INPUT ON ACCELERATING RESEARCH THROUGH INTERNATIONAL NETWORK-TO-NETWORK COLLABORATION

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Report of the Subcommittee on International Network-to-Network Collaboration
Advisory Committee for International Science and Engineering
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REPORT OF THE SUBCOMMITTEE ON INTERNATIONAL NETWORK-TO-NETWORK COLLABORATION ADVISORY COMMITTEE ON INTERNATIONAL SCIENCE AND ENGINEERING NATIONAL SCIENCE FOUNDATION (NSF) OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE)

A Network of Networks Concept—The Need for this Approach

The Dear Colleague 17-131 call for White Papers asked the community whether NSF should consider supporting international network-to-network collaborations. The idea is called "AccelNet." The community response was very positive. In the context of the AccelNet idea, the subcommittee agreed that AccelNet is a worthwhile concept that should be advanced. The subcommittee defined networks as established, coordinated and distributed groups of scientific researchers who cooperate within or across fields to collect and share resources, knowledge and expertise. Network-to-network is the action of establishing a formal link between or among networks to serve as a "force multiplier" and connectors to advance the frontiers of science.

A network-of-networks approach could tap scientific excellence around the world. Data shows that many more countries worldwide have grown in scientific and technological capacity. As the capacity grows, U.S. science could be enhanced by broadening network-to-network (N2N) connections. An initiative linking networks could add to U.S. resources and capabilities to maintain excellence in science. As more and more networks are organized around the globe, there is a clear opportunity to support their intellectual potential by providing the coordinating mechanisms to make connections. NSF, in its role as a steward of U.S. science, has a clear mandate to explore this opportunity in greater detail.

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The subcommittee discussed ways to support U.S. participation in strategic international research network collaborations. Research networks take many forms, from a loose affiliation of scholars within a single institution (intra-institutional), cross-institutional networks (inter-institutional), and ones that cross nations (international). These networks can involve sharing research activities, results, resources, educational activities, and databases, or any combination of these items. AccelNet networks are

proposed to be distinct from other existing NSF initiatives that support the development and linking of databases and equipment. Such examples include the Arctic Observing Network (AON), a network that supports integrated long-term measurements of Arctic system characteristics to address hypotheses about mechanisms underlying Arctic environmental system change and its global connections through observation and analysis. The Global Biodiversity Information Facility (GBIF) is another existing networked database initiative. NSF sponsors and supports the development and maintenance of databases such as GBIF, which draws data and combines biodiversity information from around the world. Another networked organization is the Global Seismographic Network (GSN), which coordinates links among seismographs located around the globe, collates data, and disseminates information and reports.

These formal projects serve specific scientific goals. N2N will link people who are building and working within networks like AON, GBIF, and GSN. The goal is to help them more effectively meet their goals, as well as create new opportunities for them to achieve scientific goals that would otherwise be unachievable without AccelNet. Specifically, although these types of networks provide critical infrastructure and capacity to advance science, in the view of the subcommittee, AccelNet would support a type of networking that fosters relationships of researchers *across* networks. It is proposed that AccelNet would be primarily aimed at connecting researchers to one another across networks, rather than aimed at expanding network infrastructure. This report focuses on opportunities associated with connecting researchers across scientific networks.

Opportunities for Accelerating Discovery

The N2N concept, as interpreted by the research community in response to the Dear Colleague Letter NSF 17-131, aligns with the 'network' concept discussed above. The White Papers submitted to NSF described possibilities of linking people from within institutions, professional societies, research centers, and across institutions, to encourage greater sharing of data, research processes, infrastructure and outputs in ways that enhance scientific research.

The networks discussed in the White Papers ranged from well-established to nascent. Among the White Papers, a particularly comprehensive N2N example included networks of institutions to link resources to advance astrophysics. Established networks in Australia, Europe, and Canada have different technical capabilities than the U.S. network (e.g. different observatories, accelerator facilities, computational models, etc.). An N2N relationship would allow all partners to benefit by sharing expenses and access to one-of-a-kind facilities. Similarly, in a White Paper on computational science, different nations and the European Union have developed regionally-based High Performance Computing centers that could be linked through an N2N. Coordination of HPC resource allocation and user support would increase the productivity of international research teams. Linking U.S. astrophysics networks with European counterparts or creating a network of computational science networks could enhance science by offering N2N members complementary resources and enriching the sharing of research results.

