Response

to the

Recommendations of the

GSN Review Committee

Prepared by the

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August 26, 2015

Executive Summary

"The deployment of the Global Seismographic Network (GSN) represents one of the singular achievements of the seismological community during the past thirty years." *(page 1)*

"[I]t is the unequivocal conclusion of the Review Committee that continued federal funding of the GSN and broad community participation are essential to the future of basic and applied seismological research and the use of this research in support of agency missions" *(page 1).*

"It is thus our obligation to point out that continuous earthquake recording is as important for fundamental research as it is for mission obligations, if not more so." *(page 2).*

"[C]ontinuous monitoring has allowed the basic research community to identify previously unknown modes of Earth deformation and seismic rupture, in addition to providing wholly new ways of imaging the crust and deep Earth and has established novel investigations of the oceans and the atmosphere. This new science itself confirms the wisdom of continuous support of the GSN by the NSF and other agencies (page 2)".

GSN External Review Committee Report, 2015

Summary Response

The GSN Review Committee evaluated all aspects of the Global Seismographic Network (GSN) and provided a comprehensive set of observations, findings, and recommendations. In the following section of this document IRIS responds to each individual recommendation made by the Review Committee. In many cases, there are already activities underway within IRIS that will address the recommendations, while in other cases, IRIS will take actions deriving directly from the recommendations.

In this executive summary, we highlight key findings and recommendations that emerged across multiple sections of the Review report: the fundamental scientific importance of the GSN, its funding levels, the quality of the data produced by the GSN and the overall management structure.

Key Findings

Importance of the GSN. The GSN Review Committee was unambiguous in their assessment of the fundamental importance of the GSN for scientific discovery and earthquake monitoring, as well as mission-agency objectives. The committee noted that the range of science produced from GSN data is impressive and spans investigations into fundamental structure and dynamics of the Earth's deep interior, the physics of great earthquakes and tsunamis, and unexpected applications such as the seismic signal of landslides and ice-stream processes. The GSN has played a critically important role in understanding the great earthquakes of the last decade, including the M>9 events in Japan and Sumatra. Since the deployment of the GSN, and especially in the last decade, thousands of on-scale, broad-band records have become available, providing our first real look into a fundamental, dynamical components of active tectonic processes, including new classes of co- and inter-seismic phenomena that would have escaped discovery if not for the GSN. The Committee also noted that ". . . the GSN continually contributes to transformative scientific observations and discovery" (page 8). The Committee concluded that the GSN warrants the strong continued involvement and support of NSF and the

USGS, and believes the GSN should be a cornerstone of future seismological facilities. IRIS strongly agrees with this assessment.

Funding Levels. In times of tight federal budgets, the funding of the GSN has been an ongoing challenge: **"The committee stresses that capped or declining budgets are the most significant problem facing the GSN" (page 21).** Years of reduced funding levels have started to degrade the data quality, volume, and robustness of the network, and diminished the ability to maintain cutting-edge technology that fully meets the GSN's visionary design goals. The Committee states that "NSF, IRIS and the USGS should work together to ensure that funds are available for recapitalizing station hardware when and where appropriate and in a timely manner." (page 20) IRIS agrees that reduced funding is the primary hindrance to operating the GSN at its full capacity, and encourages returning the GSN to fully funded status.

Maintaining Data Quality. Historically, the level of GSN data quality has been very high, in an absolute sense and compared to other seismic networks. The Committee notes that these quality efforts have "achieved a level of data quality that is now almost taken for granted by the research and monitoring communities". (page 19) This data quality results from exceptionally high-quality hardware, siting, and installation – but just as importantly from the development and implementation of quality-assessment and quality-control protocols. A focus on quality assessment and control in recent years has significantly improved the quality of the data, and must be a priority in the future. IRIS agrees that data quality is paramount for the GSN, and will maintain a focus on these efforts. We note that maintaining data quality will also require replacement of aging sensors and auxiliary equipment, which cannot be accomplished at current budget levels.

Management and Governance. A unique element of the GSN structure is the partnership between the NSF, IRIS and the USGS in operating the GSN. The Committee evaluated this unique structure and found that: "The utility of having two operators representing academia and government separately offers a distinct operational advantage." (page 14). IRIS supports and facilitates a community governance and oversight structure to provide advice and guidance to both IRIS/NSF and the USGS on the operation of the GSN. The Committee noted that: "Community oversight and coordinated current activities have turned out to be the most beneficial aspects of current management arrangement". (page 16) This is an important endorsement, as IRIS utilizes a similar community-based governance structure for all of the NSF-sponsored programs it manages, and believes this is a major benefit of the IRIS Consortium's role in managing seismological facilities. IRIS agrees on the importance of strong and active community oversight, and will continue to support the existing governance structure and be responsive to input from its community governance bodies.

