows via confinement. MRSEC-supported research has resulted in the engineering of active fluids that flow spontaneously with no externally applied forces. Recent work has shown that such active flows can be controlled via confinement, opening the door to applications in microfluidics and mixing at the micron scale. • The development of a new electron microscope that sets the world record for image resolution by detecting changes in distance between atoms of a *trillionth* of a meter (1 picometer). The program has had enormous impact on science, technology and society. This is demonstrated by a number of metrics, including: • Papers stemming from MRSEC-supported research published in the 2011-2019 period have received an average of 24.5 citations per paper; • Since 2015, 32 start-up companies were spun out from MRSEC-funded research;	

• Since 1985, more than 1500 patents have been awarded based on MRSEC-supported research. Especially successful examples of translational science are the development of (i) *Olaplex* – a hair product that repairs broken disulfide linkages in damaged hair and is now on the market - and (ii) inexpensive polymer films that can cool themselves even in direct sunlight, providing a new way to eliminate waste heat from windows.	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

The COV feels that the barrier for new institutions to successfully compete in the MRSEC program is extremely high. At the same time, the MRSEC program is exceptionally effective—in addition to the stellar scientific accomplishments of the program, a few of which are highlighted in Sec. IV.8 of this report, the centers have been highly successful in promoting interdisciplinary collaborations, developing important facilities, raising public awareness of science through outreach, and increasing diversity in science through education. These achievements are only possible through large centers. It is therefore important to lower the barrier to entry without jeopardizing the success of the existing MRSEC program. The COV recommends a separate track, and additional funding, to support a network model, in which several institutions can collaborate to support two joint IRGs. Such a track would require separate review criteria, additional support to administer the program, and additional funds.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

The COV recommends strongly against sunsetting MRSECs. The scientific and the translational successes of the MRSEC program have been described in Sec. IV.8. The top criterion for funding decisions of MRSECs should be the strength of the IRG proposals, in terms of the quality of the research, the case for requiring a collaborative, interdisciplinary team, and the broader impacts of the center. The eJackets show that the existing re-competition process is extremely rigorous; MRSECs that are long-lived have repeatedly reinvented themselves via turnover in participants and scientific thrusts of IRGs. In 2017, for example, only 5 of 9 previously-existing MRSECs were funded, and in the next round, it is anticipated that the program will shrink from 12 recompeting MRSECs to 8 or 9 funded MRSECs. Because the funding process is so competitive, the COV feels that it provides an effective mechanism for turnover.

Additionally, the COV notes that long-lived MRSECS have developed facilities that can be used by others and have fostered diversity that benefits the entire scientific community through their education and outreach efforts. Sunsetting MRSECs would risk destroying significant infrastructure, including expert staff, that has been developed over the years for facilities and education/outreach efforts. Short-term funding would also not be effective in transforming institutions through faculty hires that nurture interdisciplinary, collaborative research.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance**.**

4. Please provide comments on any other issues the COV feels are relevant.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

2.3 Partnerships for Research and Education in Materials (PREM)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The COV recommends that metrics for measuring reciprocity (*e.g.,* joint research, joint education) between the partner institutions be developed and assayed.	Yes
2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? The COV found that merit review criteria were mostly addressed, although some panel summaries did not always address both merit review criteria in a balanced way. Fortunately, program officers carefully addressed discrepancies while justifying outcomes in their analysis.	Yes Mostly Yes

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? The COV found that individual reviewers were not uniform in how they provide feedback. Individual reviewers often provided a mix of reviews and a range of detail to support their recommendations.	Yes

4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The COV found that panel summaries were not consistent from one review cycle to the next. For example, in one panel, a summary statement of the rationale of the panel was provided in the panel summary for all proposals, whereas in another panel such a statement was not provided.	Yes
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The COV commends the program officers (POs) for the detailed feedback they provided. The POs communicated the reasons for their final decisions to the applicants.	Yes

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The COV found that the relative weights of the criteria used in the review process are in some cases unclear from the written feedback provided to the PI.	Yes
7. Additional comments on the quality and effectiveness of the program's use of merit review process: PREM program officers practice good judgement in inviting a mixed range of reviewers to determine the outcomes of the merit review process.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? Since the PREM program connects institutions of very different characteristics, the COV commends the program officers in their selection of a wide range of reviewers with appropriate expertise, different genders, racial and ethnic diversity, and scientific/engineering backgrounds. This diversity has been used to obtain an appropriately wide range of perspectives.	Yes
2. Did the program recognize and resolve conflicts of interest when appropriate?	Yes
3. Additional comments on reviewer selection: Although the criteria used to identify suitable reviewers were discussed, the process used to identify the initial pool of reviewers was not provided.	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. The COV found that there is excellent management of the PREM program by dedicated staff members, who pay attention to the details of the program. The COV identified a need to develop better metrics, especially in the tracking of PREM success and other outcomes of the program.
2. Responsiveness of the program to emerging research and education opportunities. The COV found the PREM program is very responsive to emerging opportunities in materials research. The connections to MRSECs, STCs, MIPs, and NaFs ensures engagement in cutting-edge areas of materials research. However, the educational aspects of the program would benefit from a more rigorous assessment as well as sharing of best practices/pedagogy between PREM institutions and partner institutions. The implementation of the PREM pathway was a good step in this direction. The COV wants to especially highlight the importance of the PREM program for the development of a diverse and balanced workforce of the future. This is a key broader impact for NSF and the PREM program fulfills a unique role.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio. The COV considers the PREM seed grant program as a very good development. It is also a wise investment of limited funds. The PREM program evidently has the potential to strongly impact the development of a diverse workforce for the future. The COV recommends that the program further develop metrics to measure outcomes, such as comparison of student success with other models and the importance of research in the students' persistence through the STEM pipeline. These metrics would help in both sustaining and growing the program.
4. Responsiveness of program to previous COV comments and recommendations. The COV found the PREM program to be responsive to prior COV comments and recommendations. A commendable development was the update of the solicitation with the pathway concept, which clarified the mission of the PREM program.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? The average annual award size was ~$630K and the average total award size ranged from $3-3.5M. The COV positively commented on the increase of award duration from 5 to 6 year. The average award amounts and duration are in agreement with the PREM solicitation and found to be adequate by the COV.	Yes
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. There is an inherent high-level of risk in awards assigned through the PREM program, which very strongly depends on the reciprocity between the two institutions. This fact requires stringent assessment criteria regarding reciprocity and engagement of the partner institution. All PREM awards have a clear potential for transformative impact regarding the training of students and developing a diverse science and engineering workforce of the future. The COV supports the seed grant model to strengthen potential PREM partnerships.	Yes
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The PREM program has awardees in a wide range of geographical locations and its portfolio has an appropriate range of institutions.	Yes

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. The PREM program has currently 25% of new investigators and 13% of early career investigators. The COV finds these numbers appropriate.	Yes
5. Does the program portfolio have appropriate participation of underrepresented groups[4]? Although the numbers for underrepresented groups are either close to the national average or above and most certainly higher than in other DMR-funded programs, the COV feels that they need to be improved further. The COV was impressed by the impact of the PREM program on the STEM pipeline showing transition of 70% or more into STEM disciplines.	To some extent
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The PREM program addresses the national priority for the development of a diverse science and engineering workforce, which is also a priority in NSF's strategic plan. The coupling of research and education through the PREM program to populate the STEM pipeline is also a priority of NSF. The COV found that the PREM program portfolio addresses many of NSF's 10 big ideas (*e.g.,* Quantum Leap, Convergence and Includes) and areas highlighted in *Frontiers of Materials Research: A Decadal Study* by National Academies of Sciences, Engineering and Medicine (Polymers, Biomaterials and other Soft Matter; Materials for Energy, Catalysis, and Extreme Environments; Materials to Move, Store, Pump, and Manage Heat). The PREM program is in a unique position to impact the needs of the institutions involved.	Yes

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

7. Are any emerging research areas missing from the program's portfolio? The COV believes that the PREM program covers a wide range of research topics including emerging research areas such as Materials for Energy, Bio-inspired Materials and Quantum Materials. Future investment needs to keep pace with other emerging fields such as Additive Manufacturing, Data-Driven Materials Science and Engineering, and the Brain Interface.	Yes
8. Additional comments on the quality of the projects or the balance of the portfolio: The PREM program is a unique and innovative bridge between institutions building on the research strengths of DMR centers and facilities and the mission of primarily undergraduate Minority Serving Institutions. Doctoral education of underrepresented minorities is a critical step in feeding the pipeline in higher education and STEM-related careers. The program positively impacts the diversity of the STEM workforce by building on the graduate research and education mission of NSF in a most effective way. Increasing the diversity of the workforce is recognized as a key ingredient in the future of the materials field and the economic development of the United States. However, it is critical to sustain, evolve, and grow the PREM program that its outcomes be monitored closely, and compared with funding models of other federal agencies and NSF for graduate students. The NSF should make a commitment to develop measures of graduate student success post-graduation and apply them to PREM and other NSF programs. A study of the role of research in improving student persistence could be supported by NSF's Division of Educational Research. **The COV believes NSF must develop a data-driven understanding on how research excellence influences student persistence in STEM.**	

2.4 Designing Materials to Revolutionize and Engineer our Future (DMREF)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The proposals in DMREF combine data science, computational methods, synthesis and processing, and property characterization into a 'closed-loop' approach to materials research. Given the complexity and breadth inherent to such multidisciplinary projects, the COV agrees that the panel approach is appropriate so that all elements in the proposal can be evaluated together. Ensuring that panels have both breadth and balance across these areas is essential, as over or underweighting in one area is likely to have significant impact on funding recommendations. A potential downside, the panel system may tend to penalize truly high-risk research proposals (see Section 4.2). Nonetheless, the benefits of a cross-cutting panel review outweigh this potential drawback. The strategy of organizing the panels by material type is effective, but as the science becomes more cross-cutting, alternative approaches might be more suitable. For proposals that clearly fall outside the material-type panels in a given review cycle, it is recommended that alternate review mechanisms be utilized, including virtual panel members and mail-in (*ad hoc*) reviews. The 2015 COV suggested that more reviews should be requested; however, the current COV did not share this concern. While there may be individual cases where this is appropriate, the current COV found through examination of jackets that the use of three reviewers along with the panel discussion was sufficient to evaluate the merits and justify the program officer recommendation for the vast majority proposals.	Yes

2. Are both merit review criteria addressed	
• **In individual reviews?** The individual reviews were variable, in terms of addressing both merit review criteria and in being substantive. • **In panel summaries?** Panel summaries covered both merit review criteria, although more emphasis was placed on the intellectual merit than the broader impacts. The emphasis between the two categories seemed appropriate. • **In Program Officer review analyses?** Both merit review criteria were addressed. The program officer review analysis was substantive even in proposals that were recommended to be declined. The detail provided in the analysis was substantive, and the program officer provided clear justification for the recommendation.	Yes Yes Yes

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals?	Yes
In the jackets reviewed, the depth of responses provided by the reviewers was uneven. While in many cases the reviews fully justified the recommendation, a significant fraction of reviews were judged as not substantive. Often in these cases, reviewers simply repeated a summary of the proposal, which is not helpful to the program officer or the authors of the proposal. Reviews such as these may reflect that DMREF almost exclusively uses the panel review process; only a few members of the panel may be expert in the specific topic of any given proposal. The COV also notes that lower ranked proposals tended to receive less substantive reviews. To address this issue, NSF is encouraged to explore methods that will steer reviewers to provide more substantive and informative comments. It is recommended that NSF articulate the program-specific criteria of DMREF to the reviewers and have the reviewers comment on them explicitly. We suggest providing explicit prompts reflecting program specific issues as well as the key elements underpinning intellectual merit and especially the broader impacts criteria.	
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The summaries capture the dynamics of the panel discussion. The panel summaries were appropriate and provide the rationale for the panel recommendation.	Yes
5. Does the documentation in the jacket provide the rationale for the award/decline decision? The documentation in the jackets reviewed by the COV provided the rationale for the award/decline decision. In certain complex cases, such as co-funded efforts between divisions/directorates or for which the recommendation differs from that of the panel, the reason for the award/decline recommendation is clearly articulated by the program officer.	Yes

6. Does the documentation to the PI provide the rationale for the award/decline decision? The information provided to the PI provides sufficient detail and exposition to provide constructive feedback. Follow-up correspondence between the PI and the program officer provides additional input to the PI for the funding decision.	Yes
7. Additional comments on the quality and effectiveness of the program's use of merit review process: There were some concerns expressed among the COV members that more guidance should be provided to the reviewers who are evaluating those proposals being considered by multiple divisions under the same solicitation. Doing so would enable the reviewers to focus specifically on particular aspects of the proposal in which they are knowledgeable. Achieving this could be as simple as informing the reviewers that the proposal is being reviewed by other divisions. The previous COV reported that certain elements of the award selection process were not documented in the proposal jackets. This COV is pleased to report that this issue has been addressed. For example, from the jackets reviewed, this COV found that the recommendations were uniformly supported by the documentation in the proposal jackets, importantly including those proposals involving multiple divisions.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? Identifying reviewers for a panel with the required breadth of expertise for a program such as DMREF was recognized as a challenge. From the panel compositions reviewed by the COV, it appeared that there might have been a disproportionately large fraction of theorists. It is important that the program officer remain vigilant that panels are comprised of reviewers with expertise that covers the full spectrum of theory/computation, synthesis/processing, and characterization/property determination. The program officer should consider utilizing virtual panel participation, mail-in reviews, etc. to ensure that appropriate reviewer expertise balance is obtained	Yes
2. Did the program recognize and resolve conflicts of interest when appropriate? Conflicts of interests are identified and resolved effectively.	Yes

3. Additional comments on reviewer selection: We concur with the previous COV that DMR should develop a database of reviewers with their qualifications, including an assessment of their past contributions to the reviewing process. The reviewer selection tool that is being developed by NSF is a useful step forward to simplifying the identification of reviewers. Given the interdisciplinary nature of DMREF, it is imperative that DMREF have a balanced selection of expertise in the review panels. Furthermore, participation in reviews, individual and panels, is essential to cultivating the next generation of reviewers and is an important mechanism for early career scientists to learn how to prepare a quality proposal.	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. (timeliness, effective, efficient and good service) All data reviewed by the COV indicate successful management by the program officer in all necessary operational respects. The COV specifically notes the substantive comments written about proposals, even for ones that have been declined, the substantive and constructive comments provided on the annual reports; the visits of the program officer to labs of PIs in conjunction with trips to professional society meetings; and the communication records in the proposal jackets, which are uniformly responsive to the questions and concerns of the PIs. There has been significant growth in the number of proposals submitted to this program since it was launched. Despite the limited number of personnel assigned to the program, the dwell time has remained under six months. This is commendable, especially in light of the time and effort taken to provide detailed comments to all proposals. However, with the expected continued growth in the number of proposals and a possible further growth in the portfolio, the COV believes that this level of management effectiveness will be sustainable only if additional personnel are assigned to the program. To sustain and further build multi-divisional/directorate and outside support for DMREF, the COV see an opportunity for the program officer, with support of NSF management, to develop a more effective 'marketing' and communications strategy. The first step should be design of a DMREF website that offers ready evidence of the program's success through metrics, selected highlights, and access for the scientific community to the databases and software developed in the DMREF program. Highlights, which are in ample supply, should also find their way up through NSF leadership channels. Suitable metrics to measure impact – to be defined by DMR – are expected by the COV to be key tools in securing broad support for and growing the program. These metrics should reflect the anticipated impact of materials development enabled by the fundamental science carried out in the DMR portion of the Materials Genome Initiative spectrum, including but also going beyond publications and citations. This would be valuable as a clear articulation of the value proposition of DMREF throughout NSF. This would also put into stark relief the issue of the current nonparticipation of CHE, representing a core discipline in materials, in the DMREF program. The COV sees this as damaging to the DMREF program, the chemistry division, and the scientific community; this urgently needs to be addressed.

2. Responsiveness of the program to emerging research and education opportunities.

The COV endorses the recent decision in DMREF solicitations to target specific emerging areas and relevant NSF initiatives. The identification of the emerging areas is soundly made using multiple methods, including the National Academies *Decadal Study*, program specific assessments of the state of the field, and participation in professional society meetings. The COV views this approach as appropriate and an important component in defining future directions and directing the program resources most effectively.

One unique aspect of the DMREF program is its context within the larger Material Genome Initiative effort. The DMR projects focus on the most fundamental end of the continuum (discovery and design); to move these new materials into products requires partnership with other efforts. Joint PI meetings involving other funding agencies have been instituted. These meetings have stimulated networking activities by bringing together experts with dissimilar backgrounds but who together could contribute to solving a problem. As such, they are an important mechanism to disseminate information along the materials continuum. The COV sees the supplemental funding process incorporated into the 2017 2D Network meeting as a valuable way to respond to emerging research opportunities and build new partnerships within the DMREF framework. In addition, the COV noted that several DMREF PIs have participated in the NSF I-Corp program, which is seen as further evidence of translating the materials discovery along the continuum.

The COV sees DMREF as an important program for educating the next generation of scientists and engineers in the fundamentals of data science and data management in materials science and engineering. These are increasingly important skills for current generation scientists and engineers, and the DMREF program is an effective mechanism for providing this education. Evidence the program is striving to be responsive to educational opportunities is the driving role of the program officer in instigating the MGI Workforce Development assessment currently being conducted by TMS. The conclusions and impact of this study are expected to have significant implications for the DMREF program; the study and subsequent DMREF response should be considered by the next COV.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

As described in question 2 above, DMREF has aligned its priorities with NSF-wide initiatives, including the Big Ideas, and invested significant effort in identifying current research opportunities, needs and trends. The program portfolio shows expansion into soft matter, which is an important step in the evolution of DMREF. This expansion addresses an area of opportunity that was identified in the National Academies *2018 Materials Research Decadal study*.

An ongoing challenge and opportunity will be in gaining widespread industry acceptance of the DMREF approach. This might present opportunities for GOALI type projects on DMREF topics.
The combined PI meetings remain an important step in connecting the seven steps within the materials continuum, which is essential to meeting the overarching goal of the Materials Genome Initiative. DMREF has put effort into reviewing results of prior support through participation in national MGI review initiatives, such as the ones conducted by TMS. The planning and prioritization process should be enhanced by ongoing efforts to identify metrics to measure the impact of DMREF supported research, as discussed in question 1 above.

4. Responsiveness of program to previous COV comments and recommendations.

The program officer has addressed all previous COV comments; several instances have been noted in other parts of this report. The one exception is that the COV could find no documentation to show that the program officer had addressed the comment on documenting best practices. However, from reviewing the information available, the program officer has developed what appears to be a successful process. The COV encourages the program officer to document these processes so that the methodology is preserved. It may be beneficial to share these practices with other programs.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? Although larger grants would be appreciated by the community, the COV commends the program officer for increasing the average award size, which is now approaching $1.4M. The quantity and quality of research is a testimony to the DMREF research teams working within what remains modest support given the scope of the project and DMREF criteria for success. The COV supports the use of supplemental funds in non-competition years to build bridges with other teams that are involved in different stages of the materials continuum. For example, the partnership with the NIST, DOE and AFRL is seen as a positive. The award period for DMREF awards has been increasing recently and will be fixed at four years beginning with the current competition. The COV supports this move to four-year awards, which is commensurate with the scope and complexity of DMREF projects.	
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. Risk is subjective, contextual, and difficult to assess with the data available to the COV. One proxy for risk tolerance in the program - proposal renewal success rate — stands at approximately 50%. The COV saw this as indicative of an overly conservative approach to funding. Such a conservative bias may be an unavoidable by-product of the panel review process. The COV encourages the program officer to allocate some percentage of the total funding to projects that are deemed higher risk and to extend the use of the EAGER funding model to promote higher risk efforts.	
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The geographical distribution shows pockets of strength across the nation. A gap in participation, if one exists, is in the Plains states. The current award portfolio spans a mix of public and private universities, typically tier-one research institutions. Recognizing that this is an appropriate composition of participants, the COV nonetheless sees value in expanding the list of participating institutions to support and enhance opportunities for under-represented groups.	