Other white papers called for the development of N2N activities where participating networks are only beginning to develop. For example, an international multidisciplinary network of scholars and practitioners described how an N2N would allow sharing of facilities, information, and expertise about Open Science Hardware. No networks inside or outside the US are cited, although an excellent argument is made for how such N2N connections would accelerate research and STEM education. Another White Paper urges the establishment of N2N activities related to the Food-Energy-Nexus where networks in Europe are mentioned while networks in the U.S. have evidently lacked durability and would need to be reconstituted.

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Across the varied White Papers, the subcommittee saw four important themes for what AccelNet could accomplish: 1) growing scientific capacity; 2) training and human resource enhancement; 3) sharing of technology, data, and equipment; and 4) facilitating the ability of researchers to work with others from a quite different, but relevant, discipline or field. First, within science, it may be possible to use N2N to increase the capacity of fields to conduct research, to explore new areas, or to add a global perspective to enhance novelty and creativity. Second, many described how N2Ns could better train students and young researchers by creating broader and more varied international networks.

Third, other goals included gaining access to equipment, data sharing, development of common standards and platforms for data management, the creation of databases, and sharing models and frameworks to enhance and accelerate discovery. Fourth, facilitating the collaboration between different types of fields, ones that may well have different approaches to work, collaboration, knowledge production, norms and ethics could be very rewarding. The subcommittee presumes a network of networks would be particularly likely to be heterogeneous with regard to these elements and thus, probably in need of help in spanning the chasms. The subcommittee thought that each of these functions could help accelerate discovery and viewed AccelNet as the kind of initiative that would help N2Ns better coordinate and focus in a way that can ensure leveraging resources.

Organizational Considerations

Among the White Papers were ideas that showed varying levels of maturity of networked activities. This variation, and the insights derived from the subcommittee's review of the White Papers, brought forth important considerations for designing the initiative and assessing N2N proposals. Some of the proposed N2N ideas, such as astrophysics, were quite mature and appeared to have a clear set of goals and outcomes. As such, the possibility of gaining scientific benefit from this N2N appeared highly likely. Other proposed networks, such as a sustainable buildings network, were viewed as important, but lacked examples of any existing networks. Given this, even White Papers with good ideas, yet lacking existing networks, were viewed as projects with higher risk. From this, the subcommittee agreed that some risky projects should be considered, along with well-developed concepts, as long as the value

proposition of the risky project is strong and the need and opportunity clearly explained. As the Dear Colleague letter NSF 17-131 noted: "…areas with sufficient maturity to have nascent, but not well-established, network of researchers in the U.S. and abroad are of particular interest…" This can be difficult to quantify, but the subcommittee thought that a portfolio of approaches, with a blend of developing and established networks, is a possible way to manage the varying levels of maturity of the N2N activities.

Specific elements for consideration are described below.

A) Reciprocity and Mutual Benefits: A given network within an N2N may bring different values to the collective; for instance, a network may offer resources not found in other networks (e.g., specialized expertise, unique samples, settings, equipment) while some networks may provide similar types of resources for sharing. Both examples offer the opportunity to amplify the resource potential of the N2N as a whole. It should be clear at the start how each network contributes to the pool of resources for the N2N. Networks with fewer resources may be able to offer in-kind contributions (e.g., local support for an international workshop). To illustrate, in the ILTER Network (a network of National Long-Term Ecological Research Networks), many workshops in Asia have been conducted where the host pays for local costs and participants are responsible for travel. This was a valuable "in-kind" contribution; everyone involved has a stake in the outcome because of the financial investment. This grassroots model for funding has been far more productive in terms of maintaining lasting connections after the workshop than the model where the U.S. covers most costs.

Consideration should be given to the development of strategies to ensure transparency up front regarding what each network would bring to the N2N and how each network plans to contribute to the overall mission. Methods for outlining roles and expectations regarding network contributions and associated terms of agreement can help reduce conflicts that may arise due to perceived imbalances or differential (yet important) contributions among networks. At the start, participating networks should clearly articulate the added value the N2N connection will bring to all parties.

