Review of the United States Geological Survey Volcano Hazards Program

Authors and Review Panel Members:

Richard Aster, New Mexico Institute of Mining and Technology
George Bergantz, University of Washington
Simon Carn, University of Maryland, Baltimore County
George Serafino, National Oceanic and Atmospheric Administration
Jay Wilson, Oregon Emergency Management
Hugo Yepes, Instituto Geofisico, Ecuador
Kasey White, American Association for the Advancement of Science

American Association for the Advancement of Science
Research Competitiveness Program

Table of Contents

Executive Summary 1
Section 1.0 Introduction 6
1.1 The Volcano Hazards Program Mission and Significance 6
1.2 VHP Organizational Structure 6
1.3 Budget Environment 7
1.4 Charge of the AAAS Review Panel 8
Section 2.0 Management and Culture 9
2.1 Priority Setting 9
2.2 Human Resources 10
2.3 Moving Forward 11
Section 3.0 Hazards Science 12
3.1 Volcano Hazard Assessments 12
3.2 Volcano Monitoring for Hazard Assessments 13
3.3 VHP Connections with Other Scientific Partners 14
3.4 Applying Research to Product and Practitioner 15
3.4.1 Role of USGS and VHP with Federal, State and Local Customers 15
3.4.2 Connecting Hazard and Vulnerability to Risk-Based Assessments 15
3.4.3 Communication 16
Section 4.0 Response to Previous Reviews and Planning Documents 17
4.1 Actions of the VHP in Response to the Recommendations of the 2000 National Research Council (NRC) review 17
4.1.1 Research 17
4.1.2 Hazard Assessment 18
4.1.3 Monitoring 18
4.1.4 Crisis Response 19
4.1.5 Programmatic and Institutional Issues 20
4.2 The Degree to which the VHP Met the Goals of its Previous 5-year Plan (2000-2004) 22
4.3 The Soundness of the Current 5-year Plan (2004-2008) in the Light of the Mission of the Program 23
Section 5.0 Review of National Volcano Early Warning System (NVEWS) 24
5.1 Overview of NVEWS 24
5.2 Reaction to Key Components of NVEWS 25
5.3 Leveraging NVEWS to Increase VHP Customer Services and Public Awareness 27
5.3.1 Data Accessibility 27
5.3.2 Outreach 27
5.3.3 Collaborations and Partnerships 28
Section 6.0 Summary 29
References 30
Appendix A. Panel Agenda 31
Appendix B: Panel Biographies 34

Executive Summary

Under contract from the United States Geological Survey (USGS), the Research Competitiveness Program (RCP) of the American Association for the Advancement of Science (AAAS) convened a Review Panel in May 2007 to evaluate the Volcano Hazards Program (VHP). The review panel was charged with the following tasks by the USGS:

- Review response of VHP to the 2000 National Research Council (NRC) review (Fink *et al*., 2000).
- Review degree to which VHP met the goals of its previous 5-year plan.
- Evaluate the soundness of the current 5-year plan.
- Provide input on the National Volcano Early Warning System (NVEWS) (Ewert *et al.*, 2005).

This review is organized into four general categories that address the charges from the USGS and the key observations of the review panel. These sections are entitled *Management and Culture*, *Hazards Science, Response to Previous Reviews and Planning Documents*, and *Review of the National Volcano Early Warning System (NVEWS).*

VHP has an outstanding record of producing significant basic science results and is very well regarded by a wide variety of stakeholders. However, VHP is facing many challenges, including tight or diminishing budgets, a static or shrinking workforce, demographic imbalance, and a shift in the nature of federal research toward science for the sake of advancing society. The review panel feels that it is crucial that USGS adaptively redirect its programs and human resources in ways that sustain the mission of VHP in light of these factors. While basic science is essential to the core activities of the VHP, management is encouraged to evaluate the impact of that work in light of national hazard missions and strategies and to identify monitoring, hazard, and other activities for which VHP is especially well suited. Implicit in this is the fact that the VHP needs to more fully commit to core activities and to avoid duplicating research that is already mature in the university and private sector. In particular, core monitoring and hazard tasks and the production of scientific infrastructure should be VHP priorities.

Beyond the primary function of volcano research, hazard assessment, and monitoring for early warning, an increasing amount of attention is being directed at the relationship between hazards and vulnerability and implications of this relationship for community sustainability and resiliency from disasters. A more dynamic hazard assessment and mapping process is required to support these analyses. Risk-based interdisciplinary products that address multiple scale volcanic unrest scenarios should be prioritized to support communities in land use planning and emergency coordination preparation.

VHP has a strong track record of strategies and partnerships to deliver its research and analysis in a timely fashion to communities facing hazards. Stakeholders offered strong recognition and support of the quality of information from, and cooperation with, each of the Volcano Observatories. However, given the essential role the VHP plays with its local, state and federal partners, and with the broader media and public, the panel concludes that critical communication and outreach could further benefit from a stronger level of staffing and support.

Overall, the review panel feels that the VHP response to the 2000 National Research Council (NRC) review has been commendable, given serious budgetary and staffing constraints, with most of the NRC recommendations having been met, save those precluded by funding shortfalls. The principal recommendations of the 2000 NRC review, and the corresponding VHP responses, are reviewed under the five headings given in the NRC report: research (Section 4.1.1), hazard assessment (Section 4.1.2), monitoring (Section 4.1.3), crisis response (Section 4.1.4) and programmatic and institutional issues (Section 4.1.5).

The review panel also reviewed the current and previous 5-year plans for the program. VHP accomplishments from 1999 to 2003 clearly show that the program successfully executed the majority of the priority activities outlined in its 5-year plan (Section 4.2). The panel concludes that the current 5-year plan is sound and is a clear improvement over its predecessor in terms of its compatibility with the VHP core mission. However, with the exception of NVEWS, the current 5-year plan remains more a summary of activities than a coherent and forward-looking strategy to move towards a more effective and sustainable VHP. The review panel recommends that the next VHP 5-year plan take the form of a strategic roadmap rather than a straightforward description of activities (Section 4.3).

The review panel strongly endorses the vision and recommends the rapid implementation of NVEWS as a means to create a unifying framework for real-time monitoring of volcanic hazards in a systematic and cost-effective manner and to build a future program with adequate resources for fully addressing the needs of the nation. The panel also suggests a modest redirection of NVEWS towards a greater emphasis on public service (e.g., rechristening NVEWS as the "National Volcano Early Warning Service"). This is consistent with the strong service-oriented nature of other federal organizations that are intimately linked to hazards monitoring and mitigation, and that have attained significant visibility and long-term sustainable support in Congress and other circles through emphasis of the key roles they play in protecting life and property.

Overall recommendations of the review panel mapped to corresponding sections of the report include:

- Focusing of VHP's mission objectives and effectiveness in achieving these objectives would be significantly assisted through the establishment of a suitable advisory committee established under the Federal Advisory Committee Act (FACA; Public Law 106-503) that would report to the Director of the USGS. This committee would advance the VHP mission by obtaining broader community involvement for both solicited and

general input and would provide expert, independent advice to, and assessments of, the program. **(Section 2)**

- The aging of the workforce and resulting attrition due to retirement is a very significant problem throughout VHP. In the absence of significant funding increases it can be expected that VHP's ability to respond to national needs and to advance the best science in the Nation's interest will diminish. Some of this can be ameliorated, even under existing financial and staffing constraints, by expanding existing collaborative strategies, such as active emeritus participation, by increasing involvement with students, postdocs (e.g., Mendenhall program), and interns, and by establishing an external grant program for project advancement, as proposed in NVEWS. **(Section 2)**

- The review panel recommends that VHP collaborate with its state and local partners in developing regional risk-focused products, such as a range of scenarios (100, 500, 1,000 and 10,000 year probabilities) connecting environmental and societal vulnerability with long-term volcano hazards and emerging climate-related hazards. (**Section 3.3**)

- VHP, with major leadership from the Alaska Volcano Observatory (AVO), has established world-class multinational methodology and a strong multi-agency communications network for effectively managing ash hazards. The present budgetary shortfall in (previously earmarked) Federal Aviation Administration (FAA) funds to maintain Aleutian ash monitoring presents the strong (and in the view of the review panel, unacceptable) possibility of significantly degraded hazard mitigation for air travelers and commerce in the northern Pacific. It must be a high priority of the USGS, Department of the Interior (DOI), Department of Defense (DOD) and the FAA to maintain and expand this capability to preclude the possibility of aircraft/ash cloud interactions by establishing sub-15-minute warnings for significant ash clouds on a 24/7 basis. Authority and resources for monitoring Commonwealth of Northern Marianas Islands (CNMI) volcano hazards should be established at AVO, given AVO's exceptional expertise in ash hazards**.** (**Sections 3.3, 4.1.4, 4.1.5**)

- VHP staff and collaborators are encouraged to proactively pursue supplemental resources for nonrecurring observatory expenses, such as sole or joint funding for enhanced instrumentation, from appropriate stakeholders. Example possibilities include the states of Hawaii, Wyoming, and California, and the DOD (e.g., in the CNMI where significant training and testing is planned). **(Sections 3.3 and 4.1.4)**

- USGS acknowledges its mission to promote community resiliency from disasters, which implies an ability to mitigate and recover from volcano hazards. VHP should be a clearinghouse for best practices in volcano disaster recovery as learned from other countries, including jurisdictions directly assisted through the Volcano Disaster Assistance Program (VDAP). Such a resource could to support pre-disaster recovery planning in the U.S. and help frame vulnerabilities that may be mitigated before a disaster. (**Section 3.4.2**)

- VHP should invest a greater proportion of its resources in direct science-based hazard assessment and in interactions with emergency planners and responders. Scenarios for the most likely volcano emergencies should be developed at all observatories and rehearsed with collaborators and stakeholders (e.g., "wargamed"). **(Section 3.4.2)**

- VHP should support investment in outreach, such as fairs, workshops and exercises, as a means to generate and demonstrate support from the public and to properly emphasize its critical roles with local/state decision makers. In addition, the VHP should conduct additional outreach to the scientific community through events at major scientific conferences to raise awareness and leverage resources from the academic community. **(Sections 3.4.3, 5.3.2)**

- VHP web capabilities are highly appreciated by and useful to stakeholders. The program should continue with further enhancement and unification of web capabilities across the observatories. Attention should continue to be paid to easily exportable real-time or near-real time web products for the user community. **(Sections 3.4.3, 4.1.3)**