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? From the data presented, fewer than 10% of the awardees qualify as early-career investigators. The COV recommends increasing this number across the DMREF portfolio. Strong participation by early career investigators is viewed by the COV as an excellent mechanism to launch careers in a multi-disciplinary research program.	

5. Does the program portfolio have appropriate participation of underrepresented groups[5]? While the percentage of URM and female PIs approaches national percentages, the program officer is encouraged to explore mechanisms to increase these percentages through PREM-like initiatives. The COV suggests that the program officer look at mechanisms of increasing the number of undergraduates from under-represented groups through leveraging students from a diverse pool of existing REU programs or by introducing a summer internship effort within DMREF funded programs.	
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The DMREF program represents the NSF response to the 2011 Materials Genome Initiative, as was noted in the 2018 National Academies *Frontiers of Materials Research: A Decadal Survey* report (https://doi.org/10.17226/25244). It is also responsive to findings from other materials-focused agency and society reports, e.g., DOE Basic Research Needs and Roundtable reports (https://science.osti.gov/bes/Community-Resources/Reports), the NRC ICEM report (https://doi.org/10.17226/12199) the 2017 TMS report on "Building a Materials Data Infrastructure (http://www.tms.org/mdistudy) and others. It also supports the White House initiative on Artificial Intelligence for the American People (https://www.whitehouse.gov/briefings-statements/artificial-intelligence-american-people/). The program also fits within the NSF Big Ideas initiatives (https://www.nsf.gov/news/special_reports/big_ideas/) including *Quantum Leap*, *Harnessing the Data Revolution*, and *Developing the new Human-Technology Frontier*. It is anticipated that the DMREF program will continue to respond to and influence national and internal priorities and initiatives.	

7. Are any emerging research areas missing from the program's portfolio? The information provided to the COV demonstrates a broad portfolio, which made it challenging to identify missing specific research areas. Nonetheless, the COV identified areas that were considered under-represented and hence opportunities for future investment in a multidisciplinary program such as DMREF. These areas include: materials for the energy-water nexus, opto-electronic materials, and ultra wide-bandgap semiconductors. To assist future COVs answer this important question, it would be useful to have the funded programs be diagonalized not just in terms of materials class (*e.g.,* ceramics, alloys, polymers, etc.) but rather in terms of functionality, phenomena, or property. The DMREF program is generating and will continue to generate vast amounts of data. A challenging opportunity is the curation of these data, data accessibility and evaluating the usefulness of data to the community. The COV sees a near-term need	

[5] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

to survey the DMREF portfolio to establish best practices for efficient and effective implementation of these data-centric objectives.	
8. Additional comments on the quality of the projects or the balance of the portfolio: A notable missing element in the portfolio is the participation of the NSF chemistry division. This COV views this lacuna as counterproductive and detrimental to DMREF, to the chemistry division, and to the scientific community at large. The impact of the program is significant as evidenced by the PI highlights. From a large number the COV selected the following as examples of the program impact: • DMREF PIs Mathias Kolle and Jennifer Lewis demonstrated how color-tunable photonic fibers—photonic structures assembled from highly stretchable elastomers—improve the efficiency and efficacy of compression therapy by acting as easily-interpreted indicators of applied pressure when integrated into elastic bandages. Featured as a cover article in *Advanced Healthcare Materials* in July 2018, Kolle's and Lewis's work underscores DMREF impact to the Human Welfare pillar of the Materials Genome Initiative. • Polar metals are extremely rare because conduction electrons screen electric dipoles. Leveraging the close connection among theory, synthesis, and characterization, a DMREF team led by Chang-Beom Eom (University of Wisconsin-Madison) has used the geometric constraints afforded by epitaxial thin films to stabilize polar distortions in metallic nickel oxide perovskites. Validated by theory, this approach offers a paradigm for discovering and engineering more polar metals. • DMREF researchers at Kent State and the University of Wisconsin-Madison have developed a predictive model for chemically-responsive liquid crystals. Using a 'closed-loop' approach, Nick Abbott, Manos Mavrikakis and Robert Twieg have developed a validated computer model of the interactions of liquid crystals with surface species. This discovery offers a new route to chemical sensors, with applications to wearable sensors for toxic gases used in industrial settings. • DMREF team at University of California at Santa Barbara developed new coordinated experimental and computational tools and their deployment for discovery of new Co-based single crystal compositions. Availability of a new class of high temperature Co-based alloys that could replace Ni-based alloys would transform a wide range of power generation, aviation and space systems and substantially improve energy efficiency and performance. • The large variety and range of properties of organic-inorganic hybrid materials make them promising candidate materials for energy-efficient LED lighting and solar energy. A DMREF team at Duke University, UNC Chapel Hill and NC State has constructed and made publicly available a large database of existing, predicted and newly synthesized organic-inorganic hybrid materials, facilitating accelerated development of this materials space among the wider community of researchers interested in exploring this materials class. (Duke 1728921) • User-friendly simulation software for designing multifunctional and tunable block polymer materials, with applications including medicine, microelectronics, and energy storage, has been validated by experiments and	

made available on a public website by a DMREF team at the University of Minnesota and U California Santa Barbara. (U. Minnesota 1333669, UCSB 1332842)	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

DMREF emphasizes materials discovery and does not support research through the other levels of the materials continuum, so it may wish to consider revising the mission statement. The program mission is really to accelerate the discovery of new materials so that others can incorporate them in new products. The program does have efforts to enable the translation of these new materials to other groups.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

4. Please provide comments on any other issues the COV feels are relevant.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

2.5 Biomaterials (BMAT)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The methods are appropriate and applied well. A considerable amount of thought goes into the proposal review. Uniformity in the number of reviewers for each proposal (at least three, typically four) assures fairness and comparable chances for success. In most cases, the reviews are conducted by panel. The combination of panel/virtual/mail review serves the community well, with panels being the preferred method. The practice of review submission before the panel meets, combined with the opportunity for revisions during the meeting, provide the opportunity to adjust ratings. The COV recognizes the value of in-person panels for this reason; this component is obviously lacking when reviews are conducted by mail. Overall, current methods assure a thorough review and evaluation of proposals.	Yes
2. Are both merit review criteria addressed a) In individual reviews? In most instances, the individual reviews for the Intellectual Merit portion of the proposals were thorough. The individual reviews for the Broad Impact section of the proposals were more varied, ranging from single sentences to paragraphs. Weakness were rarely noted for the Broad Impact section. The succinctness of this section may reflect a general sentiment that this section is less important than the intellectual merit to the final ranking. One recommendation is that NSF consider scoring (E, V, G, F) each section separately and/or provide transparency as to how much this section should be weighted when ranking the proposals. Regardless, the COV recommends as best practice for the individual review the explicit highlighting of strengths and weaknesses for both the technical and broader impact sections in the individual review.	a) Mostly

b) In panel summaries? Generally, the panel summaries provided a concise, accurate assessments of the individual reviews and included strengths and weaknesses in both the Intellectual Merit and Broader Impact sections of the proposal. Whereas the individual reviews might be lacking in calling out strengths and weaknesses in the Broader Impact sections, the panel summaries are adequate in this regard. As desired, they frequently also captured the discussion in the room, for panels that had convened in-person or virtually. Ideally, these discussions should be reflected in all panel summaries. c) In Program Officer review analyses Both merit review criteria and their respective strengths and weaknesses are amply and thoughtfully addressed in the Program Officer's (PO's) review analyses. Ideal would be, if this portion of the very comprehensive part of the PO review analyses be made available to the PI. This would serve two purposes: the substantive analysis and comprehensive comments would help prepare stronger resubmissions, where necessary; they would also increase awareness and appreciation by the community of the PO's work.	b) Yes c) Yes

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? For the most part, the individual reviewers provided substantive and comprehensive comments to explain their assessments. There were a few examples of generic, shorter, less helpful reviews. These were mostly summations of the proposals, as opposed to critical assessments of the contents. As stated above, considered best practice is the explicit mention of strengths and weaknesses. In addition, those reviews that specifically addressed the 5 elements that should be evaluated in the review [*i.e.,* briefly: 1) potential to advance knowledge/benefit society; 2) creativity/transformative component; 3) the plan for carrying out the activities; 4) proposer qualifications; 5) resources available] were very helpful and demonstrated care and consideration on behalf of the reviewer. Most helpful were reviews that provided information on how the proposal could be improved for resubmission. It is noted that because NSF panels are constantly changing, resubmissions may be graded by new panelists that may not have access to past reviews and the rationale associated with changes to the proposal. While the COV does not think that these comments should be provided to a panel prior to review, thereby biasing the new panel, perhaps summaries from the panel that graded the initial submission could be provided to the new panel if the PO determines that additional context would help evaluation of the resubmission. Reviewers should be reminded of unconscious biases at the beginning of the panel review. The COV noted instances of reviewer comments such as 'she does not have enough time', 'already another grant', 'comes from a highly-valued lab', etc., considerations inappropriate for the review process.	Yes

4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The panel summaries were a concise description of the individual reviews and provide ample rationale for panel consensus, especially when the panel was largely in agreement. It is particularly important that the panel summaries capture the range of opinions and how consensus was reached especially when the initial ratings were widely distributed. This illustrates the fairness of the proceedings, as well as provides insight towards a possible resubmission. Best practices include summaries of post-discussion strengths / weaknesses for both IM/BI and comments on how to improve the proposal for resubmission. BMAT is to be commended for recognizing that sometimes panelists cannot adequately assess certain proposals. In these cases, no consensus was reached and proposals were sent out for further review, to assure review by an expert in the area of proposed research in support of the decision-making.	Yes
5. Does the documentation in the jacket provide the rationale for the award/decline decision? The jacket provides ample rationale for the award/decline decision. It is obvious that BMAT program directors go to great lengths to ensure that the review process is thorough, fair, and that decisions are well-justified. The COV was pleasantly surprised (astonished, in fact!) at the thoroughness of the review analyses. They are comprehensive and likely take a great deal of time and care to prepare. These documents in particular bring great credibility to the process and to the organization.	Yes
6. Does the documentation to the PI provide the rationale for the award/decline decision? When panelists are in agreement and the range in ratings is small at the start of the panel, the documentation provides adequate rationale for the award/decline decision. When the ratings of the reviews start with a larger range, and when the proposal is border-line with respect to fundability, the rationale can be a little more fuzzy and less helpful for the PI as a means to inform areas of possible improvement. Clarification, particularly with respect to the relative weight of the Broader Impact section vs. the Intellectual Merit section, in addition to having clearer guidelines as to what constitutes Broader Impact, might help in these situations. Currently, some proposers simply use 'graduate student education' and/or 'papers/books/symposia/workshops' as their Broader Impact, while others go to great lengths to define outreach projects that involve K-12 educational and community outreach activities in addition to 'graduate student education,' for example. While both approaches are immensely valuable, it is not clear whether the first or the latter are valued more, and how different Broader Impact programs affect the final score and fundability. Of great interest would also be a further analysis of the type of Broader Impact programs by gender- and minority group, whether fundability is affected, and whether recognition is equal for the different approaches to Broader Impact, once a proposal has been funded. Overall, the COV was very impressed by the careful documentation and fairness of the review process. This process unfortunately remains largely hidden from the PI, because it is not normally accessible to the PIs. Also to ensure an appropriate appreciation by the community, the COV recommends to share more of the currently confidential Review	Yes

Analysis by the Program Officer, possibly by providing information that may not be shared for reasons of privacy as a confidential component to NSF, and the remainder, a more comprehensive version of the current PO report, as a component to the PI. The inclusion of suggestions for improvements in the panel summary as a standard practice, combined with a more extensive sharing of the Review Analysis by the PO is to ease the revision of an unfunded proposal, on the one hand, and an overall higher quality of resubmissions, on the other.	
7. Additional comments on the quality and effectiveness of the program's use of merit review process: The COV's review of past proposals and the corresponding review process revealed that the BMAT review process is thoughtful and fair. The POs invest a considerable amount of time and energy ensuring and documenting the integrity and fairness of the process. This is highly commendable, especially because of their extreme workload (>300 proposals for 2 POs). The COV lauds them for their efforts and quality of their work; with it they assure the high standards and great credibility of the NSF. Moving forward, the COV recommends a further evaluation of existing data and collection of additional data that will allow a more thorough analysis of both the effectiveness and the impact of the BMAT program. This evaluation should start with an analysis of program participation and funding level by gender, minority group, and early-career PIs. Longer-term, the analysis should include impacts of the recommended unconscious bias training, which could include examples drawn from past BMAT panels. Similarly, an analysis of proposal topics (*e.g.,* biomineralization, biointerfaces, biopolymers) and how they change with time, as planned by the new Program Officer team, will be helpful for documenting program strategy, the inclusion of cutting edge / high risk areas of research, and an appropriate panel composition for the evaluation and selection process. The fact that 25 of the 39 DMR COV members received NSF funding for their undergraduate/graduate/post-doctoral training highlights the impact of NSF on the education of the workforce. Attempts should be made to quantify this impact. Professional associations, such as the MRS, may be able to assist in the data collection to further analyze the value of the program to education and workforce development. With materials contributing to the advancement of most technological advances, these contributions can easily be undervalued and overlooked, but are of considerable benefit to the US. The BMAT program directly contributes to the economic competitiveness of the US, in the light of considerable investments into Materials Science, in general, and Biomaterials, in particular, in countries such as China, Russia, South Korea, Switzerland, and members of the EU. Included in the evaluation of the program's success should also be metrics that better recognize impact achieved by broader impact and outreach efforts. While more difficult to assess, they provide an important measure of success of recruitment into STEM subject, beyond the number of undergraduate and graduate students, and post-docs trained, peer-reviewed publications, citations, patents, and entrepreneurship.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The reviewers' expertise represents the considerable breadth of subjects and topics of the program, ranging from fundamental physics and chemistry to biology and materials science of all classes of materials. The COV recognizes the challenge of obtaining reviewers for BMAT, due to the multidisciplinary nature of the field, and greatly appreciate the initiatives taken to overcome them. For example, in the case of a proposal, for which the panel lacked the required expertise, no decision was reached until additional input had been sought by sending out the proposal for *ad hoc* review, which resulted in the funding of the proposal. The COV also finds it helpful that the POs often included the reviewers' background in their Review Analysis. It would be ideal if this type of information were also included in the PO report to the PI to inform revision and a possible resubmission. In addition, this assessment could be provided to the reviewers, which may help them become more effective reviewers by noting the input the POs find most valuable. Additional information is required for a more thorough analysis of the balance between more junior and more senior panelists, the participation and representation of minorities, the type of home institution (public versus private, size, ranking, etc.). While privacy consideration may not allow this to become available publicly, it may be helpful to have it available as a resource for the program officers.	For the most part, yes
2. Did the program recognize and resolve conflicts of interest when appropriate? Identification of COIs are obviously important to NSF; these are addressed directly through educational videos, signing of documents, and reminders. When COIs arise, these are appropriately addressed. In one case, for example, a COI was identified only after the panel had already convened and a decision on a proposal reached. In this case the conflicted reviewer's analysis was removed and another review was solicited by mail.	Yes

3. Additional comments on reviewer selection:	
Proposals are sometimes assigned, sometimes selected by the reviewers. This latter approach has the great benefit that it minimizes the occurrence of cases in which reviews are more of a summation of the proposals, as opposed to critical constructive reviews, due to a reviewer's lacking the expertise/comfort to review the proposal. The COV recommends continuation with this practice as it has the benefit that expertise and topical interests are best aligned for a well-informed evaluation. It avoids low ratings resulting from a lack of background in a specific area, which reviewers may be more or less willing to disclose. Proposals that are not selected for review by panel members are either included in a panel with the required expertise, or sent out for mail-in (*ad hoc*) review. The COV recommends collecting statistics on the composition of review panels to quantify participation by gender, race/ethnicity, institution type (public/private/industry/ gov/large/small), level of experience, etc. With this information, they could compare panel composition versus award outcomes across the same categories, and also have the data to compare versus the pipelines for various groups (data available from outside NSF).	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. After excellent long-term stability of the team of POs until 2017, a new team has recently formed. It is wonderful to see that the POs are taking advantage of the opportunity to review and evaluate the program, and to define new directions. BMAT appears to be on a good path, strengthening existing and fostering new collaborations with other agencies, such as NIH, DOE, and DOD through square table meetings and workshops. It is admirable how well the extreme workload (>300 proposals per year) is currently managed by two POs, with a thoroughness of proposal review and analysis that is largely unknown to the community, because little of their work is visible or available to the PIs. To facilitate an adjusted workload of the traditionally expected 100 proposals/PO/year, the hiring of a third PO is recommended. Should that not be possible, the addition of a Senior Expert to the team should be considered. This additional Program Officer could, if assigned to more than one program, also provide additional support for multi-program initiatives and solicitations.
2. Responsiveness of the program to emerging research and education opportunities. The Program Directors clearly recognize emerging research and education opportunities. They enacted the review recommended by the 2015 DMR COV of the state of materials science through the initiation of a workshop on "Biomaterials: Tools and Foundry" and the solicitation of a "Frontiers of Materials Research: A Decadal Survey" by the National Academies of Sciences, Engineering and Medicine in collaboration with the Department of Energy. The committee's final report, published in 2019, identifies promising future directions, which the BMAT program will pursue in the future. The continuation of square table meetings and other workshops will ensure a concerted effort, strategic initiatives and well-aligned future programs and directions in the areas of biomaterials, biomineralization, biomimetics, interface science, biopolymers and applications of synthetic biology tools to these problems. It is critical that the POs work towards a portfolio of complementing rather than overlapping programs with other agencies, ensuring efficient stewardship of the program.

BMAT is inherently multidisciplinary. Interestingly, an analysis of funded proposals revealed that a single BMAT PI is typically awarded only 1 grant over 10 years. Rather than a measure of success of individual PIs, this metric is thought to be an indicator of the breadth of subjects covered by the program and the natural progression of the research. The work may move out of BMAT to another program in NSF, or to more applied research, funded by the engineering programs, DOE, DOD, or NIH. For example, the PI may wish to pursue NIH grants to conduct *in vitro* and *in vivo* evaluation of the material in question, or resulting device, until it returns to NSF for a translational grant through the ICORPS program. Remaining associated with a project from the beginning to its successful translation into practice, through cross-agency programs, and the communication of its success, could also help promote STEM as the facilitator of new technologies, and recruit the next generation of the national workforce for these disciplines.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

Program planning and prioritization, and portfolio development is aided by both internal and external initiatives. The new team of program directors is seeking input through a range of channels, including DOE, DOD, and NIH. The NSF-initiated NAS report *Frontiers of Materials Research: A Decadal Survey* is used as one resource, others are national meetings and panels, to which in addition to materials science community members also journal editors have been added, to inform the program directors of current fields, emerging research areas and educational opportunities for the future workforce. The COV thinks that industrial involvement may also help to guide the process of prioritization and to align it to a strategy that can be conveyed to the larger community. Currently, the breadth of the current portfolio is considerable and seems reactive rather than strategic.