B) Mission and Vision: The need for clarity of mission and vision for the N2N, as well as for specific projects proposed by the N2N, was raised by the subcommittee as a critical issue for AccelNet design. Mission statements should include key questions such as: what can be gained by participants? What is the social value? What is gained by the scientific community? What gaps are being bridged through the N2N? How will progress be monitored?

The need for shared understanding of these issues was highlighted particularly around willingness of parties to integrate resources and possibly share and analyze data together. Several issues are involved here, many of which can be contentious and lead to conflict. This includes open data sharing, publication of results, copyright or intellectual property protection, software ownership and equipment sharing. It is important that proposing N2Ns understand and

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discuss these issues and describe how they will be managed by their N2N. As an example, N2Ns should discuss from the onset who will be authors when data is shared for a publication. Given this, AccelNet should consider the development and dissemination of templates that help N2Ns manage data ownership agreements and other (possibly contentious) issues.

Furthermore, participating research networks can have many different goals (as shown in the White Papers). As such, it is important that N2N members demonstrate overarching goal alignment through the development of shared goals among partners. Shared goals include scientific and specific N2N goals and should recognize that each member network will have unique goals as well.

- **Shared Scientific Goal** - The N2N should seek links among networks with similar overarching scientific and societal aims. As an example, a White Paper on nanomanufacturing has the clear goal of establishing N2N in order to address potential risks to living systems of emerging nanotechnologies. Networks would establish best practices so that experiments run throughout the N2N would be comparable, and data curation and integration of knowledge would follow agreed protocols.

- **Shared N2N Goals** - Clearly articulated N2N goals and objectives can include the specific ways that the N2N partners work together to advance their shared scientific goals. Goals and expectations of all parties must be transparent. A clear vision and mission for the N2N should be stated in a way that is specific, measurable, achievable, relevant, and time-oriented. Expectations of the N2N leadership would need to be articulated ahead of time along with specific and agreed-upon goals for the networks.

- **Support of Unique Goals** - Different stakeholders may have unique needs/goals while working towards the larger common goals. At a minimum, recognition and respect for such goals should be acknowledged and honored. To the extent possible, projects should make explicit the unique needs/goals of participating stakeholders when developing their N2N. Shared awareness of these will enhance the capacity for collaborative success.

C) Role and Contribution Clarity: Role clarity for participating members is a key component of N2N planning. Similarly, specification of what will be contributed by which parties is important. To support this, team members would need to be clear as to the objective of their connections as well as the parameters of the cooperative activities engaged by network members. As part of this effort, building trust will be key and will take time. In support of this, N2Ns should consider development of a collaborative agreement or a team charter.

• **Trust is essential to N2N success**: Trust would need to be nurtured in numerous ways given the complexity of N2Ns. This ranges, for example, from trust about differing disciplinary approaches to varying methods for mentoring students across scientific disciplines or countries to how technology or data will be shared. Furthermore, trust across cultures can also be required. As an example, some White Papers discussed building bridges with networks in predominantly developing countries. This arose from the value of data within networks in those countries and how it could advance the research of collaborators

in other networks. In such cases, White Papers proposed building bridges through the N2N via training workshops, international exchange programs, and other capacity-building efforts. Such activities will be essential to building trust and repeated face-to-face meetings will be needed. Furthermore, clear incentives for these "South" networks to share data must be offered. Not only does the culture of data sharing, ownership, and collaboration, vary widely across countries, but N2Ns must explicitly guard against any form of data exploitation of the southern networks. Proposing N2Ns need to understand the differing scholarly norms and/or governmental policy that can exist in other cultures. As an example, network representatives attending a workshop may have no authority to share a data set owned by an institution. Such barriers to data sharing may not be clear until face-to-face meetings occur. For instance, ILTER Network workshops, designed to integrate datasets from several countries, were hampered by these kinds of issues that were not revealed in the planning process.

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• **Macro-level Role Clarity**: Macro-level role clarity is related to the role of each network and its sponsor in contributing to the mission and goals of the N2N. This includes clarification around questions such as: What is the role of each network? What unique resources and contributions do they bring to the N2N (e.g. data, equipment, access to settings/populations, etc.)?