Key Recommendations: Summary Responses by Categories
The Review Committee has provided a detailed list of recommendations, grouped into several major categories. Key recommendations of the Review Committee include: 1) a return of the GSN to full funding levels, with continued cost-conscious and efficient management and operations; 2) continued strong community oversight of the GSN; 3) continued and renewed emphasis on GSN data quality; 4) maintenance and strengthening of international partnerships; 5) continuation of the close integration between data collection, data archiving and distribution; and, 6) support for the dual-operator government-academic partnership between NSF/IRIS and the USGS.

In the following paragraphs, we present summary responses for each category of recommendation.

GSN Goals. IRIS will ask the GSN SC to convene a working group to revisit the overall GSN design goals (last updated in 2002), in order to assess current community needs, evaluate the availability of current technical innovations, and explore the possibility of expanding the GSN into the oceans. IRIS agrees that current technology has put the goal of extending the GSN into the oceans within reach, and both the GSN Standing Committee and the Ocean Bottom Seismograph Instrument Pool Oversight Committee (OBSIP OC; the OBSIP is also operated by IRIS) are exploring the topic of a pilot or demonstration project that would address the challenges and promote technological solutions for long-term deployment of GSN-quality seismic stations in the ocean basins and on continental shelves.

Technology. IRIS is actively pursuing a wide range of strategies to ensure that all of the instrumentation activities within IRIS are sharing information about the latest technology, and are actively engaged with technology companies, universities, and government agencies to identify and encourage relevant development activities. Within the GSN, an effort is underway to develop, evaluate, and procure new Very Broad Band (VBB) Borehole Seismometers designed to replace aged, failing instruments currently in place. This effort is occurring through a contractual agreement with the USGS. Both GSN operators have also been evaluating a prototype GSN VBB vault sensor. More broadly, IRIS is currently engaging with the exploration industry to evaluate areas where new trends in exploration-industry instrumentation (funded by the exploration industry's buying power) can provide new capabilities for research applications.

Management, Coordination and Community Oversight. Community oversight and coordinated activities will continue to be the hallmark of the GSN management and governance structure. IRIS will continue to support the GSN Standing Committee, which also serves as an advisory committee to the USGS, and will work to implement its recommendations. The GSN Program Manager (PM) will continue conducting bi-weekly joint meetings with the GSN network operators at ASL and IDA to discuss upcoming station visits, instrumentation development and testing and data-quality evaluation in support of GSN design goals. The GSN PM, in coordination with the USGS, will develop a high-level Quantitative Risk Assessment (QRA) to identify the risks to the GSN, to quantify their probability of occurrence and the likely costs incurred if such risks manifest. Mitigation strategies will be identified.

Data Quality. The maintenance of GSN data quality is of the utmost priority for IRIS, and is a priority that has been emphasized by the GSN Standing Committee for the past several years. Data quality is currently a major thrust across all of IRIS, and IRIS has recently adopted and documented a set of "*IRIS Quality Principles for Data Collection, Distribution, and Use".* IRIS is engaged, with the USGS, in efforts to develop new instrumentation technologies and station infrastructure, as well as data-quality assessment tools. The application of the quality-assessment tools will support the GSN Standing Committee's efforts in setting priorities for the network, and will allow the network operators to prioritize maintenance activities and ensure a seamless flow of data and metadata to the IRIS DMC. IRIS is also working to improve community access to data-quality information.

Costs. IRIS agrees with the Review Committee that the funding shortage suffered by the GSN is the largest threat to continued high-quality operation of the network, with recent real-dollar funding reductions having led to measurable network deterioration. IRIS already operates the GSN in a highly cost-conscious manner, and the GSN PM, in cooperation with the USGS, will continue to focus on efficient operations. This includes encouraging ASL-UCSD coordination of

upcoming station visits, instrument testing and deployments and general operational tasks of the network. IRIS is currently compiling a list of necessary infrastructure improvements and related costs required to maintain the GSN network at the required, high quality level. The GSN PM will continue to work closely with IRIS senior management to identify opportunities for additional funding for GSN capital equipment from multiple agencies, as well as identifying additional appropriate funding requests to the NSF and USGS for the deployment of such equipment.

International Partnerships. IRIS and the GSN currently maintain a wide range of international station host and data sharing agreements with foreign entities. Involvement with international partners will continue to be emphasized for ensuring the long-term viability of the GSN. IRIS will also continue its collaborations with individual foreign networks and participation in the Federation of Digital Seismograph Networks (FDSN) to explore ways to encourage in-country support of GSN station operations and develop multi-use applications of GSN sites.

