EXECUTIVE SUMMARY

Logistics:

The Committee of Visitors (COV) met on July 7-8, 2015 to review programs in the Civil, Mechanical and Manufacturing Innovation (CMMI) Division in the Directorate for Engineering. The review covered the three years of FY12-FY-14. During the review, the COV evaluated 180 jackets (proposal actions) that were randomly selected over the three-year time period.

This meeting was preceded by a CMMI COV Kick-off meeting that was held on May 12, 2015 where oral presentations of the programs and processes were provided by the Division Director, Dr. Deborah Goodings, the Deputy Division Director, Dr. George Hazlerigg, and the CMMI Program Directors. To facilitate the work of the COV, the CMMI Division created a workbook that included copies of all the presentations made that day, the CMMI 2015 COV Report Template and a CMMI 2015 COV Self-Study Data Book to use in conjunction with the sampled jackets. Complementing the COV Report Template, the Data Book presented data, definitions and explanations that the COV found useful in evaluating merit review and program management processes from the period under review (FY12-FY14). Each section of the Data Book directly related to a question in the template, thus making it easy to use. In keeping with the charge to the COV, the data provided in the Self-Study presented primarily retrospective information. Finally, the 2012 COV report and the Division response to that COV were also provided at the Kick-off meeting.

This 2015 COV report follows the 2015 NSF template for COV Reviews. Part I addresses the quality and effectiveness of the program's use of the merit review process, Part II addresses the selection of reviewers, Part III addresses the management of the program under review, and Part IV answers questions about the portfolio of awards. The COV report concludes with comments and recommendations under Other Topics regarding division and agency-wide issues that might be addressed by NSF to help improve the program's performance.

Research:

Research supported by the Division is critical to our international competitiveness in engineering, science and technological innovation and to the development of the future generation of researchers. In particular, research funded by CMMI plays a central role in the advancement of national priorities for domestic manufacturing, the mitigation of evolving hazards, and the development of systems-based solutions for a broad range of techno-societal issues. This is also reflected in its current organization of research exploration and activities around four major clusters: advanced manufacturing; mechanics and engineering materials; resilient and sustainable infrastructures; and operations, design, and dynamical systems.

The Division's proactive engagement in cross-cutting programs and initiatives with other NSF Divisions and other agencies (such as NIST, DOE, DOD, EPA) and industry over the last three years have helped diversify the research breadth of CMMI and have inspired new research frontiers in engineering and science. Examples of CMMI-led cross-cutting initiatives include: a) Scalable Nanomanufacturing (SNM); a CMMI-led component of the National Nanotechnology Initiative (NNI), b) Designing Material to Revolutionize and Engineer our Future (DMREF); a component of the Materials Genome Initiative for Global Competitiveness, and c) Critical Resilient Interdependent Infrastructure Systems and

Processes (CRISP); a CMMI-led NSF program that evolved from RIPS EFRI topic. Other examples of involvement in cross-disciplinary research efforts include the Division's active participation in Cyber-Physical Systems (CPS), the National Robotics Initiative (NRI), the Science, Engineering and Education for Sustainability (SEES) program, the Smart and Connected Health (SCH) program and various others. The breadth of these activities and applications extend well beyond the prior domains of CMMI programs and have made the Division a vital player in NSF's quest to address issues of national priority.

CMMI's investment in large-scale research investment is also unique within the Engineering Directorate, having been the primary home of the Network for Earthquake Engineering and Simulation (NEES) since its inception in 2000. This CMMI investment of approximately $262.9M in NEES since its inception, represents a bold, innovative investment in research infrastructure that enables the exploration, design and testing of the extraordinarily difficult problem of constructing buildings to withstand the destructive forces of earthquakes in zones of recurring seismic risk. The major future challenge identified by this COV is determining the appropriate mix of investment in construction, maintenance, management, allocation of use, and training for NEES. In particular, determining who will maintain this infrastructure, at what cost, and how this cost will be shared by those who use and benefit from it, represent major sustainability questions that will soon need to be addressed by CMMI and NSF going forward.

Management:

The Division is also to be complimented for its continued successful management of its core programs and CAREER, RAPID and EAGER programs, and for the tremendous impact on research, education and technology transfer it has had through these programs. The COV was very impressed by the active and thoughtful management, organization and new initiatives of the CMMI Division. We commend the Division Director on the outstanding team she has assembled. All processes are well managed, staff morale also appears to be high and the leadership and enthusiasm of the Division Director, Deputy Division Director and the Program Directors help keep CMMI at the forefront of engineering and science.

Program management is both professional and collaborative. The collaborative nature of the CMMI management is evident from the work that is shared within clusters and across clusters, from the coherent structuring of programs within each cluster, and from the relation among programs across clusters. Importantly, many of the program descriptions emphasize links to other divisions. The organization of CMMI clearly encourages proposals with multi-disciplinary and cross-disciplinary dimensions. The combination of permanent and rotating Program Directors provides a critical balance of continuity and fresh perspectives.

As far as portfolio award size and distribution, the COV recognizes that CMMI faces significant challenges in trying to balance among the often-competing overall goals of the division. While it is difficult to formulate and assess what the right size and distribution should be, the overall balance of the CMMI division portfolio appears to be reasonable and appropriate. Regarding the CAREER award investment, the COV noted that in response to the recent increase in the minimum CAREER award amount from $400k to $500k, the total CMMI funding for CAREER awards increased by $4.5M compared to 2014 with the number of awards remaining about the same. Given the very positive impact that this award has on a young faculty member's career, compared to other awards, the COV recommends that CMMI maintain its current total CAREER award amount.

Other observations and recommendations:

The COV's observations and recommendations about new issues or derivative issues from actions taken in the past three years are presented below, in no particular order:

1. CMMI Leadership Opportunities

   Research funded by CMMI plays a central role in the advancement of national priorities for domestic manufacturing. Advanced manufacturing has received much recent attention and activity including significant support by the White House through its NNMI and related initiatives. It is expected that this area, including obtaining a fundamental understanding of additive manufacturing and its most appropriate application domains, will continue to expand. CMMI is in an excellent position to take the lead in NSF, both internally and in its interactions with the evolution of the NNMI's, due to its clear focus on advanced manufacturing as part f its core programs.