• **Meso-level Role Clarity**: Meso-level role clarity is related to roles network members play in carrying out the specific objectives of the N2N. This includes clarification around questions such as: What are the roles of network members in carrying out N2N objectives (e.g. host meetings, arrange calls)? How do network members manage or co-manage a project database?

• **Micro-level Role Clarity**: Micro-level role clarity is related more to day-to-day functioning of particular N2N projects. This includes clarification around questions such as: What roles will be given to network members for specific projects (e.g. conduct an analysis, set an agenda)? Who is responsible for communicating with other networks?

To establish mission clarity and expectations, it may be that memoranda of understanding or contractual language are needed to move forward. Legal advice on these items may be needed during the AccelNet planning process.

D) Durability and Sustainability- The durability and sustainability of any cooperative link should be considered. If commitments are made to establish an AccelNet project, how capable are all sides to maintain and sustain the activity towards its goals? Some of the White Papers pointed out that past N2N activities have been held together by personal relationships and volunteers, and that productivity and N2N durability would be vastly increased if there was support for staff to coordinate interactions. One White Paper discussed SAON, created by the International Arctic Council, which was designed to create a network-of-networks that conduct arctic research. Pieces of SAON have been built

in different countries, but there have never been resources to support SAON as a unit to create value-added results. Collaborative infrastructure is needed to bring together the scientists to use SAON.

Sustainability concerns regarding staffing should be addressed in all countries involved in an N2N relationship. This level of interaction among N2N members needs to be considered as part of a collaboration plan among the network members. Plans would need to address communication of any outputs as well. Several of the White Papers mentioned the importance of common data management practices throughout the N2N, including the use of common standards and protocols, exchange of analytical code, and shared data management infrastructure. Any N2N project will need some form of information management support and the complexity of this support will depend on the structure/size of the N2N and its goals. A data management plan, agreed to by all members of the N2N, should indicate: 1) what data products will be produced; 2) how they will be managed and secured by each contributor; 3) how they will be made accessible to all partners; and 4) who controls and owns the data. The subcommittee recommends consideration of best practices from other NSF initiatives that focus specifically on data integration and use, such as the "Synthesis Centers". Appropriate funds to support information management must be allocated by each participant. All N2N members must commit to reciprocity and fairness where data use is concerned.

Based on the content of the White Papers, and the subcommittee's research expertise in such networks, considerations regarding the maturity of the science and the associated networks, as well as the history of potential N2N prior relationships, should be taken into account when reviewing proposals. Given this, AccelNet should consider approaches that provide varying levels and types of support depending upon the needs of the proposals.

In light of the above considerations, a key factor for evaluation of N2N proposals is the scientific readiness of fields and/or domains covered by the networks; that is, how mature the area of science being pursued is. We expect that a mature area is going to have more networks in place. But the subcommittee felt strongly that both new and emerging areas, as well as long standing areas of science, would greatly benefit from N2N support. Because the number and level of maturity of the existing networks among different areas of science will vary, the subcommittee recommended that consideration be given to whether the mature field will create its own N2N without government support. These may already be on their way to a networked relationship, and therefore, government support would be redundant.

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E. Phased Approach Suggestion

The subcommittee outlined a phased approach that addresses these variations in maturity so that any N2N effort can maximize the effectiveness and efficiency of support and reduce the potential bias in support for newer versus longer standing areas of science positioned to address complex scientific and societal challenges.

Given this, the subcommittee suggested that AccelNet acknowledge the possibility for N2Ns to enter these phases at different times (e.g. a more mature area of inquiry could start at Phase Two, while less developed areas would need to begin at Phase One). Considerations include:

PHASE ONE: FEASIBILITY AND PLANNING

- Duration: 1-2 years
- Support for activities such as:
  - Convening potential N2N members
  - Exploring shared mission and goals (scientific and N2N)
  - Identifying N2N objectives – projects and activities
  - Developing collaboration plans
  - Assessing of sustainability potential
  - Conducting gap analyses, logic models, strategic planning

PHASE TWO: N2N LAUNCH AND PROJECT IMPLEMENTATION

- Duration: 2-5 years
- Support for the following activities:
  - Establishing coordinating mechanisms to align goals
  - Implementing coordination
  - Developing of products
  - Disseminating products
  - Planning for project completion, sustainability, or expansion (Phase Three)

