Earth System Research Laboratory/Global Systems Division
Laboratory Science Review
3-5 November 2015

GSD's Response to Review Recommendations and Implementation Plan

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Introduction

Laboratory science reviews are conducted every five years to evaluate the quality, relevance, and performance of research conducted in the National Oceanic and Atmospheric Administration (NOAA) Office of Oceanic and Atmospheric Research (OAR) laboratories. The Earth System Research Laboratory Global Systems Division (GSD) appreciates the time and effort devoted by the Review Panel to thoroughly evaluate and review GSD's science and technologies. We found the recommendations to be insightful, positive, and informative for guiding GSD's future.

This review covered the ESRL/Global Systems Division research since 2010. The research themes presented included Numerical Weather Prediction, Decision Support, and Advanced Technologies. The review agenda, presentations, posters, and guiding materials are available on the GSD website: http://www.esrl.noaa.gov/gsd/research/review/2015/.

GSD's response to each recommendation is provided the following sections. Organization of the document follows that of the report and is separated into sections by Theme. A table summarizing the actions and timelines for completion of the recommendations is provided at the end of the report.

GSD Response

1. General Recommendations

B6.1. Continue to build on opportunities presented by reorganization for synergistic work in: software engineering, end-to-end forecast improvement, and re-usable core software components.

Response: We agree that this recommendation is an important area of focus for GSD especially with the recurrence of this theme in the Review Panel document (e.g., B6.15, D4.8). We will continue to build synergistic collaborations across GSD in order to take advantage of common development strategies, software modules, and common coding infrastructures. GSD recently launched a new effort to form expert teams focused on addressing the GSD Grand Challenges. These teams will discuss and explore new and innovative avenues for improving technical and programmatic alignment across the Division. Initially, the teams will assess the commonalities and reusability of various software components and systems that have been developed. This effort will streamline system creation and modification of existing systems, and reduce overall costs of development.

Action B6.1.1: Identify software engineering lead that would facilitate discussions and develop a plan for the sharing of software approaches.

B6.2. Seek, recruit, and train candidates for future hire (through graduate and/or postdoctoral fellowships) with particular attention of creating a pipeline of future employees with increased diversity.

Response: GSD Senior leadership is aggressively taking steps to seek and recruit new candidates for GSD employment. Toward this goal, GSD is implementing a multi-tiered strategy designed to identify younger and more diverse candidates for future employment. Beginning in 2015, GSD has refreshed the use of the NRC Post Doc Program by funding two NRC post-docs and increasing the stipend across ESRL by $15K per year to be more competitive with the NCAR and CU/CIRES Fellow programs. In addition, GSD is actively working with professors from Howard University, a minority-serving Cooperative Science Center, to build relationships and collaborations between PhD students and GSD scientists. The Howard University Center Director visited ESRL last fall to introduce the program, then in March the GSD Director and Deputy Director visited Howard University to meet the students and tour their new facility. Over the next month, GSD will plan an event to host a group of PhD students at the laboratory to allow for scientific exchange and to determine opportunities for future post-doc positions, collaborations and possible future employment. Finally, the GSD Director's Office is partnering with the Cooperative Institute Directors at the two local universities (Colorado State, and University of Colorado) to fund one Masters or PhD level student at each University to work directly with GSD scientists while obtaining their degree.

Action B6.2.1: Develop agreements with CU and CSU Atmospheric Science Department Chairs and the respective Cooperative Institute Directors to formalize the funding stipend for the first year.

Action B6.2.2: Work with GSD staff to develop proposals for topics for CU and CSU students to consider.

B6.2.3: Establish relationship with Minority-servicing Institution. Conduct workshop to introduce students to ESRL scientists.

B6.3. Continue to hire through CI while pursuing conversion of qualified candidates to Federal positions.

Response: In 2014, GSD senior leadership developed and periodically updated a comprehensive staffing plan that provides a mechanism for identifying requirements for new positions, prioritizing the needs of the Division, and strategically planning for new federal hires. Due to problems with lack of Federal base funding and issues with NOAA's Workforce Management, only three new Federal employees have been hired in the last five years. One was a young PhD scientist that transferred from NWS. Another was a PhD scientist women of Spanish descent, formally a CI employee. The third was a well-respected, senior NWS Science and Operations Officer (SOO) that was hired specifically to build bridges between GSD and NWS (recommendations the Review Panel has made, B6.4 and B6.5). Currently, GSD management is in the process of actively filling two leadership positions within the laboratory and several top CI staff are expected to compete well for the federal positions.

Action B6.3.1: Reinstate Local Level Review Panel (LLRP) to provide oversight, guidance, and justification for internal promotions and new federal positions.

B6.4. Senior GSD management and project managers should continue to improve good relationships with stakeholders (including the private sector) and regularly re-align strategic research priorities.

Response: GSD senior leadership and program staff continue to build relationships with its stakeholders. For example, to improve relations with NWS, GSD has just hired a senior NWS SOO whose top priority is building a more trusting relationship between GSD and NWS. For working with the private sector, GSD is currently engaged in two CRADAs (Cooperative Research and Development Agreement) with a third under negotiation. GSD has three new Interagency Agreements (IAA) in development with FAA, DOE, and NASA partners. GSD has further reestablished a 5-year agreement with the American Institute in Taiwan and obtained approval of a multi-year clearance template to allow quick transitions of Science On a Sphere® (SOS) and SOS Explorer™ technology to the private sector. In order to realign strategic research priorities, GSD senior leadership will convene a retreat of senior and mid-level leaders every 2-years to revisit and adjust priorities.

