

**Workshop: Setting a Broader Impacts Innovation Roadmap
Arlington, Virginia, May 2016**

Organizers

Sheldon H. Jacobson (217) 244-7275 Univ. of Illinois	Jerome F. Hajjar (617) 373-3742 Northeastern Univ.	Dawn Tilbury (734) 936-2129 Univ. of Michigan	Andrew Johnson (979) 458-2356 Texas A&M Univ.
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Scribes

Erick Centeno-Moreno Texas A&M Univ.	Siqian Shen Univ. of Michigan
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Executive Summary

On May 26-27, 2016, 28 researchers and administrators (hereafter, participants) in the areas of mechanical, industrial, manufacturing, and civil engineering met to propose how investments made by NSF could be enhanced via Broader Impacts contributions. The results of two days of intense discussion will be disseminated in professional magazines and in presentations at national conferences. The key issues and recommendations for NSF resulting from the workshop are as follows:

Key Issue 1: Many NSF stakeholders including program managers, reviewers/panelists, and principal investigators (PIs) have a skewed, limited, and/or partial understanding of the definition of Broader Impacts in general and the Broader Impacts evaluation criteria in particular.

Recommendations:

- (1) Provide a Broader Impacts Framework to help PIs define clearly their project's Broader Impacts and help review panels evaluate more consistently. The section "Question 2: How can Broader Impacts be classified?" suggests an explicit Broader Impacts Classification Framework and illustrates its use. The framework can be provided to PIs, reviewers, and program managers (in addition to the currently provided illustrative Broader Impacts list). Require PIs to classify their proposed/achieved Broader Impacts in proposals, project reports, and final award abstracts.
- (2) Clarify and emphasize to program managers, reviewers/panelists, PIs, Congress, the public, and the media that Broader Impacts are *not* necessarily achieved through extra activities beyond the Intellectual Merits activities and that the intrinsic merit of the research deserves further emphasis. Encourage PIs, NSF staff, and reviewers to focus on the societal benefits of the research.

Key Issue 2: Funded projects have significant Broader Impacts, but the research community in general and NSF in particular do an inadequate job of tracking and disseminating the Broader Impacts to the public and Congress, especially for medium- and long-term Broader Impacts.

Recommendations:

- (1) Improve *communications* between NSF and its stakeholders regarding Broader Impacts. Educate program managers and reviewers about the definitions of the Broader Impacts criteria and train them in the best practices for evaluating the Broader Impacts criteria.
- (2) Develop better channels to inform and keep Congress apprised about benefits of continuing to invest in NSF.

Key Issue 3: The evaluation of the Broader Impacts criteria is not homogeneous across different programs. Some programs / program managers and reviewers evaluate the Broader Impacts criteria as secondary to the Intellectual Merit criteria.

Recommendations:

- (1) Again, improve *communications* between NSF and its stakeholders regarding Broader Impacts. Educate program managers and reviewers about the definitions of the Broader Impacts criteria and train them in the best practices for evaluating the Broader Impacts criteria.

Specific suggestions to enhance *communications* between the ensuing pairs of parties are as follows (Refer to **Section 4-Further recommendations for the details about operationalization and implementation):**

- a. NSF to PIs
 - Clarification of Broader Impacts components and their evaluation criteria should be disseminated widely to program managers, reviewers/panelists, and PIs.
 - Enable and encourage PIs to report the longer-term Broader Impacts achieved.
 - Redesign the award abstracts template so PIs can report and update their Broader Impacts related activities and outcomes.
 - Add a section labelled "Broader Impacts Contributions" to the Bio-sketch.
 - NSF should implement REU-like supplemental grants or phase-two Broader Impacts follow-up grants so that PIs can propose additional far-reaching Broader Impacts activities.
 - NSF should significantly revamp its efforts to track, document, and disseminate medium- and long-term Broader Impacts, preferably via Broader Impacts awards.
- b. NSF to Program Managers
 - NSF should emphasize that program managers are responsible for seeing that reviewers follow the given criteria for evaluating Broader Impacts.
- c. NSF to Panelists and Reviewers
 - NSF should establish a certification mechanism for reviewers; the associated training/certification should include Broader Impacts and their evaluation.
- d. NSF to Congress/Public/Media

- NSF should consider revamping its efforts to disseminate the Broader Impacts and the societal benefits of its research portfolio.
- e. PIs to Public
- PIs need to understand that they are ambassadors of NSF, their universities and academia in general. NSF should educate PIs about this responsibility.