4. Responsiveness of program to previous COV comments and recommendations.

Both the initiatives taken, to date, and the future plans of the past and current Program Officer teams illustrate their responsiveness first to the 2015 DMR COV comments, to the recommendations made by workshop participants, to the NAS report and also the BMAT community. The current Program Officer team is on a good path to develop the BMAT program into one that supports and encourages emerging research and education opportunities, that prioritizes funding in single-program areas not covered by other agencies, as well as manufacturing innovation institutes or industry, on the one hand, and multi-program and multi-agency programs as most appropriate, on the other. Such an integrative approach will ensure the successful progression of a project from fundamental science and research to its translation into practice.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? A typical BMAT grant is for three years and currently funds one PhD student or one Postdoctoral Scientist (postdoc), some materials, a minimal PI effort (academic or summer). The POs are attempting to maintain a level of funding of ~$140k to continue to ensure that the grant covers at least one person. However, with inflation and increases in stipends and salary, the effective amount of funding has decreased over the past 10 years and will continue to do so. This will result in fewer and fewer grants, unless more funds are made available to BMAT. The COV learned from the POs that, based on the reviewers' and program directors' evaluations, 35% of proposals are competitively ranked and fundable, which is a little over twice the current funding rate. Avenues pursued to provide appropriate funding include the referral of proposals to other programs (biology, physics, engineering), in cases where appropriate. The program directors also consider offering the option of either a 3- or a 4-year award, extending the time-line of a BMAT grant, also to ready it for the next step in project development, possibly funded by other agencies such as NIH or DOD, for example. This is an appropriate measure to take in the light of the fact that grant productivity does not scale linearly with funding, but at a higher rate. The size of current grants does not permit inclusion of smaller-scale instrumentation and equipment, or computational capabilities (hardware and software) for the PI's lab (>$15k). Over time, this limits the ability of the PI to address fundamental research questions, and also limits the cumulative instrumental updating and growth of capabilities of an institution. As a result, labs and institutions become less competitive, nationally as well as internationally, which also affects student recruitment and workforce retention. Therefore, a grant mechanism such as the former IMR offering funding in the $15-200k range could serve as a very helpful means to close this funding gap, with larger equipment grants continuing. In this spirit, the establishment of regional centers with research facilities serving the community, and also the reactivation of international programs could be very helpful. The first would support and foster regional collaboration, international programs would help establish new initiatives as well as the continuation of collaborations with, for example, former students and postdocs, who may have returned to their home or another country.	Appropriate/ Not Appropriate

2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. Based on the data currently available, it is impossible to evaluate the proportion of high-risk level proposals and of risks of projects. EAGER grants make up a vanishingly small (1%) percentage of the total portfolio, but this does not necessarily imply that the research is therefore not innovative or transformative. However, there is concern that low levels of funding lead to an overall more conservative portfolio.	Data not available
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? Data provided to the COV indicate that in 2018, over half of the grants were awarded to 7 states (CA, MA, TX, GA, NY, OH, PA), with 29 states represented in FY18. Data were not provided as to how many of these grants were awarded to the same institutions, nor does the COV have insight into distribution of public versus private or larger versus smaller institutions.	Data not available
4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? The MPS directorate organizes workshops for new and early-career investigators including for those of the BMAT program. The COV is comfortable with the CAREER grants forming about 5% of the overall portfolio, and a funding rate that is about 50% higher than that of standard grants. Data were not provided on the level of experience/seniority for awardees for other grants in the portfolio.	Data not available
5. Does the program portfolio have appropriate participation of underrepresented groups[6]? The data provided, where PI's self-identified their gender/ethnicity/race, indicate that the gender distribution of applicants and awardees has remained steady with women and minorities forming about 30-35% of grantees over the last 4 years. Although the numbers are low (and thus may have questionable statistical significance), it was noted that, on average, men have a 15% higher chance of receiving awards than women, over the last four years. Taken at face value, this may not seem like much of a difference, but the cumulative effects of this disparity could be significant. It would be interesting to extend this analysis to all of DMR and to compare the composition of panels versus the outcome of those panels, as noted in Section II above. Interestingly, by comparison, the number of minority vs. non-minority submissions has not changed substantially, but the funding rate of both communities has become nearly equivalent over the last 4 years. Minority submissions remain very low (for TMRP, <20/year and ~10%). It is not known how this distribution reflects the distribution (or not) of the community at large. This metric is difficult to capture, however, due to the breadth of disciplines involved in BMAT.	For the most part, yes

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The DMR program generally, and the BMAT program in particular, are critical to the national priorities, forming the basis for many technologies. The foundational research performed within BMAT contributes to advancements in medicine/health, sustainment and sustainability, and supports homeland security and defense priorities. The 2019 NAS *Decadal Study* clearly called out the need for continued research in biomaterials and a 2014 DOD Technical Assessment of Synthetic Biology notes the importance of biomaterials in national defense. In addition, a recent (May 2019) forum convened by the NAS National Materials and Manufacturing Board concluded that biotechnologies, the bioeconomy and synthetic biology tools, and active materials will be critical to advancements in materials and manufacturing. Additionally, an FY21 Presidential Memorandum to all agencies discusses the importance of the bioeconomy and encourages funding of research and technologies that will support it. As noted above, the new BMAT POs are actively surveying the current state of the biomaterials/biotechnology community to better understand NSF's role in the ecosystem. BMAT has been critical in the organization of several workshops to this end. Currently, there appears to be no desire within BMAT to focus the BMAT portfolio. The COV concurs with this decision, in the short term since the field of Biotechnology (including synthetic biology) is changing rapidly. Recent domestic funding for bioenabled national Manufacturing Innovation Institutes (MII; BioFabUSA/NIIMBL and a developing BioFoundry MII), as well as DOD's and DOE's investments in synthetic biology for materials and manufacturing, will cover much of the waterfront of applied, higher Technology Readiness Level research. However, major gaps remain in our fundamental knowledge of biological materials and the systems that make them, and it is these areas that require continued investment by NSF to enable major innovations in materials and manufacturing over the next 5-10 years, especially as the broader community increases its knowledge on how to manipulate and control biology. The timing for BMAT portfolio restructuring could not be better, since it will be critical that NSF covers fundamental and high risk/high reward research that is foundational to new developments in biotechnology, and that is not covered by these other, more applied, national initiatives. It also will be necessary for NSF POs to remain engaged in the broader biotechnology community, including coordinating with AFOSR, ARO and ONR's 6.1 research activities, to optimize and deconflict US investments in this ecosystem.	Appropriate
7. Are any emerging research areas missing from the program's portfolio? While the current BMAT portfolio is still primarily based on its historical development, the ongoing review and revisions by the new team of program officers is timely, the approach taken includes program definition and alignment with those in other programs and directorates (*e.g.,* physics, chemistry, biology, and engineering) and other agencies (NIH, DOE, DOD). The COV values both the critical review of the historical development of the program, and square-table meetings, and workshop as additional means to identify areas of national need, such as those that address the end-of-life of materials, components and devices, and overall sustainability, materials resilience, with new biomaterial opportunities arising. Emerging areas such as	No

synthetic biology and adaptive, active, and self-healing materials will be excellent additions to the BMAT portfolio.	
8. Additional comments on the quality of the projects or the balance of the portfolio: The COV would like to conclude by commending the BMAT program for its initiatives, its balance of scientific areas and the topical areas described in the program's solicitation, particularly in the light of comparatively frequent changes in the PO team. The quality and productivity of the funded projects is excellent. The COV is looking forward to seeing the program develop on its trajectory, with further increase in the participation and funding of women and minorities, the development of new strategic alliances, and the support of projects in both traditional and newly developing areas, both of which are essential for a sustainable development of resilience and security, and the training of the nation's workforce.	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

The COV would like to summarize and highlight key needs identified above as: i) a mechanism for the funding of small- to medium-scale equipment/instrumentation ($15-200k) for individual PIs / universities / regional consortia; ii) mechanisms for grants also of four-year duration; iii) sustainability of materials; iv) funding rates commensurate with other DMR programs.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

Recommended are strategic inter-agency efforts to assist in project continuation and success from fundamental science to translation into practice, *e.g.,* from basic biomaterials science to the *in vivo* testing of resulting materials for biomedical applications.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

i) Capture and analysis of agency/division/program-relevant data: It would be excellent if further information could be made available to provide the community with a more complete picture as to the distribution of funding by type of institution (public, private, size), applicant (minority), and seniority of PI, for example.

ii) Guidance of PIs / panels / reviewers: Further guidance should be provided to the panel on how to avoid and address unconscious biases (including, but not limited to, race/ethnicity, gender, institutional elitism). The COV recommends mandatory training in these areas prior to the panel meeting, with a reminder during the panel meeting. Similarly, the expectations for Broader Impact section should be clarified, ideally with examples of acceptable approaches, advertised on the program's website, so that both proposers and reviewers can easily educate themselves.

iii) Scientific experts recruited from a group shared by multiple funding agencies could help reduce the high workload of POs and at the same time assist in the development of cross-agency initiatives created to ease project development and transfer, where needed, to the next funding agency.

4. Please provide comments on any other issues the COV feels are relevant.

Recommended is that international programs are revived and developed to enable international exposure and training of the future US workforce, to ease the continued collaboration with NSF trained undergraduates / graduates / postdocs, thereby ensuring international competitiveness. International programs will also help make accessible to US-based scientists otherwise difficult to obtain resources, equipment, and instrumentation; international programs, could also assist in the growth of the pool of reviewers and experts.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

The COV would like to summarize and highlight as key need easily accessible data for analysis and comparison, also between the different programs, the distribution of funding by type of institution (public, private, size), applicant (minority), and seniority of PI, budget, and duration.

2.6 Ceramics (CER)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The CER program uses mostly *ad hoc* mail reviews, and this seems to be an effective way to get between 3 and 5 thorough reviews for proposals. There was only one panel used for Career proposals in 2015. A small number of EAGER proposals were handled by the PO. These were also processed with *ad hoc* mail reviews, and several were funded (including one that was co-funded by CBET).	YES
2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? Yes, in all phases, comments were included on both of the review criteria. In panel summaries and the majority of the *ad hoc* reviews, the comments on each of the criteria are labeled. They are also clearly labeled in each of the review analyses. In cases of declinations, they are also labeled in the PO comments provided to the PI.	YES

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? The reviews were generally substantive, well-grounded, with relevant feedback (positive and negative). In cases where a reviewer was brief to the point of not providing useful guidance, other reviewers of the same proposal provided thorough, detailed information about the project that was sufficient for making a decision. Given the nature of the review process, it is probably not possible to avoid getting an occasional review without substance.	YES
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? For the one panel that was conducted, the summaries were appropriate. They gave a good summary of the rationale, referring to elements of the individual reviews, without directly repeating them.	YES
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The documentation was complete in each of the jackets that were examined. Many decisions were clear, based on the individual reviews. For proposals that were close to the fund / no fund boundary, the review analysis provides additional information that clarifies the reasoning behind the decision. These highlighted the most important aspects of the reviews. Among those recommended for funding, the analyses included concerns and responses from the PI about those concerns. Overall, the analyses provided a good summary of the rationale for the decision.	YES

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The material provided to the PI always provides the rationale for the decision. In many cases the basis for the decision is clear from the individual reviews. For borderline cases, the PO provides much more detailed information that typically includes direct quotes from the individual reviews. In these cases, there are typically tradeoffs between positive and negative input from the reviews. The PO summarizes these in her comments, typically breaking this down into both of the merit review criteria. These summaries explain the reasoning for the final decision, and include the major points that are contained in the full review analysis. Especially valuable are the PO comments that effectively summarized the points that were most important for the decision.	YES

7. Additional comments on the quality and effectiveness of the program's use of merit review process: The CER program relies principally on *ad hoc* merit reviews. This made it possible to obtain detailed feedback from experts with directly relevant expertise to each individual proposal. The synthesis of the opinions from these reviewers is effectively used to reach decisions, and useful feedback is provided to the PIs. This has led to high quality reviews, and a very effective overall process.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question**.**

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The individuals selected for the reviews were very knowledgeable – in many cases, they were senior researchers with deep knowledge of the proposed research area. From the information in the jackets, we found that recommended reviewers were used when the recommendation was appropriate. It was also noted that in several cases reviewers from the international ceramics community were included, and this is viewed as good practice.	YES
2. Did the program recognize and resolve conflicts of interest when appropriate? Cases where the PO had a conflict interest were identified prior to the review process so that the review and decision process could be handled by another qualified DMR program officer. Cases where the suggested reviewers were not at arms length from the proposer were also identified by the PO, and they were not asked to provide a review.	YES
3. Additional comments on reviewer selection: We believe that the *ad hoc* mail process allows the PO to target very knowledgeable reviewers – more so than available in panels. We also believe that NSF should make a more vigorous effort to establish a reviewer database that includes expertise keywords and contact information.	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW

1. Management of the program.

The PO has done an excellent job of managing the program's limited resources. Her methodologies for encouraging proposal submissions, organizing reviews, and interacting with investigators are carefully thought out and well defined. We also note that the PO has been willing to try new procedures to improve the management. For example, the trial of eliminating the proposal deadline had the effect of reducing the number of proposals, but increasing the quality. This latter statement has not yet been quantified but appears to be reasonable based on available evidence. The PO publishes an annual article in the *Bulletin of the American Ceramic Society* that describes the projects of the Career awardees. She also established a career development workshop to provide advice for young scholars from the ceramic science community. Finally, the program director was proactive in starting workshops to identify the most important current and future directions for ceramics research. As evidence for the success of the program, we note the strong citation metrics presented to the COV. The *h*-index of the program is highly competitive with other DMR programs and, perhaps more importantly, the *h*/$ is the highest among DMR programs.

2. Responsiveness of the program to emerging research and education opportunities.

The overall research portfolio has shifted, in line with changes that are occurring in the ceramics community (for example, with increasing support for energy materials and declining support for superconductors). At the same time the program still continues support for a broad range of research areas that are important to the community. In light of the limited funding, this requires careful and judicious balancing by the PO. As a measure of responsiveness to emerging research, one can compare the portfolio to those areas of ceramic research highlighted in the *Decadal Study* on materials research. The decadal study identifies cold sintering, interface complexions, and defects in ferroelectric materials as important future research directions. We noted projects funded in the past few years that address these topics. As an example of a high risk/high reward project, we note the recently funded project on cold sintering. This proposal was generated in response to a recent break-through discovery in ceramics – to advance some highly speculative ideas – and this contains an element of risk. The potential reward for being able to consolidate very different materials at low temperature is also very high.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

The PO has used a broad variety of methods to obtain information about current and emerging research areas. Externally, this was accomplished by sponsoring workshops, speaking at professional meetings, and as an important active participant in the American Ceramics Society (including serving on the board of directors). As a detailed example, the PO initiated a series of workshops to plot the course of future ceramic science research. The first, held in 2012, was the first such workshop in 15 years for the ceramics program. The second iteration was held in 2016. Both workshops resulted in a publication in the *Journal of the American Ceramic Society.* The paper was published in open access format so it would be available to all. These documents serve as a plan to guide the development of the portfolio. Much of what is in these reports is mirrored in the *Frontiers of Materials Research: A Decadal Survey (2019)*.

4. Responsiveness of program to previous COV comments and recommendations.

The PO has addressed all of the comments from the previous COV and has been as responsive as reasonably possible to those comments. One comment that was within the PO's control is the selection of reviewers. In

the past COV report, it was stated that the PO requested suggested reviewers, but did not use them. We found instances in the jackets demonstrating that suggestions were used, suggesting that the situation has changed. The PO evaluates these suggested reviewers and determines if they are qualified and also at arms length. In at least one case where a suggested reviewer was not at arms length, the PI was notified in the PO comments returned with the decision. In that feedback, the PO stated that it did not affect the outcome of the decision, only the time required to reach a decision. A second comment that the PO responded to has to do with strategic planning. The PO responded by organizing a 2016 workshop on emerging research areas and providing an explicit strategic plan to the current COV. This plan was contained in the slides presented to the COV and the results of the workshop were published in the *Journal of the American Ceramic Society.* Finally, there were comments about the workload (too high), travel (too little), and funding (too flat). The PO found a creative way to address the workload issue. As a consequence of eliminating the deadline, the proposals per year has decreased from approximately 150 to 100. DMR leadership considers 100 proposals per year a standard workload. With respect to support provided for travel and the program budget, there have been no changes. Support provided for travel (and uncertainty in when it is approved) continues to be a problem for the PO and makes it challenging to interact with the ceramics community.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? Awards in the CER program typically have a four-year duration. The four-year duration of the grant is useful because it is consistent with the time needed to complete a typical Ph.D. dissertation. The longer period (compared to the 3-year duration used in other programs) also positively affects the workload, lengthening the cycle between submissions from ongoing programs. The idea of focusing on awards with one or two investigators is appropriate, given the program's limited resources. The maximum size for each project has been $160,000 per year. This limit makes it possible to more effectively distribute support over as many projects as possible. This is becoming increasingly restrictive for two investigator awards, and the PO is considering an increase to $180,000 for two investigator awards. This seems reasonable to reflect increases costs of tuition and supplies. We believe the proposed size and duration of awards is appropriate for the scope of the projects.	YES

2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. Most of the high risk / high reward projects were funded with standard awards. Excellent examples are the cold-sintering work (consolidating unstable materials), the MXene work, and the work on cements derived from slag with a greatly reduced carbon footprint compared to Portland cement. Because the program does not have a submission deadline, investigators can submit full proposals based on new innovative ideas at any time. Because the PD encourages this, only a relatively small number of EAGER proposals were received (several of which were funded).	
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The portfolio is broadly distributed over a wide range of different locations, and includes programs at institutions other than R1 Universities. The CER program is currently funding projects in 32 states. Those states with no funded projects are states with relatively low populations and relatively few universities. There are multiple grants to predominantly undergraduate institutions.	YES

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. Based on the information provided to us, it was not possible to discriminate "early career investigators." However, of 109 total awards, 14 were CAREER awards and 95 were non-career awards. Each year there are 2 to 5 CAREER awards. The absolute number of awards and the fluctuations seems appropriate given the size of the community and the program.	YES
5. Does the program portfolio have appropriate participation of underrepresented groups[7]? Of the programs supported by CER, 33 % of the PIs are women and 8 % to 12 % are underrepresented minorities. These fractions are similar to (the URM fraction) or exceed (the female fraction) the demographics of US, university based Materials Science and Engineering departments.	YES

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The National Academies *Frontiers of Materials Research Decadal Survey (2019),* identifies key research opportunities in Ceramics and Glasses, associated with Energy-Efficient Ceramic Processing, The Defect Genome, and Glasses. These key areas are all well represented in the current portfolio. The CER program also supports significant work on other materials that are identified separately in this report, including energy materials, materials for extreme environments, and 2D materials.	