- The present organizational structure of the volcano observatories is not optimal for pursuing VHP's unified goals, given that the Alaska Science Center structure appears to be complicating crucial interactions between AVO and the other observatories. The panel recommends that this organizational feature be revisited, as efficiency will be improved if all volcano observatories are organizationally structured under the Volcano Hazards Team Chief. In the meantime, the USGS should take great pains in administering and coordinating AVO to ensure that it retains its ability to be a full partner among equals within an effective CUSVO. In addition, authority and resources for CNMI volcano hazards should be established at AVO, given AVO's exceptional expertise in ash hazards. **(Section 4.1.5)**

- The Volcano Observatories presently have variable levels of university involvement. The panel strongly encourages the development and maintenance of strong university research and educational ties across VHP. (**Section 4.1.5**)

- Further integration of effort and standardization of infrastructure and methodologies with the USGS Earthquake Hazards Program (EHP) at all observatories is strongly encouraged. The technical and 24/7 capabilities of the EHP should be fully leveraged for both standard earthquake and novel source (e.g., tremor-based) seismic monitoring purposes. Conversely, geodetic real-time capabilities within VHP should be integrated with earthquake and tsunami monitoring goals. **(Sections 4.1.5, 5.3.3)**

- The next VHP 5-year plan should take the form of a strategic roadmap detailing funding, priorities, schedules and contingencies, cross-referenced to pertinent VHP projects, rather than consisting primarily of a description of activities and projects. **(Section 4.3)**

- The NVEWS assessment analysis and overall initiative are generally very highly commended and endorsed by this review panel and should be the primary priority and

focus for sustaining and enhancing VHP so that it can meet the future needs of the Nation. **(Section 5.2)**

- A 24/7 watch office capability should be established at the earliest possibility, with an emphasis on partnership and integration with existing 24/7 capabilities. **(Section 5.2)**

- The establishment of an external grants program coupled with the VHP project structure is a specific NVEWS component that should be given high priority. **(Section 5.2)**

- Emulating the history of the EHP, this process should culminate in an authorized NVEWS program (e.g., as is the case for the National Earthquake Hazards Reduction Program [NEHRP]) capable of sustaining VHP hazard reduction and research activities and U.S. leadership in this field. **(Section 5.3)**

Section 1.0 Introduction

1.1 The Volcano Hazards Program Mission and Significance

The United States and its territories encompass 169 identified, active volcanic centers (Simkin and Siebert, 1994; Ewert *et al*., 2005), making it perhaps the third most volcanically active nation on Earth. Because of its enormous geographic spread and geological diversity, the U.S. harbors a wide variety of volcano types that are associated with diverse hazards and risks to the population. These hazards range from large Plinian eruption and lahar scenarios (e.g., Mount Saint Helens), to lava flows (e.g., Hawaiian Volcanoes), to hazardous degassing (Mammoth Mountain), to phreatic explosions in heavily touristed areas (Yellowstone Caldera) to aviation ash hazards (e.g., Aleutian Volcanoes). The U.S. is also exposed to risks from extraterritorial volcanoes, most notably aviation risks arising from ash plumes erupted at non-U.S. volcanoes in the northwestern Pacific. Because of the long repose intervals of many volcanic systems (commonly extending to millennial time scales), monitoring and research at non-U.S. volcanoes can provide essential knowledge of analogous eruption scenarios that is highly relevant to understanding and managing homeland volcano hazards.

The broad mission of the U.S. Geological Survey (USGS) Volcano Hazards Program (VHP) is to "lessen the harmful impacts of volcanic activity by monitoring active and potentially active volcanoes, assessing their hazards, responding to volcanic crises, and conducting research on how volcanoes work." The VHP mission is fundamentally relevant to the Robert T. Stafford Disaster Relief and Emergency Act of 1974 (Public Law 93-288), amended by the Disaster Mitigation Act of 2000 (Public Law 106-390), as the USGS, via the Secretary of the Interior, has been charged as the lead agency to issue public safety alerts for landslide, earthquake, and volcano hazards. USGS is additionally designated as the agent through which the Federal Emergency Management Agency (FEMA) will acquire and coordinate both commercial and civil aerial and satellite remote sensing during disaster and response activities. Activities of the VHP are fundamental to achieving at least four of the seven goals espoused in the USGS Geologic Division Science Strategy for 2000-2010 (Bohlen *et al*., 1998), specifically, "Conduct geologic hazard assessments for mitigation planning," "Provide short-term prediction of geologic disasters and rapidly characterize their effects," "Establish the geologic framework for ecosystem structure and function," and "Interpret the links between human health and geologic processes." VHP activities are also highly relevant to the USGS-wide decadal strategic science vision espoused in *Facing Tomorrow's Challenges, U.S. Geological Survey Science in the Decade 2007-2017* (USGS, 2007) under the auspices of a National Hazards, Risk, and Resilience Assessment Program.

1.2 VHP Organizational Structure

VHP is composed of five observatories, research labs in Menlo Park, California and Reston, Virginia and 22 projects, comprising a staff of 120 FTE in 2007. The volcano observatories - Hawaiian Volcano Observatory (HVO), Long Valley Volcano Observatory (LVO), Yellowstone

Volcano Observatory (YVO), Cascades Volcano Observatory (CVO), and Alaska Volcano Observatory (AVO) - fall organizationally under the joint purview of the Western Regional USGS Director and the USGS Chief Scientist for Geology (CSG), with budgetary flow from the Volcano Hazards Program Coordinator. Four of the five observatories are further organized under the Team Chief for Volcano Hazards, with the exception being AVO, which is located within the Alaska Science Center. Inter-observatory interactions are further coordinated through the Consortium of U.S. Volcano Observatories (CUSVO), which functions as a pan-observatory scientific working group.

VHP also supports 22 projects across observatories that provide specific intellectual and logistical resources around a common theme. Current examples include remote sensing, interferometric synthetic aperture radar (InSAR) studies, and seismology of magmatic systems. The projects provide resources, including some salary and the direct costs of research. The chiefs of the projects fall under the line-management of the Western and Eastern Regional Directors.

As is characteristic of the USGS as a whole, research and development efforts within the volcano observatories are implemented through an internally-reviewed project system. Because of the extremely interdisciplinary nature of volcanology, VHP necessarily interacts strongly with the broader USGS research community, in particular earthquakes, hydrology, tsunamis, and landslide hazards. VHP maintains extensive interactions with a wide range of university, civilian, and government collaborators and stakeholders that interact with the program in a large variety of ways. These significant outreach activities are often not clearly reflected in organizational structures or resource allocations.

1.3 Budget Environment

To be useful, the conclusions in this report must necessarily take into account the budget realities of the USGS and the Federal Government. The FY2007 USGS budget for VHP was $21.5 million. **Figure 1** shows VHP funding history since 2000, which show a flattening trend (a losing trend in the face of inflation) that is obviously worrisome for the future evolution of VHP capabilities. In addition, the program relies on congressional earmarks to the Federal Aviation Administration (FAA) for some of its core funding, making it vulnerable to changes and disruption in the congressional appropriations process.

The level of funding proposed for the National Volcano Early Warning System (NVEWS) represents a substantial increase in funding and staff resources. NVEWS provides a well-defined plan for growth based on community risk. The review panel strongly endorses the vision and recommends the rapid implementation of NVEWS as a means to create a unifying framework for real-time monitoring of volcanic hazards in a systematic and cost-effective manner and to build a future program with adequate resources for fully addressing the needs of the Nation.

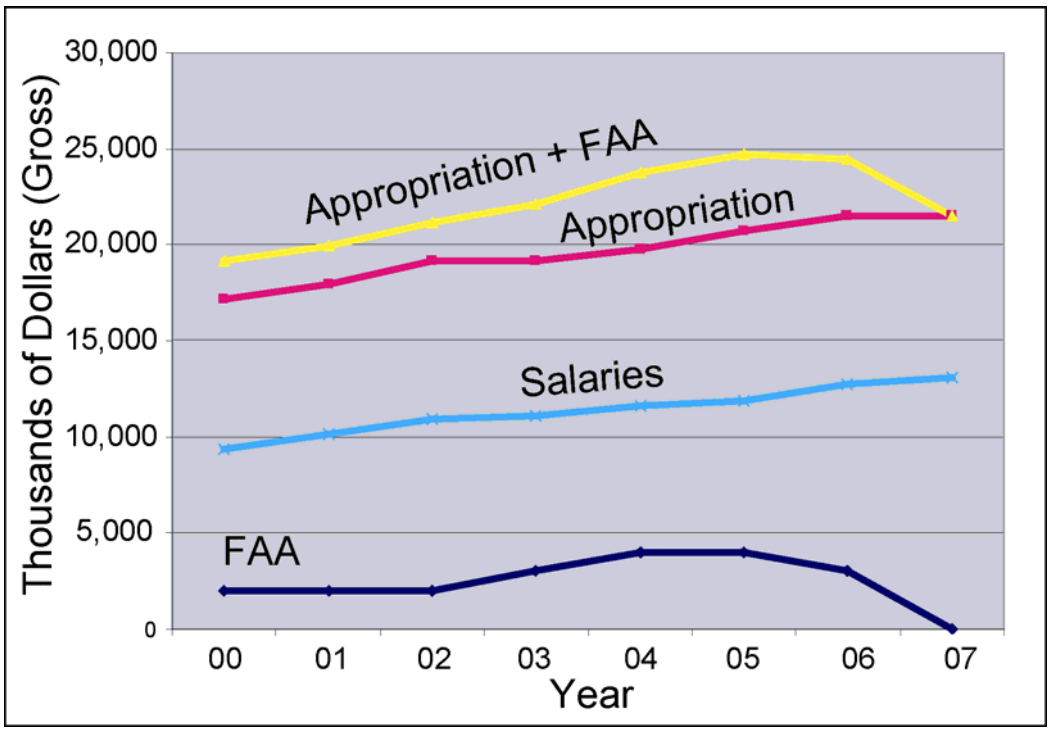

Figure 1: Funding of VHP since FY00

1.4 Charge of the AAAS Review Panel

Under contract from the USGS, the Research Competitiveness Program of the American Association for the Advancement of Science convened a review panel in May of 2007 to evaluate the VHP. This review necessarily builds upon preexisting plans and reviews, notably Fink *et al*. (2000), Ewert *et al*. (2005), and previous and current VHP 5-year plans. The panel convened June 25-28, 2007 at the USGS's Grace Hall on the campus of Alaska Pacific University. During these four days, the review panel heard testimony and extensively discussed past, ongoing, and planned activities of VHP with a wide array of USGS staff. During this review, a significant sample of program stakeholders briefed the review panel on their interactions with the program. During this time, the panel specifically asked all stakeholders to provide a candid assessment of their interactions with VHP and to provide recommendations for future improvement from their perspectives for consideration in this report. A list of participating collaborators and stakeholders is included as part of a detailed agenda of the meeting in Appendix A.