Scope. In planning for addressing future research needs and enabling discovery science, IRIS and the GSN SC are taking under consideration outcomes from workshops on grand challenges and new instrumentation, e.g., expansion of the GSN into the oceans and the development of sea floor seismometers and communications. GSN SC members and the IRIS staff actively participate in community workshops such as the Subduction Zone Observatory (SZO) and Ocean Bottom Seismology Symposia.

Data Management and Services. The GSN's goal is to provide the highest data quality and dynamic recording range, in support of scientific needs. A crucial link to making GSN station data available to the scientific community is the IRIS Data Management Center (DMC), which not only maintains the archive of data, but also provides easy, rapid, and open access to data recorded from minutes to decades ago. The GSN PM, along with the network operators, is working to analyze, quantify and improve the quality of the data at all of the GSN stations. In a coordinated effort, IRIS Data Services (DS) is developing general tools that can be applied to all of the data managed at the IRIS DMC, i.e., hundreds of permanent networks and hundreds of temporary experiments, as well as coordinating quality control with the FDSN. Improving the data quality of the GSN, as well as that from other networks archived at the DMC, is viewed as a joint and complementary effort between IRIS' Instrumentation Services (which includes the GSN) and Data Services directorates. The GSN is leveraging the tools developed by IRIS DS (e.g., MUSTANG), tools developed by ASL/USGS (e.g., Data Quality Analyzer) and UCSD-IDA, and additional custom tools to allow station operators, the GSN SC, and data users to better understand and evaluate GSN data quality in support of science goals.

IRIS will seek guidance from the Quality Assurance Working Group (a joint working group between IRIS Data Services and Instrumentation Services) in addition to the GSN SC on how best to frame an evaluation and review of the overall methods and procedures utilized by the two GSN Data Collection Centers.

Detailed Responses

In this section, IRIS addresses in detail each recommendation made by the committee in the review document. In the paragraphs below, Review Committee recommendations are in italics, while IRIS responses are in indented normal text. Bold face font is preserved from the Committee's report.

GSN Goals Recommendations: (page 8)

1. *To date, the established design goals have served both the research and monitoring communities well, and their stability over time has provided a stable target for technical innovation. However, design goals should be continuously evaluated in response to the evolution of research and monitoring needs.* **IRIS should establish a procedure that monitors community needs and technical innovation and reevaluates GSN design goals in response. Changes to design goals should occur on a timetable that allows strategic study, planning, deployment and assessment, that is, it is important that the GSN have a stable configuration for a significant (decadal, for example) period of time but not long enough to delay important design changes in response to scientific and monitoring needs.**

> IRIS agrees. The GSN SC discusses the design goals regularly, but a formal update to the design goals has not been undertaken since 2002. IRIS will ask the GSN SC to convene a working group to revisit the overall GSN design goals. We completely agree with the description of modifying goals in a manner that is neither too fast, nor too slow.

2. *Deployment of GSN-quality instrumentation in ocean basins and on continental shelves is necessary for meeting GSN design goals and for addressing key scientific questions, but it is expensive and technically challenging.* **IRIS should convene a community effort to design and propose (to the NSF and other agencies) a pilot or demonstration project that would address these challenges and promote technological solutions while providing important scientific observations and/or addressing a particular monitoring objective. A site near a potential tsunamigenic rupture could be explored, for example.**

> IRIS agrees and the GSN SC and OBSIP OC are actively discussing this topic in terms of what is needed, what objectives could be addressed, how large the initial project should be, etc. Between the existing IRIS GSN and OBSIP programs there is substantial relevant expertise, and the OBSIP Institutional Instrument Contributors (LDEO, SIO, WHOI) and UCSD/IGPP are well positioned to assist with such an effort.

3. *The GSN infrastructure, including data loggers, telemetry and the management and institutional relationships that provide geographically distributed and protected station sites, can be leveraged for other Earth-observing instrumentation.* **IRIS should work with the NSF and USGS to promote the use of GSN infrastructure, where appropriate, by other Earth observation communities.**

> IRIS agrees that such leveraging can be beneficial in many cases. The GSN is already deploying infrasound sensors at selected GSN sites using technology that has been used successfully by the Transportable Array. Both the USGS and IDA components of the GSN cooperate with several organizations to co-locate geophysical equipment at

GSN sites and thereby leverage investment in land, telemetry and host institution cooperation. These include colocation of JPL/UNAVCO GPS equipment and a geomagnetic observatory operated by the GFZ, Potsdam. IRIS will continue to work with other community and government organizations to identify opportunities for instrument co-location.