7. Are any emerging research areas missing from the program's portfolio? We did not note any gaps in the portfolio. This is an exciting time in ceramics. Several new discoveries and ideas have emerged in the last five years. This includes flash sintering, cold sintering, the control of interface complexions, the synthesis and control of 2D materials and the synthesis and control of materials that can be exfoliated into 2D materials. The current CER portfolio contains all of these elements. The quality of this research is clear from the external recognition that has been received by the PIs.	NO
8. Additional comments on the quality of the projects or the balance of the portfolio: CER is a relatively small program in DMR, yet is able to balance a wide portfolio ranging from glasses, composites, cements, carbides, nitrides, borides, and oxides. As one might expect, the majority of the work is on oxides and much of it in ceramics related to energy applications, including batteries, thermoelectrics, and fuel cells. Considering the interests in the community, this seems appropriate. The quality of the projects examined is high and evidence for this is found in the awards won by the PIs and also by citations to papers published as part of this research. Approximately 800 papers published between 2015 and the time of the COV visit were cited more than 7600 times. While it is difficult to calibrate these numbers, it is clear that the research coming from the program is of interest to others and is cited by other scientists. The CER program supports high quality research, and is unable to support all of the proposals that warrant funding.	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

The CER program supports high quality research and is unable to support all of the proposals that warrant funding. This problem will increase (because of inflation) if flat funding continues.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

- Mechanisms to support medium-size instrumentation needs are seriously lacking.
- At current funding levels, it is very difficult to support small groups of investigators (2 to 4 individuals). DMREF is an exception, but this program is somewhat limited in scope. Collaborative research involving investigators with different expertise is particularly beneficial for Materials Research, due to its interdisciplinary nature. This is particularly evident in the CER program, where a majority of the funded research occurs in collaborative or multi-investigator awards (*i.e.,* rather than single investigator awards). Here, it is noteworthy that the funding rate for the collaborative and multi-investigator awards is higher, which implies that these proposals generally receive stronger reviews. This situation is a critical concern in the current climate where the funding per award is gradually declining (*i.e.,* due to flat funding and increasing costs). In light of this, new funding mechanisms for multi-investigator efforts could be particularly useful – both to promote high quality Materials Research in specific areas, and to promote cross-cutting research that bridges the boundaries between the existing programs at NSF.

4. Please provide comments on any other issues the COV feels are relevant.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

2.7 Condensed Matter and Materials Theory (CMMT)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? For CMMT, most reviews are conducted by individual scientists by email. On an average 5-7 reviewers are contacted and 3-5 reviews are obtained per proposal. There are no reviews however in the EAGER program where submissions are by invitation only, and decisions are made solely by the program officers. The COV felt it reasonable that program officers be given some latitude in making funding decisions. The COV felt positively about the strategy of CMMT to solicit exclusively mail-in reviews due to disparate range of topics in CMMT and the sometimes disputatious nature of differing research directions. The choices of referees are subject matter appropriate and have a range of seniority. There appears to be a consideration of diversity in the choice of reviewers.	YES
2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? The COV felt that the reviews always addressed the intellectual merit of the proposal. The extent of discussion was a little varied in the level of detail, but the program officers have done a good job of extracting the import of the reviews. However the ability of the reviewers to judge the broader impacts criteria is unclear. There is generally a tendency of PIs to overpromise in this area, a tendency that is not necessarily critiqued by the referees. We feel that in terms of broader impacts criteria there should be a refocusing on items that are more readily achievable. This might include undergraduate and graduate education. We also believe that it would be valuable to have a set of defined metrics by which broader impact is evaluated, both before and after the proposal is funded.	YES

There are no panels in CMMT. The program officer review analysis was informative and detailed and often involved a short summary of the individual reviews followed by a more elaborate analysis of the different reviews. It was clear that the program officer was taking extra efforts to read between the lines and not necessarily following a simple average of the rating or using seniority as a dispositive criterion in selecting awardees.	

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? There is a mixture of the level of detail in the reviews. But because for any given proposal there a number of reviews (on the order of 3-5), there seems to always be a subset of reviews that are substantive.	YES
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? This is not applicable as panel summaries are not used in evaluating CMMT proposals.	NOT APPLICABLE
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The program officer review analysis was very informative and detailed and provided an excellent synthesis of the reviews including doing a good job of balancing between disparate reviews. It also provides a clearly stated rationale for decisions on proposals that are on the boundary of deserving funding. Some of the background information that one might want to see (correspondence between program officers in different divisions, for example) was not present. The staff diary notes could include much more than the context notes. This would be good for the continuity of the program.	YES

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The COV noted that the program officer analysis was very informative and did not contain sensitive information. The COV believes that it would be valuable that this analysis be provided to the PIs since the comments were much more informative than the standard email that was being sent to the PIs. We do however recognize that this might potentially lead to PIs to dispute and appeal the conclusions made in this analysis.	YES

7. Additional comments on the quality and effectiveness of the program's use of merit review process: The COV notes that upon resubmission, a PI provides a summary of the revisions that they have made to their proposals. The COV understood that this was a pilot program. The COV believes that this is a commendable practice and recommends that it be considered to be adopted across the DMR for resubmissions.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question**.**

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? We felt that in general the reviewers chosen had the requisite subject matter expertise. In many cases, we noted that the referees were leaders in their field. However, the COV feels that program officers should continue to engage in efforts to get research leaders to respond to review requests maybe by potentially personalizing such requests. We thus conclude that an issue flagged in the 2015 COV Report has been addressed successfully. We recognize that within the current program officers for CMMT, considerable knowledge and experience resides on the quality of reviewers. We recommend a way be found to preserve this institutional memory.	YES

2. Did the program recognize and resolve conflicts of interest when appropriate? The COV felt that the COIs were recognized either prior to or after reviews (but prior to decision process), and hence no issues of concern were noted.	YES
3. Additional comments on reviewer selection:	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. The COV felt that the CMMT was a well-managed program, with the program officer exhibiting familiarity with the leading researchers and the outstanding research questions in a broad spectrum of areas. The program officer has been active in organizing/co-organizing workshops to explore emerging opportunities. The program officer is also commended for proactive efforts to securing co-funding from other divisions within the NSF as well as for tapping into the Division Director reserve funding. The COV finds it commendable that the CMMT program officers now allow submission of new proposals at any time of the year. The COV notes that because CMMT does not use panels, this has many positive benefits including an increase in quality of the submitted proposals. The COV believes that it is beneficial to have overlap of the institutional memory of program officers in the event of sudden/unexpected departures. In cases such as CMMT where the program officers have served a long time, the COV felt that a thorough documentation of the topical area prioritization, historical areas of interest, etc. would be valuable to ensure continuity. The longer than average proposal dwell times was an issue brought up in the previous COV. The data in the intervening period suggests that that this has not improved even in the years in which the number of proposals have gone down. Long proposal dwell times make it exceedingly difficult for planning on university cycles and should be made a priority for action. The availability of additional FTEs could serve to mitigate this problem. The program's award size was deemed acceptable. However, with increased graduate student stipend rates and tuition, efforts should be made to keep the award levels at a minimum commensurate with funding a graduate student's stipend and tuition and some portion of the PIs summer salaries.
2. Responsiveness of the program to emerging research and education opportunities. The COV felt that the program was in general responsive to emerging areas in CMMT. For instance, the percentage of soft matter and quantum information science in the portfolio has increased in response to the priority areas and emerging interests among the researchers. The area of nonequilibrium phenomena seemed to be still underrepresented despite occupying a spot as one of the priority areas.
3. Program planning and prioritization process (internal and external) that guided the development of the portfolio. The COV felt that the program officer was reasonably proactive in exploring workshops and symposia to keep abreast of the emerging and new areas. However, the COV felt that some of the workshops set up on the Materials Genome Initiative and/or the *Decadal Study* were much too broad to inform the specific priorities of CMMT. In the absence of more focused reports, the program officer has had to work along broad guidelines. The COV feels that it would be beneficial for the CMMT to explore instituting topical workshops along the lines organized by the DOE to explore specific topics and identify outstanding questions. Such efforts would also be welcome by many in the scientific community to provide guidance on areas of future research.

4. Responsiveness of program to previous COV comments and recommendations.

By and large, the program has tried to address most of the comments of the previous COV. The division has strived to maintain support for the theoretical infrastructure of the country by continuing to support the activities of institutions such as ASPEN, OpenKIM, MATDAT18, etc. The division has also undertaken efforts to expand their purview by engaging other divisions in co-funding efforts. CMMT has also kept a hand on the pulse of the research community by recognizing and funding emerging areas. It would help for DMR to consider adding an FTE to ensure that it can continue to support theoretical activities in a broad spectrum of areas.

Points of concern remain on the proposal dwell times which did not seem to improve even in the times when the number of proposals declined. Further, more focused workshops which inform the prioritization of CMMT would be welcome. Finally, means to preserve institutional memory of the program officers should be explored to ensure continuity of the program.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? Regarding the size, the average award is between $110-$130K over the last four years. This is typically sufficient to fund a graduate student but not necessarily a postdoc. The stipends for graduate students and postdocs are going up every year, and with flat budgets at some point this will hit a problem. Even at this point, grants do not cover summer salaries for the PIs involved. Regarding duration: Grants right now are for three years, which is not in line with graduate student life cycle. DMREF is going to four years duration, and COV recommends that a similar model be considered for CMMT.	Appropriate

2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. The funded proposals are excellent; however, they are not necessarily disruptive/transformative. The COV did not find any cases in which a proposal was declined purely because of it being risky. The portfolio seems to reflect the work of the community.	Appropriate
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? For the most part, the portfolio geographical distribution reflects the population and institutional geographical distributions in the US. The map of regular awards from 2015-2018 seems to show a lack of CMMT awards to the Pacific Northwest, although this may be due to the statistics of small numbers. There is a satisfactory range of different types of institutions in the funded proposals.	Appropriate

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. There is a satisfactory percentage of early career and new awards.	Appropriate
5. Does the program portfolio have appropriate participation of underrepresented groups[8]? For regular grants and CAREER as well, the percentages of female funding rates seem to be increasing, which is to be commended. The funding rate for minorities is highly variable, which can be for many reasons, including the statistics of small numbers.	Appropriate
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. National priorities: Materials and research in the US is a high national priority, and CMMT has a strong focus in this area. Almost all of the funded proposals are concerned with materials or materials phenomena. Agency mission: Specifically CMMT promotes and progress of science through its funding of forefront research in condensed matter and materials theory. Both traditional theory and also computation are well covered. Prosperity and national defense are covered also with this research, which leads to advances for both industry and defense. The COV cites the *Decadal Study* of Materials, which describes the benefits to industry of materials research in many ways, as well as delineating the challenges from international competition. Some examples, among many, are: • the theoretical and computational research on new materials for batteries, self-assembling materials (design and engineering); • the Quantum Leap program; • machine learning for materials design, in particular its use for previously unsolvable problems.	Appropriate

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

7. Are any emerging research areas missing from the program's portfolio? While no notable holes were identified, the COV suggests that CMMT can potentially invest additionally on topics relating to harnessing the data revolution. Another area is layered 2D materials, where new functionalities and properties have been identified in the last few years.	
8. Additional comments on the quality of the projects or the balance of the portfolio: The NSF's policy of letting the community weigh in on the research areas in a "bottom up" leadership of topics though the proposals is considered by the COV to be a good one and should be continued.	

2.8 Condensed Matter Physics (CMP)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? Panels are the primary mechanism for reviews, and the COV views this as an excellent method. A small fraction of proposals are reviewed strictly on a mail-in (*ad hoc*) basis. The COV understands the necessity using mail-in review for unusual circumstances but encourages the program to continue to employ panels as much as possible to provide high-quality evaluations of proposals. Therefore, the COV is deeply concerned that a no-deadline format for proposal submissions that was mentioned might make the panel review process unfeasible, which would negatively impact the quality of the review process. The POs' "Review Analysis" documents have an impressive amount of assessment in them. Making as much information as possible in the Review Analysis available to the PIs would (a) be of tremendous service to the individual PI and (b) help the community understand the extent to which POs commit time and thoughtful analysis to the task of award decisions. Overall, the COV was impressed by the exemplary level of care and thoroughness the POs exercise in the review process.	Yes
2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? Overall, the individual reviews and panel summaries address both criteria substantively. The Review Analyses go into good detail in extracting the key elements of the reviews related to both criteria. While individual reviewers address Broader Impacts, the COV has concerns that different reviewers use inconsistent criteria for judging Broader Impacts despite	Yes

considerable efforts by the POs to educate the community. For example, the COV noted variation in the relative importance given to novelty versus efficacy in education and outreach efforts. The COV felt that insufficient recognition is typically given to the importance of training graduate students and postdocs when evaluating proposals. Such workforce development is essential for economic development, national security, and improving the connections between research and industry prioritized in the NAS study. This is a major broader impact of the CMP program and DMR as a whole, and the COV is concerned that this contribution is not adequately recognized by the wider community. POs are encouraged to continue their efforts to reach out to the community, to PIs, and to reviewers to bring more clarity to the Broader Impact criteria. A specific recommendation includes adding information on the CMP website at a location that is easy to find for PIs.	

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? The COV found that the vast majority of reviews contained substantive comments about the proposal content to justify the rating. The COV was troubled by a small number of reviewer comments that appear to make judgments based on things outside written proposal that could be considered bias. Examples include comments regarding the lab where a PI was trained and doubts about the perceived ability of PI to allocate sufficient time and attention to accomplish the proposed work. The POs are encouraged to note in the Review Analysis statements of potential bias made by reviewers or panelists and to make clear that they do not factor in award decisions. The COV was impressed by the new video-based training program that NSF has produced (https://tipsforreviewers.nsf.gov/) and notes other effective programs (https://implicit.harvard.edu/implicit/takeatest.html) related to bias that are available. The POs are encouraged to consider requiring reviewers to complete such training prior to writing reviews.	Yes
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? In most cases the panel summaries adequately provide the rationale for the panel consensus. As mentioned above with the reviews, the COV noted inconsistencies in application of the Broader Impacts criterion and a few instances of comments in summaries that suggest bias. Ideally, the panel summaries should distill points of agreement among the panel or important points of disagreement rather than simply provide a complete listing of comments made during panel discussion.	Yes

5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] Yes. In particular, the Review Analyses include a great deal of substantive assessment and context from the PO. The COV recognizes major time investment the POs make in preparing the Review Analyses. The COV found the depth and quality of discussion in the Review analysis to be one of the best parts of the jacket, but it appears to be under-utilized.	Yes
6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The COV felt that in the vast majority of cases, the PIs receive adequate feedback regarding the rationale for the award decisions. However, as mentioned above, the "Review analysis" includes a great deal of detailed and specific information; providing as much of this information as possible to the PI is an excellent opportunity to improve the feedback. Furthermore, disseminating this information would be of tremendous value in showing the community as a whole the high quality of the award decision process. We noted that the 2015 COV made a similar comment, so we again urge that this possibility be pursued.	Yes
7. Additional comments on the quality and effectiveness of the program's use of merit review process:	(none)

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The COV felt the reviewers are highly qualified. The COV encourages the program to continue to recruit well-qualified reviewers widely. It also supports the current practice of allowing panelists to select particular proposals according to their expertise, as this helps avoid reviews from insufficiently expert reviewers.	Yes
2. Did the program recognize and resolve conflicts of interest when appropriate? Yes, the POs seem vigilant in identifying and resolving conflicts of interest.	Yes
3. Additional comments on reviewer selection:	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. The POs have done excellent job in managing the program. They have endeavored to maintain an impressively diverse and balanced portfolio that covers the enormous breadth of topics in CMP. Importantly, the POs are also successful in keeping the focus on basic research. The quality of the review process is high despite the extreme pressure from the large number of proposals. The COV notes the POs are proactive in getting community input regarding emerging areas and critical needs with respect to science, workforce, and infrastructure. An important component of the program is the training of a large number of highly skilled scientists who will contribute to the vitality of the nation. The COV feels this strength should be emphasized. The COV is concerned that the workload demand on the POs is unsustainable given the continued increase in the number of proposals submitted. Specifically, the COV endorses the DMR standard of 100 proposals per permanent PO. In contrast, the CMP program currently entertains over 300 proposals per year, and the number is growing.

2. Responsiveness of the program to emerging research and education opportunities.

The program is severely constrained by limited resources in ways we describe below. Nevertheless, the POs are doing an excellent job in responding to emerging opportunities in several ways.

First, the POs have been proactive in reaching out to the community via workshops, which the COV sees as an effective mechanism for the program to remain responsive. As a specific example, the recent workshop on soft matter articulated the current state of the field in a way that enabled the POs to organize their evaluation of proposals more effectively.

Second, they have also been effective in defining new areas based on the science described in proposals. An example here is exciting and rapidly growing area of twistronics, which emerged from the sustained support from the program to fundamental research on graphene. The program further fostered this success by organizing a workshop on the field that included industrial representatives.

Third, they have been instrumental in developing new initiatives throughout DMR and the NSF. For example, the NSF "Big Idea" related to the Quantum Leap evolved from a white paper originally developed by the CMP PO. This proposal for a new Idea further evolved through the effort of all DMR Program Directors and Staff, followed by the leadership of MPS (Mathematical and Physical Sciences) and, once established across NSF, it was spearheaded by PDs in CMP and EPM.

Fourth, the PO has shown initiative in partnering with other divisions in NSF and other agencies to fund joint projects.

The COV encourages DMR to continue to provide time and funds for travel by POs to attend scientific meetings to enable them to interact with PIs and potential PIs. This travel is important to their staying current in emerging fields of CMP.

The program is seriously hindered by inadequate funding. The limited resources available to the program enable it to support only about a half of the highly rated proposals meriting support.

The COV sees this as a dire situation.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

The COV was very favorably impressed with the planning and prioritization process. As mentioned above, the POs maintain an impressively diverse and balanced portfolio that covers the enormous breadth of topics in CMP. The vitality of the field has benefited greatly from this approach. Also, as mentioned in the answer to question 2, the POs have been proactive in organizing workshops that help guide development of the portfolio. These include workshops on broader topics, such as soft matter, and on more focused topics, such as a workshop on topological superconductors.