The review panel was also specifically charged with the following by the USGS:

- Review response of the VHP to the 2000 National Research Council (NRC) review (Fink *et al*., 2000).
- Review degree to which VHP met the goals of its previous 5-year plan.

- Evaluate the soundness of the current 5-year plan.
- Provide input on the National Volcano Early Warning System (NVEWS) (Ewert *et al.*, 2005).

This report is organized around key thematic sections designed to encompass the broad range of VHP activities relevant to the above charge, including management and culture (Section 2), volcano hazard assessments (Section 3.1), volcano monitoring for hazard assessments (Section 3.2), VHP connections with other scientific programs/agency partners (Section 3.3), and applying research to product and practitioner (Section 3.4). In addition, specific responses to the four key charges are elucidated above are provided in Sections 4 and 5.

Section 2.0 Management and Culture

The review panel contemplated the existing management structure and work-force culture to identify how human resources are used in initiating and sustaining the flow of intellectual and logistical resources to stakeholders, and ultimately, the benefits of the program to the public. In addition, the review panel considered how the organization is reacting and facilitating needed changes in mission emphasis and deployment of resources in an environment of diminishing budgets, shrinking workforce, and demographic imbalance.

VHP is focused on measures corresponding to four major efforts: hazard assessments, monitoring, research, and outreach/communications. These activities include an extraordinary scope of basic and applied science efforts. In addition, emergency response managers, capital project professionals, the private sector, and aviation rely on VHP for objective, accurate and timely information about these hazards. Hence, the specific challenges for management and human resources are to build and renew sustainable programs whose integration and accountability arise directly from a strategic plan with long-term science goals, while remaining flexible to respond to a variety of volcanic hazards in real-time.

2.1 Priority Setting

In a time of static or shrinking budgets and workforce, and facing a national need for science for the sake of advancing society, core monitoring and hazard tasks and the production of scientific infrastructure should be priorities. While basic science is essential to the core activities of the VHP, management is encouraged to evaluate the impact of that work in light of national hazard missions and strategies.

It was not clear to the panel that there is a full commitment to the primary role of VHP in hazard identification or the establishment of a ‘war room’ mentality to address the scope of impacts to society. It is incumbent upon the program to evaluate the minimum monitoring and hazard modeling required at any observatory and see that all are staffed to that level. However, not all volcanic systems are of equal importance in terms of hazard and impact. Resources should be directed to the Volcano Observatories relative to the associated risk to the communities and

infrastructure most impacted by volcanic unrest. While the observatories will still function as science centers, priority should be placed on those observatories that are most essential to national security and social resiliency in time of crisis. The goal is to minimize surprises and to ensure continuity of operations during the management of a crisis.

All of the projects currently funded by VHP have merit. Many are innovative responses to emerging technologies that have immediate application to the VHP mission. The resulting scientific products are frequently world class. However, the proliferation of projects in a time of reduced budgets and changing mission produces pressure on resources throughout the entire VHP. Implicit in this is the fact that VHP needs to more fully commit to the activities for which the USGS is ideally suited and to avoid duplicating laboratory and field science that is already mature in the university and private sector. These efforts must directly and jointly contribute to the mid-and-long term strategic goals, especially in the area of hazard and vulnerability science. Furthermore, while shared analytical and other joint facilities are best housed in a centralized location (e.g. Menlo Park), staffing of personnel working funded by the VHP should be associated with a specific observatory to ensure that research mission and objectives are commensurate with observatory-based hazards mission.

One challenge for management and human resources is to build a culture where there is an expectation that some efforts will have a lower priority as new projects are motivated by emerging opportunities. All projects should have a putative end-date when they are proposed and annually evaluated. The expectation of ongoing projects should be the exception and not the norm. In addition, increased emphasis should be placed on intellectual products that can act as facilitating resources for other stakeholders and partnerships, with the expectation that a priority is to create incentives and mechanisms for collaboration at every step. VHP projects and products should be designed as partnerships at the outset and be managed and prioritized so that fully-internal efforts are discouraged.

2.2 Human Resources

Some of the challenges facing VHP reside in the workplace culture. The USGS has an outstanding record of producing significant results in the arena of basic science. Many of the most productive mid-and-late career VHP personnel came of age when the basic science mission was understood to be their mandate and a key attractive feature of USGS employment. Many of these scientists have contributed significantly to the modern science of volcanology through their activities at the observatories. However, volcanology has changed dramatically in the last two decades, and like much of earth science is now largely done by research teams that fluidly combine resources and expertise from diverse organizations. Though the USGS has played an essential role in this process by providing training, field opportunities and professional access to university researchers internationally, more changes are inevitable.

In addition, the aging of the workforce and the resulting attrition due to retirement is a very significant problem throughout VHP and the USGS as a whole. In the absence of significant increases it can be expected that VHP's ability to respond to national needs will diminish. Some

of this can be ameliorated by expanding existing collaborative strategies, such as active "emeriti" participation, increased involvement with students, postdocs (e.g., Mendenhall program), interns, and with their associated universities, and an external grant program for project advancement, as proposed in NVEWS.

New hires should be a mix of specialists and those who have a broad background in geological and geophysical sciences. Such a mix of personnel would be more consistent with a monitoring-based emphasis and a science mission that is explicitly tied to social needs with an expectation that basic science can be optimally leveraged in collaboration with additional expertise residing with partners and stakeholders. Performance plans for new and existing hires should reflect this change in priorities, including specific performance metrics that could be measured at the end of each review cycle.

The VHP must also identify the right organizational structure and 'business model' for the broad range of activities. Previous reorganizations of the USGS have frequently been costly without significant lasting benefits. Currently, the flow of resources and the chain of reporting for the activities that fall under the VHP purview is a complex 'matrix' of line-management and programs. In addition, the practice of rotating productive mid-career scientists into management positions can exacerbate the problem of sustaining a long-term strategy, lead to a "bunker" mentality, prevent innovation, inhibit administrators from having the scope of experience and confidence to see needful integration, and hinder the ability to obtain funding.

2.3 Moving Forward

In summary, the USGS and VHP are entering a period of pronounced change. The legacy of high quality basic science, outreach and professionalism on the international stage is extraordinary. However, there is a growing urgency on many fronts: changing expectations with respect to the emphasis on hazard science and manifest social relevance, an aging workforce and ongoing budget challenges. Taken together, this will require VHP to become more outward looking and to explicitly tie all activities to issues that are key to the national hazard reduction mission. Particularly urgent are efforts to redirect and build a workforce culture in which contributions to scientific and hazard infrastructure are balanced with basic science activities, prioritization of efforts is based on likelihood and magnitude of risk, and management systems are not reactive to external forcing but instead anticipate and allow for change within the agency.

In addition these challenges will require that VHP redirect some effort in basic science to vulnerability science and national mission issues, specifically in the hazards arena. Specific recommendations that will foster an open workplace culture include creation of a standing external advising committee (e.g., FACA), a reconfiguration of the scope of activities, and a critical evaluation to determine which observatory activities are really essential in light of Circular 1309, *Facing Tomorrow's Challenges, U.S. Geological Survey Science in the Decade 2007-2017*.

Section 3.0 Hazards Science

The current 2004-2008 plan of the VHP references three major hazard science activities to reduce volcanic risk to the Nation: preparing volcano hazard assessments, conducting research on volcanic processes, and providing reliable forecasts, warnings, and volcano-hazard information. These activities address the U.S. DOI "Serving Communities" strategic goal of "protecting lives, resources, and property by making information available to communities to use in developing volcano hazard mitigation, preparedness, and avoidance plans."

There is an increasing need for hazard research to have meaningful user applications by providing products and support for community decisionmakers. The 2003 Office of Management and Budget (OMB) review of the USGS Geologic Hazards Program implementation of the Program Assessment Rating Tool (PART) targets three outcome measures that demonstrate informational support to communities for managing risk from natural hazards: use rate of products, percent of at-risk communities served with DOI science on hazard mitigation, and adequacy of information. The OMB review also recognized four measures to evaluate output of hazard science/research, two of which pertain to measuring hazard science outreach to stakeholders: delivery of risk assessments to customers and presentation of formal workshops or training to customers.

The VHP Performance Metrics (VHP Strategy 2004-2008, p.71) provide a framework for tracking the intermediate and end outcome measures, along with other measures such as the PART review. But these metrics do not distinguish geographical gaps or needs based on capabilities of the different VOs to serve their regional stakeholders. Identifying the percentage of volcanoes having hazards assessments or the number of formal workshops/training provided does not address how well-distributed these activities are along all fronts of the VHP.

Beyond the primary function of volcano research, hazard assessment, and monitoring for early warning, an increasing amount of attention is being directed at the relationship between hazards and vulnerability and implications of this relationship for community sustainability and resiliency from disasters. Communities will look to VHP to treat the probabilistic recurrence of volcanic unrest and potential impact as pressures of increasing populations and decreasing available land push development into hazardous areas. The USGS has a unique range of expertise within its many disciplines and partner affiliations to provide context to discussions of sustainability and resiliency through the geospatial juxtaposition of hazards with land use, economy, and environmental systems. VHP stakeholders would derive a great benefit from a better targeting of volcano risk-based efforts, such as the national vulnerability-monitoring program mentioned in the USGS 2007-2017 report (USGS, 2007).

3.1 Volcano Hazard Assessments

The review panel agrees with the NRC recommendation that basic VHP research projects should be directed toward program mission goals, such as preparing volcano hazard assessments. Many federal research agencies, such as the National Aeronautics and Space Administration (NASA)

and the National Oceanic and Atmospheric Administration (NOAA), are required to link their research efforts and priorities to mission goals as a prerequisite for funding. FEMA emphasizes hazard assessment and risk analysis as the foundation of hazard mitigation and, in fact, requires states and local jurisdictions to have FEMA-approved mitigation plans in place in order to receive federal disaster assistance and mitigation project grant funding.