1. Background

Intellectual Merit and Broader Impacts both require improvements in communications in order for NSF to advance the nation's global leadership in science, technology, engineering, and mathematics (STEM). Revising the current chain of communications will depend on a grassroots effort to ensuring that NSF program managers, researchers and PIs convey the value of Intellectual Merit and Broader Impacts to the appropriate audiences (reviewers, Congress, the public, the media, etc.).

Indeed, researchers need to be encouraged to embrace Broader Impacts as a critical element of a proposal, and reviewers should be educated to embrace Broader Impacts as a substantive component in the evaluation process and not merely an add-on to the Intellectual Merit contributions. Intellectual Merit and Broader Impacts should be viewed as complementary and synergistic contributions.

2. Key Questions Discussed by Workshop Participants

To enhance Broader Impacts activities in NSF grants within CMMI, five questions were discussed during the workshop. For each question, a key take away is shown in the bubbled text. The questions are as follows:

Question 1: What is Broader Impact?

NSF requires proposals to be evaluated based on both the Intellectual Merit and the Broader Impacts of the proposed research. The America Competes Act of 2010, Section 526, provides the following Broader Impacts Review Criteria:

"The Foundation shall apply a Broader Impacts Review Criterion to achieve the following goals:

- Increased economic competitiveness of the US
- Development of a globally competitive STEM workforce
- Increased participation of women and underrepresented minorities in STEM
- Increased partnerships between academia and industry
- Improved pre-K-12 STEM education and teacher development
- Improved undergraduate STEM education
- Increased public scientific literacy
- Increased national security"

The National Science Foundation General Program Guide (Version 2016) states: "Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to the project. NSF values the advancement of scientific knowledge and activities that contribute to the achievement of societally relevant outcomes."

The National Science Board provides the following statement on Broader Impact: "The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes. These outcomes include:

- Increased participation of women, persons with disabilities and underrepresented minorities in science, technology, engineering, and mathematics (STEM);
- Improved STEM education at all levels;
- Increased public scientific literacy and public engagement with science and technology;
- Improved well-being of individuals in society;
- Development of a globally competitive STEM workforce
- Increased partnerships between academia, industry, and others;
- Increased national security;
- Increased economic competitiveness of the US;
- Enhanced infrastructure for research and education."

Based on these statements, the common thread for defining Broader Impacts is the societal benefit of the proposed research contributions and activities. In layman's terms, Broader Impacts describe how the world is better (in some dimension) as a result of or a by-product of the Intellectual Merit contributions of the proposed research. As such, Broader Impacts are the natural next step from the Intellectual Merit research outputs.

One of the main workshop findings was that participants' notions of Broader Impacts varied widely among the relatively homogenous group of leaders in their respective fields with well-established research funding track records. Therefore, extrapolating this finding to the wider research community implies that the research community as a whole likely has a vague understanding of the Broader Impacts criteria. It seems that no NSF stakeholder groups (program managers, reviewers/panelists, and PIs) have a complete understanding of the definition of Broader Impacts in general or of the Broader Impacts evaluation criteria in particular. Thus, one of the main workshop outcomes was to devise a clear classification of the diverse set of goals/outcomes encompassing the Broader Impacts criteria.

NSF should clarify and emphasize to all of its stakeholders that Broader Impacts are *not* necessarily achieved through activities beyond the Intellectual Merit activities. That is, NSF does not require proposals to have Broader Impacts activities beyond the Broader Impacts intrinsic to the Intellectual Merit. This is evident in the Intrinsic Broader Impacts class and also true for some Broader Impacts in the Direct Broader Impacts class. The Extrinsic/Far-reaching Broader Impacts class mostly comprises Broader Impacts that are necessarily achieved via activities beyond the Intellectual Merit pursue (these extra activities could be funded/incentivized via a REU-like supplement or Phase II grant as explained in section 4 of this report).

Question 2: How Should Broader Impacts Be Classified?

In view of the confusion among researchers on the definition and meaning of Broader Impact, participants concluded that NSF should provide structure that will help PIs to define and identify their projects' Broader Impacts, and make it easier for reviewers to evaluate them. Participants suggested a classification along two non-temporal dimensions and a third temporal dimension. The non-temporal dimensions elaborated in the ensuing paragraphs are: *Immediacy to the Intellectual Merit Impact*, and *Type of Societal Benefit*. Question 3 addresses the temporal dimension, called *Outcome Time Horizon*.

Immediacy to the Intellectual Merit Impact

According to their Immediacy of the Intellectual Merit, Broader Impacts can be classified as: *Intrinsic* (High Immediacy), *Direct* (Moderate Immediacy), and *Extrinsic/Far-reaching* (Low Immediacy).

Intrinsic Broader Impact: Any Broader Impacts that are accomplished through the research itself, e.g., cost reductions or health improvements if/when the results originating from the Intellectual Merit activity are implemented.