Action B6.4.1: Discuss realignment of strategic priorities (i.e. Grand Challenges) at next GSD retreat. Document changes and determine next steps forward.

B6.5. Work closely with NWS to improve relationships and develop a clear integrative partnership.

Response: GSD is working with the NWS to improve relationships in a number of ways, in addition to the hiring of the new NWS SOO. For instance, the GSD Director and Deputy Director have become directly involved in building relationships at multiple levels within NWS; GSD has reduced overheads charged to NWS (frequently requested by NWS of GSD) by reducing internal GSD recurring costs more than $3M; a new 5-year MOU was being created with NWS to clearly define roles for the development of NOAA's Next Generation Global Prediction System (NGGPS); Statements of Work (SOW) are now developed each year between GSD and NWS project managers to clearly identify tasking, funding, and deliverables; and GSD is contributing to the OAR-wide Service Level Agreement with the NWS that clearly identify program expectations, funding, and timelines for delivery.

B6.6. Take a broader perspective on the users of its technologies towards achieving a more holistic realization of WRN objectives.

Response: GSD is actively engaged with the NWS in WRN projects such as FACETS, Hazard Services, and the Forecast Decision Support Environment (FDSE) to assist with its evolution to a decision-support oriented organization. In addition, over the past 2 years GSD has actively collaborated with other organizations (including the private sector) through MOUs and CRADAs to expand and broaden our knowledge and the use of our technologies to open new opportunities. Our expectation is that the new technologies developed through these collaborations will be integrated into the tools GSD provides to the NWS providing a more holistic and integrated approach for achieving the WRN objectives.

Action B6.6.1: Continue to engage organizations through the use of CRADAs and other collaboration agreement tools.

B6.7. Coordinate a community effort on model validation and verification involving GSD with NCEP, DTC, MDL and others.

Response: GSD is working with the modeling community toward coordinating model validation and verification. Over the past year, staff at GSD, the Developmental Testbed Center (DTC), NCAR, and the NCEP/Environmental Modeling Center (EMC) have formed a team, co-led by GSD and NCAR, to work on verification and validation activities under the NGGPS program. The team is in the process of developing a plan outlining a collaborative set of objectives, tasks, and timelines that support an effort to build a unified verification system, which will serve the needs of the NGGPS modeling community. The plan and roadmap identifying system requirements and design will be delivered by October 2016. In addition, GSD staff is facilitating 'information exchange' meetings with Meteorological Development Laboratory (MDL) and DTC staff to learn more about each organization's technologies and techniques so that future

efforts can be leveraged and better collaborations can be established. In addition, GSD is funding an initial effort using Directed Director's Research Funds (DDRF) to get this started.

Action B6.7.1. Deliver NGGPS verification plan and roadmap to GSD senior leadership.

B6.8. Develop mechanisms (matrix alignments, cross-cutting programs) to foster greater symbiotic collaboration across thematic areas in GSD and ESRL so that work in each area can take advantage of knowledge and expertise across the laboratory.

Response: Yes, we agree that it is important to continue to strengthen and build upon the collaborations already occurring between the four ESRL Divisions. For example, the ESRL Divisions have been working more closely over the years and are involved in several cross-cutting activities which include: the cross-lab Atmospheric Science for Renewable Energy Program, a new effort known as the NOAA Earth System Analyzer and Predictor (NESAP) to develop a comprehensive real-time Earth decision-support system that encompasses the air, land, ocean, and ice domains, and jointly developed proposals that focus on the areas of numerical modeling and water research.

B6.9. Further consolidate and coordinate GSD activities and ensure that all innovative initiatives with long-lead development horizons receive some base funding.

Response: Given GSD's base funding is not enough to cover its Federal employees, let alone its utilities and rent, it is a challenge to raise enough funding to also fund innovation. However, GSD has been able to fund the GSD Director's Directed Research Fund (DDRF) the last three years at a level between $250K (FY14) - $500K (FY16). In addition, in FY16 GSD has been able to provide (for the first time) base funding to all Branches and GOSA that can also be used to fund innovation at the discretion of the Branch Chiefs and GOSA Chief. Also in FY16, the GSD Director's Office has funded $150K to a team of cross-Branch scientists to begin to address Grand Challenges 3 and 5. As the ideas begin to evolve through these and the other Grand Challenge teams, GSD leadership is prepared to provide additional funding to those activities and projects that will move GSD into the future.

B6.10. Identify, track and embrace broader metrics of GSD's success even if those metrics are outside of GSD's direct or sole influence, with particular focus on measures of key stakeholder outcomes.

Response: GSD has several existing mechanisms for tracking and reporting success. For instance, GSD provides high-level project targets through OAR's Annual Operating Plan to NOAA, DOC, and OMB. In addition, GSD is beginning to develop mandatory transition plans in collaboration with NWS to better communicate expectations, timelines, deliverables and better plan for product transitions to NWS platforms. Finally, OAR is developing an interactive NOAA database for tracking all projects and associated outcomes. To help OAR kick-off this effort, GSD is participating in a pilot project by providing an initial set of information that will be used to assess the functionality of the database and appropriate level of content needed for reporting.

Action B6.10.1. Explore the use of other metrics for measuring the quality of our science, tools, and technologies relative to the weather impacts on society.

B6.11. Analyze problems/obstacles in previous R2O efforts (HRRR, MADIS, AWIPS, etc.) and define clear actions that can be taken to improve the process for all GSD R2O efforts in the future. (Example: hand over responsibilities as developments transition down the TR funnel).