The review panel acknowledges that fieldwork and basic research leading to mapping and volcanic hazard assessments is time-consuming and that meeting state and local user expectations is constrained by the USGS publication process. The NRC review recommended improved timeliness for individual volcano hazard assessments. The VHP response was that timeliness was "not a factor, appraisals are now timely." Yet the review panel learned that volcano mapping and assessment in areas like the southern Cascades still follow a time-consuming review and publication process, with many projects still incomplete after years of work.

The need for a less static, more dynamic hazard assessment and mapping process is becoming evident as pressures push development into hazard areas and local officials require map revisions and updates. Local stakeholders require access to the best available science as their basis for long-term planning decisions. This calls for the elaboration of eruptive scenarios utilizing state of the art modeling techniques, better information from satellite sensors, and liaisons with NASA and other space agencies.

Volcano hazard-zone mapping is essential for policymakers, thus, VHP should consider developing probabilistic mapping products, similar to the Earthquake Hazards Program (EHP), to better achieve VHP goals in support of the "Grand Challenges" operational mission. Probabilistic volcano hazard maps are prioritized in the 1999-2003 VHP plan. The review panel recommends that VHP place a greater investment in the probabilistic analysis of long-term hazards and especially on short-term conditional probabilities of behaviors during future periods of volcanic unrest.

3.2 Volcano Monitoring for Hazard Assessments

The proposed NVEWS lays the groundwork for the future of the VHP in meeting its research and operational mandates from national and international partners and stakeholders (see Section 5 for a further discussion of NVEWS). Demands for volcanic ash monitoring and forecasting in support of air traffic continue to increase. The concept of "no remote volcanoes" emphasizes the point that exposure and vulnerability to volcanic hazards is not limited to proximal threats and that the robust and responsive transportation systems that are necessary to support the interdependency of national economies are at risk.

While monitoring is vital for providing alerts and early warning during episodes of volcanic unrest, ongoing monitoring also provides baseline activity data necessary for hazard assessments. The review panel recognizes the difficulty in monitoring Aleutian volcanoes and seasonal restrictions on monitoring many other snow- and ice-covered volcanoes. Advanced

technologies, such as Light Detection and Ranging (LIDAR) and InSAR, have promise for monitoring volcanoes in these terrains. Monitoring proposed for 57 under-monitored volcanoes through NVEWS would also enhance hazard assessment research opportunities and support the development of more comprehensive risk-focused assessments.

Similar to the NRC Review Committee's findings, the review panel commends VHP for its interdisciplinary research approach at individual VOs, but recommends integration of approaches across VOs to better utilize limited expertise and to improve consistency of VHP products.

3.3 VHP Connections with Other Scientific Partners

VHP has established a world-class methodology and a strong multi-agency communications network for effectively managing ash hazards. The review panel recommends better collaboration between VHP and its air-transportation-serving partners, including the National Weather Service (NWS), FAA, and Department of Defense (DOD), for more cost-effective risk reduction. These partners, especially FAA and DOD, could benefit from supporting VHP hazard assessments and improved instrumentation on under-monitored, high-threat volcanoes in the Aleutian Islands and CNMI. (see also Section 4.1.4)

Increasing interest in climate change and its potential long-term impacts to communities near volcanoes should be recognized by redefining volcano hazard zones that are subject to climate-associated threats, such as glacial retreat and weather-triggered debris flows of volcano materials. Collaboration with partner agencies to increase research regarding climate change could provide supplementary funding opportunities for VHP.

VHP would likely benefit from partnerships with land management agencies, such as the U.S. Forest Service (USFS), Bureau of Land Management (BLM), and United States Army Corps of Engineers (USACE), to coordinate and streamline monitoring and site permits and to better anticipate hazardous events. These types of partnerships will promote a more comprehensive delivery of federal assistance to local and state officials who are responsible for emergency response and mitigation planning in order to reduce or avoid impacts to people and property, especially public infrastructure.

3.4 Applying Research to Product and Practitioner

3.4.1 Role of USGS and VHP with Federal, State and Local Customers

Based on the stated emphasis of the USGS on supporting community resiliency and providing operational support role to FEMA, VHP, especially with NVEWS, may be increasingly seen as a service-based program for its related federal partners and local and state customers. The VHP is uniquely qualified to provide the necessary context to the understanding of volcano hazards that in turn enables its partners and customers to better serve their stakeholders.

3.4.2 Connecting Hazard and Vulnerability to Risk-Based Assessments

USGS Circular 1309 proposes a national risk-monitoring program, built on a robust underpinning of hazard assessment and research, to visualize and provide perspectives at multiple scales of vulnerability and resilience to hazards and adverse land change.
VHP has provided strong support and federal agency leadership in the development of local and regional Volcano Coordination Plans for preparedness and response activities. These plans formalize emergency response roles to be played by local, state, and federal authorities during a period of volcanic unrest. Likewise, the engagement of VHP staff during the development and regular exercising of the plans leverages greater district buy-in and recognition of the shared responsibility of regional volcano hazards and illustrates the social/economic interdependency of vulnerability.

Local and state emergency managers require information about a range of potential scenarios based on volcano eruption processes (which may have long duration impacts to communities) rather than the traditional event-based planning assumptions used for most emergency response scenarios. Concepts of probable and possible volcanic processes are important to decisionmakers and land-use managers in analyzing long-term planning and development strategies. VO participation in local workshops and scenario-based planning activities provides tangible experience for officials who place a high value on contact with volcano scientists.

Risk-based, interdisciplinary products that address scenarios of volcanic unrest across multiple scales can provide local and state officials with a "state of the science" platform to support communities as they determine an acceptable level of risk for land use planning and emergency coordination planning. The review panel recommends that VHP collaborate with its state and local partners in developing products focused on regional risk, such as a range of scenarios (100, 500, 1,000, and 10,000 year probabilities) connecting environmental and societal vulnerability with long-term volcano hazards and emerging climate-related hazards.

Promoting resiliency in relation to volcano hazards requires more than just understanding volcanic processes, monitoring, and forecasting unrest. Promoting sustainable development implies understanding the relationship between the built/social/economic environment and the hazard and must consider society's limited understanding of complex volcano processes.

Resiliency implies an understanding of *ex ante* estimations of potential impacts, of the need for adequate provision for future eventualities, and of appropriate recovery approaches from an inevitable hazard event. VHP should be a resource/clearinghouse for best practices learned during recovery from volcano disasters in other countries, perhaps jurisdictions directly assisted through VDAP. Such a resource could support pre-disaster recovery planning in the US and help frame vulnerabilities that may be mitigated before a disaster.

The review panel recommends that VHP assist local communities as they interpret their vulnerability to hazards through collaborations with other USGS disciplines, such as Geography. VHP should utilize existing USGS expertise to assist in analyzing social/economic/natural environmental system relationships in order to help stakeholders understand community and regional scale vulnerability, exposure, and sensitivity to volcano hazards; assess community and regional risk based on probable volcanic hazards; and provide and interpret graphical and statistical information to support high risk communities in allocating appropriate levels of community investment for volcano safety measures.

3.4.3 Communication

> USGS Strategic Action: Develop communications strategies and decision-support products that focus on understanding societal risk and resilience to natural hazards, and develop new individualized ways of communicating hazards and hazard assessments to local audiences and to targeted audiences with different needs (USGS Circular 1309, p.35).

For all of the research and analysis that precedes it, communication is the final process for getting accurate and timely information into the hands of those who need it and also provides for a feedback channel to program scientists. The ability for the VHP to provide appropriate interpretation of its research to its partners and stakeholders reflects a key goal of the DOI to "provide information to assist communities in managing risks from natural hazards and ensure the quality and relevance of science information and data to support decision making."

Strong recognition and support of the quality of information and cooperation from each of the VOs was conveyed to the review panel by all of the invited VHP stakeholders. But based on the important role VHP plays among its local, state and federal partners, communication and outreach could benefit from a stronger level of staffing and support. Based on the service-type model suggested for NVEWS in Section 5, communications/outreach will require enhanced treatment within VHP in order to deliver the end product, but also to facilitate the reciprocal information exchange with the practitioners.

The review panel recommends that VHP work with state and local volcano hazard managers on a regular basis on regionally-driven volcano awareness/appreciation activities and products. This type of participation provides public visibility for the program and generates potential long-term benefits due to the elevated engagement of local stakeholders and elected officials. USGS should

support VHP investment in outreach, such as fairs, workshops and exercises, as a means of generating support from the public and demonstrating its critical role to local/state decision makers. The popularity of VO Open Houses and Volcano exhibits, such as those at YVO and Johnston Ridge, demonstrate the public's interest and support for the presentation of volcano research and the operational role of VHP to the public.

The review panel supports the decision that the new face of VHP outreach/communications will be invested in the common website and recognizes the benefits of having a single portal for partners, customers and the general public. This is necessary to deliver a uniform voice from the VHP between all of the VOs and other program areas.

Section 4.0 Response to Previous Reviews and Planning Documents

4.1 Actions of the VHP in Response to the Recommendations of the 2000 National Research Council (NRC) review

The VHP provided the review panel with an itemized list of responses to the actions recommended by the 2000 NRC review (Appendix F of the Current VHP 5-Year Plan), which is not reiterated in detail here. Overall the panel feels that the VHP response to the 2000 NRC review has been commendable given the budgetary and staffing constraints that continue to affect the program, with most of the recommendations having been met save those precluded by funding shortfalls. The principal recommendations of the 2000 NRC review, and the VHP response, are reviewed below under the five headings given in the NRC report.

4.1.1 Research

The 2000 NRC review committee concluded that basic research in the VHP was threatened by budgetary and personnel constraints and argued that reducing in-house basic research in favor of monitoring and crisis-response functions might be one way to address continuing budget shortfalls. It recommended that the VHP collaborate more on research projects with non-USGS scientists from universities and other government laboratories and initiate an extramural grant program to catalyze investigations germane to the VHP mission.

Despite the persistence of essentially flat, ‘event-driven’ budgets, the response of the VHP has been to emphasize that USGS science policy is to maintain a balance of basic and applied research. The VHP is committed to maintaining high-quality in-house research capabilities with research projects focused on 5-year goals and subject to annual review. Cooperative grants with universities have been expanded and new staff and postdocs have been recruited. Establishment of an extramural grant program has thus far been precluded by funding but is proposed as a component of NVEWS.