4. Responsiveness of program to previous COV comments and recommendations.

Most comments and recommendations by the previous COV have been successfully addressed. The COV, however, did feel that the suggestion about making information in Review Analyses available to PIs was not sufficiently addressed.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? Most grants funded by the program are for three years, which the COV felt was appropriate. The size of most grants seems at the minimum to fund projects by PIs with fully functioning labs well equipped for the work. The program is hence missing opportunities to support potentially excellent proposals from PIs who would require equipment with non-negligible cost (*e.g.,* more than ~$15,000). This serious problem appears to be pervasive throughout DMR. This trend is already leading to serious loss of productivity and global competitiveness. An example of the consequences is the growing number of prominent scientists at various career stages moving to institutions abroad.	Appropriate/Not appropriate
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. The program has produced many exciting and innovative advances in basic materials science. There are too many advances to enumerate but the COV finds it useful to cite four examples for illustration: • The creation of metallic hydrogen. This is the culmination of a decades-long search and demonstrates the payoff of long-term persistence in funding. This new material could have many important properties and uses such as a novel superconductor or as a rocket propellant. • The discovery of the novel properties of twisted bilayers in two-dimensional materials. This dramatic discovery shows that a material such as graphene can turn from an insulator to a superconductor by simply twisting the layers. This discovery opens the door to rapid development of future quantum materials. • The development of the sub-field of active matter — systems where energy is generated at the level of the individual material components. CMP-funded study of these materials, which display collective behavior and states of matter that are not seen elsewhere in nature, has provided fundamental understanding of the physical processes underlying a broad range of phenomena, particularly in biology. Specific applications include shape-morphing living composites and cytoskeleton of biological cells. This area has grown to include BMAT and CMMT and is relevant to biology (in the flocking of birds and other animals). • The study of braiding Majorana quasiparticles. With CMP leadership, EAGER-based Dear Colleague Letters came out. Majoranas provide a quantum state that is protected from decoherence and hence ideal for a stable quantum qubit. Experiments provided the first hard evidence for Majorana quasiparticle from measuring spin.	Yes

The COV has no data to evaluate the level of risk of funded projects. However, although the review process is effective in identifying highly worthy proposals, the COV worries that the very low funding rate leads to an aversion of risk.	
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The geographical distribution appears adequate.	Yes

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. The COV notes that the PDs of the program pioneered the workshops for new PIs, which have grown to encompass all of MPS and which appear to be an effective mechanism for helping early-career scientists navigate the proposal process.	Data not available
5. Does the program portfolio have appropriate participation of underrepresented groups[9]? Yes, data provided to the COV indicates the program has appropriate participation of underrepresented groups.	Yes
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The CMP program addresses basic science of materials. This contribution is crucial in understanding and realizing the role of materials in technology and national needs and fits squarely within the mission of DMR and the NSF. The program has been very successful in this regard. The PDs have maintained a broad and relevant research portfolio. The COV is confident in the procedures employed by the POs to minimize the possibility that any key science areas or relevant fields are left behind. The POs have taken advantage of important input from the community to ensure that the portfolio evolves in a dynamic fashion. Given the importance of materials to the national need*, the COV recognizes the critical role of fundamental materials research in the future well-being of the nation. The COV also notes the important role the program plays in the training of a scientifically skilled workforce. We commend the POs' efforts to reach out to industry and to collect data on the need for new workforce development. As an example, the COV points to PO discussions with major US companies that showed strong evidence of an urgent need for workforce development in the area of quantum materials. We encourage publication	Yes

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

of such data whenever possible. Going further, it would be important for DMR as a whole to develop a way to quantify the need for workforce development. Quantifying the economic impact of DMR-supported trainees who join the workforce would be a very valuable tool to measure DMR impact. As an example, in 2016 a study by the American Physical Society concluded "U.S. physics-based companies directly contributed approximately $2.3 trillion to the U.S. economy (12.6% of GDP) and exported about $1.1 trillion of goods in 2016." [https://www.aps.org/programs/industrial/upload/APS-Report-Economic-Impact-of-Industrial-Physics.pdf] This statistic is general to physics, so that it includes non-materials areas while also leaving out some components of DMR activity. It therefore does not overlap DMR completely. A study of this kind that is specifically on the impact of materials-related trainees would be very valuable. * "Over three-quarters of all economic growth in coming decades will be attributable to the development and application of advanced materials, and that investments in MR are tied directly to national competitiveness and economic prosperity." (Source: *Frontiers of Materials Research: A Decadal Survey (2019)*, National Academies Press, http://nap.edu/25244.)	

7. Are any emerging research areas missing from the program's portfolio? The COV feels that the program has been highly effective in identifying and supporting emerging research areas. However, due to the ever-changing landscape, continued success will require vigilance that every important area remains covered.	No
8. Additional comments on the quality of the projects or the balance of the portfolio: In summary, the COV is very impressed with the quality of the projects and the balance of the portfolio with respect to scientific areas. As mentioned above, the COV is deeply concerned that the health and competitiveness of the CMP portfolio will deteriorate rapidly without significant influx of support for instrumentation for individual investigators.	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

Here we summarize the COV's overall recommendations for CMP, including ones that might be relevant across DMR.

1) The panel-based review process is successful and very important for maintaining program quality. We recommend against going to a no-deadline process, as we are concerned that this will prevent effective panel organization.

2) We believe that continued effort to clarify the 'broader impact' criteria is needed. Examples include:

- to what extent novelty vs effectiveness should be assessed in education and outreach plans, and
- possibly elevating the importance of training graduate students and postdocs when evaluating broader impacts.

3) Make elements of the "review analysis" available to PIs.

4) We offered suggestions about anti-bias training, noting that NSF has some new web-based materials that the COV found to be quite useful. Consider making this required of reviewers.

5) Work toward quantifying the industrial and government-lab needs for a trained workforce – both present and future.

6) Work toward quantifying the broader impact from DMR in terms of total trained workforce. For example, what fraction of scientists out there were supported by NSF and what is their share of economic impact?

7) There needs to be additional PO staff. Presently, the workload of POs is too high, as clear from the ratio of submitted proposals to the number of POs. Aside from that, we are making recommendations that require more time on the part of POs and the resources should be made available to do this.

8) The total funds available for grants needs to be substantially increased. We cited two forms of evidence:

- Only about half of the meritorious proposals are funded
- DMR TMRPs need to provide major support for relatively low-cost equipment, lest we lose our international competitiveness in materials research.

2.9 Electronic and Photonic Materials (EPM)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The review methods are appropriate. For non-EAGER proposals, reviews are carried out by three to four independent reviewers. This is followed by panel discussions that leads to a panel summary based on discussion and the different perspectives from the reviewers. The outcome from the discussions is a panel recommendation on the priority of the proposal for consideration for funding. Agreement from the panel is required before any recommendation is made to the program officer. Both virtual panels and in-person panels are used for review, with occasional *ad-hoc* reviews provided by others. The combination of independent reviews, panel discussions, and the effort to form agreement among panel members, ensures that each proposal receives careful evaluation. EAGER proposals are reviewed primarily by the POs. The COV finds the review methods in EPM to be appropriate and to be implemented carefully and fairly.	Yes
2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? The two criteria are intended to address both the impact on science and the impact on society. Both intellectual merit and broader impacts are considered in both the independent reviews and in the panel reviews. Judging from these reviews, it is also clear that the proposals also address both criteria. The Program Officer review analyses address both merit review criteria. In the past, the PO Comments, which go to the PIs, did not always address Broader Impacts, but this has been remedied in more recent reviews.	Yes

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? The feedback from individual reviewers varies greatly. However, they do provide substantive comments, and the program does solicit sufficient reviews to make a reasoned decision. NSF does request that reviewers address specific questions, but this is not followed strictly by every reviewer. NSF might consider providing a template with a section titled "Specific examples in the proposal supporting your critique." This might ensure more structured feedback is provided to the proposer.	Yes
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The feedback from panel also varies considerably. However, they do provide at least some level of rationale for the panel consensus. NSF might consider requiring a more structured response by the panel such as addressing the rationale directly. This could provide more useful feedback to the proposer.	Yes
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The jackets are very through and provide a clear rationale for the decision on decline or award. It includes a review analysis which indicates the careful evaluation made by the program officer after the independent and panel review. NSF might consider sharing more of the review analysis with the proposal PIs.	Yes

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The documentation provided to the PI provides a very through package of the different stages of the review process. However, the program officer comments provides the most direct rationale for the award/decline decision and NSF might consider sharing more of the review analysis with the PIs.	Yes
7. Additional comments on the quality and effectiveness of the program's use of merit review process: Judging from the reviews it is clear that many more proposals should be considered for funding. PO statements on declined proposals sometimes used a phrase that referred to "the fast-moving nature of the electronic/photonic materials research". The intention of this statement is to alert PIs to ensure that any re-submission is up-to-date at the time of re-submission. However the phrasing is ambiguous and may be misinterpreted by PIs. The POs are encouraged to consider re-writing this phrase to clarify their message.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question.

SELECTION OF REVIEWERS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The broad intellectual scope of the EPM program requires reviewers with diverse backgrounds. POs intentionally select reviewers and build panels that are knowledgeable in the scientific topics under consideration. The qualifications of reviewers are confirmed by the presence of detailed scientific comments in many individual reviews. In addition, POs make an effort to include newer investigators alongside experienced participants on the panel, as well as panelists from a variety of types of institutions. The 2015 COV noted that it is "essential that program officers have access to funding and time to attend technical meetings" in order to interact with the professional community and stay abreast of emerging research areas. The NSF response indicates that such funding has been increased. We encourage continued allocation of resources to support this.	Yes
2. Did the program recognize and resolve conflicts of interest when appropriate? The procedures for dealing with conflicts of interest are well-established and seem to be consistently carried out within the program. None of the jackets we read indicated any problems with conflicts of interest.	Yes
3. Additional comments on reviewer selection: The COV did not identify any problems with reviewer selection. However the process for identifying potential reviewers and selecting reviewers for panels seems to be determined individually by PO, and may consume a disproportionate amount of time especially for new POs. The new tool currently being tested by NSF should address this issue.	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW	
1. Management of the program. The program is very well managed, especially given the limited personnel in EPM and the large number of proposals. The number of proposals per PO is 135-150 per year, which is above that for other programs in the Division and Directorate, *i.e.,* 100 proposals per year per PO. In addition, both of the POs are rotators. For continuity, it would be advantageous to have a permanent PO in the program. In order to manage workload and ensure longevity of institutional knowledge, the COV recommends allocation of an additional FTE to the EPM program. The methods of announcing new initiatives, particularly NSF-wide programs, is reasonable and sufficient. The program officers put great effort into announcing opportunities relevant to their program based on their understanding of EPM PIs' research portfolios. The number of awards among underrepresented groups is reasonable given the pool of proposals.	
2. Responsiveness of the program to emerging research and education opportunities. EPM has been very proactive in pursuing emerging research opportunities, such as materials for quantum science and devices, plasmonic materials, perovskites, topological materials, two-dimensional quantum materials, and ultra-wide bandgap and other next-generation semiconductors. To make this possible, investment has been reduced in other areas to respond to evolving needs in basic materials research and the maturity of some materials into engineering applications and manufacturing. It would be beneficial to track the progression of research on particular materials from fundamental studies, funded by EPM, to engineering and manufacturing research funded by other Directorates. In EPM, EAGER awards in particular have been used to explore new research areas while appropriately balancing risk and resources. EPM is commended for advancing the Quantum Leap initiative, which to date has resulted in 22 funded research projects. Moreover, EPM proposal topics strongly overlap the areas identified by the 2017 EPM workshop. However, there is not an easy way to track this within NSF's systems. The COV would like to see continued and even broader participation of EPM POs in formation of DCLs and solicitations for NSF-wide initiatives, *e.g.,* beyond Moore's law and sustainability. The EPM proposals include a variety of educational initiatives, including in CAREER awards. These initiatives are often linked closely to the projects' state-of-the-art research work.	

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio. To delineate current gaps in knowledge and new areas for programmatic expansion, EPM held a workshop in 2017, entitled "Current Challenges and Future Opportunities in Electronic and Photonic Materials." The results were published in a long-form report and an executive summary in the *MRS Bulletin.* The workshop identified four core areas for future growth: epitaxially-grown materials, van der Waals materials, organic and flexible materials, and meta-materials. Since the workshop, the POs have considered these areas in the development of their portfolio. In addition, in the period since the last COV, the NSF requested the National Academies of Science, Engineering and Medicine to identify the direction of future research, particularly in light of the expansion of materials research world-wide. The resulting in-depth and broad review, published in 2019, represents only the second such effort in recent history. The survey was based on review of the pertinent literature as well as discussions with the materials community. The initiative identified principal changes that occurred over the past ten years and noted promising areas for investment over the next decade. In addition, the study pointed to areas which have had a major impact on existing technologies as well as those poised to transition to R&D and industry. The report also included suggestions for addressing challenges identified during the development of the survey. Significantly, the final chapter provides a thorough perspective on the approach to materials research throughout the world including the rapidly rising eastern countries, particularly China. The initiation of the National Academies *Decadal Study* and the 2017 Current Challenges Symposium is applauded by the COV. The use of these studies to identify and form priorities within EPM is encouraged by the COV and it is noted that incorporation of these ideas is already ongoing in the program. In addition, continuation of such initiatives, where time and money is available, is encouraged.	
4. Responsiveness of program to previous COV comments and recommendations. Overall, the program has addressed all of the comments/suggestions from the previous COV. The 2015 COV recommended, in recommendation 2, that there should be "a process at the Division level by which investments are deliberately evaluated and transformed over time." This has been addressed in the Division by keeping base budgets for each program constant, and reserving 7-11% of the Division's budget to provide additional funds for each program, at the discretion of the Division Director based on demonstrated need. While this approach has merit, the COV suggests that the overall distribution of funds between programs should be re-considered on a regular basis as part of long-range strategic planning in the Division. In recommendation 7 in the 2015 report, the COV encouraged "DMR to explore new mechanisms that enable international interactions without the overhead of the prior programs." Since the last COV, the International Materials Institutes (IMI) and Materials World Network (MWN) programs have been sunset. Meanwhile, EPM has supported two awards in the new U.S.-Israel Binational Science Foundation (BSF) program, and has funded EPM research awards with international activities with Europe and Africa. In the future, it may also be worthwhile to consider collaborations with emerging technological powerhouses like China.	

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? Within EPM, the award duration and size are appropriate for the scope of the projects. However the COV notes that PIs face inflationary increases in costs which, over time, reduce the purchasing power of NSF awards. The 2015 COV noted the low level of funding on projects. During the COV period, the DMR responded by increasing the median award value per year by about 33%. The COV commends the DMR for their responsiveness to the 2015 COV recommendation.	Appropriate
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. Judging from the reviews, comments like "This is high risk but can have significant impact on computing." were present in around 10% of the reviews. These 'high-risk' proposals resulted in strong research outcomes, with publications in high-profile journals with broad readership, such as *Soft Matter* and *Science,* on topics of "self-organizing in dipole cube fluids" and "Majorana spin litmus test," respectively. Meanwhile, most funded proposals have significant impact judging from the fact that most awards result in three to five publications. At least 10% of funded proposals can be considered innovative or transformative as evidenced by publications in the leading world-wide journals like *Nature, Science,* and *Physical Review Letters,* on innovative concepts in material science like amorphous topological insulators (*Nature*), dynamics in vortex tubes (*Science*), fracture in sheets (*Nature Materials*), spin canting in nanoparticles (*Scientific Reports*), observation of discrete-time-crystal signatures (*Physical Review Letters*), twistronics (*Nature*), and quantum phases (*Nature*).	Appropriate
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The portfolio has good geographical distribution of PIs, with the majority of US states represented. The COV reviewed the number of submissions and awards by state. The success rate of each state is 15-25%, within the typical range for NSF. The data available on awards do not provide details on types of institutions. Therefore as a proxy, we evaluated the number of Research in Undergraduate Institutions (RUI) awards made by EPM. The number is quite small – four awards during the COV period. The program may wish to more strongly encourage submissions from primarily undergraduate institutions.	Appropriate

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. According to the information provided to the COV, in the period under consideration, 9% of all EPM proposals were submitted by new investigators, while 6% of all EPM awards were made to new investigators. Data on awards to early-career investigators, as defined above, were not available. As a proxy, we examined CAREER awards funded by EPM. Over the past four years, CAREER awards represented 29 (14%) of 206 non-EAGER proposals awarded by EPM. Some of the CAREER awards may also be included in the new investigator statistics. Over the past four years, CAREER awards have a slightly higher funding rate of 21% compared to the 18% funding rate for all EPM non-EAGER proposals. The COV finds these rates and the balance of awards to CAREER proposers and new investigators to be appropriate. In addition, workshops for new investigators have been held every year, run variously by CMP (2014-2017), DMR (2018) and MPS (2019), with more than 100 participants in 2019. These workshops are seen by the COV as an excellent way to broaden participation and strengthen the quality of proposals by new/early-career investigators.	Appropriate
5. Does the program portfolio have appropriate participation of underrepresented groups[10]? The program portfolio has appropriate participation of female and male PIs. Out of all TMRP proposals received by the EPM program over the COV period, on average about 45-50 per year (around 20%) are from female PIs. Proposals submitted by female PIs are funded at a rate of around 18%, which is on par with the funding rate for all proposals. The program receives very few proposals from under-represented minorities, typically less than 10 proposals per year (< 5%). The number of awards granted by EPM is reasonable given the limited number of submissions. The program has participated in cross-cutting NSF activities to encourage broader participation and maximize the success rate, and encourages PIs to use the Alliances for Graduate Education and the Professoriate (AGEP) program to broaden graduate student participation. Additionally, the COV notes that demographic data is self-reported and not mandatory and thus these values may under-estimate the true participation of underrepresented groups in EPM research awards.	Appropriate

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The 2019 National Academies' *Frontiers of Materials Research: A Decadal Survey* and 2017 *NSF-EPM Workshop Report on Current Challenges and Future Opportunities in Electronic and Photonic Materials* outline research priorities critical to the nation's prosperity and security as well as the mission of NSF. These reports highlight new directions for traditional as well as emerging materials systems. The EPM portfolio clearly reflects all areas of national priorities, the mission of NSF, as well as constituent needs. For example, the *Decadal Study* points out the need to investigate fundamental spin and excitonic physics of materials, and EPM is currently funding projects to investigate spin phenomena for next-generation computational devices, and 2-D structures that are needed for revolutionary quantum emitters. The *Decadal Study* also identified topological and plasmonic materials as important materials categories, and EPM is funding work on nanostructured plasmonic materials and superlattices that capitalize on plasmonic effects needed for multi-modal lasers. In sum, EPM's awards strongly reflect the national priorities in electronic and photonic materials. EPM's funded work on broader impacts are also well-aligned with NSF's mission and national priorities to broaden participation. For example, one PI has implemented MESA-Physics Day on which hands-on demonstrations and research lab tours are available to about 100 students from traditionally underrepresented groups (EPM Highlight: Boehme). In another project, social media is being used to 'spread the word' on photon emitters to a new generation of scientists (EPM Highlight: Vuckovic).	Yes

7. Are any emerging research areas missing from the program's portfolio? The COV hesitates to identify particular areas, because of the fast-moving nature of the field. Nonetheless, we suggest some emerging areas in EPM which may benefit from greater EPM investment. These include: materials for flexible and wearable systems, radiation-hard materials, materials for extreme environments, high-frequency materials, materials for new transistor concepts, and bio-designed materials.	
8. Additional comments on the quality of the projects or the balance of the portfolio: We have no additional comments.	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

Materials research is the backbone on which all technology innovation is based. Research supported by DMR is critical for the U.S. to maintain its historical world-leadership in technological innovation. Recently, China has been investing heavily in both personnel and materials research infrastructure. China has successfully recruited faculty from US academic institutions to positions there. Those of us who serve as editors at journals have seen a strong uptick in the number and quality of Asian-only authored manuscripts in materials-related fields. Therefore, we perceive an urgent need for the US to expand its investment in materials exploration.

There is an urgent need for a funding mechanism for small/medium-scale instrumentation / instrument upgrades/repairs, in the range of $20k to $150k, *i.e.,* smaller than an MRI. Currently the only Federal funding opportunity in this range is the DURIP, which requires a defense contract, which is not appropriate for every DMR PI's research program. This could be done as a supplement to existing NSF funding, or as a stand-alone program.