Response: GSD has extensive experience with the transition of its technologies to NWS, FAA, and other outside agencies. To address the Review Committee's recommendation, GSD will convene a team of experienced staff to discuss and document the lessons learned by studying recent major transitions. The information will be summarized to help guide and improve future transitions. In addition, GSD will include in its senior leadership team meetings, and normal seminar schedule for staff, a review of lessons learned within various transition efforts with a desired outcome of sharing experiences and honing our ability to accelerate this process, while minimizing its burdens.

Action B6.11.1: Schedule meeting with GSD experts to analyze and document R2O obstacles across projects. Share lessons learned with staff.

B6.12. Establish a process to continually set/realign priorities together at least every 2 years involving key scientists, mid and upper level management.

Response: GSD leadership concurs with this recommendation and is committed to a retreat every 2 years that would involve key scientists and mid- and upper-level management to align priorities and discuss progress on the 5 Grand Challenges. GSD senior leadership is also considering establishing a Research and Development Council to discuss, establish, reassess, and realign the scientific goals for the organization.

See Actions B6.4.1 and B6.8.1

B6.13. Actively pursue visiting scientist and engineer programs to continue to infuse external knowhow into GSD in key areas of research.

Response: Yes, we agree. Initial ideas for pursuing collaborations with science and engineer programs with the Universities that are working with GSD is underway. GSD senior leadership will develop a plan for investing in these activities.

See Action B6.2.2

B6.14. Make continuous workforce education and training a priority of mid-level management to ensure employees remain fully up up-to-date in terms of scientific, project management and software engineering methods.

Response: Yes, we agree and this is in progress and ongoing. Over the past 2 years, GSD has invested significantly in mid-career training by hiring an executive coach and on-site software training. More effort and investment needs to be directed toward providing project management training. GSD will discuss a plan with a timeline for continued education with a focus on project management.

Action B6.14.1: Determine opportunities for project management training and continued coaching for senior and mid-level leaders.

B6.15. Introduce GSD-wide standards for software engineering (e.g. agile development, code reviewing, unit testing, regression testing, automated continuous integration systems, transparent issue and feature tracking.

Response: Yes, we agree. Many GSD projects do follow software engineering strategies and would benefit from cross-branch collaboration and sharing of ideas. Therefore, GSD will facilitate a discussion and sharing of approaches with key software engineers and develop a plan for building GSD-wide standards.

See Action B6.1.1

2. Numerical Weather Prediction

C4.1. Identify core competencies within NOAA and the broader community and develop a strategy for how it can best utilize this expertise to improve the research and operational NWP suite.

Response: Before GSD embarked on the re-organization in 2014, a retreat was held with key senior and mid-level career staff to analyze GSD's core competencies, strengths, weaknesses, opportunities, threats to the organization, and future potential customers. This analysis provides the foundation for GSD to begin aligning its expertise in specific scientific areas that would improve and greatly benefit the research and operations of NWP in NOAA. The strategy moving forward is twofold: 1) continue to engage the NGGPS program, other modeling organizations, such as Naval Research Laboratory (NRL), and our key partners DTC, NCAR, GFDL, and AOML to exploit, integrate, and align GSD's strengths with NOAA's modeling efforts, and 2) develop a comprehensive vision for the future of GSD's NWP by developing a roadmap to Grand Challenge 1 (Develop a continuous global to storm-scale ensemble data assimilation and ensemble forecasting capability for global situation awareness) and Grand Challenge 2 (Create a fully coupled earth system modeling predication capability).

Action C4.1.1: Determine lead and members to begin cross-branch, cross-ESRL discussions of Grand Challenges 1 and 2. The team would develop and deliver a plan summarizing a strategy to improve the research and operational NWS numerical weather suite. This plan incorporates recommendation C4.5.

C4.2. Build on the current success of HRRR as a basis to help develop a convection-permitting ensemble capability for the nation. One reviewer specifically recommends that "research efforts for convective resolving ensembles should focus on full-fledged ensembles as opposed to time-lagged ensembles." Achieving a good spread/skill relationship is key for a convective resolving ensemble system (and associated ensemble data assimilation system).

Response: We agree that NOAA needs to move toward a "full-fledged" HRRR ensemble. At this point, the lack of available HPC resources is the limiting factor preventing a "full-fledged" HRRR ensemble. GSD will continue to lead the community toward this end, but in the meantime, here is the current situation:

- HRRR time-lagged ensemble (HRRR-TLE) development in the short-term will leverage existing temporal and spatial filters and bias correction techniques to produce statistically reliable weather hazard probabilities that will be applied to "full-fledged" convection-permitting ensembles in the future. "Full-fledged" HRRR 20-member hourly-cycled initial condition (GSI-EnKF) perturbation ensemble (HRRRE) development is underway including real-time forecasts and evaluation on a limited, but moveable, ⅙ CONUS domain with expansion planned in 2017 as computer resources permit.
- HRRRE real-time forecasts are being used to initialize a prototype Warn-On-Forecast Ensemble in collaboration with NSSL.
- Development of radar reflectivity assimilation within the GSI-EnKF framework, stochastic kinetic energy backscatter (SKEB), stochastically perturbed physics tendencies (SPPT), and stochastic physical parameterizations will drive improvements in ensemble spread/skill relationship. Code supporting these capabilities are being installed in the HRRR.

C4.3. In global modeling, finalize and implement a plan to contribute to NGGPS with selected NGGPS core and develop a longer-term plan for GSD's global modeling efforts, including a reduction in FIM, NIM work, and especially the hydrostatic FIM.