   Research funded by CMMI also plays a central role in the mitigation of evolving hazards, and the development of systems-based solutions for a broad range of techno-societal issues. Similar to advanced manufacturing, CMMI is uniquely positioned to chart a national course for resiliency and sustainability in the 21st century and should also be NSF's leader in this area.

   Undergraduate enrollment in mechanical engineering programs is growing rapidly across the country. Given that mechanical engineering is one of the least popular choices of engineering majors for women, efforts directed at broadening participation are necessary. Identifying best practices and partnering with related efforts for broadening participation and implementing these practices will be critical to meeting the high demand for mechanical engineers in industry. Due to its focus on mechanical systems and mechanics and involvement of many mechanical engineering researchers, CMMI should assume a leadership role in this area and seek collaboration with relevant partners.

2. Responsiveness to previous COV comments and recommendations

   CMMI provided the 2012 COV comments and recommendations and their responses to this COV.

   a) While CMMI is exploring various alternatives to in-person panel reviews (as emphasized by the 2012 COV), it has continued primarily with in-person panels while also meeting travel budget restrictions. This COV was not able to assess whether alternative approaches (e.g., virtual panels and the mechanism design approach) were as effective as in-person panels.
   b) CMMI program management recognizes the importance of helping researchers submit high quality proposals, establishing diversity in the reviewer pool, and balancing support for core area versus new initiatives.
   c) The 2015 COV finds that some of the challenges/concerns in the 2012 COV still persist and deserve continued attention.

3. Understanding the Broader Impact Merit Review Criteria

   The COV found that there was far more attention placed on Intellectual Merit than Broader Impacts in the reviewer evaluations. The lack of in-depth comments regarding the broader impacts of the proposed research is an indication that the overall Broader Impacts definition is still not well understood by many of the reviewers.

   The COV also feels that it should be made clear whether novelty of Broader Impacts is a requirement for proposal success. Reviewers did not seem to understand whether NSF desires innovative or effective efforts to satisfy Broader Impacts requirements. Some proposals were discounted by reviewers for lacking novelty in Broader Impacts; a well-executed, but standard, outreach plan was seen as a negative, when it might have significant impact by reaching many individuals using established best practices.

   In summary, there is still a lack of understanding and confusion in the community regarding the Broader Impacts criteria. Communicating clear guidelines for the evaluation of Broader Impacts is still needed to improve panel reviews. Specific recommendations to assist with this guidance are provided in the "Other Topics" section of this COV report.

4. Benchmarking and Best Practices

   The COV suggests a comparison of CMMI approaches to other NSF divisions, as well as comparable national/international funding agencies and private foundations. This benchmarking could highlight both strengths and weaknesses and provides assessments of program impacts. The COV also recommends that metrics be defined that represent the success of a particular program, including both Intellectual Merit and Broader Impacts. In order to assure consistency between programs, the COV recommends that best practices be captured and made readily accessible to new and existing program directors on an on-going basis. More details on all these comments are provided in the "Other Topics" section of this COV report.

5. CMMI Grantees Conference

   One agency-wide issue discussed by the COV was the importance of Program Director visibility within the research community. Personal interactions with both new proposers and funded investigators are important for the program's relevance and mission. While individual investigators may visit NSF to achieve this goal, the COV strongly recommends re-implementing the CMMI grantees conference as a much more effective way of achieving this end. This conference strengthens CMMI by clearly communicating program goals, supporting high-quality proposal submission, and developing community through informal interactions among between Program Directors, PIs, graduate students and relevant industry participants. Based on the discussions at the COV July 7-8 meeting, it was understood that the primary obstacle to this re-implementing this conference is government-wide travel restrictions, including size and budget. Nonetheless, this COV has no doubt that not having this conference is negatively impacting the ability of CMMI to carry out its mission.

CORE QUESTIONS and REPORT TEMPLATE
for
FY 2015 NSF COMMITTEE OF VISITOR (COV) REVIEWS

Guidance to NSF Staff: This document includes the FY 2015 set of Core Questions and the COV Report Template for use by NSF staff when preparing and conducting COVs during FY 2015. Specific guidance for NSF staff describing the COV review process is described in the "COV Reviews" section of NSF's Administrative Policies and Procedures which can be obtained at https://inside.nsf.gov/aboutnsf/hownsfworks/rolesresponsibilities/Pages/Committee-of-Visitors.aspx [1] .

NSF relies on the judgment of external experts 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. Committee of Visitor (COV) reviews provide NSF with external expert judgments in two areas: (1) assessments of the quality and integrity of program operations and program-level technical and (2) managerial matters pertaining to proposal decisions.

The program(s) under review may include several sub-activities as well as NSF-wide activities. The directorate or division may instruct the COV to provide answers addressing a cluster or group of programs – a portfolio of activities integrated as a whole – or to provide answers specific to the sub-activities of the program, with the latter requiring more time but providing more detailed information.

The Division or Directorate may choose to add questions relevant to the activities under review. NSF staff should work with the COV members in advance of the meeting to provide them with the report template, organized background materials, and to identify questions/goals that apply to the program(s) under review.

Suggested sources of information for COVs to consider are provided for each item. As indicated, a resource for NSF staff preparing data for COVs is the Enterprise Information System (EIS) – Web COV module, which can be accessed by NSF staff only at http://budg-eis-01/eisportal/default.aspx. In addition, NSF staff preparing for the COV should consider other sources of information, as appropriate for the programs under review.

Guidance to the COV: The COV report should provide a balanced assessment of NSF's performance in the integrity and efficiency of the ***processes*** related to proposal review. Discussions leading to answers of the Core Questions will require study of confidential material such as declined proposals and reviewer comments. ***COV reports should not contain confidential material or specific information about declined proposals.*** The reports generated by COVs are made available to the public.

We encourage COV members to provide comments to NSF on how to improve in all areas, as well as suggestions for the COV process, format, and questions. For past COV reports, please see http://www.nsf.gov/od/oia/activities/cov/covs.jsp.

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[1] The COV Reviews section has three parts: (1) Policy, (2) Procedures, and (3) Roles & Responsibilities.