The review panel was impressed by the scope and quality of research conducted under the VHP project system, with notable contributions in several fields including geodetic monitoring of

volcanoes using InSAR (achieved through partnerships with NASA and the EROS Data Center), volcano seismology and the modeling of rock avalanche and debris flow runout.

4.1.2 Hazard Assessment

In the area of hazard assessment, the NRC review recommended that the VHP initiate a form of collaborative prioritization and utilize a team-based approach. Implementation of this approach has yielded numerous hazard assessments and/or maps of U.S. volcanoes since 2000, primarily in Alaska and the Aleutians, but also in the Cascades, CNMI and at Yellowstone. In collaboration with local scientists and university partners, the VHP (through VDAP) has also conducted hazard assessments at several volcanoes in Guatemala, El Salvador and Nicaragua. The team-based approach appears to have streamlined the hazard assessment and map production process, but the review panel urges the VHP to prioritize completion of hazard assessments and maps for high-threat volcanoes. In particular, production of geological maps of certain Cascade volcanoes continues to experience delays, perhaps due to the legacy of the former 'one volcano, one scientist' approach. The NVEWS gap analysis would be a good basis for such prioritization.

4.1.3 Monitoring

The 2000 NRC review recommended that VHP observatories make their data available on a near real-time (NRT) basis. The review panel saw abundant evidence that the VHP is committed to this task. Delivery of geophysical data streams in NRT is crucial if the VHP is to provide timely warnings of eruptions at remote volcanoes in the Aleutians and the CNMI to the aviation industry, a task that is an increasingly important part of the VHP mission. The VHP has embraced new technologies such as Wi-Fi to facilitate data transfer from remote sites and is standardizing the way data are displayed and analyzed through its VALVE visualization and plotting software, which allows comparison of seismic, deformation, and gas data.

A new web-based interface for the VHP, which will be more consistent with the format of the EHP and Landslide Hazards Program (LHP) websites, is scheduled for release by the end of 2007. The website will feature information on activity at U.S. volcanoes distributed in various formats, including Common Alerting Protocol (CAP) alerts, RSS feeds, and KML (Google Earth) to improve timeliness and accessibility. For some time, AVO has been a leader in website distribution of NRT data, including satellite data, webcam images of active volcanoes, and webicorders (seismic data). The VHP is encouraged to follow the AVO model as it upgrades its web presence. The AVO website was widely praised by stakeholders as an invaluable resource for information on volcanic activity in the north Pacific, including Kamchatka and the Kuriles. The HVO website is regarded as lagging behind those of AVO and CVO in terms of data sharing, but webcams and some deformation data are available. Continued IT infrastructure upgrades require funding and specialized staff.

The 2000 NRC review also encouraged the USGS to work with NASA to support an InSAR satellite specifically designed for natural hazards monitoring. A dedicated U.S. InSAR satellite

would enhance geodetic monitoring of U.S. volcanoes, but reduced NASA funding for Earth Science satellite missions in recent years has impeded progress on this front. The need for a U.S. InSAR mission was affirmed by the 2007 NRC Earth Observation Decadal Survey, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (NAS, 2007).

Until the launch of a U.S. InSAR satellite, the USGS will continue to rely on data supplied by foreign missions, several of which are compromised as they are either not L-band (needed for vegetation and snow penetration) or suffer from poor data quality or coverage. ALOS, a recently launched Japanese L-band InSAR satellite, will image much of East Asia several times per year. However, due to data rate constraints, it will not image the U.S. swaths more than once or twice per year over its five-year lifetime.

To ensure continued access to, and exploitation of, state-of-the-art remote sensing data, the review panel recommends not only that the VHP leverage current satellite platforms for remote sensing and volcano monitoring but also that it prepare to exploit future operational missions (e.g., NPOESS). Remote sensing instrumentation aboard European operational polar-orbiting satellites (e.g., MetOp) could also be leveraged in partnership with NOAA/NESDIS as data exchange agreements are already in place between NOAA and Eumetsat.

4.1.4 Crisis Response

A principal recommendation of the NRC review was that the VHP should initiate a more formal mechanism for VDAP staffing to expose as many personnel as possible to crisis response at active volcanoes. However, the VHP believes that formalization of VDAP recruitment may not be appropriate. Several dozen USGS scientists and a number of external collaborators have participated in VDAP missions, so the benefits of VDAP involvement are not restricted to the VDAP core staff (5.5 FTE). The review panel acknowledges that incorporating less-experienced staff who have research aspirations (such as students and postdocs) into a team with a mandate to focus on disaster assistance and capacity building may not be appropriate. VDAP conducted numerous successful responses in 1999-2003, and the review panel agrees that the success of VDAP should be measured more by the increased autonomy of volcano observatories in host countries than by publication of results. However, expansion of VDAP, and securing funding for such, should continue to be a priority of the VHP. This would permit hiring of additional core and engineering staff, provide VDAP personnel with more time to transfer knowledge gained overseas to the VHP, and enable VDAP to incorporate state-of-the-art volcano monitoring techniques into responses.

In addition, the NRC review advised the VHP and VDAP to work more closely with NASA, the Department of Energy, DOD, and NOAA, as well as with consortia funded by the National Science Foundation (NSF), such as UNAVCO and IRIS, in the development of new instrumentation and approaches for monitoring erupting volcanoes. Although not directly linked to crisis response, the VHP has coordinated with the Plate Boundary Observatory (PBO) component of the NSF Earthscope program (supported by UNAVCO and IRIS) to install GPS

receivers and strainmeters at Yellowstone, Mt. St. Helens (MSH) and in Alaska. The USArray component of Earthscope will also provide the VHP with unprecedented 3D seismic imaging of crustal structure as it moves across the western U.S. and Alaska in the coming years. Fruitful partnerships have also been established with NASA and NOAA to support InSAR projects and activities related to aviation hazards.

The review panel concluded that there is significant opportunity for more cooperation with DOD given the increased exposure of DOD resources to volcanic hazards. A prominent example is the U.S. military presence in Guam (Andersen AFB) and the Farallon de Medinilla target range, close to active CNMI volcanoes such as Anatahan. Airborne volcanic ash accounted for 23% of all weather-related reroutes of Air Force global airlift missions during 2002-2004. There may also be potential for coordination with the Environmental Protection Agency (EPA) on air quality impacted by tropospheric volcanic gas and ash emissions, for example on Hawaii and in the CNMI. Partnerships should also be sought to develop the use of emerging technologies such as infrasound and Doppler radar for operational volcano monitoring and eruption detection under crisis conditions. The VHP is already making progress in this regard with its VolcRad portable Doppler radar.

4.1.5 Programmatic and Institutional Issues

The NRC review cautioned that the VHP would not be able to maintain response readiness if the program did not begin to hire new staff immediately. VHP recruitment has been impacted by flat or declining budgets since fiscal year 2005, and although ~10 new staff have been added since 1999, new hires are not keeping place with retirements. To partially offset the reduction of in-house staff, partnerships with observatories' university partners have been expanded through cooperative grants. The review panel encourages the VHP to engage in serious succession planning to determine what knowledge and skills will be most critical in the near and long term given the evolving VHP mission and capabilities. These attributes should be determined for scientist, IT, engineer, technician, science management, and programmatic management tracks.

The VHP has long depended on rapid redeployment of personnel between volcano observatories to meet needs for rapid response to volcanic eruptions and to support long-term monitoring. Removal of AVO from line management of the Volcano Hazard Team has increased the bureaucracy involved in rapid deployment, long-term reassignment of employees, and redirection of resources, negatively impacting response readiness. The review panel questions what value has been added to VHP operations or to the mission by this organizational anomaly. The panel recommends that this organizational feature be revisited, as efficiency will be improved if all volcano observatories are organizationally structured under the Volcano Hazards Team Chief. In the meantime, the USGS should take great pains in administering and coordinating AVO to ensure that it retains its ability to be a full partner among equals within an effective CUSVO. In addition, authority and resources for CNMI volcano hazards should be established at AVO, given AVO's exceptional expertise in distal (ash) hazards.

In the face of these staffing issues, has the VHP maintained response readiness? Since 2000, the VHP has responded to two significant domestic volcanic eruptions: MSH and Augustine. There have also been numerous successful responses to foreign volcanic crises through VDAP. Judged on the success of the domestic responses, the VHP has maintained a certain level of response readiness, but neither eruption constituted a major crisis and yet they absorbed significant VHP resources. In its FY2007 budget request (p. H-24), the VHP itself recognized that if the eruption of Augustine had been prolonged or the activity at MSH had intensified, then redirection of VHP resources would have significantly impacted many other program activities. Hence there is concern that in its current configuration and funding status the VHP may not be prepared to respond effectively to a major domestic eruption.

The NRC review also recommended that the VHP increase its coordination and collaboration with researchers from other parts of the USGS, other federal agencies, academic institutions, and industry. Several examples illustrate the positive response of the VHP to this recommendation, including joint efforts between the VHP and other USGS programs. Monitoring of groundwater flow and pore pressure within volcanoes is an ongoing collaboration with the LHP and Mineral Resources Program (MRP). The VHP collaborates with the USGS EROS Data Center, Land Remote Sensing Program (LRSP) and other USGS programs on InSAR studies of volcanoes. Seismic networks operated by the VHP and the EHP are well-integrated or in transition to integration in some regions (e.g., California, Pacific NW, Hawaii), and future upgrades of the Advanced National Seismic System (ANSS) regional networks will benefit the VHP.

There is potential for further coordination with the EHP on seismic monitoring, particularly in Alaska and Wyoming, and also on real-time geodesy (GPS). The review panel strongly encourages further integration of effort and standardization of infrastructure and methodologies with the EHP at all observatories. The substantial technical and 24/7 capabilities of the EHP, which have been enhanced since the 2004 Sumatra tsunami, should be fully leveraged for both standard earthquake and novel source (e.g., tremor-based) seismic monitoring purposes. Conversely, geodetic real-time capabilities within VHP should be integrated with earthquake and tsunami monitoring goals. The panel also heard concern expressed over the degree of coordination between the upper echelons of the VHP and ANSS in Reston. The panel recommends that a joint ANSS/VHP task force be established to make recommendations to ensure that VHP and ANSS networks and resources can be best integrated and shared and how VHP seismic and other time series data can be more efficiently and comprehensively archived and redistributed.