Direct Broader Impact: Any Broader Impacts that are accomplished through activities directly related to a specific research project, e.g., training graduate students, involving undergraduate students in research, bringing research into the classroom, and increasing the participation of women and underrepresented minorities.

Extrinsic/Far-reaching Broader Impact: Any Broader Impacts that are accomplished through activities supported by but complementary to the project, e.g., STEM activities in K-12 environments, citizen science activities, communications/outreach via social media, websites, blogging, videos, and traditional media.

A main workshop finding was participants' consensus that the intrinsic merit of the research provides major societal benefits. Consequently, the Intrinsic Broader Impacts class deserves a renewed emphasis because society will benefit from focusing on these benefits. Renewed emphasis on intrinsic Broader Impacts may encourage researchers to tackle potentially transformative research that addresses major societal challenges and serves as inspiration for fundamental research. Participants suggested modifying the review process to recognize/emphasize the importance of intrinsic benefits (see subsections "NSF to reviewers" and "NSF for program managers" for recommendations).

Type of Societal Benefit

According to the Type of Societal Benefit they bring, the participants classified Broader Impacts into six categories: *Information/Communications, Global Leadership, People, Economic, Quality of Life, and National Interests.*

Information/Communications: Any activity that brings new insights into existing and anticipated societal issues, or promotes and protects professional standards may lead to better informed societal decisions, which in turn enhance economic and societal well-being. Also, any activities that promulgate societal benefits and/or inform population sectors may improve quality of life and enhance public literacy. Example activities include communications and outreach via social media, websites, blogging, videos and traditional media.

Global Leadership: Any activity that strengthens the United States' world leadership in the areas of economic, technological, productivity, sustainability, etc. The Broader Impacts in this category generally, but not necessarily, will be a direct or indirect result of the Broader Impacts achieved in other societal benefit categories, e.g., maintaining the lead in strategic technologies such as information systems.

People: Any activity that educates people or increases diversity in the human pool of skills resulting from the research, e.g., bringing STEM activities into K-12 environments, enhancing opportunities for underrepresented populations, or training a more capable workforce.

Economic: Any activity that directly or indirectly leads to economic value being created or facilitating the creation of economic value, e.g., enhanced productivity, job creation, or cost reductions.

Quality of Life: Any activity that enables the improvement of life quality, e.g., developing new health devices and medicines and provides new insights into existing or anticipated health issues. Such contributions are not of a clinical nature, but rather include societal impacts related to health.

National Interests: Any activity that brings advancements aligned with national interests, such as National Security (any activity that reduces or eliminates the threat of attacks via nuclear, biological, and chemical weapons) or National Stability (any activity that enhances the viability and stability of national systems including energy supply, transportation infrastructure, financial markets, the environment, etc.).

The following list and table provide a limited set of Broader Impacts examples and illustrate their connection to the two-dimensional classification framework.

- [1] Increased economic competitiveness of the US;
- [2] Enhanced infrastructure for research and education;
- [3] Development of a globally competitive STEM workforce;
- [4] Increased participation of women, persons with disabilities and underrepresented minorities in STEM;
- [5] Increased partnerships between academia, industry, and others;
- [6] Improved STEM education at all levels;
- [7] Increased public scientific literacy;
- [8] Increased public engagement with science and technology;
- [9] Improved quality of life/well-being of individuals in society;
- [10] Increased national security;
- [11] Improved logistics leading to cost reductions in transportation;
- [12] Improved efficiency in emergency room scheduling;
- [13] Training graduate students;
- [14] Involving undergraduate students in research;
- [15] Bringing research into the classroom;
- [16] Citizen science activities;
- [17] Communications/outreach via social media, blogging, videos, and traditional media;
- [18] Developing new health devices and/or medicines;
- [19] Bringing new insights into existing and anticipated societal issues;
- [20] Promoting and/or protecting professional standards;
- [21] Strengthening US leadership in strategic technologies such as information systems;
- [22] Enhanced opportunities for underrepresented populations;
- [23] Training a more capable workforce;
- [24] Enhancing productivity;
- [25] Increasing job creation;
- [26] Reducing or eliminating the threat of attacks via nuclear, biological, and chemical weapons;
- [27] Enhancing the viability and stability of the national energy supply;
- [28] Enhancing the viability and stability of the transportation system;
- [29] Enhancing the viability and stability of the financial markets;
- [30] Enhancing the viability and stability of the environment.