FY 2015 REPORT TEMPLATE FOR
NSF COMMITTEES OF VISITORS (COVs)

Date of COV: July 7-8, 2015

Program/Cluster/Section: All

Division: Civil, Mechanical, and Manufacturing Innovation (CMMI)

Directorate: Engineering

Number of actions reviewed:

Awards: 84

Declinations: 84

Other: 12

Total number of actions within Program/Cluster/Division during period under review:

Awards: 1,643

Declinations: 8,527

Other: 1,008

Manner in which reviewed actions were selected: Stratified Random Sample

Jackets were randomly selected to include the desired distribution of awards, declinations, and returned proposals within each cluster across the 3 fiscal years under review. Another set of jackets were randomly selected to include the desired distribution of awards, declinations, and returned proposals for special initiatives including scalable nanomanufacturing, cyber-physical systems, etc. Two adjustment jackets were selected for each fiscal year to provide geographic or demographic balance as needed. COV members were notified that additional jackets were available upon request, however no additional jackets were requested.

Total: 84 DECs, 84 AWDs, 12 RWRs = 180 jackets, 15 jackets per COV reviewer, 1.6% of reviewable jackets in CMMI FY 2012-2014

	2012	2013	2014
AM	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR
MEM	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR
RSI	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR
ODDS	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR	6 DECs, 6 AWDs, 1 RWR
Special Programs	3 DECs, 3 AWDs	3 DECs, 3 AWDs	3 DECs, 3 AWDs
Adjustment	1 DEC, 1 AWD	1 DEC, 1 AWD	1 DEC, 1 AWD

Date of program portfolio review:

CMMI COV Kick-off on May 12, 2015; with COV Meeting July 7-8, 2015

COV Membership

	Name	Affiliation
COV Chair or Co-Chairs:	Louis Martin-Vega, Chair	North Carolina State University
	Tony Schmitz, Co-Chair	University of North Carolina at Charlotte
COV Members:	Andrew Alleyne	University of Illinois at Urbana-Champaign
	Anant Balakrishnan	The University of Texas at Austin
	Trevor Harding	California Polytechnic State University, San Luis Obispo
	Winston Soboyejo	Princeton University
	Mary Frecker	The Pennsylvania State University
	Mary Roth	Lafayette College
	Louise Comfort	University of Pittsburgh
	Henri Gavin	Duke University
	Albert Wavering	National Institute of Standards and Technology
	Elijah Kannatey-Asibu Jr.	University of Michigan
	Virginia Davis	Auburn University

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, and withdrawals) that were *completed within the past three 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? Comments: The review process was found to be appropriate. It included external reviews where required, program director assessments, and panel summaries. Proposals received multiple reviews when warranted. Proposals that did not meet the criteria for submission (e.g., missing Broader Impacts or submitted late) were returned without review in accordance with NSF policy. In our evaluation, the clearly-stated policies for returning proposals without review were followed. In general, the review methods were appropriate with multiple perspectives applied to establish the recommendation for each proposal. There was, however, a distribution of details provided by the individual reviewers, i.e., some were more detailed than others. The COV believes that an absolute uniformity of detail would be difficult to achieve and the observed variation, while less than desirable, was still acceptable. The panel summaries were more representative of the overall decision and the variation in detail level was less than that of the individual reviewers. The panel summaries were well-written and clearly conveyed the overall panel sentiment, which included input from the panelists who provided individual written reviews. It was found that the virtual panels provided a similar level of detail in PI feedback as the in-person panels for the small number of virtual panel jackets examined. This could be because domain experts were identified to serve in this capacity. While this is a positive outcome, the COV feels that the virtual	YES

panels should be used as a supplement rather than a replacement for the in-person panels. Should a significant number of panels be held virtually, the loss of personal interactions made possible by the in-person panels could degrade the consistent selection of the best proposals. If virtual panels are used sparingly, they could be a good tool for the effective program director. However, the majority of panels should remain in-person. There was little difference in efficacy, from the perspective of overall assessment, between the one-day and two-day panels. The choice of panel duration should be left to the discretion of the program director based on the panel requirements. Approximately 30% of panel reviews in 2014 were hybrid meetings, a combination of in-person and virtual presence (30% of meetings in that year were fully virtual and 40% were fully in-person meetings). Within this paradigm, NSF may wish to examine hybrid models where all proposals are evaluated virtually initially, but the panel then gathers for one day to discuss those that warrant consideration for funding. Data Source: EIS/Type of Review Module	
2. Are both merit review criteria addressed **a) in individual reviews?** **b) in panel summaries?** **c) in Program Officer review analyses?** Comments: Similar to the distribution in individual review detail from Question 1, there was also variation in the focus on the merit criteria. Most reviews, panel summaries, and program director analyses considered Broader Impacts and Intellectual Merit. In some individual reviews, however, the Broader Impacts and Intellectual Merit were not explicitly identified separately. Additionally, in a few cases there was no mention of Broader Impacts. Overall, there was far more attention placed on Intellectual Merit than Broader Impacts in the reviewer evaluations. This may be because typical reviewers are more comfortable evaluating Intellectual Merit. That said, the lack of in-depth comments regarding the broader impacts of the proposed research is an indication that the overall Broader Impacts definition is not well understood by many of the reviewers. While they are generally well-trained in STEM fields, most have less experience with Broader Impacts evaluation; this is demonstrated in the reviews. NSF may wish to consider publishing clear guidelines for Broader Impacts definition and for assessing content in the Broader Impacts category.	YES

Additionally, it should be made clear whether novelty of Broader Impacts is a requirement for proposal success. Effective implementation of best practices could be considered acceptable, for example. Reviewers did not seem to understand whether NSF desires innovative or effective efforts to satisfy Broader Impacts requirements. Some proposals were discounted by reviewers for lacking novelty in Broader Impacts; a well-executed, but standard, outreach plan was seen as negative, when it might have had significant impact by reaching many individuals using established best practices. In summary, there is still confusion in the community. The program directors effectively synthesize the panel recommendations and input. Their attention to the program, including the flexibility to consider quality proposals that were not top ranked for funding, is to be lauded. Data Source: Jackets	

