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The U.S. Geological Survey Volcano Science Center Response Plan for Significant Volcanic Events

Circular 1518

U.S. Department of the Interior
U.S. Geological Survey

Photograph of Alaska Volcano Observatory scientist Tim Plucinski installing a new seismic station on the northwest flank of Augustine Volcano, Alaska, during its 2006 eruption. U.S. Geological Survey photograph by Michelle Coombs, March 15, 2006.

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By Seth C. Moran, Christina A. Neal, and Thomas L. Murray

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U.S. Geological Survey, Reston, Virginia: 2024

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Suggested citation:
Moran, S.C., Neal, C.A., and Murray, T.L., The U.S. Geological Survey Volcano Science Center's Response Plan for Significant Volcanic Events: U.S. Geological Survey Circular 1518, 65 p., https://doi.org/10.3133/cir1518.

ISSN 2330-5703 (online)
ISSN 1067-084X (print)

Photograph showing an aerial view of the first steam and ash explosion in the crater of Mount St. Helens, Washington, during the 2004 eruption. U.S. Geological Survey photograph by John Pallister, October 1, 2004.

Contents

Figures

Table

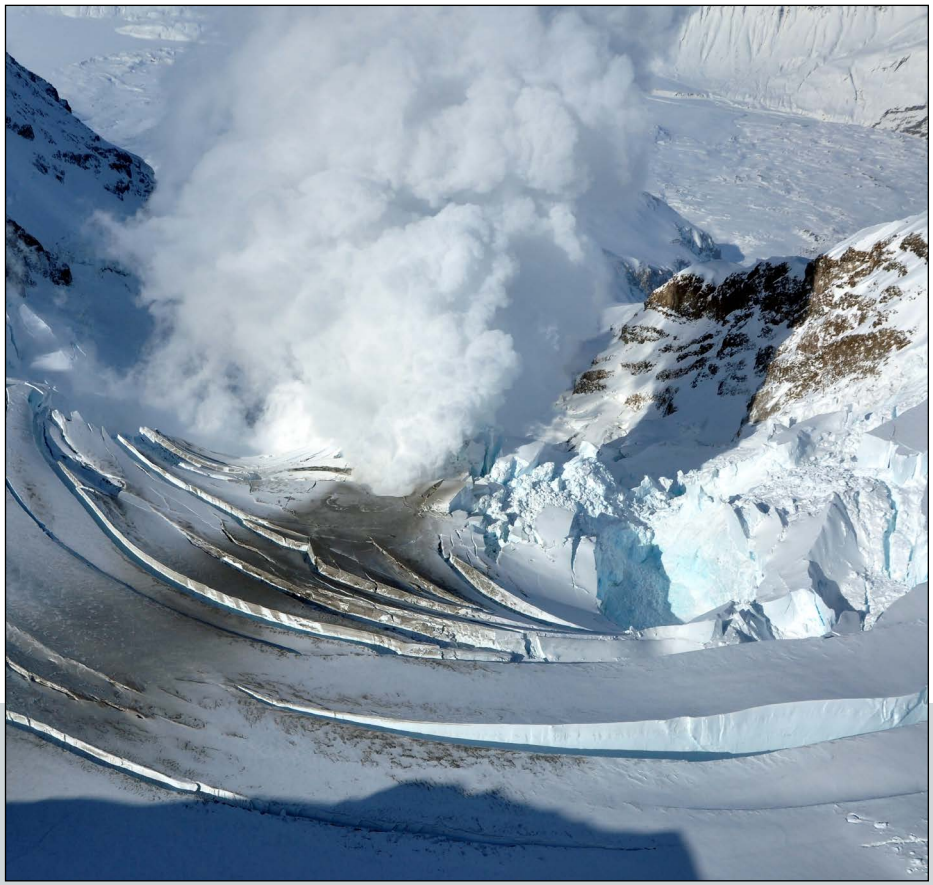
Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = (1.8 × °C) + 32.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C = (°F – 32) / 1.8.



Photograph of an ice piston coated with ash at Redoubt Volcano, Alaska. This photo was taken the day before the start of the March 2009 Redoubt eruption and shows the glacier that filled the crater collapsing due to increased ground temperatures. U.S. Geological Survey photograph, March 21, 2009.