In addition, there is no funding mechanism for supporting technical staff needed to support high-value instrumentation such as MBE, research-specific microscopy, etc., which is critical to long-term productivity of NSF's investments in infrastructure.

4. Please provide comments on any other issues the COV feels are relevant.

During the Division Director's (DD's) presentation to the COV, the DD showed a table with current versus needed PD staffing levels for the TMRPs. At present, there are 6 FTEs plus 7 Rotators, whereas the DD stated that 10.5 FTEs plus 8 Rotators are needed based on workload analysis. The COV agrees with the DD's assessment that DMR is under-staffed, and that, in particular, more FTEs are needed to ensure longevity of institutional knowledge. However, it was not immediately clear whether there is a plan or path to achieve this.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

Investigation of many of the questions in Section IV would benefit from a searchable list (spreadsheet) of all funded awards in the program during the COV period. We downloaded the publicly available information from the nsf.gov list of recently awarded proposals. However the downloaded data are missing critical information. Specifically, we need:

- Type of institution (PUI, HBCE, R-1, etc.)
- Demographics (URM/gender) of PI, if reported
- Is the PI a new investigator (according to NSF definition)
- Is the PI an early-career investigator (according to NSF definition)
- Total budget and total duration

In addition, to answer III.3, it would be helpful to be provided with the geographical distribution of submitted proposals. Maps were provided of funded awards, but not of submissions.

We note that for this year's COV, the PDs were able to provide the information needed.

2.10 Metals and Metallic Nanostructures (MMN)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? Since the last COV report in 2015, the MMN program has essentially abandoned on-site panel reviews and has relied increasingly heavily on virtual panel reviews. The number of *ad-hoc* mail reviews has fluctuated but increased from less than 10 in FY 2017 to about 20 in FY 2018. This balance is appropriate. On-site panels benefit younger investigators, who would like to visit NSF, but inadequate and dwindling resources favor current review methods. No clear distinctions could be drawn between *ad hoc* versus panel reviews. The PO did note that the use of virtual panels allowed for the selection of smaller, better qualified panels, which led to higher quality reviews.	YES
2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? Intellectual Merit (IM) and Broader Impacts (BI) are bedrock components of all NSF proposals, and the MMN program is no exception. Reviewers occasionally slip up on providing detailed analyses of BI, but both are fastidiously addressed in panel summaries and PO review analyses.	YES

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? In most cases the answer is affirmative. Reviewers span the spectrum of breadth and depth of detail, but even the briefest reviews provide at least some justification for the decisions taken.	YES
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? When proposals are rated, they are placed into categories ranging from "do not consider" to "must fund". Proposals on the borderline of "fund" or "decline" arrive there primarily by consensus, but rarely unanimity. It is then up to the PO to decide the fate of the project, using all the NSF criteria involved in arriving at a decision. The panel summaries provide rationale for the panel rating.	YES
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The rationale for a decision to award or decline is thoroughly documented, considering not only IM and BI, but other factors such as geographic balance and the participation of underrepresented groups. The documents in the jacket are consistent with the decisions that were reached. This is particularly evident in the program officer review analyses, which are very detailed. Careful attention has been given to incorporating comments from the panels/reviews along with the opinions of the program officer. Most decisions were in line with the reviews. When different decisions were made, the program officer was careful to explain and justify the decisions.	YES

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] It is not clear whether the PI is informed, in writing by the PO, of the underlying analysis leading to a decision. The PO encourages telephone conversations with the PIs, especially to present the reasons for a decline.	YES

7. Additional comments on the quality and effectiveness of the program's use of merit review process: Proposals are not always evaluated well, even by the most experienced and qualified reviewers. Some are sometimes overrated by the letter reviews and vice versa. In such cases the PO must rely on his own expertise and research, leading to the declination of above-average rated proposals and the awarding of slightly below-average rated ones. The COV finds that the PO has made difficult but courageous decisions, augmenting the merit review process.	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question**.**

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The COV finds that the MMN reviewers have been thoughtfully chosen, not only for their expertise in the research area of the proposal, but also because of their sense of fairness and sensitivity to the PI. The use of smaller virtual panels has allowed the PO to assemble more focused groups of reviewers which has increased the quality and depth of reviews. This has increased the workload for the program officer but should be continued.	YES
2. Did the program recognize and resolve conflicts of interest when appropriate? No examples were found of a conflict of interest slipping through the cracks.	YES
3. Additional comments on reviewer selection: The selection of reviewers can be a very frustrating activity, especially when qualified reviewer opts out of reviewing a proposal. The MMN program has chosen reviewers wisely.	YES

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW

1. Management of the program.

Since the 2015 COV report the MMN program has been managed by one rotating PO. Two POs, working separately, have managed the program during the period of time under review. They have managed the program's portfolio of projects and reached out to other Divisions in NSF and other funding agencies to explore co-funding opportunities. Even though there were a large number of proposals to review in FY 2018 (151, including 14 CAREER proposals), the PO and DMR administrative team managed to process the proposals effectively. Notable by their absence are EAGER proposals, which have been absent from the MMN portfolio since the last COV report. EAGER proposals involve reaching out to the MMN community, which is difficult to do given the existing workload. Given that MMN funding levels have been flat for the past 4 to 5 years, the program has managed its resources quite well. The program has maintained a funding rate of around 20% while managing to gradually increase the mean award size. The portfolio includes single PI, multiple PI, and collaborative proposals and has evolved to focus less on structural metals and alloys and more on core physical metallurgy. There appear to be opportunities for funding more GOALI programs; however, they may be a clearer fit with the Engineering directorate.

2. Responsiveness of the program to emerging research and education opportunities.

The 2015 COV report expressed concern that the MMN program was lagging in identifying new areas of research, including new materials, innovative interrogation tools and novel experimental techniques. The COV feels that the MMN POs have done a good job staying abreast of developments in the field and investing its available resources. The COV also feels that the MMN program has sponsored cutting-edge research in several areas, including additive manufacturing, property-microstructure relationships in new complex alloys, *e.g.,* high-entropy alloys, electrochemistry, oxidation and classical nucleation. It is hard to identify new techniques that have NOT been initiated by metallurgical research, high-resolution TEM and STEM, atom-probe tomography emerging from field-ion microscopy, advance x-ray methods, etc. Many of these areas have been mentioned as critical areas for investment in the 2019 *Decadal Survey*. These activities all have a positive influence on the education of undergraduate students, grad students and postdocs.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

The MMN portfolio has changed significantly since 2015. For example, the investment in core Physical Metallurgy research has decreased from ~70% in 2015 to ~50% in 2018 while that in Structural Metals and Alloys has increased from ~10% to ~30%. The current portfolio includes increased investments in high-entropy alloys, oxidation and nucleation. Consider nucleation, the classical theory of which has been with us for well over a century. What is there new to learn about it and why is it important? For one thing, nucleation theory is on firm semi-quantitative footing, but quantitatively it cannot predict anything. Discovery of the reasons for this failure will assist important engineering activities such as process modeling and additive manufacturing. New insights into mechanisms of oxidation will benefit the development of new advanced Ni- and Co-based superalloys, which are important areas of research across the board in several funding agencies, including NSF.

4. Responsiveness of program to previous COV comments and recommendations.

It is difficult to separate the response to this question from the response to question #2. The COV recommends that the MMN program encourage EAGER proposals to implement new research activities in emerging areas

where the risk of success is high, but the rewards are potentially transformative. The COV also suggests that the MMN program sponsor workshops on focused areas of research which are deemed important and potentially game-changing by the PO. An example is a workshop on nucleation, bringing together experts in theory, modeling and computation, as well as end-users in the manufacturing community.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? The program portfolio includes a mixture of single PI, multiple PI, and collaborative proposals. The PO has made a conscientious effort to increase the size of awards, which is of great benefit to the PIs. On average, the award size has increased from ~$123K/yr to ~$157K/yr from 2015 to 2018 with the awards being for three years. Despite the flat budgets and essentially identical funding rates in 2015 and 2018, the PO has managed to maintain excellence in the awards by managing the proportion of standard and continuing grants. In at least two instances, the PO deliberately increased the money allocated to two female CAREER awardees over their original budget requests. This was done because the PO felt that the budgets were deliberately reduced by the PIs to increase the chances of funding, knowing full well that the proposed research would measurably benefit by increasing the sizes of the awards.	APPROPRIATE
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. The COV is impressed with the portfolio of projects but held varying opinions regarding the level of risk in the supported projects. New mechanisms allowing additional investment in very “high risk” projects should be identified. One potential avenue might be the aforementioned EAGER awards, which are missing from the current portfolio. There certainly seems to be an opportunity for investment in this program where appropriate.	SOMEWHAT APPROPRIATE
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? The geographical distribution of the MMN portfolio is like that of DMR as a whole. A significant part of the upper Midwest is either sparsely represented or not represented at all, and the Southern states of Arkansas, Mississippi and Louisiana are unrepresented. Proposals submitted by PIs at institutions in these states cannot be funded if they do not rate highly, no matter how desirable it is to maintain geographical distribution. On the other hand, two RUIs were funded, one in Kentucky and the other in Pennsylvania.	APPROPRIATE
4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation	APPROPRIATE

awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. The MMN program has funded approximately 20 new awards each fiscal year since 2015, which the COV is quite happy with. But no information has been provided regarding whether or not the PIs themselves are new to NSF. The MMN has funded between two and three new CAREER awards each year at an average award size of ~$550K, averaging ~$110K/y for a typical 5-year grant. The COV is not provided with benchmarks that enable determination of appropriate balance. The CAREER statistics over the past four years show a steady trend, which the COV deems appropriate balance for the MMN program.	
5. Does the program portfolio have appropriate participation of underrepresented groups[11]? The program portfolio includes a large number of from PIs who self identified as minorities and/or women. The level of participation and support appears appropriate.	APPROPRIATE
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The COV has identified numerous projects supported by the MMN program, identified as relevant to national priorities in the NAS-NAE 2019 *Decadal Study*. These include 11 projects on Metallic Glasses, 7 on High Entropy Alloys and 13 on High-Performance Alloys. One of the projects on metallic glasses was recognized by the reviewers as transformative.	APPROPRIATE

7. Are any emerging research areas missing from the program's portfolio? The COV is impressed with the breadth and depth of the MMN portfolio. We are unable to identify emerging areas of research that are missing.	APPROPRIATE
8. Additional comments on the quality of the projects or the balance of the portfolio: The COV believes that the MMN portfolio is well balanced in nearly every respect, including the breadth and depth of the research projects, the representation of women, and the quality of the Intellectual Merit and Broader Impact.	APPROPRIATE

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

A funding avenue for the acquisition of low to mid-range equipment ($20k - $200k) is needed.

The MMN program should invite more EAGER proposals.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

Workload is a serious problem that can be mitigated only by increased funding for DMR across the board. The agency must find ways to reduce PO workload. Possible avenues might include increasing the number of rotators in conjunction with permanent POs. One envisions a permanent PO plus a rotator in each program. This could provide stability, consistency and innovation to the existing programs.

4. Please provide comments on any other issues the COV feels are relevant.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

2.11 Polymers (POL)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? The program officer has developed very efficient processes and methods to obtain high quality, timely reviews including mail-in (*ad hoc*) reviews for all submissions, and additional virtual panels for the CAREER and SusCHEM submissions. We appreciated the special attention given to the CAREER panels (10% of submissions) and summaries which serves the program extremely well, and continues to provide critical professional development to emerging PI's with regards to both proposal feedback and participation in the review process. The fact that the program typically requests 5-7 reviews and obtains at least 3, and, frequently, 4 or more reviews for every proposal is commendable considering the pressure on the program and community from the high number of submissions. The exceptionally high percentage of responses within the six month window (99%) is another testament to the efficiency of the program. We took a closer look at the EAGER program, since it does not use external peer-review to determine recipients. The 5% cap on spending for this program appropriately restrict the POL program to only one or two of these awards a year. At least one of the PM's selections for this program resulted in the only funding source cited in a recent *Science* paper – a good indicator of a wise investment in a high-risk idea. Another proposal was based on a *Nature Communications* paper, but did not initially review favorably due to the level of risk involved and the large scope. With some feedback, it was revised for an EAGER award. The panel agreed with the high-risk, high-impact nature of the work in that revised proposal, making it a smart choice to fund.	YES

2. Are both merit review criteria addressed a) In individual reviews? b) In panel summaries? c) In Program Officer review analyses? We found that the vast majority of reviews provided substantive comments regarding both strengths and weaknesses in both criteria. There are a plurality of interpretations of Broader Impacts, as well as lighter feedback in reviewer comments relative to Intellectual Merit. For some reviewers, better delineation between strengths and weaknesses may have facilitated synthesis of the overall feedback. All summary documents provided by the program officer included comprehensive, systematic, succinct analysis of all reviews. The tone conveyed support, encouragement and excitement as appropriate for the given decisions, which the panel found particularly impressive.	YES

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? Overall, the general quality of the reviews was very high. With few exceptions, at least one or two justification statements were included for all criteria in the written reviews. The high number of reviews obtained per proposal ensure that there is extensive feedback and the rare case of limited comments of one reviewer is mitigated.	Yes
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The Program Officer does an excellent job of soliciting a broad range of reviews from the community. We did not see any evidence of a lack of consensus in any of the summary documents. All of the summaries reviewed had well-moderated, considerate feedback relative to stronger opinions reflected in some individual reviews. This is particularly important in the case of early-career PI's, where feedback can be critical to future success. Because of the high number of reviews per proposal, there can be a mix of experience levels and depth of comments/justification. The program officer does an outstanding job of weighting experience levels and other contributing factors in the quality of the reviews. This has two positive effects: it enables early career scientists to gain experience, and increases diversity in participation from the community. These summaries showcase the wisdom and insight of the program officer in creating a diverse and complex portfolio of funded research in POL.	Yes

5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] There was ample documentation justifying decisions in the review analyses. We appreciated the concise, comprehensive nature of the summaries, which always included or referenced content from all reviews in addition to summative recommendations of the PO.	YES

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The POs responses to the PIs were generally brief and direct, which was greatly appreciated by the COV panel. Most of the comments included both enthusiasm and support for future submissions as well as specific reasons for decisions. This is particularly critical, given that in many of the review panels, a range of individual ratings was obtained (*e.g., E, V, G, F*). In the absence of good justification, this could lead to frustration and confusion for submitters of declined proposals. In these cases, the PM's empathy was apparent and appreciated by the COV. Furthermore, his excitement and enthusiasm for the successful proposals was also apparent in the memo's congratulating the PI's. These documents are also accompanied by extensive personal communications, usually by phone, with submitters, which is broadly valued by submitters. His dedication to this personal involvement and ownership of decisions is also laudable.	YES
7. Additional comments on the quality and effectiveness of the program's use of merit review process:	

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question**.**

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? In all the reviews surveyed by the committee, there were always at least two or three reviewers with deep expertise and outstanding alignment with the proposed work. Because of the diversity of reviews and the sheer numbers solicited, occasional reviewers with peripheral expertise were included. The judicious and consistent inclusion of prominent international reviewers was particularly valuable. The committee viewed this as another asset to the program since those comments often provided complementary points of view with respect to the broader impacts and the idea's high-level potential or relevance to the extended polymer community.	YES
2. Did the program recognize and resolve conflicts of interest when appropriate? We did not see evidence of COI issues in the e-Jackets. We assume this was managed prior to assignment and requests for reviews. From our informal probing of the community, as well as the program presentation and ensuing discussion, it was clear that the PM takes proactive action in preempting any issues.	YES
3. Additional comments on reviewer selection:	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. The program officer does an outstanding job with the program. It is apparent that the portfolio is comprised of a complex set of high-merit and diverse activities, whose merit is well-documented by the PO. The resulting metrics (# of publications, and high levels of citations of portfolio output, recognized leaders in the field) are a testament to the effectiveness of the program's management. The diversity of the program extends across a remarkable number of axes, including gender, race, age, discipline, geography and institution (*e.g.,* PUI and EPSCoR). We also recognize the extensive engagement of the PO across all of NSF, and his remarkable ability to leverage NSF resources. In particular, his ability to support multi-disciplinary, multi-directorate support for POL-related work is a testament to his leadership, as well as the central role of polymer science and soft matter in so many advanced areas of research and innovation.

2. Responsiveness of the program to emerging research and education opportunities.

The PO is clearly engaged in the community and related societal needs. This is manifested in new, growing investments in areas such as SusCHEM, and especially the relevant new topical areas in sustainable materials, especially in waste plastics and recycling in the DMREF and MRSEC programs. These are viewed as critical societal needs, which will only be addressed with breakthroughs in basic research, including new materials and new processes, in polymer science and engineering.

Furthermore, we call attention to the emergent field of self-healing, re-shapeable polymers (*e.g.,* vitrimers), in which core POL investments (PI and CAREER) have played a seminal role. Fundamental understanding of this class of materials will have long-term impacts in many megatrends, such as the Circular Economy, where programmable creation, destruction, and re-arrangement of materials will radically extend their value and decrease their environmental impacts. In the last four years, we have observed the expansion from one or two PIs in this field to a significant fraction of the community studying this class of materials. This investment is coming at the expense of research in electrical, optical and energy-related polymer science. This is the result of both mature work in the area, and a shift in the area to more inorganic materials, such as perovskites. The program continues to defer bio-related proposals to the BMAT program appropriately.

The panel was impressed with the array of educational outreach and curricula development examples in the e-jackets.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

The Polymers Decadal Study prepared under the leadership of POL is considered a world-leading and critical contribution to the development of priorities in the field. These guiding documents have provided important direction not just for POL, but for other agencies as well. This was further reinforced by the full endorsement of the recommendations of the report in the Materials Science *Decadal Study* published in 2019.

It is also clear that the program officer exerts considerable effort in advocating the role of polymer research in the appropriate NSF initiative areas as well. For example, the important role of polymer science in sustainable chemistry and DMREF programs was captured, and has been supported and is showing significant impact in the community.

4. Responsiveness of program to previous COV comments and recommendations.

There were three recommendations specific to the POL program in the previous report. All of them were adequately addressed in the response and in the presentation of the program overview.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? The average annual award size ($130k per year) is smaller relative to that in CER or MMN ($150-160k). Ideally, this amount of funding per year should be higher, but it is an understandable tradeoff given the flat budget of the program. This appears to be within the personal purview of the individual POs. We commend the PO's goal of keeping success rates in POL as high as possible, funding as many proposals as he can given the rate of submissions with highly rated reviews. It is also noteworthy that he is not just reducing overall proposal amounts. We saw an example of awarding a recipient more than they asked for when he felt it was too low. The PO informed us that he does this for several proposals every year. In particular, the POL program, which is highly leveraged across NSF (co-funding on average more than $550K per year in other programs), has growing societal impact and significance in technological innovation, and a diverse and vibrant community is being limited by its own success. In addition to a lower per annum funding rate, it is clear that there are multiple declined proposals (at least 5-10%) in the e-jacket that were near the cutoff. We felt there were missed opportunities in confined thin film dynamics, chemistry and flow induced crystallization of functional materials, and functional networks. These ideas should be fundable with a larger budget for the program. When asked, the PO felt that he could justifiably fund 50% of the proposals he has to decline. More investment from DMR in the Polymers program is strongly recommended.	Appropriate under the circumstances
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. In our review, we considered the use of formally defined high-risk activities, EAGER and Creativity Extensions. There is a healthy number of these innovative investments which are complementary to the overall portfolio. Most of the funded proposals presented calculated degrees of risk in highly innovative areas, particularly in the areas of controlled assembly precision synthesis, and transport phenomena.	YES
3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? As the data were presented to us (funded proposals from the period in review) we initially thought there was over representation of institutions in the northeast or at least along the east coast. After further discussion with the PO, and looking at the data a different way (all currently funded/active POL programs), we noticed a much more balanced distribution of activities. We felt this was a more holistic view of the data, since there are relatively few actions within the period of review on which to base an opinion.	YES

DMR may want to consider presenting the data in this form for future reviews or combining them with a color code to provide context for how new awards fit into the active portfolio of the program. This will help avoid misinterpretation of short-term data.	