3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? Comments: Overall, the collective feedback from the reviewers is substantial and useful, particularly for Intellectual Merit with some variation among reviewers in the level of detail. However, the detail in the individual evaluations tends to correlate with the proposal rating. The individual reviews may change during the course of panel discussions, so the reviews were interpreted together with the panel summary to provide an appropriate proposal assessment. The comments provided, particularly those with significant depth, offered a high level of expertise. Based on the comments, the COV concluded that the reviewers were well versed in the technical content of the proposal and its impacts. For several collaborative proposals that spanned disciplines, the reviewers were drawn from multiple disciplines to provide appropriate feedback. While the comments were substantive overall, the level of comments on the Broader Impacts could be improved for most of the proposals evaluated. In addition, summary statements were not provided in several of the individual reviews. Overall, most jackets contained substantial panel reviews; those with less detail generally corresponded to lower ranked proposals. Proposals recommended for funding had a uniformly high level of detail for the individual reviews, the panel summaries, and the review analyses complete by the program director. Data Source: Jackets	YES
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? Comments: Overall, the panel summaries provided strong rationale for the panel consensus. In some cases, panels were careful to reflect on both the strengths and weaknesses of the proposal providing valuable feedback to the PIs, though this was not the case for all panel summaries. Panel summaries also reflected the individual reviews with some natural divergence due to the dynamic process of panel deliberation. This divergence is to be expected and is the result of the important dialogue between reviewers. The quality of the panel summaries was, in general, sufficiently high and provided both the rationale for the panel's decision and a balance of strengths and weaknesses. Panel summaries addressed both Intellectual Merit and Broader Impacts of the proposed work. However, more emphasis was often placed on Intellectual Merit.	YES

It was noted that in some isolated cases the panel summaries only stated whether the proposal was competitive or not, depriving the PI of possible feedback from the panel. In one of the jackets reviewed, no panel summary was submitted or approved and no indication for this lack of a panel summary could be derived from the Review Analysis from the program director. It is understood there is no requirement for each proposal placed on a panel to be discussed (Chapter V.D.4 of the NSF Proposal and Award Manual). However, the result of this regulation is that some researchers do not get the benefit of discussion from the panel members and that may put those researchers at a further disadvantage when applying for future support. Data Source: Jackets	
5. Does the documentation in the jacket provide the rationale for the award/decline decision? Comments: Program directors demonstrated clear and in-depth knowledge of the proposal under consideration. Their review analyses included details about the program, the review process, and a summary of the individual reviewers' scores for the proposal. The program directors' summaries of the panel discussions were often more detailed and insightful than the panel summaries. Program directors were careful to address both merit review criteria. Review analyses were clearly written and thorough. In one case from the sampled jackets, the review analysis was found to be deficient; the program director failed to adequately address both merit review criteria and provided no strengths or weaknesses of the proposal. In another case, the program director provided a thorough review analysis, but provided no rationale for a reduced project budget. Data Source: Jackets	YES

6. Does the documentation to the PI provide the rationale for the award/decline decision? Comments: Clear and substantive feedback to PIs is important for providing evidence to the PI that the review process was fair and reasonable and for providing guidance to the PI that enables the improvement of future proposals. The documentation to the PIs in the jackets reviewed was, in almost all cases, thorough and provided a sound basis for the decision. There were two areas in which some jackets provided insufficient feedback to the PI: details concerning Broader Impacts and information regarding the rationale for a decline decision. As noted in the response to Question 1, feedback to PIs concerning Broader Impacts is generally less substantive than feedback concerning Intellectual Merit. Individual reviews and panel summaries in general provided less information regarding discussions and rationale concerning Broader Impacts and comments that were provided, e.g., lack of innovation, did not provide guidance to the PI for improving future proposals. With respect to information provided with a decision to decline funding, there were a few jackets where the rationale focused on ranking alone. In these jackets, insufficient information was provided to the PI regarding how this specific proposal could have been improved such that it would have been more competitive. Although the level of detail in individual reviews and panel summaries varied, the combined package of information provided to proposers established sufficient rationale for the award/decline decision. Data Source: Jackets	YES
7. Additional comments on the quality and effectiveness of the program's use of merit review process. The Broader Impacts definition is apparently ambiguous to some reviewers. NSF may wish to consider publishing clearer guidelines on expectations for Broader Impacts. These should include whether novelty is a requirement for proposal success. For example, creating novel educational components may be valuable, but it is not clear that it should be a requirement for successful proposals. Effective implementation of best practices may be an acceptable target, for example.	

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? Comments: Overall the reviewer selection process is effective. Through a review of the proposals and reviewer comments, as well as the program directors' analyses, it was evident that significant effort and careful consideration were applied in the reviewer selection process. Every effort was made to include reviewers with the appropriate technical background necessary to evaluate each proposal. While there are limitations imposed by the number of reviewers that could be on any given panel and the diversity of technical fields addressed in the proposals, the COV believes that the majority of proposals was reviewed by personnel with the necessary expertise. A general weakness, however, was multi-disciplinary proposals, where additional care must be exercised to retain reviewers with adequate expertise in the relevant fields, including those outside traditional engineering disciplines. The COV used several categories to analyze the selection of reviewers. Specifically, gender, ethnicity, institution type, geographical location, conflict of interest, reviewer background (industry or academia), the rating given to the proposal, the reviewer's department, and reviewer's specific discipline were considered. The discussion that follows considers the distribution of panelists, taking into account as many of these categories as possible, based on available data. An example proposal set of 15 is discussed here for demonstration purposes. From this randomly selected set, one was returned and one was reviewed by the program director (EAGER). Six of the proposals were submitted in 2012, five in 2013, and four in 2014. The panel sizes ranged from 4 to 12 with a mode of 8 and mean of 7.7. The proposal types were: CAREER (1), EAGER (1), GOALI (1), collaborative (5), and unsolicited (7). A total of 100 panelists reviewed the 15 proposals. Of these, 20 were female (20%), five were unknown, and the remainder were male. The number of female reviewers per panel ranged from 0 to 4. Of the 13 panels, four had no female participants. This sample is representative of CMMI as a whole. Regarding institution type, one panelist was from a national laboratory (Sandia National	YES

Lab) and four were from industry. This established a 95% participation by reviewers from academia. Generally, each proposal was handled by a reasonable number of reviewers, with an average of three or four reviewers for each proposal. State representations on the panels were generally diverse. Ethnicity information was sparse for the reviewers because only approximately half provided the necessary data.	
2. Did the program recognize and resolve conflicts of interest when appropriate? Comments: All instances of conflict of interest were appropriately resolved for the proposals considered by the COV.	YES
Additional comments on reviewer selection: Based on this limited sample set and given the importance of innovation and commercialization, the COV recommends that additional effort be applied to recruiting reviewers from national laboratories and industry.	

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.