4. *International collaborations play an important role not only in basic research, but also in supplementing monitoring efforts and exploring efficiencies in maintenance and operations. However, relying on international networks to help fill the necessary global coverage is risky, because the longevity of those networks and their adherence to GSN--level quality standards cannot be guaranteed.* ***Discussion of design goals should solicit input from international interests.***

IRIS agrees that soliciting greater international input and collaboration on the GSN may enable improved global coverage and/or improved network resilience. IRIS maintains memoranda of understanding (MoU's) with international partners, including other seismic network operators, at many sites. IRIS will work to strengthen its engagement with such partners through formal and informal channels, and will solicit input from international partners as it reviews GSN design goals.

We also note the rapidly evolving "Federated System" initiated by the FDSN, which is extending QA procedures to FDSN-wide activities and enabling a more comprehensive evaluation of the availability and quality of data from other networks.

5. *The IRIS publications database does not capture the totality of scholarly output resulting from the analysis of GSN data. This limits community and agency awareness of the significance of the GSN. We recognize that tracking use of a freely available, open dataset such as that provided by the GSN is extraordinarily difficult.* ***Nevertheless, IRIS should strive to keep the GSN publication database as complete and current as possible.***

IRIS is presently working on the development of improved tools and procedures for capturing and tracking publications related to all IRIS activities. Also, through IRIS efforts and international collaboration, the GSN networks (II and IU) now have Digital Object Identifiers (DOIs) assigned to them to facilitate the citation of the GSN in research journals.

Technology Recommendations: (page 12)

1. ***IRIS, through its Instrumentation Services division, should conduct regular technology reviews across the components of the GSN and other IRIS instrumentation and infrastructure.*** *Such a review, say every few years, should include a survey of instrument research activities in universities along with commercial R&D.*

IRIS Instrumentation Services (IS) monitors technical innovations for developments that are relevant to IRIS programs. This is done by conducting Instrumentation Technology Symposia which are open to industry and academia (although fewer symposia will be held in the future due to reduced funding for the SAGE facility), technical interchange meetings including all engineering personnel working on all IRIS IS projects, attending technology-related conferences, and conducting meetings with individual vendors.

2. *Promising technological R&D should be presented to the relevant IRIS committees for discussion.* **Instrumentation Services should develop metrics that measure the costs and benefits associated with the deployment of particular technologies, and, for those technologies deemed ready for deployment, an implementation plan and budget.** *New technologies should be clearly linked to existing or evolving GSN program goals.*

> The identification of promising R & D technology is well underway, and IRIS and the GSN are well connected to this development. The GSN PM, GSN SC, and network operators regularly review new technology developments, including new and emerging very-broad-band sensor technology and advanced digitizer and data-acquisition systems. In addition, developments in other IRIS programs are closely monitored (e.g., use of posthole sensors by the TA and trials of all-in-one posthole sensors by PASSCAL Polar). Instrumentation Services is working on an over-arching sustainability analysis and strategic plan that will address equipment costs and benefits, and deployment costs, for presentation to IRIS governance committees.

3. *Instrumentation and other technical R&D in other fields, including the development of new modes of marine operations and technologies that would improve/enable deployment and O&M in oceans and other harsh environments, should be included in the regular review.* **IRIS should work with its consortium members and NSF to identify such developments, which may, in fact, be funded separately from the usual NSF programs.**

> IRIS agrees, and will consider such R&D results as it evaluates strategies for obtaining GSN coverage in the oceans. Efforts in this area include the OBSIP program which engages in a wide range of marine seismology and the OBSIP OC which provides community input on marine seismology research needs. In addition to managing all of the OBSIP data, IRIS is working with Neptune Canada and OOI on the management of data from cabled ocean bottom instruments. We note that UCSD is particularly active in marine observations, including both their participation in OBSIP and developmental work such as UCSD's Wave Glider/ADOSS project, supported by NSF OCE.

4. **The GSN Program Manager and the IRIS Director of Instrumentation Services, together with the appropriate IRIS Standing Committees,** should **encourage university and commercial innovators to self identify, perhaps through an agency or foundation partnership offering seed-money support.** *The IRIS website (and other publications) should have a page devoted to technical innovation.*

> IRIS has been working to achieve visibility for innovators in seismic technology. At the last IRIS Seismic Instrumentation Technology Symposium (SITS) the NSF program officer representing the I-CORPS program (NSF funding for certain classes of commercial innovation and spin-offs from research) gave a presentation that generated substantial discussion and interaction. IRIS is presently establishing an Industry Working Group with the goal of encouraging greater dialog and partnership between academia and industry across multiple fronts, including technology.