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. The program has sustained a very stable distribution of funding for early career PIs in the portfolio. We were pleased to see the steadily increasing numbers of CAREER recipients, indicative of the large number of young people choosing to work in the field, and obtaining support from POL.	YES
5. Does the program portfolio have appropriate participation of underrepresented groups[12]? The panel found this question challenging to assess quantitatively. We know from probing the community that the PO has a reputation for a commitment to mentorship and support of broadening participation in his portfolio. Ultimately, he has to consider the proposals that are submitted. Among those submitted, there is further challenges posed by the low amount of self-reporting on demographics. With regards to race/ethnicity, the success rates based on self-reporting are still too low to consider statistically significant, however, there are obviously high levels of co-PI participation, which is encouraging (16%). Furthermore, the PO has maintained consistently high diversity in his overall participation numbers (PI & co-PI) for gender and race/ethnicity (27-29% female, 15-16% URM) for an extended period of time (ten years).	YES
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The program relies heavily on the direction posed in the Polymers Decadal Study, which includes contributions from academic, government and industrial representatives. These include new investment in renewable, sustainable polymers and self-healing/responsive materials. The POL program is effective in delivering innovation in soft materials that lead to successful new businesses and technologies, for example the three successful companies emerging from the CLiPS STC.	YES

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

The program also continues to contribute to many other NSF programs, as evidenced by the co-funding offered by POL to other programs (>$550k/yr).	

7. Are any emerging research areas missing from the program's portfolio? 1. The panel would like to see more investment in depolymerization. After 100 years of fundamental research into precise design of polymer molecules, the same attention to fundamental chemistry, physics, processes and uses of deconstructed or rearranged molecules would be both timely, and well-suited to the POL community. 2. We heard many program officers defer questions regarding data to the DMREF program. There is an opportunity to work with the experimental PIs within the TMRPs on the creation of FAIR data within their data management plans or other aspects of their proposals. This was an outcome of the *Decadal Study* which has yet to be acted on, and would be of critical, fundamental value to the community.	
8. Additional comments on the quality of the projects or the balance of the portfolio: Because the Polymer Community has such a natural and fundamental link to commercial innovation, the program might consider expanding the GOALI investments beyond the three active grants. This may be limited by submission from the community, unfortunately, but should continue to be encouraged. In our solicitation for input on the COV review, there was additional encouragement of the use of INTERN and iCORPS, as well as I/UCRC's and ERCs to encourage more partnerships between academia and industry.	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

   - The polymer community has a strong need to refresh instrumentation with costs in the range of $50-350k (*e.g.,* SEC, rheometers, AFM, DSC, TGA), yet there is no current mechanism to enable them to do so. Restoration of the IMR program or a similar new program which would support procurements at this scale, including upgrades, accessories, or even service contracts for 1-5 years would be extremely valuable to the United States' polymer research infrastructure. The panel feels that this is critical to international competitiveness in polymer research.
   - With respect to broader impact, society's perceptions of everyday materials (steel, paper, glass, plastics, concrete, asphalt, etc.) and their use/re-use and the practical consequences of these actions with respect to energy consumption, safety, cost, etc. is poor. Programs and research to close the real gaps, educate the public on misconceptions/realities, and point the direction to a more sustainable future would be a worthy NSF materials research endeavor.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

   - We recommend a more organized effort to recruit detailees from local other agencies (NIST, NASA Goddard and Langley, NIH internal research programs, etc.) in order to ease the work load on individual programs and provide professional development opportunities to scientists at National Labs. For example, NIST maintains a permanent detail position at OSTP that is filled on a rotating basis. An interagency agreement identifying mutual benefits of such a position in materials research should be fairly easy to negotiate.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

   - From the low submission rates and general lack of awareness of the Career/Life Balance program, it seems that greater effort publicizing and educating the community, not just to its existence, but who can participate would be a good idea.
   - We feel that a budget process that took into consideration at least inflationary growth in core programs in addition to high level, cross-cuts such as the 'Big Ideas' would be a healthier form of growth for the Foundation.

4. Please provide comments on any other issues the COV feels are relevant.

   - We were pleased to hear of the Division Director's deliberate encouragement of teamwork among the program management staff. Greater awareness across programs of the state-of-the-art and opportunities within all of the DMR programs will build a stronger management team and facilitate difficult conversations regarding the rationale behind the balance of DMR investments. We feel this is particularly important since a rationalization beyond historical or legacy funding levels for the various DMR programs is important to the Division's future.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

2.12 Solid State Materials Chemistry (SSMC)

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, returns without review, and withdrawals) that were *completed within the past four fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

I. Questions about the quality and effectiveness of the program's use of merit review process. Please answer the following questions about the effectiveness of the merit review process and provide comments or concerns in the space below the question**.**

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? SSMC conducts reviews using in-person panels at NSF, *ad hoc* mail reviews, and virtual panels. Since 2015 about 210 proposals per year (TMRP and CAREER) were reviewed by SSCM with a funding rate of roughly 18%. The number of proposals has been fairly steady near 210, with one high year in 2017 with almost 280 proposals. The POs have done an excellent job managing the reviews of this large number of proposals using virtual panels, on site panels and mail in reviews. The shift has been from 50:50 virtual to on-site panels in 2015 and 2016 to predominantly on site review panels. This approach has worked very well and there is an advantage in on-site panels, particularly given the breadth of the SSMC as this allows the POs to learn from the panel in guiding their decision. The interdisciplinary nature of the SSMC requires diverse perspectives to effectively evaluate the proposals; to achieve consensus in-person interactions are essential. Furthermore, in-person panels serve to equalize rating scales between the different communities served by SSMC. The panels typically triage the lowest ranked proposals, specifically those that have no chance to be funded. This leaves more time for discussion of the more meritorious submissions. The downside is that the individuals who are triaged do not receive feedback summaries from the panel, although they do receive the individual comments from each reviewer. Overall, the POs make a strong effort to provide constructive and specific feedback on proposals that are not funded, in order to help submitters understand the decisions. The makeup of the panels is very appropriate, and the POs are well acquainted with the SSMC community and chose panel members carefully and very appropriately. The POs are aware of the different cultures in different SSMC sub-areas and take those into account when evaluating the panel outcomes. Overall this process is effective and extremely fair and equitable to the individuals submitting proposals. A concern has been the high turnover in SSMC, multiple rotators and permanent staff, as this makes it challenging to preserve the institutional knowledge that is necessary to	YES

maintain the high quality of the proposal review process. Maintaining the longevity of the permanent staff member is therefore important; in particular when supported by rotators who add fresh perspectives.	
2. Are both merit review criteria addressed a) In individual reviews? All the individual reviews do an excellent job in addressing the intellectual merit of proposals and the vast majority do an excellent job in providing constructive praise and criticism of the proposed science. Not everybody does equally well commenting on the quality of the Broader Impacts, however and, in fact some reviewers gloss over that component. Furthermore, many reviewers focus more on the scientific impact on society for the Broader Impacts rather than on development of human resources, education, and outreach. While proposals that presented well thought out Broader Impact sections seemed to receive a modest benefit in the panel evaluations, a strong Broader Impact section can result in a positive funding decision for proposals that are on the border. Importantly, for the CAREER awards, the quality of the Broader Impacts have a very substantial impact on the panel evaluations of the submitted proposals. The POs inform each panel of the importance of Broader Impacts and how to weigh them when ranking the proposals. A strong effort should be made to make the weighing of Broader Impacts consistent between panels. The POs have little influence over how extensively the Broader Impacts are used in the proposal rating in the individual reviews that are provided to the panels. Perhaps a stronger statement in the instructions to the reviewers with respect to the Broader Impacts is warranted across the NSF. b) In panel summaries? The two review criteria are explicitly addressed in the panel summary. Often there is more detail as to the specifics of the proposal in the individual reviews. The panels summarize the discussion and are guided in this process by the PO. This assures that the more meritorious proposals receive more positive panel summaries than the less meritorious ones and normalizes the message from the panel to the PI. The panel messages, as a result of this, are somewhat terse and while summarizing the overall consensus (or lack thereof) of the panel often provide less detailed feedback to the PI. But the panel reviews certainly comment on the Broader Impacts and provide important feedback to the PI by highlighting the most important factors in the decision for funding priority. Proposals that have been triaged do not receive a panel summary as they are not discussed by the panel. c) In Program Officer review analyses? The POs write exceptionally clear and detailed summaries to explain why a proposal was or was not funded. They address both the Intellectual Merit and Broader Impacts. For many borderline proposals the review analyses do an extremely effective job of capturing the dynamics of the panel discussion and the PO comments provided to the PI are very helpful in explaining the funding decision and address both intellectual merit and broader impact considerations.	YES

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? In general, all the individual reviewers provide substantive feedback to the PIs of each proposal. The usefulness of the review is a function of the reviewer's experience and knowledge. Reviewers who are experts in the subject can provide very substantive and useful comments, whereas reviewers who are less familiar with the subject typically	YES

give broader, less detailed feedback. For this reason, the correct choice of reviewers is vital for a well-balanced review process. For this reason the presence of experienced POs who know the different communities represented in the SSMC community at large is essential for assuring that the composition of the panels is optimal for the subject matter. This is time consuming and for that reason it is important to keep PO workload reasonable. In a panel, the subject experts typically carry more weight when it comes to assessing the Intellectual Merit and can have a large influence on a panel. In those cases, the PO does solicit additional *ad hoc* reviews to provide breadth and balance in terms of subject matter experts. As mentioned earlier, most reviewers are more focused on the Intellectual Merit of the proposal than the Broader Impacts, and although the PO's often encourage the panel reviewers to expand on that aspect of their reviews, it is up to the community to make sure we are reviewing Broader Impacts in a thoughtful way.	
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? The panel summaries provide the PI with a good rationale for the consensus reached by the panel. In cases where diverse reviews were submitted, the panel does a good job in detailing the arguments for and against funding that were used to arrive at the panel's consensus. The panel summaries of proposals that are weak do not provide as much of a detailed rationale, as there are often too many flaws to list. Overall the panel summaries accurately reflect the proposal quality and the panel ranking (although not numerically listed). Unfortunately, almost 50% of proposals that reviewed well and which the panel liked could not be funded due to insufficient funds. Currently the funding rate is approximately 18%. Even increasing that rate to 35% would not negatively impact the quality of the awards. This assessment is based on our survey of proposals submitted over the past 4 years. The POs do a great job of assisting the panels to accurately document the consensus evaluation, positive or negative, of the proposal, and to make sure that the panel reviews truly reflect the panel discussion and the overall ranking. As mentioned earlier, the proposals that were triaged did not receive a panel summary as there was no panel discussion.	YES
5. Does the documentation in the jacket provide the rationale for the award/decline decision? [Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.] The documents in the jacket were complete and provided a complete picture of the review process of each proposal. The PO in his/her review analysis does an excellent job in summarizing the Intellectual Merit, the Broader Impacts, the panel discussion, and made it very clear why a proposal was funded or not funded. It should be emphasized that there is rarely a single fatal flaw that prevents a proposal from being funded, so in many cases the rationale can seem somewhat vague to the PI, *e.g.,* a research direction needs to be "better motivated". The PO should be prepared to direct the PI to look at individual reviews in order to obtain more specific critiques or examples of what can be improved. There were a few instances where the PO gave the PI a chance to rebut some critiques of the panel, however, it was not clear why or when this was done, as it was only done for a very small number of proposals. This decision should be justified in the POs review analysis.	YES

6. Does the documentation to the PI provide the rationale for the award/decline decision? [Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the basis for a declination.] The panel summaries combined with the individual reviews typically provide excellent feedback to the PI as to why a proposal was awarded or not awarded. This is not true, as mentioned, for triaged proposals, where only the individual reviews are provided to the PI. In these cases, it is essential for the PIs to contact the PO to obtain more insight into the decision.	YES
7. Additional comments on the quality and effectiveness of the program's use of merit review process: The review process works exceedingly well and represents an unbiased and transparent review method. The panel reviews are excellent for providing a fair review and ranking the proposals. However, each panel is unique and for a PI to address the critique from one panel, in particular if a proposal was close to being funded, does not assure that the next panel will rate the science equally high and recommend that the proposal be funded. This is where the role of the PO and the longevity of the PO become very important. The PO provides the institutional memory – in large part via the jackets and in particular via the review analysis from the previous year.	YES

II. Questions concerning the selection of reviewers. Please answer the following questions about the selection of reviewers and provide comments or concerns in the space below the question**.**

SELECTION OF REVIEWERS	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE**
1. Did the program make use of reviewers having appropriate expertise and/or qualifications? The reviewers that are chosen have the appropriate expertise and qualifications. The POs pick strong reviewers and can do so based on their knowledge of the specific research community in SSMC. The PO provides the institutional memory and it is therefore important to have, or if it doesn't exist, create a database of reviewers, their expertise, and a rating of the quality of their reviews. The POs make an effort to reach out to the community by attending conferences to learn about the field and to meet the members of the research community to identify potential reviewers. Providing sufficient time and resources for the POs to attend meetings is therefore imperative. Changing the funding and approval structure by providing a travel allocations to the POs at the beginning of the fiscal year will ensure that they can meet the registration deadlines of meetings that are often far in advance of the meeting taking place.	

2. Did the program recognize and resolve conflicts of interest when appropriate? The program is very proactive in trying to identify COIs and avoiding them. All reviewers and panel members are informed about COIs. This is via e-mail prior to reviewing, as well as through in-person presentations at the panels. There is a consistent, even redundant, effort by the program to avoid conflicts of interest, and it appears that reviewers take this very seriously.	
3. Additional comments on reviewer selection: The high quality of NSF-funded research depends on the review process, which in turn depends on the ability of the POs to pick effective reviewers for *ad hoc* reviews, virtual panels and in-house panels. This requires considerable time and effort, and POs' knowledge of the specific community they serve is essential for maintaining the high standards of NSF proposal reviews.	

III. Questions concerning the management of the program under review. Please comment on the following:

MANAGEMENT OF THE PROGRAM UNDER REVIEW
1. Management of the program. The SSMC program is managed extremely well and has clear goals and objectives. It is a challenging program to manage due to the diversity of research fields that make up SSMC. The materials field is very broad and continues to grow as new phenomena and materials are discovered every year. The PIs whose proposals are funded are extremely productive and generate high impact publications, patents and start-up companies. To maintain the exceedingly high quality of this program it is important to limit the overall workload of the POs to no more than 100 proposals per year. Due to the 50% increase in submitted proposals, this will require hiring an additional PO for the SSMC program, which will ensure that they have the time to effectively manage their portfolio. The SSMC does a very good job of co-reviewing proposals that fall between two program areas and potentially co-funding them when warranted. The POs are very proactive in seeking out opportunities to co-fund proposals. Given budget constraints, this provides additional ways to bring needed resources to the program. The SSMC has two POs, one permanent and one rotator. Given the overall proposal load of almost 300, this places a heavy burden on the POs, in particular when one looks at the significant efforts they expend on each and every proposal – starting with selecting appropriate reviewers, to convening panels, spending time at the panels and completing the Jackets.
2. Responsiveness of the program to emerging research and education opportunities. The SSMC program is responsive to new and emerging areas in so far as they fit into the overall portfolio of the program. The program has been able to fund investigators in emerging areas, *e.g.,* energy storage, organic materials, 2D and hybrid materials. Identification of new research areas is facilitated by the POs' involvement in the community through conference attendance and panels. To augment this informal process, it is important to continue to convene representative groups to help identify future directions of solid state and materials chemistry. Specifically, in order for the POs to identify emerging areas and for SSMC to remain responsive to emerging areas, new educational opportunities, and to pursue cutting edge science, it is necessary that such groups be convened on a regular basis, ideally every 5 years, to generate reports. This will assure that the SSMC POs can identify and be responsive to new emerging areas of relevance to the SSMC program.

The SSMC also does an excellent job of supporting education opportunities by funding conferences and workshops, REU programs, and research grants to primarily undergraduate institutions. An important component of the SSMC program are EAGER awards that are used to support emerging areas and to achieve proof of concept studies of high risk proposals.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

The SSMC program takes full advantage of studies by the National Academy of Sciences to help construct the topical areas of the program and identify emerging new research areas. One significant example is the *Frontiers in Crystalline Matter* 2009 NAS report, which spurred the renewed focus in building crystal growth expertise in the US in order to stay globally competitive. In terms of the "Frontiers of Materials Research" 2019 *Decadal Survey* has helped SSMC focus on emerging areas of materials research, such as high entropy alloys and quantum materials. SSMC POs also make a conscious effort to reach out to the community by attending conferences, learn about the individual research programs of the PIs and others in the materials community. Because of this, the SSMC portfolio is on the leading edge of many of the areas identified by the NAS reports. As an example, the 2019 *Decadal Study* mentioned hybrid and nanocomposite materials as an emerging area. SSMC, however, had already started to support numerous investigators in these areas before the report was published and at present, within SSMC, their science has advanced significantly beyond the state described in the decadal report. Furthermore, these studies provide input to identify mature areas that need less support.

Importantly, as a topically diverse program SSMC has the ability to rapidly adapt to changes in the research landscape and to incorporate new, exciting and promising research directions. This is a particular strength of this program. However, the program would benefit from a more formal process to guide the identification of new research areas and prioritize current efforts, ideally taking advantage of the aforementioned periodic reports on emerging areas relevant to SSMC. For example, there is currently much interest in composite and nano/meso-structured materials. It is worth considering what aspects of this broad field would be supported in the SSMC program. Careful consideration of how SSMC could contribute to the Quantum Leap program is also recommended.

SSMC is a topically diverse program that is grounded in experiment and while computational contributions are welcome and, in fact essential for the success of the program, it is vital that computations are connected to experimental material science. The connection between computation and experiment is essential for validation, as exemplified by the Materials Genome Initiative approach.

4. Responsiveness of program to previous COV comments and recommendations.

DMR has addressed the staffing issues raised in the previous COV study by adding a new PO. However, at the same time the number of proposals has gone up by 50% strongly suggesting that additional staff support is warranted.

The feedback to the PIs is now very complete and they are provided with in-depth analyses of their proposals, both strengths and weaknesses. While the panel summaries provide a sense of the panel discussion and decision-making process, the PO comments, that contain additional details and analyze the main reasons for declination decision, are also shared with the PI.