Comments:

Consistent with the findings of the previous COV, program management is both professional and collaborative. The collaborative nature of the CMMI management is evident from the work that is shared within clusters and across clusters, from the coherent structuring of programs within each cluster, and from the relation among programs across clusters. Importantly, many of the program descriptions emphasize links to other divisions (e.g., DMR, ECCS, BCS, and CBET), cross-cutting programs, and other agencies (NIST, FEMA, FHWA, and USGS). The organization of CMMI clearly encourages proposals with multi-disciplinary and cross-disciplinary dimensions. The combination of permanent and rotating program managers provides a critical balance of continuity and fresh perspectives. CMMI has undergone significant restructuring from 2012-2014 and changes continued into 2015. For example, in FY 2013 the Materials Engineering & Processing (MEP) program was formed by the combination of Materials & Surface Engineering and Structural Materials & Mechanics. Additional reorganization details are provided in response to Question 3.

From 2012-2014, 12 program managers rotated out of service and 10 program managers rotated into service. During this time the division handled the reviews for 11,916 proposals and awarded 1,643 grants. Within each program, the number of proposals varied by 15% to 30% from year to year; the total number of proposals for this COV period is about the same as from the previous COV period (2009-2011). The number of CAREER proposals submitted and awarded was also consistent (300 and 45). The award rate for CAREER proposals is close to the net division rate. In the MEM program, however, the number of proposals increased by 136% from 2013 to 2014. This increase is attributed to growing interest in additive manufacturing.

The RAPID and EAGER programs continue to enable quick response to unique research opportunities and the exploration of high-risk concepts. The RAPID program supported investigations related to hurricanes, tornados, typhoons, earthquakes, and industrial accidents in the US and globally. Once NHERI grants are funded, ENH will also see an increase in proposals associated with NHERI facilities. From 2005 to 2014, the number of proposals managed by CMMI increased by 38%, while the number of awards increased by 16%. The success rate has decreased slightly.

The sample of jackets reviewed by the COV included reviews, panel summaries, and the program managers' review analyses. The review analyses draw from a careful reading of the proposal, reviews, and panel summaries – even for proposals that were not recommended and not funded. These review analyses demonstrate the program managers' thoroughness.

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

Comments:

CMMI uses the RAPID program to fund research on urgent problems or in highly transient environments, such as those following natural disasters. This mechanism has funded studies to collect perishable data and to assess the impacts of extreme environmental loads.

CMMI funds innovative and exploratory research with potentially high impact through the EAGER program. Prior to 2009, work of this type was funded through the SGER program. EAGER replaced SGER, although some SGER grants continued until the end of the award period. Ninety EAGER grants totaling $10.3M were awarded from 2012 to 2014, as compared to 171 EAGER and SGER awards totaling $13.6M from 2009 to 2011 and 180 SGER awards totaling $9.1M from 2006 to 2008. EAGER budgets are about twice as large as the former SGER budgets and enable more substantive work to be completed (the maximum amount for EAGER is $300k, while the maximum amount for SGER was $200k). An outcome of the division's commitment for leadership in supporting emerging and transformative research is the division's reorganization; see the Question 3 comments.

The division responds to emerging research within the regular unsolicited proposal program through workshops and other resources to craft research agendas within each program. Upon reviewing the list of workshops in the program descriptions, the COV felt that these workshops were somewhat narrowly focused, perhaps based on the expertise of the workshop PIs. Moreover, the COV was not able to access reports from some of the workshops and, therefore, could not assess the outcomes in terms of any emerging research opportunities that were identified. Since engagement of the broader research community is vital for identifying emerging research, the COV suggests that the division develop a coherent strategy for such proactive efforts and also broadly disseminate the main discussion thrusts to the research community.

Finally, in response to the Question 2 title "Responsiveness of the program to emerging research and *education* opportunities", the materials reviewed by the committee contained little or no information on the topic of emerging opportunities in education. A lack of information was also noted on CMMI's encouragement of proposals with substantive content related to innovations in education.

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

Comments:

The planning and prioritization of research and education opportunities in CMMI are informed by a combination of workshops, the NRC, the NAE, strong working relationships between CMMI staff and directors of other divisions and agencies, and the expertise of the program managers, the deputy division director, and the division director.

The division has also undergone significant restructuring during this review cycle. This has impacted the planning and prioritization of research and education opportunities. Some programs were slightly re-focused, new programs were created from existing programs, and cluster titles were revised. Changes made in FY 2013 are summarized here. (Programs that were not changed are not listed.)

- Materials Processing & Manufacturing (AM) → Materials Engineering & Processing (AM)

- Materials & Surface Engineering (MEM) + Structural Materials & Mechanics (MEM) → Materials Engineering & Processing (AM)
- New programs in Systems Science (SYS)
- Dynamical Systems + Sensors & Sensing Systems + Control Systems → Sensors, Dynamics & Control (SYS)
- New program in Design of Engineering Material Systems (MEM)

Further organizational changes of CMMI programs and clusters were made in 2014 and 2015.

The COV was not able to determine the rationale and all drivers for these organizational changes. However, it is noted that interactions between clusters appear to have been maintained, while programs and emphasis areas with significant overlap have been combined. The COV noted that Coastal Engineering is not represented in the reorganized structure. Since the CMMI reorganization began near the end of the COV period and continued into 2015, the impact of the changes cannot easily be assessed by this COV. Key questions are the longer term impacts on funding and whether or not the changes to the organization are yielding the desired effects. To help clarify the reorganization to proposers and reviewers, the program web pages should reflect the precise focus of each program and cluster so that they can serve as a roadmap for researchers who are planning to submit proposals to the division. Providing such guidance is particularly important since the division strives for coordination across clusters, divisions, and agencies. These issues should be examined during the next review cycle.

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

Comments:

CMMI provided the 2012 COV comments and recommendations and their responses to this COV. CMMI is exploring various alternative approaches to harness the benefits of in-person panel reviews (as emphasized by the 2012 COV), but has continued with in-person panels while also meeting travel budget restrictions. The committee was not able to assess whether these alternative approaches (e.g., virtual panels and the mechanism design approach) were as effective as in-person panels. CMMI division and program management recognize the importance of helping researchers submit quality proposals, establishing diversity in the reviewer pool, and balancing support for core areas versus new initiatives.

The 2015 COV finds that some of the more challenging issues persist.

- Reviewers may benefit from more consistency in guidance when evaluating Broader Impacts.
- The COV found it difficult to locate the workshop reports.
- Written reviews and panel summaries are not uniform in detail or in the relative emphasis placed on Intellectual Merit and Broader Impacts. The 2012 COV report included some suggestions to ensure that reviewers provide substantive explanations of their assessments, as well as some suggestions to ensure consistency in panel summaries.