	Intrinsic	Direct	Extrinsic/Far-reaching
Quality of Life	12, 18		
Information/Communications	19-20		5, 7-8, 16-17, 19-20
Global Leadership	1-2, 18, 20-21, 23-24	2, 23	5, 6, 20, 23
People	9, 20, 22-23	3, 4, 13-15, 22-23	6-8, 16-17, 20, 23
Economic	1-2, 11-12, 23-25, 27-29	2-3, 23	5-6, 23
National Interests	1, 9-10, 18, 21, 26-30	3	6

It is important to emphasize that this classification framework is not prescriptive or exhaustive, i.e., a Broader Impacts may fit in several classes or in none the above table illustrates. The classification framework is only meant to: (1) facilitate framing the Broader Impacts and considering additional Broader Impacts by researchers; (2) make explicit the diverse and vast Broader Impacts attained by the activities funded by NSF.

Question 3: What is the Timeframe for Broader Impact?

Intellectual Merit contributions are often realized during and after the funding period of a grant. These contributions are typically disseminated in peer-reviewed journal articles and conference proceedings, with appropriate reference to the funding source supporting the research. Each type of Broader Impacts is often associated with distinct time horizons, e.g., *Economic* Broader Impacts are often realized over medium- and long-term horizons, with research output improving productivity of existing industries, or leading to the creation of new economic drivers and entities (--hence, fostering entrepreneurship); *People* Broader Impacts are often realized over short- and medium-term time horizons, with the training of students involved in the research and attracting diversity into such pools; *Information* Broader Impacts are often realized over long-term horizons, with research results being used to identify societal issues and provide possible solutions and improvements that set higher societal standards; and *Communication* Broader Impacts are often realized over medium- and long-term time horizons, with novel approaches to reach large and diverse audiences and beneficiaries of the research results.

Broader Impacts dissemination mechanisms are typically more limited compared to mechanisms available for Intellectual Merit. No peer-reviewed journals archive Broader Impacts contributions. Workshop participants concluded that although funded projects had significant Broader Impacts, the research community in general and NSF in particular are failing to track and disseminate the medium- and long-

term Broader Impacts resulting from funded projects. Specifically, the main mechanism to track the Broader Impacts of funded projects is the annual and final project reports. Moreover, PIs can append/update the final award abstracts only to add publications and not to add Broader Impacts. Consequently, only short-term Broader Impacts are likely to be tracked/documentated.

NSF should revamp its efforts to track, document, and disseminate the medium- and long-term Broader Impacts. A first step allows PIs to append/update the final award abstracts with Broader Impacts (these abstracts are public documents available for all to see). A second step requires PIs to report the Broader Impacts achieved 5 or 10 years after the project end date.

NSF should implement a highly prestigious and widely broadcasted/disseminated Broader Impacts award. There can be one such yearly award for each Type of Societal Benefit Broader Impacts category, one for each Immediacy to Intellectual Merit Broader Impacts category, and one for each Outcome Time Horizon Category, as well as career long awards (with visibility similar to the PECASE awards) targeting researchers with lifelong achievements of Broader Impacts. These awards will incentivize PIs to report their Broader Impacts, and help NSF to disseminate them.

Participants acknowledged that it is probably not feasible for NSF to systematically track broader impacts beyond annual and final reports. The suggested Broader Impacts awards, however, should help to track longer-term Broader Impacts. While the awards will not guarantee a detailed tracking, they will allow capture information about the impacts of the most influential projects (which are ultimately the ones worth publicizing and reporting to Congress).

Question 4: What is an appropriate balance between Intellectual Merit and Broader Impact? Is there a tradeoff between Intellectual Merit and Broader Impact, or should they be inextricably linked?

PIs tend to take the path of least resistance by focusing on Broader Impacts activities that require little or no additional effort beyond what is necessary to achieve the Intellectual Merit. Often, PIs focus on People Broader Impact, by training graduate and undergraduate students and supporting diversity within such groups. This focus allows more space in the proposal's project description for describing the Intellectual Merit contributions, and hence, positions Broader Impacts as an afterthought rather than a critical component of the proposed research activity. Moreover, if funding decisions allow reviewers to weight Intellectual Merit more heavily than Broader Impact, the incentive system, i.e., funding decisions, promulgates this evaluation imbalance. As emphasized throughout this report, incentivizing researchers to embrace Broader Impacts as a critical facet will require them to embrace Broader Impacts as a substantive component in the evaluation process. Reviewers' comments should inform PIs how

Broader Impacts activities can be enhanced to make a proposal more competitive. Intellectual Merit and Broader Impacts cannot be viewed as either/ or, but as complementary and synergistic contributions.

NSF should consider a portfolio approach, i.e., the goal of each program manager is to build a strong and balanced funded-projects portfolio. Specifically, a portfolio would consist of proposals having either very strong Intellectual Merit and/or unusually strong Broader Impacts. The strong Intellectual Merit and Broader Impacts could be enforced on the whole portfolio of funded proposals, rather than on each individual proposal.