To help with the change of the panel membership between years, the POs solicit either *ad hoc* reviews from previous panel members or ask some previous panel members to again participate as panel members in the proposal review process.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Are awards appropriate in size and duration for the scope of the projects? The 3 year time frame is generally effective and provides enough time to establish a program and show results. Unfortunately it does not match the graduate student timeframe. The award size of ~$140K/yr is acceptable, however, costs, in particular fringe, has now made it impossible to fund a postdoc on a single PI grant at most universities. Also, the increase in award size is not keeping up with increase in graduate stipend and tuition. Unlike the NIH, the award sizes are "total" dollars and not "direct" funds. This makes it difficult to compare award sizes and how appropriate they are for the PIs. Given a scientific inflation rate of 5%, over 4 years the cost of research has escalated by 20%, while the grant funding level has remained flat. There has been a steady erosion in purchasing power of NSF grants that will eventually become reflected in lower scientific output, especially when compared to other nations (*e.g.,* China) where the inflation-adjusted funding levels are increasing.	Appropriate and in some cases data not available in easy to research form.
2. Please comment on the level of risk in projects supported in the program portfolio and whether awards are innovative or potentially transformative. It is important to fund "new" work, but at least equally important to provide sustained funding for productive groups who are amassing expertise and know-how in specific areas. Often transformative results emerge from a sustained research effort in a more established field that is not described as "high risk". A balance has to be struck between pushing back the boundaries of science and achieving in-depth understanding of science that has already produced preliminary results. The low funding rates and limiting funding levels, combined with the restriction of only being able to submit a single proposal during a given year, has naturally driven the SSMC community to be more conservative in its proposals. In the current climate, it is difficult to obtain funding for high-risk proposals until some proof of concept or preliminary results have been obtained. Given this trend, the SSMC management has done a good job of trying to identify novel and potentially transformative science. The level of innovation in the submitted proposals is generally quite high. The EAGER program provides a mechanism for funding "risky" projects and it would be beneficial to expand funding for this program to make sure that good ideas do not languish for lack of funding.	

3. Does the program portfolio have an appropriate geographical distribution of Principal Investigators and different types of institutions? Accounting for the number of highly research active universities in different states, it seems that the geographical distribution is reasonable. Overall, more than 35 states had active SSMC awards in the 4-year window covered by the report.	YES

4. Does the program portfolio have an appropriate balance of awards to new and early-career investigators? NOTE: A new investigator is an individual who has not served as the PI or Co-PI on any award from NSF (with the exception of doctoral dissertation awards, graduate or post-doctoral fellowships, research planning grants, or conferences, symposia and workshop grants.) An early-career investigator is defined as someone within seven years of receiving his or her last degree at the time of the award. There is no evidence of any bias against new investigators. New investigators submit 11% of all submissions and receive 7% of all awards made. This is an appropriate yield. For early career investigators the data are not available, however, in the case of SSMC it is reasonable to use the CAREER proposals as a proxy for early career investigator success rates. By that metric, the success rate is slightly higher, 20%, compared to the TMRP award success rate of 18%. Again, there is no evidence of any bias. The SSMC has consistently supported new and early career investigators and if one considers repeat submissions, then the eventual award rate reached 50%.	
5. Does the program portfolio have appropriate participation of underrepresented groups[13]? The SSMC program has made a concerted effort to identify underrepresented minority investigators, and their funding success rate is comparable to that of the population as a whole. Given the very low number of proposals from URM investigators, often as low as zero or one, it is not clear that these statistics are very meaningful. Enhanced outreach to the URM scientific community, in the form of conference attendance and invitations to workshops and panels, might improve the number of submissions and help expand the diversity of PIs funded by SSMC.	YES
6. Is the program relevant to national priorities, agency mission, relevant fields and other constituent needs? Include citations of relevant external reports. The SSMC program funds research that directly supports national priorities, including training the advanced materials workforce that is a primary driver of the U.S. economy. The 2019 National Academies *Decadal Study* has estimated that over ¾ of all economic growth in the US from 2020 to 2050 will be attributable to the development of advanced materials. Advanced materials touch every area of the nation's economy, from transportation to energy to manufacturing. New materials are incorporated into medical devices and implants. To enable this economic and societal	

[3] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

impact, SSMC awards support undergraduate, graduate students and postdocs who will join the US workforce in the immediate future. This development of tomorrow's STEM workforce helps sustain the US global leadership in advanced materials. Research funded by SSMC enhances the nation's security via the development of new scintillator materials for radiation detection that can support homeland security. Research funded by SSMC also enhances the economic well-being of the nation via the development of new materials for energy-efficient solid state lighting, the development of new thermoelectric materials, as well as the development of new battery materials for stationary power storage, portable electronics and environmentally friendly, all-electric transportation. Research funded by SSMC to develop new crystal growth methods and grow new materials in single crystal form will help the US sustain global leadership in this important area of material preparation.	

7. Are any emerging research areas missing from the program's portfolio? The SSMC program funds a very large variety of research, from liquid crystals to oxide and organic semiconductors to exotic two-dimensional and topological materials. This breadth of portfolio means that it touches on almost every area of materials research. While there are no obvious gaps in the current portfolio, the field is fast-moving and new directions and opportunities can arise quickly. The program would be well-advised to pay attention to developments in several emerging areas. One such area is reconfigurable materials that can change their properties in response to their environment or an external energy input. A second area is materials that control the placement of potential qubits elements, like electron spins, and control their interactions. Such materials will be of high interest for the construction of quantum computers and other quantum applications. Third, the creation of materials that are structured on multiple length-scales, or that precisely organize multiple components on nanometer length-scales, is an emerging field that lies at the interface between engineering, chemistry, and physics.	
8. Additional comments on the quality of the projects or the balance of the portfolio:	

OTHER TOPICS

1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

For materials science, the importance of state-of-the-art materials characterization equipment, high-speed computer clusters for MGI computations, and instruments to synthesize or characterize materials under extreme conditions, cannot be overstated. This is true for the original acquisition, but applies equally to maintaining, operating and, at a reasonable time interval, replacing outdated equipment. A program that allows faculty to acquire new instruments, for example, to take advantage of new emerging research directions or to replace an outdated piece of equipment in order to remain globally competitive, is needed. Cutting edge research requires a strong foundation of functional equipment. Much of the equipment needed for a materials research lab is too expensive to be included in a TMRP grant, but not expensive enough for the high end major research instrumentation grants. There are no programs currently in the US (within NSF and across other agencies) to fund such acquisitions. China has quadrupled its expenditures on materials research since 2011, which provides them with state-of-the-art equipment not readily available to most US research groups. This situation needs to be remedied immediately in order for the US to be competitive in materials research globally.

2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

Across the world there is broad recognition that new materials yield economic growth, enabling new technologies in fields ranging from medicine to manufacturing. Countries in both Europe and Asia devote increasing funding to focused efforts in new materials, like ceramics and graphene. For example, China has increased its funding for materials research by approximately 400% over the last decade ("Materials science is helping to transform China into a high-tech economy," Nature, 2019). It is critical to increase the DMR budget to maintain the research infrastructure and human capital in the United States, but it is unlikely that funding levels will be able to keep pace with the rapid growth internationally, and in Asia in particular.

Given this increasingly competitive research environment, the NSF as a whole needs to consider how it can maintain the pre-eminent position of the United States in materials research. The solution is for the agency to become more agile in responding to emerging problems and opportunities in materials science. DMR cannot accomplish this by itself. In order to exploit cross-cutting opportunities that arise at the interface between materials and other disciplines, there needs to be a mechanism that enables collaboration and funding for research that spans different areas within MPS. For example, a new frontier is the design of multi-scale materials, from the molecular level to the mesoscale. Successful materials development will require researchers from chemistry and engineering to work together closely to design molecules that can successfully assemble into large arrays. A second example would be the design of new materials for biological implants. Biological scientists can define and model degradation mechanisms that must be resisted by new polymers or surface treatments.

DMR is the ideal division to spearhead such collaborative research, because its program already spans different academic fields, including chemistry, physics and engineering. However, a serious effort to engage other divisions, specifically Physics, Chemistry and Biology, will be necessary to leverage all available scientific expertise to solve grand challenges in materials science. One mechanism to lay the foundation for such collaborations would be the creation of small (2-5 PI) grants that require investigators from different divisions to work together on a materials problem with a well-defined application. Other mechanisms to encourage cross-cutting research efforts that bring together researchers from different areas should also be considered. We think that only a flexible, adaptive approach that breaks down divisional boundaries can maintain the current position of the United States in materials research.

4. Please provide comments on any other issues the COV feels are relevant.

5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

Appendix A: Members of the COV

Alan Ardell	University of California, Los Angeles, Retired
Christopher Bardeen	University of California, Riverside
Kathryn Beers	National Institute of Standards and Technology
David Bishop	Boston University
Rena Bizios	University of Texas, San Antonio
Luigi Colombo	Texas Instruments
Anthony Dinsmore	University of Massachusetts, Amherst
Venkat Ganesan	University of Texas, Austin
Miguel Garcia-Garibay	University of California, Los Angeles
Murray Gibson	Florida A&M-Florida State University
Wendy Goodson	Air Force Research Laboratory
Melissa Hines	Cornell University
Barbara Jones	IBM/ALMADEN
Alamgir Karim	University of Houston
Dimi Katsoulis	Dow Chemical
Robert Konik	Brookhaven National Laboratory
Ilona Kretzschmar	City College of New York
Robert Leheny	John Hopkins University
Michael Lilly	Sandia National Laboratory
Andrea Liu	University of Pennsylvania
Kai Liu	Georgetown University
Cristina Marchetti	University of California, Santa Barbara
John Mitchell	Argonne National Laboratory
Margaret Murnane	Colorado University, Boulder
Sidney Nagel	University of Chicago
Rebecca Peterson	University of Michigan
Dragana Popovic	Florida State University
Amy Prieto	Colorado State University
Karin Rabe	Rutgers University
Ian Robertson	University of Wisconsin
Greg Rohrer	Carnegie Mellon University
Gregory Salamo	University of Arkansas
Brian Sheldon	Brown University
Winston Soboyejo	Worcester Polytechnic Institute
Jesus Velazquez	University of California, Davis
Nancy Washton	Pacific Northwest National Laboratory
Mark Weaver	University of Alabama
Ulrike Wegst	Dartmouth College
Hans-Conrad zur Loye	University of South Carolina
Mary Ellen Zvanut	University of Alabama-Birmingham

Appendix B: Breakout Groups

COV Chair	Melissa Hines	Cornell University
MPSAC liaison	Miguel Garcia-Garibay	University of California, Los Angeles
BMAT	Wendy Goodson	Air Force Research Laboratory
BMAT	Ulrike Wegst	Dartmouth College
CER	Greg Rohrer	Carnegie Mellon University
CER	Brian Sheldon	Brown University
CMMT	Venkat Ganesan	University of Texas, Austin
CMMT	Barbara Jones	IBM/ALMADEN
CMMT	Robert Konik	Brookhaven National Laboratory
CMP	Anthony Dinsmore	University of Massachusetts, Amherst
CMP	Robert Leheny	John Hopkins University
CMP	Sidney Nagel	University of Chicago
CMP	Dragana Popovic	Florida State University
DMREF	John Mitchell	Argonne National Laboratory
DMREF	Karin Rabe	Rutgers University
DMREF	Ian Robertson	University of Wisconsin
DMREF	Jesus Velazquez	University of California, Davis
EPM	Rebecca Peterson	University of Michigan
EPM	Gregory Salamo	University of Arkansas
EPM	Mary Ellen Zvanut	University of Alabama-Birmingham
MMN	Alan Ardell	University of California, Los Angeles, Retired
MMN	Mark Weaver	University of Alabama
MRSEC	David Bishop	Boston University
MRSEC	Andrea Liu	University of Pennsylvania
MRSEC	Kai Liu	Georgetown University
MRSEC	Cristina Marchetti	University of California, Santa Barbara
NaFI	Luigi Colombo	Texas Instruments
NaFI	Michael Lilly	Sandia National Laboratory
NaFI	Margaret Murnane	Colorado University, Boulder
NaFI	Nancy Washton	Pacific Northwest National Laboratory
POL	Kathryn Beers	National Institute of Standards and Technology
POL	Alamgir Karim	University of Houston
POL	Dimi Katsoulis	Dow Chemical
PREM	Rena Bizios	University of Texas, San Antonio
PREM	Murray Gibson	Florida A&M-Florida State University
PREM	Ilona Kretzschmar	City College of New York
PREM	Winston Soboyejo	Worcester Polytechnic Institute
SSMC	Christopher Bardeen	University of California, Riverside
SSMC	Amy Prieto	Colorado State University
SSMC	Hans-Conrad zur Loye	University of South Carolina

Appendix C: Charge to Committee

Division of Materials Research – Charge to 2019 Committee of Visitors (COV)

By NSF policy, each program that awards grants and cooperative agreements must be reviewed at four-year intervals by a COV comprised of qualified external experts. NSF relies on their judgment to maintain high standards of program management, to provide advice for continuous improvement of NSF performance, and to ensure openness to the research and education community served by the Foundation. Reports generated by COVs are used in assessing agency progress in order to meet government-wide performance reporting requirements and are made available to the public.

The COV is charged to address and prepare a report on:

- ! the integrity and efficacy of processes used to solicit, review, recommend, and document proposal actions;
- ! the quality and significance of the results of the Division's programmatic investments;
- ! the relationship between award decisions, program goals, and Foundation-wide programs and strategic goals;
- ! the Division's balance, priorities, and future directions;
- ! the Division's response to the prior COV report of 2015; and
- ! any other issues that the COV feels are relevant to the review.

The COV report is made available to the public to ensure openness to the research and education community served by the Foundation.

Decisions to award or decline proposals are ultimately based on the informed judgment of NSF staff, based on evaluations by qualified reviewers who reflect the breadth and diversity of the proposed activities and the community. Systematic examination by the COV of a wide range of funding decisions provides an independent mechanism for monitoring and evaluating the overall quality of the Division's decisions on proposals, program management and processes, and results.

The review will assess operations of individual programs in DMR as well as the Division as a whole for four fiscal years: FY 2015, FY 2016, FY 2017, and FY 2018. The DMR programs under review include:

- ! Biomaterials
- ! Ceramics
- ! Condensed Matter and Materials Physics
- ! Condensed Matter Physics
- ! Crosscutting Activities in Materials Research
- ! Designing Materials to Revolutionize and Engineer our Future
- ! Electronic and Photonic Materials
- Materials Innovation Platforms
- Materials Research Science and Engineering Centers
- Metals and Metallic Nanostructures
- Solid State and Materials Chemistry
- National Facilities and Instrumentation
- Partnerships for Research and Education in Materials
- Polymers

Appendix D: Meeting Agenda

WEDNESDAY, SEPTEMBER 11, 2019 – (Embassy Suites – Virginia Salon Meeting Room)

7:30 am	Morning Refreshment
8:00 am	Welcome & Introduce COV Chair Linda Sapochak, Division Director, DMR Melissa Hines, Chair DMR COV
8:10 am	Overview of COI Policies Tomasz Durakiewicz, Staff Associate, Mathematical and Physical Sciences
8:25 am	Charge to the Committee of Visitors Anne Kinney, Assistant Director, Mathematical and Physical Sciences
8:35 am	Overview of Division Linda Sapochak, Division Director, DMR
9:50 am	Staff Environment & Activities Velma Lawson, Program Support Manager, DMR
10:05 am	COV Chair Explains Agenda and Tasks
10:15 am	Coffee Break
10:30 am	Program Review COV assembles into 6 breakout groups in breakout rooms Introduction to Programs by Program Directors
12:30 pm	Working Lunch (Review Jackets and Ask Questions)
1:30 pm	COV Reviews Jackets in Breakout Groups
3:30 pm	Coffee Break
3:45 pm	Finish Reading and Taking Notes
5:30 pm	Adjourn

THURSDAY, SEPTEMBER 12, 2019 – (Embassy Suites)

8:00 am	Morning Refreshment
8:30 am	COV Prepares Reports in Breakout Groups
10:30 am	Coffee Break
10:45 am	Breakout Groups Complete Draft Reports
12:00 pm	Group Discussion on Part 4 (Working Lunch)
1:00 pm	COV Prepares Reports in Breakout Groups
3:00 pm	Coffee Break
3:30 pm	COV Prepares Reports in Breakout Groups
6:00 pm	Adjourn

FRIDAY, SEPTEMBER 13, 2019 – (National Science Foundation Room E2020)

8:00 am	Morning Refreshment
8:30 am	Group Discussion on Key Recommendations
10:00 am	Coffee Break
12:00 pm	Working Lunch (Prepare for Briefing the AD)
1:00 pm	Meeting with Anne Kinney, Assistant Director, Mathematical and Physical Sciences
2:00 pm	Close

Appendix E: Materials Reviewed by Breakout Groups

Date of COV: September 11-13, 2019
Program/Cluster/Section: National Facilities and Instrumentation (NaFI)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 17 **Awards: 5** **Declinations: 12** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 5** **Declinations: 43** **Other:**
Manner in which reviewed actions were selected: **10 Randomly selected proposals; 7 manually selected proposals**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Materials Research Science and Engineering Centers
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: **Awards: 6 full proposals** **Declinations: 10 full proposals** **Other: 10 preliminary proposals**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 8 full proposals** **Declinations: 10 full proposals** **Other:**
Manner in which reviewed actions were selected: **All full proposals submitted to program during period under review, only excluding conflicted proposals**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Partnership for Research and Education in Materials (PREM)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 33 **Awards: 12** **Declinations: 21** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 20** **Declinations: 36** **Other:**
Manner in which reviewed actions were selected: **All proposals submitted to program during period under review, only excluding conflicted proposals**

Date of COV: September 11-13, 2019
Program/Cluster/Section: **Designing Materials to Revolutionize and Engineer or Future (DMREF)**
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 98 **Awards: 20** **Declinations: 78** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 92** **Declinations: 686** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Biomaterials (BMAT)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 146 **Awards: 42** **Declinations: 102** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 192** **Declinations: 983** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Ceramics (CER)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 56 **Awards: 15** **Declinations: 41** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 111** **Declinations: 334** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Condensed Matter and Materials Theory (CMMT)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 117 **Awards: 34** **Declinations: 83** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 254** **Declinations: 691** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Condensed Matter Physics (CMP)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 148 **Awards: 51** **Declinations: 97** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 316** **Declinations: 915** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Electronic/Photonic Materials (EPM)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 144 **Awards: 43** **Declinations: 101** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 230** **Declinations: 938** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Metal and Metallic Nanostructures
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 74 **Awards: 22** **Declinations: 52** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 119** **Declinations: 460** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Polymers (POL)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 69 **Awards: 25** **Declinations: 44** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 147** **Declinations: 408** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**

Date of COV: September 11-13, 2019
Program/Cluster/Section: Solid State and Materials Chemistry (SSMC)
Division: Division of Materials Research
Directorate: Mathematical and Physical Sciences
Number of actions reviewed: 116 **Awards: 33** **Declinations: 83** **Other:**
Total number of actions within Program/Cluster/Division during period under review: **Awards: 168** **Declinations: 755** **Other:**
Manner in which reviewed actions were selected: **10% Random selection and 2.5% Manual Selection based on proposal categories**