Review of the jackets provided to this COV reveals that some of these issues deserve continued attention.

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

In examining the division's portfolio, the COV's input would be appreciated on:

- Award size and distribution

  i) Are CMMI awards the right size to achieve these outcomes (advance knowledge, launch academic careers, broaden participation)?

The COV recognizes that CMMI faces significant challenges in attempting to achieve balance among the sometimes competing overall goals of the division in determining award size and distribution. Advancing knowledge requires significant, sustained critical mass investments. Launching academic careers also requires investments that will provide a substantial foundation of funding stability for the early career researcher. However, larger awards typically result in a lower success rate and make it more difficult to achieve broader participation in the CMMI research enterprise. While it is difficult to formulate and assess what the right size and distribution should be to optimize performance against these competing goals, the overall balance of the CMMI division portfolio appears to be reasonable and appropriate. One indicator of this balance is that, although the number of submissions significantly decreases with increased academic age, the award success rates are generally consistent across PI academic-age groups (see Figure 1).

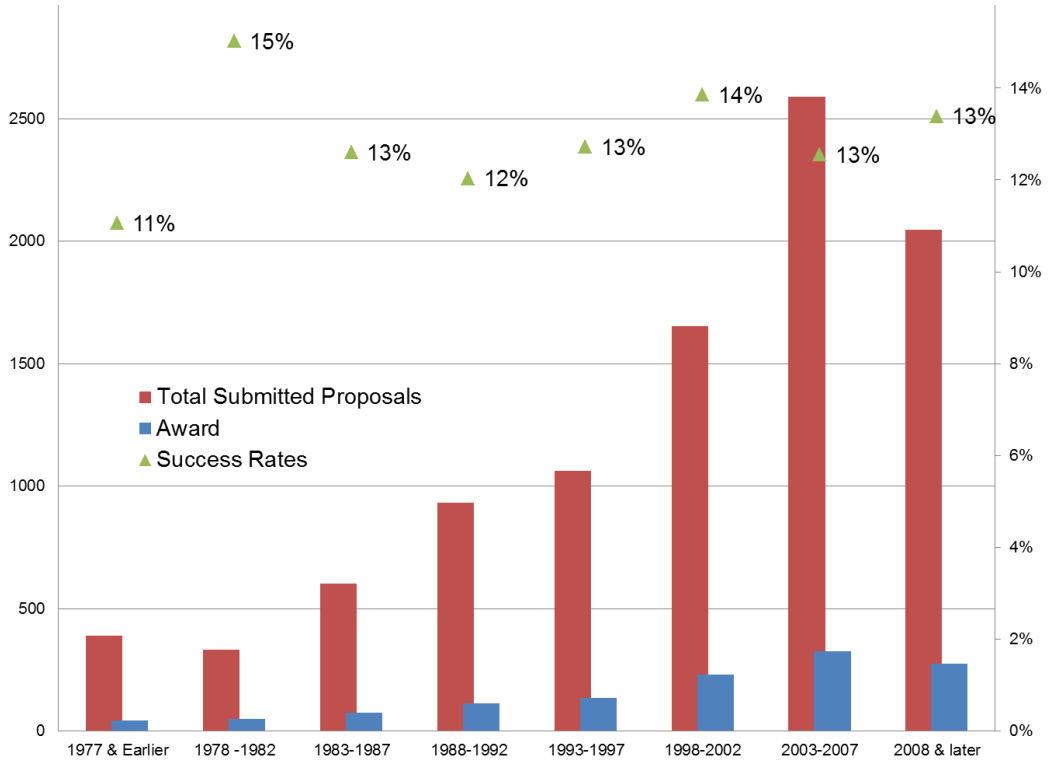

Figure 1: Distribution of proposals and awards by academic age of the PI, including success rates, for FY 2012-2014.

There is a trend toward somewhat fewer, somewhat larger awards, although smaller awards persist.[2] There also appears to be a trend toward encouraging and awarding more cooperative research projects involving multiple institutions, which the COV commends as a way to both achieve a substantial level of effort to support difficult and important research problems and at the same time broaden participation. The COV recommends that the CMMI division assess the effectiveness of these projects in terms of actual collaboration and results and attempt to identify collaboration success predictors. In summary, the COV believes that the current mixture of award sizes is appropriate and the emphasis on student support, broad participation, and project scope and depth should persist. However, it is also important to monitor the average annual award size relative to the rising costs of university research and student support.

ii) Is our CAREER award investment the best use of those funds to develop early career faculty?

With the increase in the minimum CAREER award amount from $400K to $500K for all divisions in the Engineering Directorate in FY 2015, the total CMMI funding for CAREER awards has increased by $4.5M compared to FY 2014 with the number of awards remaining about the same.[3] Maintaining this number of CAREER awards at the higher amount results in some reduction in overall participation, since those funds could be invested in a somewhat larger number of smaller and/or shorter unsolicited awards. However, the larger amounts help to compensate for increasing researcher support costs and CAREER awards have a disproportionately positive impact on a young faculty member's career compared to other awards. The COV recommends that the CMMI maintain the current CAREER award amount.

The COV notes that the CAREER award distribution is somewhat concentrated with respect to receiving institutions. Five universities received more than 20% of all CMMI CAREER awards over the three-year assessment period and Very High Research institutions received 78% of the funds.[4] CAREER award proposal success rates vary dramatically across institutions (from 0% to 36% among the top institutions by number of submitted proposals).[5] The COV recommends that the CMMI continue and strengthen efforts at the institution level to help broaden the success of CAREER proposal efforts. For example, it may be helpful to compile best practices for mentoring and preparing CAREER proposals and to share these best practices across all universities/institutions.

iii) Broadening PI participation

The COV finds that the CMMI division has been generally effective at ensuring that reviewers and awardees are well-distributed with respect to geography, gender, and underrepresented minority participation.

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[2] CMMI 2015 COV Data Book, Table 4: Average Award Size and Duration of CMMI Competitive Awards, FYs 2005-2014 (EIS Award Size Duration Report), p. F-24.
[3] CMMI Division Overview (presentation), CAREER Awards 2012-2015 table, slide 25.
[4] CMMI Division Overview, CAREER Award Profile 2010-2015table, slide 27.
[5] CMMI 2015 COV Data Book, Figure 29 CMMI CAREER Proposal Load, Success Rate and Award Funding by Institution, FY 2012 – FY 2014, p. F-30.