The review panel heard widespread praise for the VHP from stakeholders in many federal agencies including the NWS, FAA and the USFS. The panel strongly supports further coordination with the FAA, one of the major VHP stakeholders, on aviation hazards. This should be a high priority for the VHP, in a bid to restore FAA funding for AVO that was withdrawn in FY2007. If this funding is not reinstated, AVO equipment located on land owned by the U.S. Fish and Wildlife Service (FWS) may have to be pulled out and the land restored at additional expense to the VHP.

The Volcano Observatories presently have variable levels of university involvement, ranging from very high and integral (AVO) to relatively low (HVO). The VHP is currently partnering with NASA, NOAA and the University of Maryland Baltimore County (UMBC) on a project to incorporate NRT satellite measurements of volcanic SO_2 emissions into volcano observatory operations, and collaborates with many other universities on volcano monitoring. Postdocs have also been recruited from academia through the USGS Mendenhall Fellowship Program. The review panel strongly encourages the development and maintenance of such strong ties to university research and educational across VHP.

A related NRC recommendation was that the VHP should improve outside communication (i.e., outreach) and better integrate its programs with those of other relevant organizations and government agencies that deal with volcano hazards. The redesigned VHP website discussed above will improve the public face of the program and is a key step towards improved outreach. Since 2000, the VHP in cooperation with the Smithsonian Institution (SI) has communicated updates on global volcanic activity through the SI/USGS Weekly Volcanic Activity Report (http://www.volcano.si.edu/reports/usgs/), which is distributed widely in the volcanological community and beyond. Other relevant VHP efforts include a workshop in volcano hazards with the National Park Service (NPS) in September 2000 and the implementation of a memorandum of understanding (MOU) with Yellowstone National Park for YVO, which enhanced communications and established mutual priorities. The outreach and communication efforts of the VHP were widely praised by stakeholders who testified to the review panel, although some requested an increased frequency of USGS briefings due to rapid staff turnover in their agencies.

To facilitate wider access to volcanological data generated by the VHP, the NRC committee recommended that the VHP set standards for documentation, archiving, and access policies, including the length of the proprietary period, utilizing existing resources where possible, such as the IRIS Data Management System. To this end, VHP members spearheaded the WOVOdat initiative, with the goal of establishing a modern, web-based database of worldwide volcanic unrest. The VHP is committed to the digitization and indexing of legacy datasets. The USGS Alert Notification System for Volcanic Activity has standardized volcano alerts across VOs. However, stalling of the WOVOdat effort is a cause for concern, and there is a need for more IT input into the National Volcano Data Center proposed as part of NVEWS.

4.2 The Degree to which the VHP Met the Goals of its Previous 5-year Plan (2000-2004)

The scientific priorities of the 1999-2003 VHP 5-year plan were defined as responses to the following questions: Where are the potentially high-hazard volcanic areas? Where is volcanic unrest occurring and in what manner? Is a restless volcano going to erupt? When? How long and dangerous will the eruption be? How will eruptive style change over time? How can the potential for short- and long-term volcano hazards best be communicated?

A range of programmatic activities was planned to address these questions, including expansion of real-time seismic monitoring (especially in Alaska), expanded use of real-time geodetic

monitoring (GPS), further development of InSAR, improved coupling between seismic, geodetic and volcanic gas emission measurements, development of an automated lahar detection system for Mount Rainier, preparation of hazard assessments and zonation maps at all monitored volcanoes (including application of probabilistic methods), creation of a GIS database on U.S. volcanic centers, and basic research on eruption processes.

A breakdown of actual VHP accomplishments and highlights in 1999-2003 is given in Appendices A and D of the 2004-2008 VHP 5-year plan. VHP activities in this period were also influenced by the recommendations of the NRC review, as discussed in section 4.1 above. A review of VHP accomplishments in 1999-2003 clearly shows that the program successfully executed the majority of the priority activities outlined in its 5-year plan. The broad span of VHP activities in this period included detection of volcano deformation using InSAR (Yellowstone, Mauna Loa, Aleutians, Three Sisters); expansion of seismic monitoring in the Aleutians (assisted by FAA funding, 27 of 43 historically active Alaskan volcanoes were monitored seismically by 2003); submarine exploration of the Hawaiian Islands that provided insights into volcano growth, submarine landslides, and tsunamis; a reassessment of the explosive eruption history of Kilauea Volcano; laboratory simulations of vesiculation in rhyolite and dacite magmas; computer modeling of debris flows and rock avalanches; recognition of the importance of CO_2 and H_2S gas monitoring at 'wet' volcanoes and the development of an airborne gas monitoring system; and numerous VDAP deployments to foreign volcanoes. Many of these activities and others not listed here represent significant and novel contributions to volcano monitoring within the U.S. and to volcano science in general.

The 1999-2003 5-year plan therefore resulted in a wide range of basic and applied volcano science and new monitoring infrastructure for U.S. volcanoes. One criticism of the plan is that it lacked a strategic focus and was essentially a diverse suite of activities designed to increment monitoring and scientific understanding of U.S. volcanoes in a piecemeal fashion, without clear prioritization of targets. Many of these activities have subsequently evolved into components of NVEWS, which provides a more rigorous and quantitative framework for the targeting of VHP efforts and resources and is strongly supported by the review panel.

4.3 The Soundness of the Current 5-year Plan (2004-2008) in the Light of the Mission of the Program

The mission of the VHP is to enhance public safety and reduce losses from volcanic events through effective forecasts and warnings of volcanic hazards based on a comprehensive understanding of volcanic processes. This mission is addressed through monitoring of volcano unrest and eruption, preparation of volcanic hazard assessments, research on volcanic processes, and provision of reliable forecasts, warnings, and volcano-hazard information. The goals of the current VHP 5-year plan are broader in scope than the priority activities called for by the 1999-2003 5-year plan and are more clearly aligned with the four major activities that address the VHP mission.

Some of the priority goals for 2004-2008 build on activities conducted in 1999-2003, particularly those that are acknowledged strengths of the VHP or that the VHP is uniquely qualified to accomplish. These include detailed geological field investigations of U.S. volcanoes and the use of GIS databases to enhance hazard assessments, the utilization of InSAR to characterize deformation fields at hazardous volcanoes, and the reduction of volcano risk abroad through VDAP. The review panel particularly welcomes the focus on NVEWS planning, the greater emphasis on the important tasks of outreach and delivery of VHP products to end-users, and the commitment to address VHP staffing issues through strategic hiring and the strengthening of partnerships with academia. The latter will ensure that the human resources needed to address the VHP mission remain available.

Highlights of VHP activities since 2004 include further expansion of monitoring networks in Alaska and the Aleutians, progress towards an implementation plan for NVEWS, significant steps towards an improved web presence, improved tools for data analysis and sharing, expanded partnerships in support of aviation safety, the adoption of a uniform alert system, continuing production of hazard assessments, and numerous successful responses to unrest and eruptions domestically and abroad. These achievements demonstrate that the VHP is on track to fulfill most of the goals of the current 5-year plan.

The review panel concludes that the current 5-year plan is sound and a clear improvement over its predecessor in terms of its compatibility with the VHP core mission. However, with the exception of NVEWS the current 5-year plan remains a summary of activities rather than a coherent strategy. The panel recommends that the next VHP 5-year plan instead take the form of a strategic roadmap (similar to those used by other federal agencies such as NASA) detailing funding, priorities, schedules and contingencies, cross-referenced to pertinent VHP projects. USGS Circular 1309 expresses the agency's long-term strategic goal to "develop a national risk-monitoring program, built on a robust underpinning of hazard assessment and research, to visualize vulnerability and resilience to hazards." To ensure compliance with this goal, the panel strongly advocates that future VHP planning documents convey a greater emphasis on applied hazard and vulnerability science, and on the communication of this science to stakeholders. This may have to occur at the expense of basic volcanological research within the VHP.

Section 5.0 Review of National Volcano Early Warning System (NVEWS)

5.1 Overview of NVEWS

NVEWS is a proactive and systematic approach to identifying, prioritizing, and carrying out volcano hazards mitigation in the U.S. and is part of the Grand Challenges for Disaster Reduction presented by the White House Office of Science and Technology Policy. It is a major component of the USGS 2007 strategic and capital investment plans and is fully consistent with the VHP mission "to enhance public safety and reduce losses from volcanic events through effective forecasts and warnings of volcanic hazards based on the best possible scientific information." It is envisioned that initial funding of $22 million/year will be required to support

a staff of 150, which encompasses all of the NVEWS partner organizations that will aid in setting up the essential infrastructure, functionality, and operational capabilities of the system. The eventual goal, in order to attain full functionality and final operational configuration, is to procure $44 million/year and 230 staff. This final configuration will serve to:

- Significantly improve and modernize the volcanic hazards monitoring infrastructure
- Reduce community vulnerability to volcanic hazards
- Provide continuous situational awareness via a 24/ 7 watch office
- Provide a data and information clearinghouse with rapid and easy access to real-time and retrospective volcanic data
- Institute an external grants program to tap into expertise residing at national universities, state and local agencies, and other federal agencies engaged in volcanic hazards research and systems development

5.2 Reaction to Key Components of NVEWS

The review panel strongly endorses the implementation of NVEWS as a means to create a fully-integrated, national-scale framework for real-time monitoring of volcanic hazards in a systematic and cost-effective manner. The panel also suggests changing the nomenclature of NVEWS, renaming it the National Volcano Early Warning Service, to properly reflect the service provided to the public at large. This is analogous to the strong service-oriented nature of other federal agencies, such as NOAA's National Weather Service, that are intimately linked to hazards monitoring and mitigation and have obtained significant visibility and long-term sustainable support by properly emphasizing their key roles in protecting life and property. In addition, according to reports issued by the International Strategy for Disaster Reduction, an effective and complete early warning system includes four interacting elements: (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication and (iv) response capability (ISDR-PPEW, 2005a,b). While element (i) is under the purview of the VHP, and elements (iii) and (iv) primarily a responsibility of decision-making institutions and local authorities, element (ii) clearly calls out a need for "service" that can provide the critical link between the science and the end user of hazards information.

The proposed methodology for mapping the level of support at specific volcanoes to a "threat score" representing a composite of several key factors serves as a reasonable and flexible means to optimize the use of both infrastructure and personnel resources. For example, one NVEWS threat score factor entails ranking the exposure of nearby communities and air traffic to the volcano hazard. An especially important result from the NVEWS "gap analysis" (relating a threat score to the current monitoring capability) is that the Very High Threat Cascades Volcanoes (CV) are under-monitored compared to those of the other observatories, implying that additional resources should be directed to the CV. Along with monitoring and alert operations, one of the goals of NVEWS is to reduce community vulnerability, and the 2007 USGS Bureau Science Strategy references NVEWS' aim to "work with communities to increase disaster resilience." A risk-based approach, augmented with improved background monitoring, will

direct needed information and resources to authorities who are responsible for volcano emergency planning and land use management.