Participants asked whether separating Intellectual Merit and Broader Impacts allows PIs to make Intellectual Merit the objective (to be maximized) and Broader Impacts the constraint (to be satisfied so as to be feasible). Is NSF proposal evaluation producing this schism, or can the current evaluation system encourage innovations in both Intellectual Merit and Broader Impact? We often think of transformative research in terms of Intellectual Merit; can we also think of it in terms of Broader Impact?

Intrinsic and Direct (and usually short-term) Broader Impacts are *inextricably* linked to Intellectual Merit, whereas Extrinsic/Far-reaching Reaching Broader Impacts are not. A two-phase process to incentivize Extrinsic/Far-reaching Broader Impacts activities is proposed. First, evaluate and select proposals based on strong Intellectual Merit, and Intrinsic and Direct Broader Impacts. Second, PIs of funded proposals can propose additional Extrinsic/Far-reaching Broader Impacts activities and request an additional funding supplement. The size and review procedures for such Broader Impacts supplements are analogous to those of the REU supplement. This two-phase process will give PIs more information, time, and resources to pursue more difficult and substantial tasks in terms of innovating educational forms and communicating with the public. Since these activities are funded, it will be easier to track results and hold PIs accountable.

3. **Examples of Successful Broader Impacts of CMMI Grants**

Participants assert that every funded project contains Intrinsic Broader Impacts. This section gives some examples of projects that have had tremendous Extrinsic/Far-reaching Broader Impacts.

Example 1 (Economic Broader Impact)

PI: Karl Grosh, University of Michigan

Broader Impacts achieved: Fundamental research in electroacoustic transduction led to the development of piezo MEMS microphones. Subsequently, further NSF programs such as STTR/SBIR enabled the creation of Vesper Technologies Inc.,

which is now building those microphones. (CAREER: Cochlear Analogues for Engineering Acoustics, Grant number 9876130; STTR Phase I: High Performance Piezoelectric MEMS Microphones, Grant number 0930630; STTR Phase II: High Performance Piezoelectric MEMS Microphones, Grant number 1127487)

Example 2 (People, Quality of Life, and National Interests Broader Impact)

PI: Jonathan P. Caulkins; Carnegie Mellon University; RAND, Drug Policy Research Center

Broader Impacts achieved: The PI explained drug adoption using the Bass (1969) Product Diffusion Model which was developed for the adoption of traditional new products. Better datasets and measures for understanding drug consumption behavior and its relation to the drug prices adjusted by expected-purity were developed. Tangible findings included: (a) marijuana use among high school seniors inversely correlated with price; (b) a sudden drop of ambulance calls due to drug overuse in Australia was due to a purity-adjusted soar in price. These findings have guided some of the current public policies on drug-related issues. (NSF Young Investigator, Grant number 9357936)

Example 3 (Information/Communications, and Economic Broader Impacts)

PIs: Ozlem Ergun, Reginald DesRoches, and Pinar Keskinocak; Georgia Tech

Broader Impacts achieved: An editorial published in the New York Times on Haiti's cleanup process motivated a diverse set of stakeholders to significantly speed up Haiti's cleanup. It increased the economic competitiveness of the US and Haiti, increased public scientific literacy, and increased national security. (NSF CMMI Award: RAPID: Earthquake Debris Management in Haiti: Data-driven Decision-Support, Grant number 1034840)

4. Further Recommendations

I. Enhance (broadly defined) communications between NSF and its stakeholders

Participants concluded that funded projects have significant Broader Impacts but the research community in general and NSF in particular are doing a poor job tracking and disseminating (to the general public and Congress) Broader Impacts; this is especially true for medium and long term Broader Impacts. In addition, the evaluation of the Broader Impacts criteria is not homogeneous across different programs. In particular, it seems that some programs do not place much emphasis in the Broader Impacts criteria and evaluate it as secondary to the Intellectual Merit criteria (it is unclear who is at fault: program managers, reviewers, or both).

Broadly speaking, participants concluded that the issues of tracking and dissemination and the lack of homogeneity across different NSF programs can be addressed by improving *communications* between NSF and its stakeholders regarding Broader Impacts. To improve the evaluation of the Broader Impacts criteria, NSF needs to communicate better with program managers and

reviewers to educate them in the Broader Impacts definitions and train them in the best practices for evaluating the Broader Impacts criteria. Similarly, NSF needs to better inform Congress of the Broader Impacts that are being achieved and the outstanding value that society is receiving from investing in NSF.