PHASE THREE: N2N EXPANSION TO MAXIMIZE SCIENTIFIC ADVANCES

- Duration: 5-10 years
- Support activities such as:
  - Expanding efforts and growing objectives
  - Defining a path to sustainability (if this is a worthwhile goal)
  - Reporting on effectiveness

F. Metrics of Success

N2Ns will have different objectives, so metrics of progress and success will also be different. Nonetheless, the subcommittee did not think it wise to detail metrics for N2N projects ahead of time. More specifically, they felt strongly that the benefit of the N2N to science and society must be articulated by the projects themselves. The value may change over time—so flexibility and scalability are needed. Some N2Ns will produce new datasets integrated across participating networks, models, or new analytical platforms. Some will produce more papers with an international slate of authors, which may be more frequently cited than papers generated from a single network. New protocols or methods may be an output, or possibly, new equipment. Capacity building may be a significant goal. Given this, N2Ns will have to specify in Phase I what they anticipate their outputs to be so that the N2N can be

evaluated in later phases. If the goals are not met, this is not always a mark of 'failure,' but, rather, can indicate a shift in purpose or the development of an unforeseen opportunity.

After each phase, the N2N would need to demonstrate value, sustainability, utility, and quality in order to advance to the next phase. A goal might be that, after a certain number of years, the network would need to become independent of government assistance. The committee also felt strongly that that NSF should not predetermine disciplinary versus interdisciplinary focuses. Given the varying scientific and societal goals of notional N2Ns, the degree of disciplinary integration should be driven by the project. Neither should there be geographic requirements, such as including developing countries. Proposals should detail these specifics for any N2N project.

As for methods, measures, and best practices that can support the collaborative elements of N2Ns, the NIH Team Science Toolkit has a wealth of resources that can be useful to the NSF team as they consider questions such as agreements, teaming arrangements, trainings, and processes. The NSF Synthesis Centers program can also offer useful resources for managing the complexities inherent in data integration, sharing, and use.

The table below has examples of networks that may provide features for AccelNet consideration.

Model	Description
Federation of Associations in Behavioral and Brain Science (FABBS)	FABBS promotes human potential and well-being by advancing the sciences of mind, brain, and behavior; promoting scientific research and training in these fields; educating the public about the contributions of research to the health and well-being of individuals and society; fostering communication among scientists; and recognizing scientists who have made significant contributions to building knowledge.
International Society of Learning Societies (ISLS)	A professional society dedicated to the interdisciplinary empirical investigation of learning as it exists in real-world settings and to how learning may be facilitated both with and without technology
Synthesis Centers	Synthesis centers foster collaborative research by bringing interdisciplinary groups of specialists and experts together for an extended period of time in a collegial setting aimed at stimulating creative thinking, catalyzing insight, and facilitating group learning. The centers generally provide the technological expertise to help researchers collect, analyze, and synthesize diverse and disparate datasets to address critical science questions.

Building Interdisciplinary Research Careers in Women's Health (BIRCWH)	Connects junior faculty, known as BIRCWH Scholars, to senior faculty with shared research interest in women's health and sex-differences research. Since the program was created in 2000, 77 grants to 41 institutions supporting more than 613 junior faculty have been awarded by ORWH and BIRCWH program co-sponsors.
G8 Multilateral Research Funding Initiative	This initiative gives an unprecedented opportunity for the Funding Agencies to work together across a broad range of disciplines. An important goal of the Pilot initiative is for the Funding Agencies to gain experience in the funding of multilateral research in a flexible manner and eventually allow them to make long-term decisions on how to further promote multilateral research, preferably bottom-up projects.
SAVI	Formally launched in January 2013, the Finland-USA Science Across Virtual Institutes (SAVI) collaboration connects sixteen research groups in the Finland and the US in an effort carry out significant advances in education and the learning sciences.
International LTER Network	ILTER is a network of national networks. Each country organizes its own network and then applies for membership. This organization is funded by dues and operates on a shoestring with lots of volunteer enthusiasm. There is no funding for a secretariat. Research ideas bubble up from a grassroots level, and partners often seek small grants from their own network in order to collaborate. Meager resources are pooled so that all countries can be involved in a project. This has been a successful model for ensuring that less wealthy members of the ILTER can participate in research projects.