Geographic distribution of reviewers correlates well with the geographic distribution of submitted proposals.[6] As with the CAREER awards, proposal success rates vary significantly across institutions (9% to 30% among the top institutions by number of submitted proposals).[7] Gender representation correlates well between submitting PIs and co-PIs, awardee PIs and co-PIs, and reviewer PIs and co-PIs. Females are slightly overrepresented in reviewers overall and awardees overall compared to proposals submitted.[8] Underrepresented minorities appear to be slightly underrepresented in reviewers overall and awardees overall.[9]

The COV also discussed the influence of institution type on award submissions and success rates. Table 1 demonstrates that while top 100 research intensive PhD institutions generally have higher success rates, there is not a significant gap in performance relative to other institution types.

Table 1: Success rate of competitive proposals across types of institutions, FY 2012-2014.

Institution Type		2012		2013		2014	
		Awards	Total Proposals	Awards	Total Proposals	Awards	Total Proposals
Business, State & Local, Foreign, Other	Proposals	16	87	6	41	8	46
	Success Rate	18.39%		14.63%		17.39%	
Academic - Baccalaureate	Proposals	0	9	2	6	1	8
	Success Rate	0.00%		33.33%		12.50%	
Academic - Masters	Proposals	14	147	14	124	15	135
	Success Rate	9.52%		11.29%		11.11%	
PhD Institutions	Proposals	99	965	95	836	87	893
	Success Rate	10.26%		11.36%		9.74%	
Research Intensive PhD Institutions (Top 100)	Proposals	407	2272	441	2166	438	2434
	Success Rate	17.91%		20.36%		18.00%	

- Large-scale research infrastructure investment

Determining the appropriate mix of investment in construction, maintenance, management, allocation of use, and training for large-scale research infrastructure is a major challenge for NSF. In CMMI, this is seen in the investment of approximately $262.9M in the Network for Earthquake Engineering and Simulation (NEES) program over a 20-year period. NEES, initiated in 2000 and continuing through 2014, represents the kind of bold, innovative investment in research infrastructure that enables the exploration, design, and testing of the extraordinarily difficult problem of constructing buildings to withstand the destructive forces of earthquakes in zones of recurring seismic risk. Yet, once built, the infrastructure needs to be maintained. Determining who will maintain this infrastructure, at what cost, and how this cost will be shared by those who will use it and benefit from it represents a second set of questions, worthy of systematic inquiry. In particular, a sustainability plan should be completed at the proposal stage

[6] CMMI 2015 COV Data Book, Figure 9 Geographic Distribution of CMMI Communities, FY 2012 – 2014, p. F-9; Figure 21 Geographic Distribution of CMMI Awards, FY 2012-2014, p. F-25.
[7] CMMI 2015 COV Data Book, Figure 28 CMMI Proposal Load, Success Rate and Award Funding by Institution, FY 2012 – FY 2014, p. F-29.
[8] CMMI 2015 COV Data Book, Figure 8 Demographic Profiles of CMMI Communities, FY 2012 - FY 2014, p. F-9; Figure 20 Demographic Profile of CMMI Awardees, FY 2012-2014, p. F-25.
[9] *Ibid.*

to address maintenance requirements and related factors. These issues warrant careful attention since large-scale research infrastructure offers the potential for societal benefits, but requires costly management and maintenance. The COV raises three additional questions.

i) What alternatives can be leveraged to maintain the investment in large-scale research infrastructure, once designed and built?

The usual approach has been to engage commercial partners in maintaining infrastructure investments in broadly conceived public/private partnerships, but private companies may not be consistently able or willing to accept that role. Long-term maintenance of infrastructure becomes especially challenging because, if it is denied or delayed in large-scale investments, the benefit of the original investment may be lost or the leadership of US science and engineering may be superseded by other nations willing to make that investment.

One alternative may be for the NSF to broaden its effort to create partnerships with other federal agencies in maintaining infrastructure investments, as it has done successfully with the Natural Hazards Research and Application Center at the University of Colorado, Boulder. A second alternative may be for NSF or the infrastructure host institution to engage private philanthropic foundations, such the Carnegie Foundation or the Rockefeller Foundation, in a shared effort to support the maintenance of research infrastructure that addresses fundamental issues of public interest.

ii) To what extent could collaborative partnerships be designed to maintain and support large-scale research infrastructure on an international scale?

As fundamental questions of science and engineering become increasingly complex and global, the need to frame a research agenda that stretches beyond national borders is essential. Questions such as the search for safe energy, clean water, clean air, and the design of resilient, sustainable communities cannot be addressed by a single nation alone. The example set by NASA working in collaborating with other nations to design and create international partnerships that enable the construction of the large-scale infrastructure required for global space exploration offers a constructive alternative. Space exploration is only one example of fundamental research that benefits from the participation of international partners in the design, development, and maintenance of large-scale research infrastructure.

iii) To what extent could large-scale research infrastructure developed for simulation and modeling of technical systems, such as NEES, be adapted creatively for the exploration and design of large-scale organizational and inter-organizational systems needed to operate in a more dynamic and global world?

One opportunity for the volume of data collected using the large-scale research infrastructure is its use for new efforts in data mining, big data, and large-scale computing. A second is the use of application-specific simulation and modeling techniques in new disciplines.

In a larger sense, a fundamental challenge for the NSF is to anticipate the major research questions of the next 20, 50, and 100 years, and design and adapt its research infrastructure to address the increasingly complex issues that are essential to maintain and sustain the planet under the strain of a burgeoning population and fragmentation of local norms and values. The use of exploratory workshops and interdisciplinary venues for iterative processes of discovery, validation, and documented information exchange could become an essential element of

identifying the next set of issues for research investment and the socio-technical infrastructure needed to support continuing inquiry and learning.

- Emerging research challenges and opportunities

Opportunities exist for CMMI to participate in a number of emerging research areas. As Dr. Goodings outlined in her presentation to the COV on May 12, 2015, emerging research opportunities and challenges for CMMI lie in advanced manufacturing, understanding the brain, infrastructure engineering for multi-hazards, smarter cities, smarter health, international, and best practices for broadening participation. In fact, CMMI is already participating in cross-cutting initiatives related to some of these areas, e.g., Scalable Nanomanufacturing (SNM) and Critical Resilient Interdependent Infrastructure Systems and Processes (RIPS/CRISP). The COV agrees that the identified topics are important and timely opportunities and endorses CMMI's efforts and participation in these areas. Additional opportunities to consider are in the areas of the materials genome initiative and applications of engineering in the service economy.