Response: The unforeseen retirements of both Dr. MacDonald and Dr. Jin Lee has in effect brought the NIM project to an end within ESRL. The FIM, however, does appear to have a niche in the subseasonal to seasonal arena where it will be necessary to run operationally at resolutions where the hydrostatic approximation is valid for several more years. It has shown unanticipated skill in predicting sudden stratospheric warmings and has been used effectively to address some crucial questions related to the Madden-Julian Oscillation. In the short term, FIM is a useful tool to test concepts important to NGGPS prior to the dynamical core decision expected later in 2016. Negotiations are nearing a final stage between GSD management and NGGPS management on a 5-year MOU describing how GSD (the agreement includes ESRL, AOML, and GFDL) and NWS will work together on NGGPS goals. Year 1 of the agreement has just been put in place in April 2016. Year 2 negotiations will begin in the summer of 2016 for FY17. Included in the agreement will be tasks to implement and test scale-aware physics to compose a physics suite that works well at both convection permitting and coarser resolutions.

Important work toward the Global Model Test Bed is also underway at GSD. We believe it is essential to have both a dynamical core and a physics suite that is capable of predicting mode of convection (e.g., isolated supercells, quasi-linear with leading line / trailing stratiform, pulse storms, etc.) with sufficient skill to provide forecasters at SPC and WPC with useful guidance for severe storm intensity and mode (e.g., mainly wind and hail versus high likelihood of tornado) as well as flash flooding. Looking farther into the future beyond NGGPS, GSD has initiated discussions with NRL, potentially leading to collaboration toward making their advanced global model that uses a spectral-element dynamical core into a viable forecast model.

Acting C4.3.1: Complete negotiations on Year 2 of the NGGPS MOU by March 2017 to be implemented in April 2017 (consistent with the NGGPS Program's funding cycle).

C4.4. To improve quality metrics, develop and implement concrete mechanisms within GSD to encourage and reward publications and other types of scientific engagement in the research community beyond GSD and ESRL. Develop and implement mechanisms to mentor scientists on how to publish R2O and applied work, given constraints of funded efforts.

Response: Yes, we agree. GSD senior leadership will take this as an action and develop a process for addressing quality metrics including increasing publications.

Action C4.4.1: Schedule meeting with SLT to develop process and incentives for increasing quality metrics including number of publications. Document process and share with staff at quarterly All-hands meeting for comment and input.

C4.5. Design strategies for prioritizing future GSD NWP efforts in a way that balances advancing the science and technology of NWP with stronger operational partnerships, including more robust understanding of users' needs from early on in system planning and development.

Response: Yes, we agree. This work will be addressed through the planning and discussions of Grand Challenges 1 and 2 outlined in Recommendation C4.1. Engaging users' needs earlier in the planning and development process is being addressed by the NOAA push to formalize the R2O efforts that include a database to identify and track projects beginning at TRL 4 with project transition plans. The main purpose of the transition plan is to engage the operational partners very early in the development phase.

Action C4.5.1: Complete or update projects in VLAB to include transition plans for projects at stage TRL 4 or greater. Assign focal point for tracking projects through the transition process and for updating the information as needed.

C4.6. It is essential that a plan for national OSSE and OSE research be developed in collaboration with AOML, JCSDA, NASA/GMAO, NESDIS, perhaps via QOSAP. Test

systems should include existing and possible ground-based remote sensing and in situ systems.

Response: The NOAA's Quantitative Observing System Assessment Program (QOSAP) coordinates advancements in the assessment of current and new observations across NOAA. The primary objective of QOSAP is to improve quantitative and objective assessment capabilities to evaluate operational and future observation system impacts and trade-offs to assess and prioritize NOAA's observing system architecture. The Global Observing Systems Analysis (GOSA) Group leads global OSE/OSSE studies, under the auspices of QOSAP, and in close collaboration with AOML, NESDIS, NASA/GMAO and JCSDA. These OSE/OSSE activities are coordinated under QOSAP, which ensures coordinated development efforts among these agencies.

C4.7. Work to clarify and tighten GSD's roadmap, make necessary efforts to ensure buy-in across NOAA. Incorporate a clearer understanding of who might be using the predictions, how, and why into NWP system development from the beginning.

Response: Yes, we agree. GSD will use its recently finalized Strategic Plan, which incorporates the 5 Grand Challenges, and develop a roadmap outlining steps needed to move forward that includes a process to seek buy-in across NOAA.

Action C4.7.1: Develop initial roadmap outlining steps toward Grand Challenges 3 and 5.

Action C4.7.2: Develop steps for seeking buy-in across OAR, NWS, and NOAA.

C4.8. Collaborate with the National Water Center. This seems like a natural fit and could lead to some productive and interesting innovation in the area of water forecasting.

Response: GSD leadership agrees that collaborating with the National Water Center (NWC) is a great fit and exciting and productive collaborations with the NWC are already underway. For example, the NWC Initial Operating Capability (IOC) is driven by the RAP/HRRR for short-term water forecasts, based on past interactions and planning (e.g. participation in workshops). In addition, GSD directly participated in the planning for the next generation national water model (week of May 15 2016, at the NWC) and is participating in the 2016 Summer Institute at the NWC. Furthermore, GSD is represented on the NOAA Water Team and is the lead of the NOAA Water Team's Integrated Modeling and Prediction Focus Group (Schneider, in both cases). GSD also contributes the California Advanced Quantitative Precipitation Information (AQPI) project; PSD provides overall leadership; GSD collaboratively leads the Systems Integration and the Prediction activities (Pratt and Alexander/Benjamin/Schneider, respectively). Discussions leading to coordination between NWC and AQPI are ongoing.