Abbreviations

AVO	U.S. Geological Survey Alaska Volcano Observatory
CalVO	U.S. Geological Survey California Volcano Observatory
CVERT	Center Volcanic Event Response Team
CVO	U.S. Geological Survey Cascades Volcano Observatory
DOI	U.S. Department of the Interior
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
GIS	geographic information system
GNSS	Global Navigation Satellite System
HANS	Hazard Notification System for Volcanoes
HVO	U.S. Geological Survey Hawaiian Volcano Observatory
ICS	Incident Command System
NASA	National Air and Space Administration
OCAP	U.S. Geological Survey Office of Communications and Publishing
OVERT	Observatory Volcanic Event Response Team
PIO	Public Information Officer
SAC	Science Advisory Committee
SIC	Scientist-in-Charge
SRC	Staff Rotation Coordinator
UAS	Unoccupied Aviation Systems
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VSC	U.S. Geological Survey Volcano Science Center
XVO	X Volcano Observatory
YVO	U.S. Geological Survey Yellowstone Volcano Observatory

Photograph of Cascades Volcano Observatory Scientist-in-Charge Cynthia Gardner holding recently retrieved samples from the growing lava dome at Mount St. Helens, Washington, during the 2004–2008 eruption. U.S. Geological Survey photograph, March 2005.

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Photograph of U.S. Geological Survey scientists speaking to reporters at a press conference held during the 2009 eruption of Mount Redoubt, Alaska. U.S. Geological Survey photograph by Alaska Volcano Observatory staff, April 6, 2009.

Photograph of Research Corporation of the University of Hawai'i scientist Liliana DeSmither measuring surface temperatures with a thermal imaging infrared camera from a road crack in the Leilani subdivision on the Island of Hawai'i during the 2018 eruption of Kīlauea. U.S. Geological Survey photograph by Brian Shiro, May 9, 2018.

Abstract

This publication describes the U.S. Geological Survey Volcano Science Center (VSC) Response Plan for Significant Volcanic Events (hereinafter referred to as "the plan") that has been developed for U.S volcano observatories over the past several years in consultation with the lead scientist, or Scientist-in-Charge (SIC), of each of the five U.S. Geological Survey (USGS) volcano observatories. The goal of the plan is to define a standardized management system that ensures the VSC can achieve the following during a volcanic crisis:

- maintain situational awareness and issue timely warnings and hazard assessments,
- fulfill internal and external agency requests for information as well as requests from the public,
- sustain financial and technical support, and
- gather critical scientific data.

The plan addresses situations in which the scale of a response at least temporarily eclipses the response capabilities of a single observatory. The plan features two integrated response structures for managing and carrying out operations within the VSC during a crisis: the Observatory Volcanic Event Response Team (OVERT) and the Center Volcanic Event Response Team (CVERT). The design of these structures reflects lessons learned from past volcanic responses and is influenced by the Incident Command System used by the U.S. Federal Government for managing emergency responses. The plan clarifies expectations regarding the flow of information during a response, summarizes required tasks of the responding observatory and VSC to ensure a successful response, defines response-team roles and responsibilities, and describes the internal communication practices critical for an effective and coordinated response.

Photograph of California Volcano Observatory scientists Josh Crozier and Lauren Harrison installing a temporary seismic station to monitor debris flows on Mount Shasta, California (in the background). U.S. Geological Survey photograph by Phil Dawson, July 1, 2021.

Introduction

Since the establishment of a formal observatory in Hawai‘i in 1912, the volcano observatory system of the U.S. Geological Survey (USGS) has led scientific responses to hundreds of episodes of unrest and eruption at U.S. volcanoes. The most recent large-scale response was for the 2018 eruption of Kīlauea, Hawai‘i. Although led by USGS Hawaiian Volcano Observatory (HVO), the response also involved staff from other USGS volcano observatories, staff from other parts of the USGS, scientists from other agencies and academia, and even other bureaus within the U.S. Department of the Interior (DOI). Although the response was highly successful in many ways, an after-action review by Williams and others (2020) identified several opportunities for improvement. A primary recommendation was the need for more formal eruption-response planning at USGS volcano observatories, particularly for significant crises with potential to exceed the response capacity of the responding observatory.

This publication describes the USGS Volcano Science Center (VSC) Response Plan for Significant Volcanic Events (hereinafter referred to as “the plan”), developed for U.S volcano observatories over the past several years in consultation with the lead scientist, or Scientist-in-Charge (SIC), of each of the five USGS volcano observatories. The goal of the plan is to define a management system that ensures the VSC can achieve the following during a volcanic crisis:

- maintain situational awareness and issue timely warnings and hazard assessments,
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- gather critical scientific data.