The specific suggestions and the associated operationalization and implementation details to enhance the broadly defined *communications* between parties are as follows:

NSF to PIs

- Educate program managers, reviewers, and PIs on the Broader Impacts criteria. A clarification of Broader Impacts components and their evaluation criteria should be disseminated to PIs through the NSF website, workshops, public events, webinars, and a Dear Colleague Letter (DCL). Emphasize the Broader Impacts criteria in proposal writing workshops.
- Help PIs to communicate effectively with the public and Congress to disseminate the Broader Impacts of their research work by using mechanisms such as:
 - Implement REU-like supplemental grants or phase-two Broader Impacts follow-up grants. In these grants PIs can propose additional far-reaching Broader Impacts activities to enhance the research generated with the original grant. Since PIs are receiving additional funding for these activities, they would be obliged to report the outcomes, which would also facilitate detailed tracking of these Broader Impacts.
 - Arrange informational conference calls with aides in order to disseminate Broader Impacts that are relevant for their Representatives and Senators.
 - Invite Congressional staff to attend NSF awardees' meetings.
- Enable and incentivize PIs to report Broader Impacts results of their work to NSF even after the grant has ended.
 - Add a section on Broader Impacts achieved to the Bio-sketch.
 - Redesign the award abstracts template to allow and encourage PIs to report and keep updating their Broader Impacts related activities and outcomes.
 - Implement prestigious Broader Impacts awards, e.g., an annual award for each Type of Societal Benefit BI category, each Immediacy to Intellectual Merit BI category, and each Outcome Time Horizon Category. Implement awards (with visibility similar to the PECASE awards) for researchers with lifelong achievements of Broader Impacts.

Participants acknowledge that PIs are encouraged to voluntarily report all significant outcomes regarding both intellectual merit and broader impacts no matter how long after the initial award to their project officers, and that OLPA works hard to disseminate major outcomes via social and traditional media, special meetings and activities, Congressional presentations, etc. Apparently, however, this voluntary reporting is rarely used and consequently is not effective in tracking medium- and long-term Broader Impacts.

NSF to Universities

- Communicate with department chairs and university administrators about the changing expectations related to Broader Impacts.
- Maintain the NSF's detailed system for partnering with universities to inform the media about funded projects and outcomes. Under the current partnership, universities share their press releases/media coverage for NSF-funded awards and NSF adds links to its website/social media sites etc. When PIs notify NSF of publications in process for major discoveries, NSF works directly with the publishing journal and media to coordinate publicity on social and traditional media on the date of publication/release.

NSF to Panelists and Reviewers

- NSF needs certification/training mechanism for reviewers that focuses on Broader Impacts and their evaluation. The mechanism requires reviewers to participate in a workshop/webinar in order to become eligible to serve as a panel reviewer. NSF will ultimately have to define the certification mechanism.
- Require conference calls between program managers and all reviewers at the proposal assignment time to re-emphasize the review criteria on Broader Impacts before each panel starts.

NSF to Program Managers

- Stress that program managers are responsible that reviewers follow the given criteria for evaluating Broader Impacts.
 - Screen randomly sampled review comments before each panel starts and require reviewers to correct irresponsible or inconsistent comments regarding Broader Impacts.
 - Randomly sample unfunded proposals and evaluate whether the review comments on Broader Impacts follow the training criteria.
- To ensure that program managers fulfill these duties, NSF should including in program managers' annual review a discussion of the program's Broader Impacts.
 - Screen a sample of the reviewer comments after the proposal review process is finalized. An example of an inappropriate review is one

where the fact that a proposal does not include a specific type of Broader Impacts is cited as a negative/weak point, e.g., “a negative point of this proposal is that it does not propose to make an effort to recruit underrepresented students”.

- Instruct program managers to take an active role in the proposal review discussions about Broader Impacts, e.g., a program manager is responsible to ensure that the Broader Impacts criteria is not evaluated as secondary criteria.

NSF to Public

- NSF needs to revamp its dissemination of the Broader Impacts of its research portfolio.
 - Encourage PIs to develop “30-second thesis” to describe succinctly the research activities and outcomes related to funded projects.
 - Provide list of speakers, e.g., work with TED talks to invite grantees to speak.
 - Create videos about beneficiaries’ opinions of funded research.
 - Use the suggested Broader Impacts annual awards as a communications tool.

PIs to Public and Media

- PIs are ambassadors of NSF, their universities, and academia in general. NSF can educate PIs about this responsibility, e.g., using the REU-like supplemental awards to promote outreach by PIs and leverage the broader impacts network and the national alliance for broader impacts.