5. **The GSN and IS managers should charge their technical staff to develop professional ties with industry and university innovators,** perhaps **by adding side events at professional conferences and workshops and travel support for technical meetings.**

> IRIS agrees that this is an important means of ensuring the staff (and IRIS) stay current with the latest technology and R&D. IRIS actively participates in the Society for

Exploration Geophysics (SEG) annual meetings as a good means to stay abreast of exploration industry technology. IRIS also sends staff to an annual Polar Technology conference. The GSN PM will seek to engage with community and industry innovators at all available opportunities.

6. *The testing and commissioning of new primary sensors should be accelerated.* ***IRIS/IS and GSN and the USGS/Reston/Golden should develop a plan to better coordinate instrumentation testing and commissioning between IDA and ASL.***

IRIS agrees that identifying and ensuring the availability of the next generation of GSN primary sensors is critical. The first prototype of a new VBB borehole sensor is scheduled to be available for initial testing in October of this year. The timeline for development and testing of this sensor is controlled by contractual agreements between the vendor and the USGS. The USGS is monitoring this process closely to ensure on-time delivery and completion of this primary sensor replacement effort, and routinely sharing monthly progress reports with IRIS and the GSN SC.

A new VBB vault sensor has not yet been identified. Promising sensors are currently being tested by both network operators. A temporary ad-hoc instrument panel is being assembled to review, update as needed, and approve specifications for a GSN vault sensor. The GSN SC reviews progress related to several primary sensors in development at each committee meeting. The GSN PM will continue to work to coordinate testing and evaluation of results, and will interact with vendors as necessary to try to speed development progress.

7. ***Particular attention should be given to technical developments that might underlie a cost-effective pilot program for ocean deployments of GSN quality stations.***

IRIS agrees that GSN coverage in the oceans is important and will continue to pay special attention to relevant technical developments, e.g. participate in 2015 Ocean Bottom Seismology Symposium.

8. ***NSF planning within the Geosciences Directorate at both program and major facility levels should develop a cross-disciplinary program to fund Earth observation R&D at universities, the private sector, and university-commercial partnerships****. Concerns about the future capabilities of a technical workforce could be met in part by ensuring that such programs support graduate student and post-doctoral programs.*

IRIS agrees that career development for scientists focused on instrumentation is important and should be supported. A key topic for the new Industry Working Group that IRIS is forming is to address workforce development issues. The IRIS staff liaisons to this new working group are the Directors of Instrumentation Services and Education and Public Outreach.

Management, Coordination and Oversight Recommendations: (page 18)

1. *The existing GSN management structure is performing well*. ***NSF and the USGS should continue to support the dual operator model.***

IRIS will continue to work to maximize the benefits of the dual-operator structure of the GSN.

2. ***A full-time Program Manager dedicated entirely to the GSN should be a permanent part of any management structure,*** **and** ***should have a "dotted-line" report from IRIS central administrative staff to assist in monitoring subaward performance.***

> The current IRIS structure is aligned with this recommendation. IRIS made significant staffing changes in the past year in order to provide a full-time GSN Program Manager who reports directly to the Director of Instrumentation Services, who reports directly to the IRIS President. The GSN PM also has access to resources provided by a group of IRIS Project Associates who can assist with, among other things, monitoring and following up with any discrepancies in quality metric values with the network operators.

3. ***The GSN PM should work to ensure coordination of operations and maintenance between the two operators, and develop and implement plans to ensure standardized reporting of station metadata***.

> The IRIS GSN PM conducts bi-weekly joint meetings with ASL and IDA, where upcoming station visits, instrumentation developments and data quality metric definitions and calculations are reviewed. Station metadata (in terms of the specific station metadata represented in SEED) are highly structured and the reporting is highly standardized. More general metadata, related to station performance, station calibrations, or other characteristics (e.g., station uptime, etc.) are less uniform and this is a focus topic for the GSN PM and network operators, at the request of the GSN SC.

4. ***The GSN PM and GSN SC should study the methods and procedures of individual DCCs and report to the IRIS BoD on the benefits and costs of promoting common QA/QC procedures and software development.***

> IRIS has already begun to implement this recommendation. The GSN has created and regularly updates a Data Quality Goals document to articulate quality goals for the GSN. As a step towards a common understanding of QA/QC methods and measures, the GSN SC tasked the GSN staff to produce common metrics, and to identify and understand any differences in QA/QC algorithms or methodologies. The GSN PM and SC will continue to review QA/QC operations, and will communicate their findings to the BoD as part of their regular reports.