The plan also clarifies expectations regarding the flow of information during a response, summarizes required tasks of the responding observatory and VSC to ensure a successful response, defines response-team roles and responsibilities, and describes internal communication practices that are critical for an effective and coordinated response.

We document and publish this response plan in order to (1) describe the philosophy, organizational structure, and high-level procedures that define the response of the USGS volcano observatory system to significant volcanic eruptions or unrest in the United States; (2) have the plan readily accessible for USGS and non-USGS scientists alike; and (3) share with external partners the scope of challenges faced by observatories during large-scale crises. By publishing this plan, we hope to help the broader scientific community understand how to better coordinate and collaborate with the responding observatory during a crisis at a U.S. volcano.

The U.S. Geological Survey Volcano Science Center

The USGS is the Federal authority responsible for monitoring U.S. volcanoes, assessing related hazards, and publishing timely information and research regarding volcanic activity in support of public safety. This authority is codified in Public Law 116–9 (approved March 12, 2019), entitled the John D. Dingell, Jr. Conservation, Management, and Recreation Act. To accomplish this mission, the USGS divides responsibility for the 161 potentially active U.S. volcanoes (Ewert and others, 2018) among five observatories: HVO (founded in 1912), the USGS Alaska Volcano Observatory (AVO; a consortium of the USGS, the University of Alaska Fairbanks Geophysical Institute, and the State of Alaska Division of Geological & Geophysical Surveys, founded in 1988), the USGS California Volcano Observatory (CalVO; founded in 2010), the USGS Cascades Volcano Observatory (CVO; founded in 1982), and the USGS Yellowstone Volcano Observatory (YVO; a consortium of nine State and Federal agencies, founded in 2001). See figure 1 for an overview of each Volcano Observatory's area of responsibility. These five observatories and the Volcano Disaster Assistance Program (a program created to mitigate volcanic crises and build capacity abroad, co-funded by the USGS and the U.S. Agency for International Development) are administratively organized under the VSC (Dietterich and Neal, 2022). The VSC receives funding from the USGS Volcano Hazards Program in support of the USGS mission to assess, monitor, and reduce the effect of volcanic hazards.

The volcano observatory system is the foundation of the VSC. Over 170 Federal scientists, technicians, and support professionals work across all five observatories and Volcano Disaster Assistance Program at four primary physical facilities, located in Vancouver, Washington; Anchorage, Alaska; Hilo, Hawai‘i; and Mountain View, California. Most observatories have at least one cooperating agency (for example, academic or State institutions), some of which are considered formal parts of their observatory structure. Additionally, all observatories work with other USGS programs and science centers, as well as other Federal, State, and local entities, to accomplish their mission objectives.

Photograph of participants in a tabletop exercise held by the Yellowstone Volcano Observatory during its 2022 biennial meeting. Photograph courtesy of Scott Johnson, EarthScope Consortium, May 12, 2022