II. Alternative submission/review mechanism for GOALI proposals

NSF established the special program solicitation, Grant Opportunities for Academic Liaison with Industry (GOALI; NSF 12-513), which “promotes university-industry partnerships by making project funds or fellowships/traineeships available to support an eclectic mix of industry-university linkages. Special interest is focused on affording the opportunity for Faculty, postdoctoral fellows, and students to conduct research and gain experience in an industrial setting; Industrial scientists and engineers to bring industry’s perspective and integrative skills to academe; and Interdisciplinary university-industry teams to conduct research projects”.

GOALI proposals explicitly require industry involvement and participation in the project, i.e., projects have a more applied nature than unsolicited proposals and the GOALI solicitation specifically targets the development of

innovative collaborative industry-university educational programs and the direct transfer of new knowledge between academia and industry.

Presently, review panels review both GOALI and unsolicited proposals, which introduces an undue inequity/imbalance between the two proposal types. Participants suggest that GOALI and unsolicited proposals could be reviewed in distinct panels and possibly using different procedures.

III. Employ best practices prior to, during, and after implementing these suggestions

The non-exhaustive list of best practices to enhance the benefits and limit the undesirable/unintended consequences that may arise when implementing the proposed recommendation is as follows:

1. Each recommendation needs to be carefully evaluated by a committee that is inclusive of NSF staff, program managers, reviewers, and researchers.
2. The recommendations need to be implemented using a change management plan including the following characteristics:
 - a. [Justify and announce the change] The change should be justified to all stakeholders. Stakeholders need to understand that change is inevitable.
 - b. [Thoroughly vet the change] Set a feedback period to allow stakeholders outside the committee to voice their opinions and recommendations. The committee should respond to these suggestions, and perhaps revise the implementation details according to the suggestions.
 - c. [Thoroughly evaluate the change] Set a trial period for the change and evaluate the outcomes. Adjust and re-evaluate. If possible, implement the change side-by-side with the previous process to improve the ability to measure the effect of the changes.
 - d. [Follow-up] Hold a follow-up workshop to do a final evaluation.

5. **Post Workshop Insights**

The outputs from the workshop were shared at a number of venues and conferences (e.g., an annual meeting for the Institute for Operations Research and the Management Sciences (INFORMS), the National Alliance for Broader Impacts (NABI) Summit, the NSF Engineering Education and Centers (EEC) Grantees Conference) and with researchers who have been supported by NSF and/or served on NSF panels. Several messages came across, though three consistent messages resonated from many of the stakeholders with respect to Broader Impacts and the review process. One point is that there is limited or no mechanism to communicate Broader Impacts via traditional scholarly publication outlets. This suggests the

need for scholarly publications that provide both a venue for communication and an archival outlet to accrue academic value for Broader Impact contributions. Given the upheaval that is taking place in the academic publishing eco-system, with regard to open access, new models for publication and dissemination may emerge that create opportunities for new outlets to communicate Broader Impacts contributions.

The second point is that the two components for peer review, Intellectual Merits and Broader Impacts, create an unintended hierarchy in the review process, with one criterion placed as the primary and the other placed as the secondary. Invariably, reviewers and proposers place Intellectual Merits as the primary, and Broader Impacts as the secondary. Indeed, when presented with two objectives, human nature inherently prioritizes them, based on internal biases or external values. A solution to this schism is to create a single criterion that embodies both peer-review criteria. One possibility is *Advancing Knowledge for Society*. This criterion embodies the *Intellectual Merit* criterion for advancing the frontier of knowledge, both fundamental and applied, and the *Broader Impacts* criterion for societal benefits. The name of the criterion is less critical than the need to identify a unifying measure for evaluation.

The third point, which is related to the second point with respect to the review process, is how transformative research relates to Broader Impacts. Although transformative research is an ideal for all funded projects, the reality is that there is a continuum, traversing from research that is transformative to research that incrementally advances a field and/or body of knowledge. It was observed that reviewers often used the lack of transformative ideas as a reason to poorly rate a proposal. This was viewed as using a valuable criterion as a negative weapon rather than a positive tool, which many people considered inappropriate. It was observed that Program Managers need to be more effective in mitigating such activities in the review process, since it could serve to suppress or limit support for outstanding Broader Impacts projects.

As the discussion on Broader Impacts continues, it is clear that more thought is needed to reach an optimal point whereby Broader Impacts is appreciated, valued, and advanced by all stakeholders. The workshop served as the beginning of this discussion, and will hopefully provide new ideas to enhance the impact of Broader Impacts so that the full value of NSF funded research can be optimally realized for society.