A key element in any monitoring operation is the observing system, which includes in-situ and remote sensing instrumentation, the network transmission paths, and the data processing and distribution systems that generate and disseminate information used by researchers, interdisciplinary and applications users, and the public. Since the fidelity of the observing system represents the basis of informed and accurate decision-making, a sizeable portion of the NVEWS budget should be dedicated to improving and modernizing the volcanic hazards monitoring infrastructure, with periodic technical upgrades built into the budget to ensure that NVEWS leverages the latest advances in observing technology. This will also ensure that an inordinate amount of funding will not be spent operating and maintaining older or obsolete equipment at the expense of other important elements of the system.

NVEWS can provide the impetus to forge ahead on the development of a common IT infrastructure across the geographically distributed volcano observatories, thus facilitating interoperability among these components and reducing maintenance costs in the process. With a common IT infrastructure, the implementation of new data analysis and visualization tools for hazards monitoring and prediction will be much easier to accomplish and will allow for additional streamlining of procedures across the observatories. Such interoperability will also significantly improve the exchange of critical data and information among the observatories as well as improve data accessibility by researchers, decision-makers and other users with a critical need for timely and reliable receipt of such information. In this capacity, NVEWS will serve as a one-stop-shop data broker for any user with access to a web browser.

The review panel is particularly pleased with the concept of an NVEWS external grants program similar to those in use at other federal agencies. Such a program will add a new dimension to the VHP by leveraging existing expertise and skill sets resident at universities and other institutions, maximizing output through a competitive process. Analogous programs have been successfully executed at NASA through the multidisciplinary Research Opportunities in the Space and Earth Sciences (ROSES) grants program. A VHP grant program would integrate promising young scientists into USGS activities and would foster collaborative efforts among a diverse set of partners, each of whom could bring expertise to the project.

The 24/ 7 Volcano Watch Office component of NVEWS is supported by the review panel in several ways. First, it provides a single point of contact for user queries or issues pertaining to data accessibility at a particular observatory. Secondly, such a centralized watch office will be of immense aid to partner organizations and other hazards agencies (e.g., the 24/ 7 Volcanic Ash Advisory Centers or VAACs) during volcanic eruptions when timely and accurate information is needed from ground-based instrumentation to augment the operations of the respective organizations. Finally, the existence of such a watch office could greatly facilitate coordination efforts across internal and external organizations engaged in hazards monitoring and mitigation should a significant amount of volcanic unrest occur, triggering a heightened state of alert.

5.3 Leveraging NVEWS to Increase VHP Customer Services and Public Awareness

NVEWS would provide an opportunity for the VHP to make progress on several fronts that were tagged as gaps or areas in need of improvement during the panel discussions with both observatory personnel and stakeholders of the VHP program.

5.3.1 Data Accessibility

Based on the feedback the review panel received from users and stakeholders of VHP services, NVEWS should undertake an effort to maximize the amount of data and information that is catalogued and retained online via an easy-to-use search mechanism. A single user interface should be implemented that facilitates intuitive navigation and makes use of the data clearinghouse concept envisioned by NVEWS. Basic capabilities including a search capability supported by an appropriate level of metadata should be employed. Standardization of formats would be a worthy goal to ensure data interoperability but this will take time and effort especially when dealing with retrospective data in a variety of legacy formats. To facilitate data exchange between the VOs, NVEWS should investigate existing interoperability methodologies in use at other organizations to see if any can be adopted or modified to meet the needs of the volcanic hazards community. In undertaking all of these efforts, it is important that NVEWS actively engage the user community to ensure that the functional and performance requirements for such a system will address their needs for access to volcanic data and information.

On a related note, in order to ensure uninterrupted service in the issuance and delivery of critical volcano hazards information to end users and stakeholders, the NVEWS program may wish to conduct a study on a comprehensive Continuity of Operations (COOP) and/or Critical Infrastructure Protection Plan (CIP) for VHP operations. This is an increasingly important component in many government organizations that are engaged in missions to preserve life and property when faced with man-made and natural hazards. For example, as part of a COOP plan NVEWS may want to recommend the establishment of dual 24/7 watch offices, with a primary office at one location and stand-up capability elsewhere in case of an extended outage. Similarly, should NVEWS funding be acquired for the centralized data warehouse concept, plans should be developed for a remote back-up site that users can readily access for retrospective and near real-time volcanic data.

5.3.2 Outreach

NVEWS-level funding can provide a unique opportunity to institutionalize a comprehensive outreach program with dedicated resources to advocate the benefits of the VHP for public safety and property preservation. Such an outreach program would also engender public support for the VHP and even lead to the formation of constituencies at the congressional level. In addition, outreach is currently performed at the individual observatory level by the science staff on a “as resources permit” basis. The panel recognizes that the observatories are performing an admirable

job at outreach, education and public awareness considering the limited staffing. However, a formal program of cross-VO outreach, coordinated by NVEWS with the development of annual plans and goals, would be of great benefit to stakeholders. Such a program would also enhance efforts to optimize the use of resources in the VHP by streamlining processes and reducing redundancies in the current outreach efforts.

Finally, NVEWS should take a leading role in organizing and conducting strategic workshops, town hall meetings, and special sessions at major scientific conferences (both cross-disciplinary as well as discipline-specific) to raise awareness on the part of, and leverage resources from, the academic community. As an example, such meetings could serve to market the NVEWS external grants program, which would be of particular interest to the academic community given the dwindling support for volcano research from other agencies such as NASA, as well as to market the suggested realignment of USGS VHP activities toward a more applications-oriented program intimately aligned with community vulnerabilities and the associated risk-mitigation efforts.

5.3.3 Collaborations and Partnerships

NVEWS could play an important role along with its federal partners in investigating and establishing data exchange agreements with international agencies, especially for access to unique observations from space-based instrumentation that can aid in continuous monitoring and prediction of volcanic hazards (e.g., SAR-type data). The European space agencies in particular have been heavily investing in an expanding program of space-based measurements, with Japanese and Chinese remote sensing capabilities making rapid advances in the collection of environmental measurements.

Similar to the congressionally authorized NEHRP, NVEWS could also consider the inclusion of other federal agencies that have a stake in volcanic hazards (e.g., NOAA, Smithsonian, FAA, DOD) as potential partners in the NVEWS effort. Such a consortium would allow the leveraging of unique capabilities, resources, and strengths resident at multiple organizations in efforts aimed at reducing the risks posed by volcanic activity. NVEWS could also play a key role in promoting and/or coordinating collaborative efforts with programs such as the EHP as a means to obtain successful tools, methodologies and processes already in place within well-established programs, as well as promote the sharing of research results.

Another area of potential partnership involves the utilization of the NVEWS infrastructure as a testbed for new monitoring and mitigation methods developed by VHP research partners (e.g., as spearheaded or enhanced through the external grants program). Access to results could be provided to a group of "beta testers" drawn from stakeholders, partners, and users of volcanic hazards information. Such a group could also provide guidance on the evolving infrastructure and functions of NVEWS as it ramps up to full operational configuration, as well as provide valuable feedback on value-added products that would benefit state and local hazards mitigation efforts or disaster response units.

Section 6.0 Summary

After hearing from a wide variety of VHP staff and stakeholders, the review panel found a legacy of excellence in scientific research from the VHP. As it examined the items in its charge, the panel found a commitment from the VHP to implementing recommendations of previous reviews and meeting goals and activities set forth in program plans. These accomplishments are particularly commendable given the budgetary and staffing constraints that have affected – and continue to affect -- the program.

In this state of budget constraints and a shifting mission of federal research in support of societal benefits, however, VHP must redirect some effort in basic science to applied hazard and vulnerability science. As part of this shift, there is a need for a less static, more dynamic hazard assessment and mapping process that focuses on areas of greatest vulnerability. Much of our analysis is predicated on the need for emphasizing a new role for scientific infrastructure, especially monitoring; the importance of managing projects specifically for partnerships; and reducing the scope or eliminating those projects whose specific hazard application is unclear. Such allocations must be done strategically.

NVEWS provides an opportunity to move forward with a system for prioritizing monitoring efforts, expanding partnerships through the external grants program, and better communication: core ideas supported by the review panel. The review panel strongly recommends implementation of NVEWS as means for sustaining and enhancing VHP so that it can continue its legacy of excellence and meet the future needs of the Nation.

References

Bohlen, S., Halley, R., Hickman, S., Johnson, S., Lowenstern, J., Muhs, D., Plumlee, G., Thompson, G., Trauger, D., Zoback, M.L., *Geology for a Changing World*, *A Science Strategy for the Geologic Division of the U.S. Geological Survey*, 2000-2010, USGS Circular 1172, U.S. Department of the Interior, 1998.

Committee on Earth Science and Applications from Space, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, Space Studies Board, Division on Engineering and Physical Sciences, National Research Council, National Academies Press, Washington, D.C., 2007 (http://www.nap.edu/catalog/11820.html).

Ewert, J., Guffanti, M., Murray, T., An Assessment of Volcanic Threat and Monitoring Capabilities in the United States: Framework for a National Volcano Early Waning System (NVEWS), *USGS Open-File Report 2005-1164*, 2005.

Fink, J., Connor, C., Ernst, W.G., Fiske, R., Hickson, C., Kim, H., Rojstaczer, S., Segall, P., Stix, J., Swanson, F., *Review of the U.S. Geological Survey's Volcano Hazards Program*, Committee on the Review of the USGS Volcano Hazards Program, Board on Earth Sciences and Resources, Commission on Geoscience, Environment, and Resources, National Research Council, National Academy Press, Washington, D.C., 2000.

ISDR-PPEW 2005a, The 4-element view of effective people-centered early warning systems is discussed at http://www.unisdr.org/ppew/whats-ew/basics-ew.htm and in ISDR-PPEW (2005b). ISDR Platform for the Promotion of Early Warning (PPEW), Bonn.

Simkin, T, Siebert, L., *Volcanoes of the world*, Geoscience Press, Tucson, 349 p, 1994.

U.S. Geological Survey, *Facing Tomorrow's Challenges, U.S. Geological Survey Science in the Decade 2007-2017*, USGS Circular 1309, U.S. Department of the Interior, 2007.