3. Decision Support

D4.1. Improve partnerships with national level programs to complement current efforts to support forecasters in the field. Perhaps opportunities like FACETs and WRN pilot programs could serve as shared initiatives to better integrate the efforts.

Response: GSD has embraced both the WRN and FACETS programs and believes there is strong alignment with GSD's core mission objectives. GSD's collaborative work on the FACETs project ties us directly to national level programs across multiple NWS and OAR organizations.

Action D4.1.1: Continue to explore new partnerships and opportunities with national level programs, such as those with the GOES-R program. To begin, invite GOES-R focal point for presentation and discussion of new opportunities.

D4.2. Begin incorporating social science perspectives and knowledge into decision support activities to help realize Grand Challenge goals.

Response: GSD leadership agrees that embracing social science is critical to the successful design of decision support systems. Some efforts toward this goal have already begun. GSD began discussions with NCAR's social science team early in 2015 with the intent not to create an internal social science capability within GSD, but rather to tap into the expertise that already exists at NCAR. The initial areas of discussion have been centered on the impact, within the WFO, of future forecast processes. Opportunities for specific collaboration between GSD and NCAR are being discussed.

Action D4.2.1: Schedule follow-on meetings with NCAR social science group to develop opportunities for collaboration. Identify leader to continue this interaction.

D4.3. Develop a broader strategic direction for GSD Decision Support, or update existing strategic directions.

Response: GSD leadership has recently charged the ATO and EDS Branch Chiefs to develop a plan to address Grand Challenges 3 and 5, which describe many decision support elements and attributes. In this process, we are seeking to coalesce strategies and requirements to best suit, not only our current partners, but anticipated partners across NOAA, other government (e.g., the FAA, NASA, etc.), and non-government entities (such as the private sector through CRADAs). The Grand Challenge plans will address current and anticipated user needs, the direction of the underlying technology, the direction of influencing science, and specific strategies for both the near- and long-term efforts within GSD and its partners to achieve the Grand Challenges. The GSD Director has recently provided initial funding from the Director's Directed Research Fund for this effort.

Action D4.3.1: Provide a plan for addressing Grand Challenges 3 and 5 to the Senior Leadership Team for review and approval - December 2016.

D4.4. Clarify what "decision support" means for GSD.
Response: Decision support for GSD means: providing relevant information for decisions to be made. This includes work to provide users with relevant information needed to understand, analyze, assess, and disseminate the impact of current or anticipated environmental conditions on their operations or activities. The information needed may be current weather and weather forecast information, or expanded to include a wide array of environmental information ranging from space weather, ocean and ecological information, geophysical actions such as volcanic activities and ocean currents, and human-based information such as population density, transportation routes, infrastructure, extraction, and construction activities.

Currently, GSD decision support activities are limited to weather impacts, and the primary users are the NWS, FAA, the Bureau of Land Management, and development partners such as the Central Weather Bureau of Taiwan. Future users may include other NOAA line offices including NOS, NMFS, OMAO, and NESDIS, as well as other Government partners including DOI and FAA.

D4.5. Consider the appropriateness of developing technologies that support broader sets of users and uses while maintaining current competencies.

Response: Yes, we agree that developing technologies that support a broader set of users is appropriate.

See Action D4.3.1.

D4.6. Balancing meeting the needs of current users with taking a more active role in offering capabilities and pursuing new opportunities that leverage existing work to serve broader sets of users.

Response: This, too, is related to the work in planning for Grand Challenges 3 and 5. For instance, the development of a holistic view for decision support technologies in GSD to serve a broader set of users is underway. A plan will be developed that will outline initial activities that would need to be pursued to move GSD in the direction of the Grand Challenges. As part of that plan, current technologies would be considered or may be augmented with base funds to balance the current work with those efforts that require longer term research and development.

See Action B6.1.1 and D4.3.1.

D4.7. Enhance awareness of other public and private sector decision support activities to remain competitive and collaborate where beneficial.

Response: Our current activities in this area include hosting conferences and workshops and attending recent meetings hosted by others. These activities provide innovative ideas for us to consider. We also send people to visit organizations that are performing cutting-edge development in order to learn what they are doing.

Action D4.7.1. Investigate whether there are other new innovative approaches, including workshops and conferences, which would provide opportunities for expanding our knowledge of decision support.

D4.8. Seek opportunities to build a set of common core tools that can be leveraged across GSD.

Response: GSD is developing a plan in response to its Grand Challenges 3 and 5 to select the best common tools available within and outside GSD as a core toolbox for development of new system components and methods.

See Action D4.3.1

D4.9. Utilize knowledge from Best Practices in aviation program: Assessment reports, methodology reviews by stakeholders and developers to guide other programs.

Response: Yes we agree. With FAA leadership, GSD develops a 7-year plan that outlines a direction and common goals between the agencies. The FAA planning process instills discipline resulting in better planning and allows research to mature to provide the FAA with better products and services. Therefore, one way to apply this approach would be to work with NWS to develop a roadmap that would integrate GSD vision and ideas developed from the GSD Grand Challenges with the NWS strategic plan vision. This effort would be a heavy lift and would require that a strong partnership and desire for NWS to engage with GSD on long-term joint planning.

Action D4.9.1. Explore the feasibility for developing a joint roadmap with NWS for GSD projects.

4. Advanced Technologies

E4.1. Continue to support and mature the highly successful SOS, MADIS and HPC initiatives. Including the use of base funding to ensure long-term sustainability of these programs.