Data Quality Recommendations: (Page 20)

1. ***GSN should develop plans to integrate QC, QA and metadata collection and verification to the extent possible, in order to provide end users with a common tool that presents a uniform view of GSN data quality and uniform access to metadata.*** *This should develop into a standard operating protocol for the GSN data stream. Where feasible, input from other networks should be solicited, and the needs of the PASSCAL community might also be addressed.*

> This recommendation is in strong agreement with the IRIS Data Quality Principles, and efforts to provide such tools are underway. The MUSTANG data QC tool, combined with the LASSO display and viewing tool, currently provides end users with limited ability to examine data quality for the GSN. IRIS will work to extend the functionality

currently available in order to provide data users with a clear picture of GSN data quality and efficient access to related metadata. IRIS will remain cognizant of the utility of making such tools generalizable for other datasets, as is the intent with MUSTANG and LASSO. Input on these topics is being sought from other networks via FDSN Working Group activities. All metadata for the GSN stations are stored at the IRIS DMC and are available via multiple tools.

2. ***In addition to the feedback provided by the CMT, NEIC and other routine data product producers, GSN should explore methods to solicit and aggregate feedback from the broader user community***

IRIS agrees that this is a good suggestion, in line with the IRIS Data Quality Principles, and IRIS will work to achieve broader feedback on data and metadata issues. The GSN and DS have recently discussed possible approaches, and will continue working to move forward on this issue.

3. *While the GSN SC is presumably kept well-informed of GSN performance, it would benefit broader awareness of the GSN if a more public view of real time network performance and data quality could be made available, although this is of lower priority. In particular*, **the daily distribution of useful data quality and metadata metrics (State of Health, for example) would benefit some specific users as well as improve awareness of the excellent performance of the GSN. These reports should be aggregated by the GSN PM (and perhaps be included as a function of IRIS IS), rather than distributed by the two operators.**

IRIS agrees, and is working towards this goal. Initial efforts include the generation by the GSN PM of a prototype data-quality report on all GSN stations and the development of a map-based display of aggregate GSN quality status.

4. *Data stream quality control protocols are useless if the station hardware is not functioning.* **NSF, IRIS and the USGS should work together to ensure that funds are available for recapitalizing station hardware when and where appropriate and in a timely manner. Continuing assessments of station vault and borehole conditions are also necessary.**

IRIS agrees, and will continue to work with NSF and the USGS to identify and address the GSN's recapitalization needs.

Costs Recommendations: (page 23)

1*. The committee sees no alternative management models that would significantly reduce costs without negative impact. However*, **IRIS senior management and the Board of Directors should be encouraged to critically review the budget distribution among the major programs and prioritize near-term issues across the programs.**

IRIS recognizes that the GSN is underfunded compared to the level required to meet its design goals. The IRIS Board of Directors (BoD), as representatives of the scientific community, are charged with ensuring that they maximize and optimize the scope of work IRIS performs given available resources. Program budgets are critically reviewed annually with input from the entire suite of IRIS Standing and Advisory Committees, as well as integrated input from the IRIS Coordinating Committee. Most recently, the BoD

asked all IRIS programs to conduct a "scope management exercise" to evaluate the effect of flat funding on each program. As part of this budget review, the distribution of funds among the major programs was re-evaluated and near-term issues across the programs prioritized.

2. ***The GSN Program Manager should work with both operators to review the schedule of O&M station visits and develop mutually agreeable travel schedules and itineraries.***

    The GSN PM conducts bi-weekly meetings with ASL and IDA at which upcoming station visits and travel plans are discussed. These activities are coordinated between the groups whenever possible. A joint ASL/IDA trip to Japan was conducted in July 2015 to increase the familiarity of the operators with each other's stations and operating approaches.

3. ***The GSN PM and IRIS Director of IS should develop a plan to assess station site conditions that impact data quality and data return, and develop cost estimates for renovation or relocation.***

    The IRIS GSN PM has been developing a list of necessary infrastructure improvements and related costs at the GSN stations. This information will be combined with data-quality and data-return metrics to prioritize station visits and the rebuilding of infrastructure, as allowed by available funds. These estimates are separate from the costs associated with deployment of new primary sensors at stations where the primary sensor has failed or is performing poorly.

4. ***NSF and the USGS should be encouraged to include GSN equipment recapitalization costs in their multi-year program budget plans.*** *The procedures used by major facilities in the Ocean Sciences or other divisions and directorates might be adopted as funds allow.*

    IRIS agrees that the episodic recapitalization process that IRIS programs must rely on can be risky and has the potential to create instability in operational and quality performance.