6. Workshop Structure

The objective of the two-day workshop was to create a roadmap for enhancing Broader Impacts activities in NSF grants within CMMI. The emphasis was to create an environment that facilitated innovative and transformative ideas for Broader Impacts rather than defining as a checklist for PIs' specific Broader Impacts activities. Academic institutions should be encouraged to create a mechanism, such as a center, that tracks and facilitates Broader Impacts contributions over different time horizons and to provide a fertile environment supporting and incentivizing

Broader Impacts innovations. Moreover, the broader impacts should closely align with the Intellectual Merit contributions.

7. **Workshop Format**

The questions above were provided to participants prior to the workshop. Each of the first three sessions focused on one type of Broader Impacts. The objective was to create a roadmap for each type of Broader Impacts. The sub-topics were “The Integration of Technical Merit and the [respective] Broader Impact” and “Transformative [respective] Broader Impacts.” The fourth session focused on how academic institutions could facilitate, support, incentivize, and track Broader Impacts activities. All sessions had a facilitator and a scribe. A wrap-up session summarized the findings.

Themes (and titles) of workshop sessions (breaks not included):

1) Economic Broader Impacts (Day 1: 2 Hours)

Speaker: Karl Grosh, University of Michigan

1.1) Success story of a grant with a measurable, transformative Economic Broader Impact

1.2) The Integration of Technical Merit and Economic Broader Impacts

- How can Technical Merit drive innovations in Economic Broader Impacts?
- Can transformative Economic Broader Impacts enhance Technical Merit contributions?
- What can institutions do to facilitate the synergy between Technical Merit and Economic Broader Impacts?

1.3) Transformative Economic Broader Impacts

- How can an Economic Broader Impacts be fully realized?
- What can institutions do to facilitate creative and innovative Economic Broader Impacts?

2) People Broader Impacts (Day 1: 2 Hours)

Speaker: Jonathan Caulkins, Carnegie Mellon University

2.1) Success story of a grant with a measurable, transformative People Broader Impact

2.2) The Integration of Technical Merit and People Broader Impacts

- How can Technical Merit drive innovations in People Broader Impacts (beyond the standard ones)?
- Can transformative People Broader Impacts enhance Technical Merit contributions?
- What can institutions do to facilitate the synergy between Technical Merit and People Broader Impacts?

2.3) Transformative People Broader Impacts

- How can People Broader Impacts be fully realized?
- What can institutions do to facilitate creative and innovative People Broader Impacts?

3) Information/Communication Broader Impacts (Day 1: 2 Hours)

Speaker: Reginald DesRoches, Georgia Tech

3.1) Success story of a grant with a measurable, transformative Information/Communication Broader Impact

3.2) The Integration of Technical Merit and Information/Communication Broader Impacts

- How can Technical Merit drive innovations in Information/Communication BIs?
- Can transformative Information/Communication BIs enhance Technical Merit?
- What can institutions do to facilitate the synergy between Technical Merit and Information/Communication Broader Impacts?

3.3) Transformative Information/Communication Broader Impacts

- How can an Information/Communication Broader Impacts be fully realized?
- What can academic institutions do to facilitate creative and innovative Information/Communication Broader Impacts?

4) Common Themes for Broader Impacts (Day 2: 2 Hours)

Lessons learned from Day 1 discussion.

5) Wrap-up session (Day 2: 2 Hours) - Discuss Key Recommendations

Academic Workshop Participants:

Pinar Keskinocak	Georgia Tech
J. Cole Smith	Clemson University
Brian Denton	University of Michigan
David Goldberg	Georgia Tech
Kash Barker	University of Oklahoma
Phil Kaminsky	University of California (Berkeley)
Jonathan P. Caulkins	Carnegie Mellon University
Regginald DesRoches	Georgia Tech
Maria Garlock	Princeton University
Tracy Kijewski-Correa	University of Notre Dame
Jerry Lynch	University of Michigan
Karl Grosh	University of Michigan
Jon Stewart	University of California (LA)
Burcu Akinci	Carnegie Mellon University
Shirley Dyke	Purdue University
Glaucio Paulino	Georgia Tech
Tequila Harris	Georgia Tech
Alison Flatau	University of Maryland
Bill Messner	Tufts University
Andrew Alleyne	University of Illinois Urbana-Champaign
George Chiu	Purdue University
Laura Ray	Dartmouth College
Lei Zuo	Virginia Tech
Michael Arnold	University of Wisconsin-Madison
Susan Renoe	Missouri University of Science and Technology

Workshop Organizers

Sheldon H. Jacobson

Jerome F. Hajjar

Dawn Tilbury

Andrew Johnson

Erick Moreno-Centeno (Scribe)

Siqian Shen (Scribe)

University of Illinois Urbana-Champaign

Northeastern University

University of Michigan

Texas A&M University

Texas A&M University

University of Michigan