U.S. Geological Survey, *Priorities of the Volcano Hazards Program 1999-2003*, U.S. Department of the Interior, 199? (http://volcanoes.usgs.gov/Products/1999_5Year.html).

U.S. Geological Survey, *Understanding Volcano Hazards and Preventing Volcanic Disasters: A Science Strategy for the Volcano Hazards Program 2004-2008*, U.S. Department of the Interior, 200? (http://volcanoes.usgs.gov/pdf/vhp5yrplan.pdf).

Appendix A. Panel Agenda

AAAS Review of USGS Volcano Hazards Program
June 25-28, 2007
Grace Hall, Alaska Pacific University Campus
Anchorage, Alaska

Monday 25 June, 8:30 -11:30 AM		Open session
Overview of Volcano Hazards Program and its major initiatives		
8:30	Welcome and overview of Volcano Hazards Program	Jim Quick
9:10	Volcano Hazards Program from the USGS perspective	Linda Gunderson
9:30	Overview of the Volcano Hazards Team	Jeff Wynn
9:50	The Alaska Science Center	Leslie Holland-Bartels
10:10	Break	
10:30	The National Volcano Early Warning System (NVEWS)	John Ewert
10:50	Volcano Hazards Program web-based interface	Dina Venezky
11:10	Volcano Hazards Program information technology	Peter Cervelli
11:30	Lunch	

Monday 25 June, 1:00-3:00 PM		Open session
Volcano Hazards Program from perspective of observatory Scientists in Charge		
1:00	Alaska Volcano Observatory Scientist in Charge	Tom Murray
1:20	Hawaiian Volcano Observatory Scientist in Charge	Jim Kauahikaua
1:40	Cascades Volcano Observatory Scientist in Charge	Cynthia Gardner
2:00	Long Valley Volcano Observatory Scientist in Charge	David Hill
2:20	Yellowstone Volcano Observatory Scientist in Charge	Jake Lowenstern
2:40	Break	
		Closed session
3:00	Group session with panel	all SIC's
4:00	Panel meets	Panel
5:00	End	

Tuesday 26 June, 8:30 - 11:05 AM		Open session
Principal projects of the Volcano Hazards Program		
8:30	Overview of projects of Volcano Hazards Program	Jim Quick
8:45	Mapping and research, laboratories, geochronology	Manny Nathenson
9:15	Volcanic emissions	Ken McGee
9:30	Geodesy and InSAR	Dan Dzurisin
9:45	Remote sensing	Dave Schneider
10:00	Break	
10:20	Hydrothermal geochemistry, mass and heat transport	Bill Evans
10:35	Ash and aviation	Marianne Guffanti
10:50	Volcano Disaster Assistance Program	Andy Lockhart
		Closed session
11:05	Group session with panel	Project Chiefs
11:45	Lunch	
Tuesday 26 June, 1:00-5:00 PM		Closed session
Research collaborators of the Volcano Hazards Program		
1:00	University of Alaska-Fairbanks Geophysical Institute	Steve McNutt
1:25	Alaska Division of Geological and Geophysical Surveys	Chris Nye
1:50	University of Utah	Bob Smith (phone)
2:15	Break	
2:35	University of Washington	Steve Malone
3:00	University of Hawaii	Don Thomas
3:25	Air Force Weather Agency	Charles Holliday
3:50	USGS Earthquake Hazards Program	Bill Leith and Woody Savage (phone)
4:15	Panel meets	Panel
5:00	End	

Wednesday 27 June, 8:30 AM-12:00 Noon		Closed session
Stakeholders of the Volcano Hazards Program		
8:30	DOI Office of Insular Affairs	Francisco Taitano (phone)
	Commonwealth of the Northern Mariana Islands	Pedro Tenorio (phone)
	Airline Pilots Association	Ed Miller (phone)
	Yellowstone National Park	Hank Heasler (phone)
	Federal Aviation Administration	Gail Ferguson
9:30	Mono County Sheriff's Office	Sgt. Dave O'Hara
	Gifford Pinchot National Forest	Claire Lavendel (phone)
	County of Hawaii	Harry Kim (phone)
10:30	Break	
11:00	AK Aviation Weather Unit/Volcanic Ash Advisory Center	Tony Hall
	AK State Emergency Coordination Center	Tom Smayda
	AK Dept. of Environment Conservation/Air Quality Div.	Heidi Strader
	NOAA/ Alaska Tsunami Warning Center	Paul Whitmore
	Elmendorf AFB	Lt. Col. Scott Magnan
	Inyo National Forest	Lynn Oliver (phone)
12:00	Lunch	

Wednesday 27 June, 1:00-5:30 PM		
USGS Director speaks; Panel deliberation and exit briefing		
1:00	USGS Director addresses panel	Open session, followed by Closed session
1:30	Panel deliberates	Closed session
4:30	Exit briefing to Volcano Hazards Program	Closed session
5:30	End of meeting	

Thursday, 28 June Panel field trip
Aerial Reconnaissance of Cook Inlet Volcanoes.

Appendix B: Panel Biographies

Richard Craig Aster is a Professor of Geophysics and Research Geophysicist in the Department of Earth and Environmental Science and Geophysical Research Center at the New Mexico Institute of Mining and Technology. He has been awarded the New Mexico Tech Faculty Award (2005) and the NSF Antarctic Service Medal (1999). Since 1998, he has been a Principal Investigator for the PASSCAL and EarthScope programs. In addition to serving on various Incorporated Research Institutions for Seismology (IRIS) working groups, he served as Chair of the IRIS Education and Outreach Standing Committee from 2002 - 2006. He received his Ph.D. in Earth Sciences from Scripps Institution of Oceanography. He holds an M.S. in Geophysics and a B.S. in Electrical and Computer Engineering as well as Physics, from the University of Wisconsin-Madison.

George Bergantz is a professor in the Department of Earth and Space Sciences at the University of Washington, where he previously served as assistant and associate professor. He has also held geoscience positions with Lawrence Livermore National Laboratory, the U.S. Geological Survey, and a consulting firm. He is an Associate Editor of the *Journal of Petrology* and *Journal of Volcanology and Geothermal Research* and is a Fellow of the Geological Society of America. He was awarded a Ph.D. in Earth and Planetary Sciences from The Johns Hopkins University. He holds an M.S. in Geophysical Sciences from the Georgia Institute of Technology and a B.Sc. (Cum Laude) in Geological Engineering, Minor in Mathematics from the Mackay School of Mines, University of Nevada, Reno.

Simon A. Carn is an Assistant Research Scientist at the Joint Center for Earth Systems Technology at the University of Maryland Baltimore County, where he previously served as a research associate. Prior to that, he was a volcanologist at the Montserrat Volcano Observatory. He received the NASA Group Achievement Award and NASA Goddard Space Flight Center Group Achievement Award for his work with the Aura Project. Carn was awarded the Remote Sensing and Photogrammetry Society Len Curtis European Award for best scientific paper published in the open remote sensing literature during the year 2000. He was awarded a Ph.D. in Volcanology from St. Catharine's College, University of Cambridge, UK. He also holds a D.E.A from Université Blaise Pascal and a B.A. from Exeter College.

George Serafino has served as head of the NOAA's National Environmental Satellite, Data, and Information Services (NESDIS) Satellite Analysis Branch of the Satellite Services Division since August 2002. The Satellite Analysis Branch continuously provides the National Weather Service, the National Center for Environmental Prediction and other users of environmental data with near real-time satellite imagery and products from geostationary and polar orbiting instruments. Serafino worked as a contract scientist at NASA's Goddard Space Flight Center (GSFC) from 1983-1991, developing remote sensing techniques for ozone and temperature profile determination involving both traditional and combinatorial optimization methods. He joined NASA GSFC as a civil servant in 1991 specializing in large-scale scientific data processing, data management and science data support for the EOSDIS Distributed Active Archive Center. He has received many NASA honors, including Goddard Certificate of

Outstanding Performance, Goddard Performance Award, Goddard Special Act Award and Goddard Productivity Group Award. He holds a B.S. in Physics from Trinity College and a M.S. in Meteorology from the University of Maryland.

Jay Wilson is the Earthquake, Tsunami, and Volcano Programs Coordinator with Oregon Emergency Management. He has provided invited testimony to the U.S. House Science Committee on the status of tsunami preparedness, managed development of the Central Cascades Volcano Coordination Plan, and coordinated the public release of the Mt. Hood Volcano Coordination Plan. Wilson has also served as Earthquake Policy Analyst for the City of Berkeley, Earthquake Program Coordinator for the City of Oakland, Knowledge Management Consultant for Risk Management Solutions and was a disaster reservist in community education and outreach for several FEMA regions. He received his M. A. in Geography with a Research Emphasis on Earthquake Risk Perception of Vulnerable Populations and has a B. A. in Film, both from San Francisco State University.

Hugo Yepes is a seismologist with a graduate degree from Saint Louis University (Missouri) with 25 years of experience in geological hazards evaluation and risk mitigation. His principal area of expertise is the development of early warning systems, specifically the implementation of seismic and volcanic monitoring networks, the elaboration of earthquake and eruption damage scenarios, as well as scenarios of the resulting impact on society. He is a specialist in quick response to seismic and volcanic crises, especially in their scientific evaluation and communication to the public. He was appointed Director of the Geophysical Institute of the National Polytechnic University (in Quito) in 1997 and has been a professor at the Geology Department of the same University since 1985. Yepes has been co-responsible since 1985 for the initiation and development of Ecuador's National Seismic Network and the Network of Volcanic Observatories. He has been awarded the Quito City Council medal, Congress Medal, and Pichincha Province Medal.

AAAS Staff

Kasey Shewey White joined the AAAS Center for Science, Technology and Congress as a Senior Program Associate in June 2005. She focuses on climate change and environmental issues, as well as the use of science in policymaking. White came to AAAS from the Joint Oceanographic Institutions. As Director of Public Affairs, she led outreach efforts to the media, general public, and Congress related to the Ocean Drilling Program. White previously worked with the Intergovernmental Panel on Climate Change as a co-editor of the report *Climate Change 2001: Impacts, Adaptation, and Vulnerability* and the lead author of the Technical Summary of the report. She has also worked for the American Geological Institute's Government Affairs Program. White has a B.A. in Environmental Science and Policy from Duke University and a M.A. in Environmental Sciences from The Johns Hopkins University.