5*. **In the absence of NSF and USGS program action to fund recapitalization, IRIS and USGS senior management should continue to explore funding opportunities from other agencies and foundations.***

    The IRIS GSN PM works closely with IRIS senior management to identify additional opportunities for funding of recapitalization of capital equipment through the DOE, DOD and other agencies, and will continue to pursue these activities energetically.

Partnerships Recommendations: (page 26)

1. ***IRIS and the USGS should work together to conduct a partnership inventory and risk assessment.*** *Such an assessment should include technical, economic and political factors that would impact GSN operations and affect open and real-- time access to data. The risk assessment should be made available to the GSN SC (and other standing committees and oversight boards as appropriate*).

    The GSN PM will work to implement this recommendation. IRIS has recently compiled a comprehensive list of the MOUs associated with the GSN with links to the original

documents. Many of the risks associated with these agreements are known in general terms by both the USGS and IRIS. The GSN PM in coordination with the USGS will develop a high level Quantitative Risk Assessment (QRA) that identifies risks to GSN operations, quantified by probability of occurrence and the cost impact if the risk should manifest. Mitigation strategies will be identified for each risk. IRIS found the QRA to be a useful tool in managing the USArray project and believes it will be useful here to help communicate risks and challenges faced by the GSN.

2. *US representatives on FDSN committees should ask for an assessment of potentially duplicative activities across the member networks of the Federation*, *in the context of looking for opportunities to reduce recapitalization, deployment and ongoing O&M costs.*

> The GSN will discuss this suggestion within the FDSN. The GSN PM is a member of the relevant FDSN working groups.

3. *Following past practice,* **IRIS should leverage opportunities presented by its membership to expand GSN station coverage or promote national partnerships that might reduce O&M costs,** *following the examples of Chile and AfricaArray. The former IRIS Development Seismology Committee and Director of Planning played significant roles in exploring connections with the Department of State and USAID.* **IRIS should reexamine whether there are ad hoc or standing governance structures that could assess leveraging opportunities.**

> The upcoming IRIS workshop provides an opportunity to instigate a more structured dialog on this topic with active community members. Recent changes to the IRIS governance structure will assist in identifying leveraging opportunities. For example, the International Development Seismology Steering Committee (IDS SC) has crossover membership on each of the Instrumentation Services, Data services, and Education and Public Outreach Standing Committees. The Instrumentation Services Standing Committee explores the linkages between IRIS' ongoing program activities, and international development. Further, an Instrumentation Services staff member is taking on the role of liaison to the IDS SC, which will further enhance this dialog.

4. **The GSN PM should examine existing partnerships, as part of the risk assessment, for collaborative strategies that could be applied across the board to other relationships.**

> The GSN PM will consider such partnerships when working on the risk assessment and management plan discussed in recommendation #1 above.

5. **Senior management of IRIS should encourage IRIS's foreign affiliates to further develop their respective national seismographic capacities in ways that could supplement GSN coverage, operations and maintenance.** *While this could be accomplished also through the FDSN, the IRIS Foreign Affiliates Program could provide the venue for a more focused discussion.*

> IRIS agrees, and the GSN PM will continue to develop and expand interactions with international network operators. The IRIS Foreign Affiliates are perhaps a somewhat overlooked resource for identifying, tapping, or leveraging the national seismographic capacities of other countries. The GSN can work with our IDS SC to organize a

structured interaction with the Foreign Affiliates. An example of such an interaction is occurring right now with Latin America. As an outcome of the recent GroChile workshop the countries across Latin America are collaborating with each other, and with IRIS, to identify and catalog existing national resources. A similar effort related to data sharing, and referred to as the Bogotá Challenge, came out of the IRIS Data Management workshop held in Colombia in 2014.

6.   *Although prospects are uncertain, continuing discussions with NOAA and the CTBTO concerning support of O&M costs are worthwhile.* **This is a general recommendation for IRIS senior management.** *Similarly, opportunistic discussions with the managers of other regional, national or global Earth observing networks should be a general responsibility of both IRIS and NSF management.*

> IRIS agrees and will attempt to reinvigorate discussions with NOAA. IRIS senior staff recently attended the CTBTO Science and Technology meeting and are working to reinvigorate relationships with those organizations.

Scope Recommendations: (page 29)

1.   *Frequent review of the GSN scope, including siting considerations, should encourage broader community engagement on a more frequent basis.* **The GSN SC should be charged with developing a community engagement plan.**

> The GSN SC is a primary conduit for input from the community to GSN management and operations. IRIS will continue to seek members for the GSN SC who are representative, active, and engaged members of the seismological community. An important task of the GSN PM is to engage actively with the community, and the PM will continue to do this. The GSN SC will also consider additional approaches to ensuring robust community engagement with the GSN, including regarding GSN scope.