Response: GSD is very grateful for the Review Panel's positive comments regarding the success of SOS, MADIS and HPC development. Funding support from NOAA, including base, has been and remains strong for both HPC development and MADIS.

Specifically, HPC is funded through the NOAA OCIO at a consistent level of about $2.18M/year with additional support, which began in FY15, of ~$800K/year from the Software Engineering for Novel Architectures (SENA) and some support for computational and fine-grain development from NGGPS.

In regard to the MADIS program, funding resources are being reduced as the transition to NCEP operations winds down. Over the next couple of years, GSD will continue to provide base funding to MADIS to continue new development, while NWS assumes the costs for operations and maintenance. In addition, GSD is negotiating with NWS to provide supplemental funding to GSD in support of NWS requested new capabilities, data types, and data sources.

GSD has evolved the SOS program in such a way that it is sustainable and virtually cost neutral. The SOS program receives less than 5% of its funds from NOAA sources. The rest of the funding is provided by sponsors and partners, mainly in the private sector, who desire new installations of the system. GSD is also working across NOAA line offices to find additional funding support for the SOS Explorer project and is working with GSD leadership to reprioritize some GSD Base funds to support more of the SOS development in FY17.

E4.2. Work with NOAA ops to tighten the R2O process for GSD's role in the continued evolution of operational MADIS, including acquiring new data sets and improve data latency.

Response: GSD is working very closely with the NCEP Central Operations (NCO) MADIS team to continually improve the R2O process. NWS is investing in enhancements to MADIS and related data services within GSD in a close partnership that is positioned to carry on for many years. For example, in the past year GSD provided training for the NCO MADIS collaborators. As a result of the training, improvements have occurred in the scripting for building the operational MADIS system, in the documentation for installing, executing, and verifying that MADIS is working correctly, and in the enhanced monitoring scripts.

Data latency improvements are central to MADIS development efforts, with latency being reduced from 25 to 20 minutes in 2010 and we anticipate the latency to be less than 5 minutes by the end of 2017.

There is a significant effort to continue to acquire new data sets by the end of CY2017 for MADIS (with more planned in the future). Current actions include:

- Transition the Hydrometeorological Automated Data System (HADS)/Automated Flood Warning System (AFWS) and the SNOw TELEmetry (SNOTEL) systems to MADIS,
- Transition the Federal Highway Administration's (FHWA) Clarus system to MADIS,
- Work with the WMOs and the Airlines 4 America (A4A) to ensure MADIS is the international gateway for acquiring Aircraft Based Observations and the NWS gatekeeper for all access to ABO observations, and
- Work on next generation delivery standards following Open Geospatial Consortium standards for Web Feature Services (WFS).

E4.3. Along with all of GSD's NWP initiatives, become a contributor to, integral to, and tightly aligned with NOAA-wide strategic and tactical plans to develop next generation

global and regional modeling capabilities: including establishing benchmarks for model optimization success and a program to reach those benchmarks.

Response: GSD's current plans involve significant investments of resources toward developing, optimizing, and operationalizing the NOAA-selected next generation global forecast model. This effort includes the establishment of agreements on cooperation with both GFDL and NCAR related to their candidate global models, agreement with AOML on applications of OSSE and OSE on global and regional scales, and significant coordination with NWS on strategic objectives for these efforts. The knowledge gained, and techniques learned, during this development with regard to extreme computing will be shared for use across NOAA and its partners. GSD established the benchmarks used for selection of the new NOAA Massively Parallel Fine Grain computer (expected delivery data is August 2016) and continues to be a leader in establishing computational performance metrics for weather forecast models on HPC equipment.

Action 4.3.1 In collaboration with the NGGPS Program, develop a plan for establishing a baseline and associated metrics for speedup of NOAA's next generation global model.

E4.4. Work with NCEP/EMC to inject GSD's HPC talent and capabilities into the development of NCEP operational models, and in particular the NGGPS program and expand the GSD HPC activities as necessary to support this national imperative.

Response: GSD's HPC research efforts are being utilized by NOAA in two ways. First, to explore new computing technologies and second, to support integration of new capabilities into NCEP operational models. Early work focused on demonstrating new technologies and its potential benefit to the NWS. As the tools and technologies have matured, GSD has been collaborating with NCEP, GFDL, and other laboratories to apply our knowledge and expertise in fine-grain computing toward advancing our research and operational models. Specifically in regard to the NGGPS program, they have provided GSD $400K in FY16 to support a fine-grain computing assessment and evaluation of candidate dynamical cores (FV-3 and MPAS models) under consideration by the NWS to become the nation's next global weather model.

Action 4.4.1 Continue to work with the NGGPS Program to identify areas in which GSD's HPC talent can directly contribute to optimizing the dycore selected, as well as assisting/leading in the optimization of associated model components such as the data assimilation and model physics.

E4.5. Rather than developing new visualization tools, consider how to integrate new visualization technologies into existing visualization tools to avoid creating niche applications with limited utility - but rather create capabilities that will have broad use and distribution.

Response: GSD agrees that there may be opportunities to integrate elements of its visualization tools to broader applications. If successful, integration could lead to a more sustainable development effort with greater benefits to NOAA and other potential users, including the private sector.

Action 4.5.1 Review GSD's visualization tool development and identify areas in which these tools could be generalized for broader use.