Advanced manufacturing has received much recent attention and activity, including support by the White House[10]. It is expected that this area, including obtaining a fundamental understanding of additive manufacturing and its most appropriate application domains, will continue to expand. CMMI is in an excellent position to take the lead due to its focus on advanced manufacturing.

- CMMI's research portfolio approach

CMMI currently organizes its research exploration and activities around four major program clusters: advanced manufacturing; mechanics and engineering materials; resilient and sustainable infrastructures; and operations, design, and dynamical systems. This approach, developed in an effort to identify the major research areas confronting the nation, is a valid means of assessing and organizing research needs and investment. However, the portfolio should be reviewed periodically against a continually changing society to identify whether these four program clusters continue to constitute the most appropriate classification of research needs and investment areas.

The COV recommends the continued monitoring of research sponsored in these four program clusters to assess the outcomes of their investment and the interactions among the clusters that are likely to generate modifications and potentially new areas of research. This can be achieved using evidence-based outcomes to inform the design of the next set of research portfolios. Applications of simulation and modeling tools, such as Bayesian influence diagrams, could inform decisions regarding possible strategies of research investments and likely trade-offs among different options. Assessing the interaction among research investments using appropriate metrics will provide insight and guidance into the iterative process of defining the research agenda for the nation.

[10] https://www.whitehouse.gov/administration/eop/ostp/pcast/docsreports

OTHER TOPICS

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

The COV suggests a comparison of CMMI approaches to other NSF divisions, as well as comparable national/international funding agencies and private foundations. A comparison to similar programs (benchmarking) could highlight both strengths and weaknesses and provide assessments of impact.

The COV recommends that metrics be defined that represent the success of a particular program, including both Intellectual Merit and Broader Impacts. For example, to address broadening participation, the number of students from under-represented groups supported by NSF funds could be collected and presented. Regarding appropriate grant size, the number of students supported per year could be tracked to observe whether the trend is increasing or decreasing. For career development, the number of assistant (untenured), associate, and full professors could be monitored.

In order to ensure consistency between programs, which may be directed by IPA or permanent staff, the COV recommends that best practices be captured and made readily accessible to new and existing program directors in an on-going basis. This enables consistent treatment of proposals and the continuation of successful approach and techniques. For example, the distribution of a representative high-quality review to panelists, the use of uniform review templates, and the clear guidance on Broader Impacts could be implemented agency-wide.

The COV emphasizes the need to balance IPAs and permanent program director due to the clear value of the IPA/permanent balance within CMMI. This necessarily requires continuous recruiting efforts by CMMI and financial and administrative support from NSF.

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 encourages CMMI to improve dissemination of program agendas, priority research areas, and the overall portfolio approach. Community-wide workshops or, preferably, the grantees conference could be leveraged to improve communication and address these issues.

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

One issue discussed by the COV was the importance of program manager visibility within the research community. Personal interactions with both new proposers and funded investigators are important for the program's relevance and mission. While individual investigators may visit NSF to achieve this goal, a more efficient approach is program manager's presence at a large-scale grantees conference and/or domain-specific conferences and workshops. This enables broader participation in question and answer sessions that are of direct benefit to both investigators and the program. For example, a program director's observations about proposal submissions in general may be clearly conveyed. Additionally, the program's research objectives can be stated to a broad audience.

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

The COV strongly recommends re-implementing the grantees conference. This conference strengthens CMMI by clearly communicating program goals, supporting high-quality proposal submission, and developing community through informal interactions among program directors, PIs, and graduate students. Based on discussions at the COV July 7-8 meeting, it was understood that the primary obstacle to this conference is government-wide travel restrictions, including size and budget. The COV believes that these restrictions are negatively impacting the ability of CMMI to carry out its mission.

As noted in Section I, Question 2, communicating clear guidelines for the Broader Impacts evaluation could improve panel reviews. The COV suggests that evaluation guidance could be provided via several avenues, such as:

- the program director could provide pre-review briefing to panelists
- all new reviewers could complete an online briefing prior to his/her first panel.

This approach assumes that the definition of Broader Impacts already exists within CMMI (and, by extension, NSF). Confirming this shared definition is, of course, a first step toward addressing this issue.

The COV discussed the importance of panel demographics for high-quality evaluations and PI feedback. Questions included:

- What effect, if any, does panel size have on proposal recommendations?
- How is panel effectiveness related to the diversity of panel member demographics, including discipline, gender, ethnicity, and institution type?

The COV recommends that these issues be considered by CMMI and an appropriate study be completed.

Undergraduate enrollment in mechanical engineering programs is growing rapidly across the country. Given that mechanical engineering is one of the least popular choices of engineering majors for women[11,12], efforts directed at broadening participation are necessary. Identifying best practices and partnering with related efforts for broadening participation and implementing those practices will be critical to meeting the high demand for mechanical engineers in industry. Due to its focus on mechanical systems and mechanics and involvement of many mechanical engineering researchers, CMMI should assume a leadership role in this area and seek collaboration with relevant partners.

Research funded by CMMI plays a central role in the advancement of national priorities for domestic manufacturing, the mitigation of evolving hazards, and the development of systems-based solutions for a range of techno-societal issues. CMMI is uniquely positioned to chart a national course for resiliency and sustainability in the 21st century.

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

The COV was provided with the required information, the CMMI personnel were highly supportive and transparent, and the expectations for the report were clearly expressed. The only suggestion for improvement is that earlier identification of the chair and co-chair would enable a draft schedule to be developed and presented to the candidate committee members to help establish their availability.

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[11] http://www.asee.org/papers-and-publications/publications/college-profiles/2011-profile-engineering-statistics.pdf
[12] http://www.nsf.gov/statistics/2015/nsf15326/#chp2

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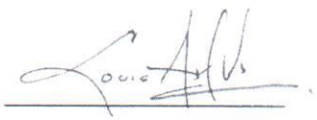

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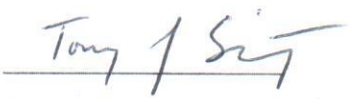

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