2.   **NSF should coordinate, and IRIS could help convene, an agency-wide review of Earth-observing networks.** *Such a review would explore the potential for common infrastructure (such as telecommunications and siting) that might lead to reduced O&M costs.*

> IRIS would welcome an opportunity to organize and participate in a broad discussion such as recommended here.

3.   **The GSN SC should be charged with reviewing the outcomes of recent workshops on grand challenges and new instrumentation and address the impact of workshop recommendations on GSN scope and planning.**

> The GSN SC regularly discusses and evaluates the outcomes of planning, science, and instrumentation workshops in the context of GSN goals, as one means of fulfilling the charge to the GSN SC. The recent appointment of a full-time GSN PM is anticipated to provide important support to the GSN SC in this effort, and the GSN PM will also be engaging directly with such workshops and their outcomes.

Data Management and Services Recommendations: (page 32)

> In the current IRIS structure, the operation and management of the IDA and USGS DCCs is primarily coordinated through IRIS Data Services and the IRIS DS SC. The

GSN PM and network operators work closely with DS to ensure seamless data flow of the highest-quality data from the field to the DCCs who then validate metadata correctness, and conduct quality assurance for both waveforms and metadata.

1. ***The Committee recommends maintaining separate IDA and USGS DCCs.***

    IRIS agrees with this recommendation and will continue tasking IDA with operation of the DCC for the II stations. Tight integration of DCCs and field operations has proven to be a successful strategy for identifying and addressing station or data problems when they occur.

2. ***The Committee encourages the IDA and USGS DCCs and the EarthScope Array Network Facility to maintain and strengthen recently implemented synergistic activities*** such as technical interchange meetings, exchange of data quality software, and general communication about best practices. ***The Committee encourages IRIS to consider these activities in its annual evaluation of DCC performance.***

    IRIS appreciates the encouragement in this regard and is already planning the 2016 Technical Interchange Meeting. We will also evaluate whether additional meetings specifically focused on DS/ DCC activities are warranted, or are sufficiently covered in the broader technical interchange meetings.

3. *IRIS, working through the IS and DS committees and the GSN PM, should continue to emphasize the holistic approach to data quality as well as the aggregation of uniform data quality metrics and station metadata. In particular,* ***the GSN PM should work with the two DCCs to better coordinate data quality assessment procedures. The GSN PM should also work with the DMC to develop a single portal for access to station calibrations, other metadata and quantitative station quality information. The portal should offer end--users a structured way to submit feedback on data quality.***

    IRIS agrees with this recommendation, and the GSN PM and the Director of Data Services are actively working on quality assessment procedures from a variety of angles. The GSN PM has been working on defining better the metrics in the GSN Data quality goals document and comparing how the metric(s) are calculated using the IRIS/MUSTANG and USGS/DQA (Data Quality Analyzer) tools. The GSN PM is coordinating with the IRIS web team on developing a GSN network quality monitor webpage that presents a graphical representation of GSN quality using the values from the USGS/DQA tool that is now operating at both UCSD and ASL. The Director of Data Services has been leading the effort on developing MUSTANG and making MUSTANG output available via open, web services interfaces.

4. *The DCCs should continue to look for opportunities for prudent leveraging of external resources as a way to reduce costs and improve data collection.* ***Such opportunities should be coordinated with the GSN SC and GSN PM.***

    The GSN SC, IDS SC and the GSN PM will work with DCCs to actively seek such leveraging opportunities.

5. ***The Committee suggests that the IRIS DMC consider establishing a link with Center for Engineering Strong Motion Data (CESMD),*** *a cooperative center established by the USGS and the California Geological Survey (CGS), in order to provide raw and processed*

strong--motion data for earthquake engineering applications. Such a link could expand the
user base for GSN data.

The USGS National Strong Motion Project (NSMP) is building a system that will monitor earthquakes and then request strong motion data from a set of known sources, including the GSN stations. Waveform snippets are extracted and then processed to create COSMOS V0 format files. These files are then pushed at the recently developed PRISM software, which will generate the higher-level COSMOS data products. The automatic processing will produce V1, V2, and V3 level files ("uncorrected" acceleration, instrument corrected acceleration, and response spectra, respectively), with quality checking to remove traces that fail certain criteria.   Links and acknowledgements to the GSN will be made at the http://www.strongmotioncenter.org/ and http://www.cosmos-eq.org.