GSD Science Review Action Sheet						
Section	**Recommendation**	**Action**	**Person Responsible**	**Target Date**	**Date Done**	**Status/Notes**
B6.1	Continue to build on opportunities presented by reorganization for synergistic work in: Software engineering, end-to-end forecast improvement, re-usable core software components	***Action B6.1.1: Identify software engineering lead that would facilitate discussions and develop a plan for the sharing of software approaches.***	John Schneider	2/2017		
B6.2	Seek, recruit, and train candidates for future hire (through graduate and/or postdoctoral fellowships) with particular attention of creating a pipeline of future employees with increased diversity.	***Action B6.2.1: Develop agreements with CU and CSU Atmospheric Science Department Chairs and the respective Cooperative Institute Directors to formalize the funding stipend for the first year.*** ***Action B6.2.2: Work with GSD staff to develop proposals for topics for CU and CSU students to consider.*** ***B6.2.3: Establish relationship with Minority-servicing Institution. Conduct workshop to introduce students with ESRL scientists.***	*Kevin Kelleher and Jennifer Mahoney (B6.2.1 and B6.2.2)* *Melinda Marquis (B6.2.3)*	B6.2.1 – 6/2016 B6.2.2 – 7/2016 B6.2.3 – 9/2016		
B6.3	Continue to hire through CI while pursuing conversion of qualified candidates to Federal positions	***Action B6.3.1: Re-instate Local Level Review Panel to provide oversight, guidance, and justification for internal promotions and new federal positions.***	Kevin Kelleher and Jennifer Mahoney	7/2016		
B6.4	Senior GSD management and project managers should continue to improve good relationships with stakeholders (including the private sector) and regularly re-align	***Action B6.4.1: Discuss realignment of strategic priorities (i.e. Grand Challenges) at next GSD retreat. Document changes and determine next steps forward.***	*Senior leadership Team*	10/2017		

	strategic research priorities					
B6.5	Work closely with NWS to improve relationships and develop a clear integrative partnership	***On-going***	-	-	-	
B6.6	Take a broader perspective on the users of its technologies towards achieving a more holistic realization of WRN objectives	***See Action D4.3.1***	-	-	-	
B6.7	Coordinate a community effort on model validation and verification involving GSD with NCEP, DTC, MDL and others	***Action B6.7.1. Deliver NGGPS verification roadmap to GSD Senior leadership.***	Bonny Strong	12/2016		
B6.8	Develop mechanisms (matrix alignments, cross-cutting programs) to foster greater symbiotic collaboration across thematic areas in GSD and ESRL so that work in each area can take advantage of knowledge and expertise across the laboratory	***Action B6.8.1. Decide whether or not to institute a GSD Research and Development Council and determine membership.***	Senior leadership Team	8/2016		
B6.9	Further consolidate and coordinate GSD activities and ensure that all innovative initiatives with long-lead development horizons receive some base funding	***In process through the Directed Director's Research Fund***	Kevin Kelleher and Jennifer Mahoney	6/2016	Completed 6/15/16	
B6.10	Identify, track and embrace broader metrics of GSD's success even if those metrics are outside of GSD's direct or sole influence, with particular focus on measures of key stakeholder outcomes	***Action B6.10.1. Explore the use of other metrics for measuring the quality of our science, tools, and technologies relative to the weather impacts on society.***	Jennifer Mahoney	5/2017		

B6.11	Analyze problems/obstacles in previous R2O efforts (HRRR, MADIS, AWIPS, etc.) and define clear actions that can be taken to improve the process for all GSD R2O efforts in the future. (Example: hand over responsibilities as developments transition down the TR funnel)	***Action B6.11.1: Schedule meeting with GSD experts to analyze R2O obstacles across projects. Share lessons learned with staff.***	Jennifer Mahoney and Melinda Marquis	9/2016		
B6.12	Establish a process to continually set/realign priorities together at least every 2y involving key scientists, mid and upper level management	***See Actions B6.4.1 and B6.8.1***	-	-		
B6.13	Actively pursue visiting scientist and engineer programs to continue to infuse external knowhow into GSD in key areas of research	***See Action B6.2.2***	-	-		
B6.14	Make continuous workforce education and training a priority of mid-level management to ensure employees remain fully up up-to-date in terms of scientific, project management and software engineering methods	***Action B6.14.1: Determine opportunities for project management training and continued training for senior and mid-level leaders.***	Senior leadership Team	Assess Quarterly		
B6.15	Introduce GSD-wide standards for software engineering (e.g. agile development, code reviewing, unit testing, regression testing, automated continuous integration systems, transparent issue and feature tracking)	***See Action B6.1.1***	-	-		
Numerical Weather						

C4.1	Identify core competencies within NOAA and the broader community and develop strategy for how it can best use utilize this expertise to improve the research and operational NWP suite.	***Action C4.1.1: Determine lead and members to address Grand Challenges 1 and 2.*** ***The team would develop and deliver a plan summarizing a strategy to improve the research and operational NWS numerical weather suite. This plan incorporates recommendation C4.5.***	Melinda Marquis	5/2017		
C4.2	Build on the current success of HRRR as a basis to help develop a convection-permitting ensemble capability for the nation.	**On-going**				
C4.3	In global modeling, finalize and implement a plan to contribute to NGGPS with selected NGGPS core and develop a longer-term plan for GSD's global modeling efforts, including a reduction in FIM, NIM work, and especially the hydrostatic FIM	***Action C4.3.1: Complete negotiations on Year 2 of the NGGPS MOU by March 2017 to be implemented in April 2017 (consistent with the NGGPS Program's funding cycle).***	Kevin Kelleher	3/2017, implement 4/2017		
C4.4	To improve quality metrics, develop and implement concrete mechanisms within GSD to encourage and reward publications and other types of scientific engagement in the research community beyond GSD and ESRL. Develop and implement mechanisms to mentor scientists on how to publish R2O and applied work, given constraints of funded efforts.	***Action C4.4.1: Schedule meeting with SLT to develop process and incentives for increasing quality metrics including number of publications. Document process and share with staff at quarterly All-hands meeting.***	Senior leadership Team	12/2016		

C4.5	Design strategies for prioritizing future GSD NWP efforts in a way that balances advancing the science and technology of NWP with stronger operational partnerships and including more robust understanding of users' needs from early on in system planning and development.	***Action C4.5.1: Complete or update projects in VLAB to include transition plans for projects at stage TRL 4 or greater. Assign focal point for tracking projects through the transition process and for updating the information as needed.***	Susan Cobb and Phyllis Gunn	9/2016		
C4.6	It is essential that a plan for national OSSE and OSE research be developed in collaboration with AOML, JCSDA, NASA/GMAO, NESDIS, perhaps via QOSAP. Test systems should include existing and possible ground-based remote sensing and in situ systems	***No Action***	-	-		
C4.7	Work to clarify and tighten GSD's roadmap, make necessary efforts to ensure buy-in across NOAA. Incorporate a clearer understanding of who might be using the predictions, how, and why into NWP system development from the beginning	***Action C4.7.1: Develop initial roadmap outlining steps toward Grand Challenges 3 and 5.*** ***Action C4.7.2: Develop steps for seeking buy-in across OAR, NWS, and NOAA.***	John Schneider and Mike Kraus	5/2017		
C4.8	Collaborate with the National Water Center. This seems like a natural fit and could lead to some productive and interesting innovation in the area of water forecasting.	***In process and on-going***	-	-		
Decision Support						

D4.1	Improve partnerships with national level programs to complement current efforts to support forecasters in the field. Perhaps opportunities like FACETs and WRN pilot programs could serve as shared initiatives to better integrate the efforts.	***Action D4.1.1: Continue to explore new partnerships and opportunities with national level programs, such as those with the GOES-R program. To begin, invite GOES-R focal point for presentation and discussion of new opportunities.***	Mike Kraus	12/2016		June presentation on GOES-R opportunities provided by Daniel Nietfeld
D4.2	Begin incorporating social science perspectives and knowledge into decision support activities to help realize Grand Challenge goals.	***Action D4.2.1: Schedule follow-on meetings with NCAR to develop opportunities for collaboration. Identify leader to continue this interaction.***	Melinda Marquis	7/2016		
D4.3	Develop a broader strategic direction for GSD Decision Support, or update existing strategic directions	***Action D4.3.1: Provide a plan for addressing Grand Challenges 3 and 5 to Senior leadership Team for review and approval - December 2016.***	John Schneider and Mike Kraus	12/2016		
D4.4	Clarify what "decision support" means for GSD	***No Action***	-	-	Done	
D4.5	Consider the appropriateness of developing technologies that support broader sets of users and uses while maintaining current competencies	***See Action D4.3.1***	-	-		
D4.6	Balancing meeting the needs of current users with taking a more active role in offering capabilities and pursuing new opportunities that leverage existing work to serve broader sets of users	***See Action D4.3.1***	-	-		

D4.7	Enhance awareness of other public and private sector decision support activities to remain competitive and collaborate where beneficial	***Action D4.7.1. Investigate whether there are other new innovative opportunities, including workshops and conferences that would provide opportunities for expanding our knowledge of decision support and report to SLT.***	Mike Kraus	5/2017		
D4.8	Seek opportunities to build a set of common core tools that can be leveraged across GSD	***See Action D4.3.1***	-	-		
D4.9	Utilize knowledge from Best Practices in aviation program: Assessment reports, methodology reviews by stakeholders and developers to guide other programs	***Action D4.9.1. Explore the feasibility for developing a joint roadmap with NWS for GSD projects.***	Daniel Nietfeld	5/2017		
Advanced Technologies						
E4.1	Continue to support and mature the highly successful SOS, MADIS and HPC initiatives. Including the use of base funding to ensure long-term sustainability of these programs.	***No Action***	--	-		
E4.2	Work with NOAA ops to tighten the R2O process for GSD's role in the continued evolution of operational MADIS, including acquiring new data sets and improve data latency	***No Action***	-	-		
E4.3	Along with all of GSD's NWP initiatives, become a contributor to, integral to, and tightly aligned with NOAA-wide strategic and tactical plans to develop next generation global and regional modeling capabilities: including establishing benchmarks	***Action 4.3.1 In collaboration with the NGGPS Program, develop a plan for establishing a baseline and associated metrics for speedup of NOAA's next generation global model.***	Mark Govett	5/2017		

	for model optimization success and a program to reach those benchmarks.					
E4.4	Work with NCEP/EMC to inject GSD's HPC talent and capabilities into the development of NCEP operational models, and in particular the NGGPS program and expand the GSD HPC activities as necessary to support this national imperative.	***Action 4.4.1 Continue to work with the NGGPS Program to identify areas in which GSD's HPC talent can directly contribute to optimizing the dycore selected, as well as assisting/leading in the optimization of associated model components such as the data assimilation and model physics.***	Mark Govett	5/2017		
E4.5	Rather than developing new visualization tools, consider how to integrate new GDS-developed visualization technologies into existing visualization tools to avoid creating niche applications with limited utility - but rather create capabilities that will have broad use and distribution.	***Action 4.5.1 Review GSD's visualization tool development and identify areas in which these tools could be generalized for broader use.***	John Schneider	12/2016		