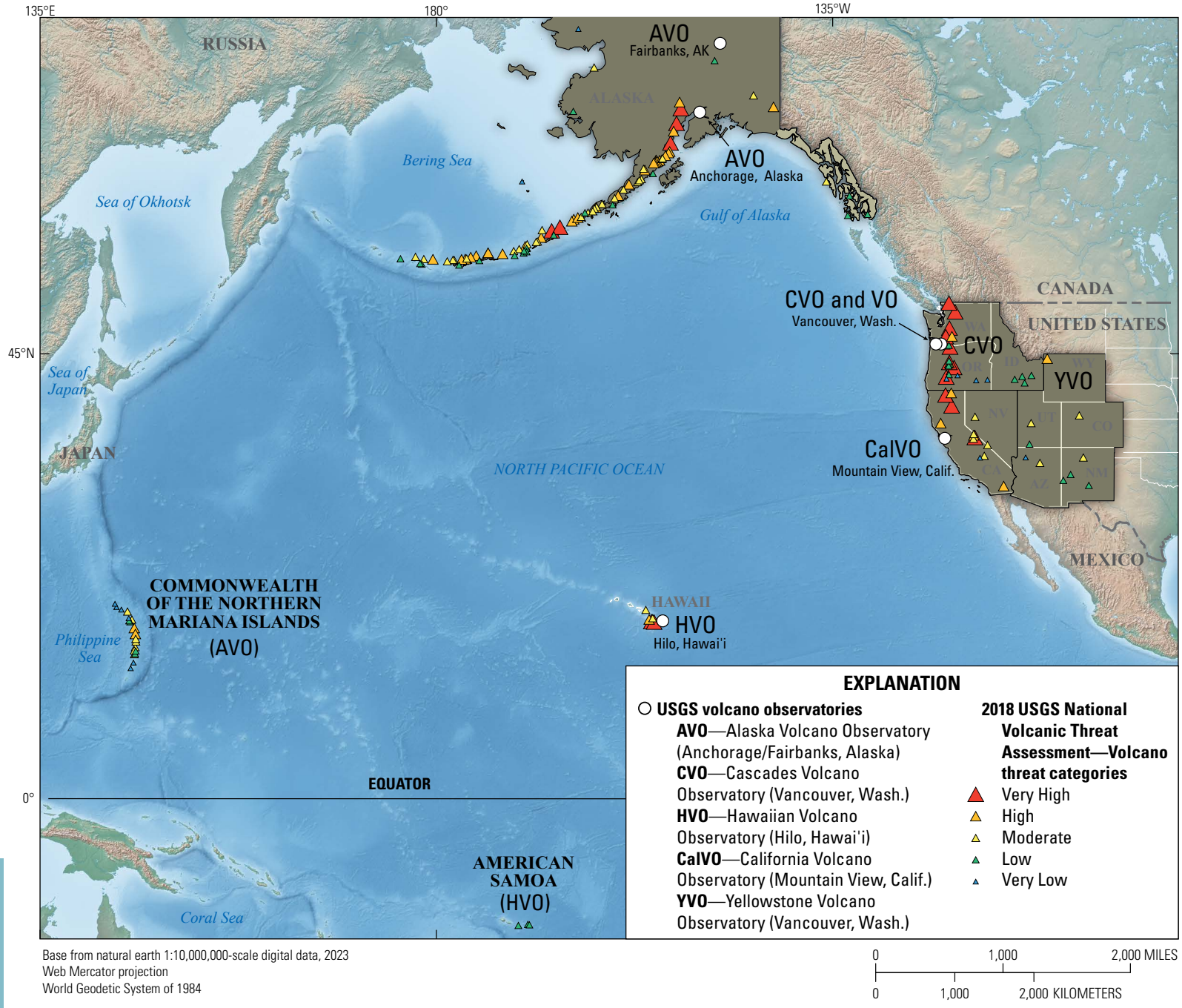


Figure 1. Map of U.S. Geological Survey (USGS) volcano observatory areas of responsibility. The Commonwealth of the Mariana Islands are under the jurisdiction of the Alaska Volcano Observatory, whereas American Samoa falls under the USGS Hawai'i Volcano Observatory. Volcanic threat levels assigned by Ewert and others (2018).

Response Plan Motivation and Influences

All USGS observatories have formal plans, informal plans, or both that guide internal response, media management, interagency response, and interagency coordination before, during, and after volcanic events in their areas of responsibility (for example, Hill and others, 2002; YVO, 2010, 2014; Driedger and Westby, 2020; AVO and others, 2022). These response plans, which are the responsibility of the SIC for each observatory, are typically unpublished, dynamic documents. One of the primary recommendations of Williams and others (2020) was that the VSC develop more formal incident response plans, motivating the development of the plan presented herein. We intentionally use "volcanic event" in the plan title rather than "eruption" because some instances of heightened volcanic unrest may require a large-scale response even without magma reaching the surface (for example, the 1980 Long Valley unrest [Hill, 1984]).

Within the USGS, multiple organizational levels above a responding observatory may become engaged in a significant response (fig. 2). However, the primary focus of this plan is the responding observatory and the VSC. The plan features a response structure designed for the peak of a large-scale response; however, the plan can be used to manage a response of any scale. The plan does not dictate precisely how individual observatories structure their response; rather, it provides a guide for SICs and their management teams as they prepare for and progress through a significant response.

Although the initial motivation for the plan came from the after-action review of the 2018 Kīlauea eruption (Williams and others, 2020), further development was influenced by multiple factors, including:

- Domestic and international USGS responses to hundreds of significant volcanic events, carried out since HVO became a permanent part of the USGS in 1947 (Babb and others, 2011),
- Published and unpublished after-action reviews (for example, Saarinen and Sell, 1985; Williams and others, 2020) and response plans (for example, YVO, 2011; YVO, 2014).
- Tabletop exercises organized by the VSC or other agencies and groups (for example, Fischer and others, 2021),
- Discussions regarding the scientific response to volcanic events at U.S. volcanoes facilitated by:
  - The Committee on Improving Understanding of Volcanic Eruptions (2017) and their report "Volcanic Eruptions and their Repose, Unrest, Precursors, and Timing," (National Academies of Sciences, Engineering, and Medicine, 2017), and
  - The Community Network for Volcano Eruption Response (CONVERSE) Research Coordination Network, funded by the National Science Foundation (Fischer and others, 2021).
  - Discussions among colleagues from observatories around the world, including Volcano Observatory Best Practices workshops in 2011, 2013, 2016, and 2019 (Pallister and others, 2019; Lowenstern and others, 2022), and
  - Recent VSC experiences with the U.S. Incident Command System (ICS), which was developed in the 1970s and 1980s to standardize the command, control, and coordination of emergency responses in the United States (Federal Emergency Management Agency [FEMA], 2008).

Describing the specific ways each of these factors influenced the plan described herein is impractical; however, the following sections highlight two notable influences: (1) VSC experience in responses to domestic volcanic unrest and eruption and (2) the ICS.

Examples of Significant Volcano Science Center Responses at U.S. Volcanoes

Diefenbach and others (2009) and Ewert and others (2018) presented a comprehensive list of modern volcanic unrest and eruptive episodes at domestic volcanoes that required some level of response by the USGS. Most have occurred in Alaska, but the conterminous United States, Hawai‘i, and the Commonwealth of the Northern Mariana Islands have all had volcanic activity requiring significant responses (table 1).

Each response was unique in terms of scale, duration, and context, though some common challenges include: (1) maintaining observatory- and center-wide situational awareness, especially as the complexity of a response escalated, (2) adjusting the scale of the observatory response structure during rapidly developing unrest and eruption sequences, (3) balancing the need for efficient decision-making with the desire to include as many staff as possible, (4) staff burnout (especially for responses longer than a few weeks), (5) budget limitations, (6) access limitations, and (7) overconcentration of responsibilities on select employees. Local observatories developed response plans for many of these responses, including a plan developed by AVO for the 2006 Augustine eruption (Neal and others, 2010) that contained several elements similar to elements in the plan described herein. Of all the responses at domestic volcanoes since 1980, two particularly influential for the design of the VSC plan were Mount St. Helens (2004–2008) and Kīlauea (2018).

Table 1. Significant responses to volcanic unrest and eruptive episodes at U.S. volcanoes since 1980.

[”Significant response” is any response in which the VSC expended significant time and (or) resources. ”Unrest” is activity (such as vigorous earthquake swarms) near a non-erupting volcano. Data from Diefenbach and others (2009) and Ewert and others (2018)]

Volcano	Response year(s)	Event type
Mount St. Helens	1980–1986	Eruption
Long Valley Caldera	1980–present	Unrest
Yellowstone caldera	1980–present	Unrest
Kīlauea	1983–2018	Eruption
Mauna Loa	1984	Eruption
Augustine Volcano	1986	Eruption
Redoubt Volcano	1989	Eruption
Mount Spurr	1992	Eruption
Shishaldin Volcano	1998	Eruption
Three Sisters	2001	Unrest
Three Sisters	2004	Unrest
Mount St. Helens	2004–2008	Eruption
Mount Spurr	2004	Unrest
Anatahan Island[1]	2005	Eruption
Augustine Volcano	2006	Eruption
Kasatochi Island	2008	Eruption
Mount Okmok	2008	Eruption
Redoubt Volcano	2009	Eruption
Bogoslof Island	2017–2018	Eruption
Kīlauea	2018	Eruption
Kīlauea	2020–2023	Eruption
Mauna Loa	2022	Eruption

[1]Part of the Commonwealth of the Northern Mariana Island

Photograph of Hawaiian Volcano Observatory staff participating in a community meeting held in Pahoa on the Island of Hawai‘i to brief community members about the status of lava flows approaching their town. U.S. Geological Survey photograph by Steve Brantley, September 14, 2014 .

Photograph of Cascades Volcano Observatory scientists preparing to evacuate from a site on the north flank of Mount St. Helens, Washington, where they were attempting to install a broadband seismometer. The evacuation was prompted by the first explosion of Mount St. Helens during the 2004–2008 eruption. U.S. Geological Survey photograph by Seth Moran, October 1, 2004.

Mount St. Helens, 2004–2008

As described by Scott and others (2008), Driedger and others (2008), and Frenzen and Matarrese (2008), the 2004 reawakening of Mount St. Helens rapidly escalated within several days of initial unrest to the point of exceeding the response capacity of CVO and other agencies involved. Within days of the first earthquakes, personnel at CVO, the Pacific Northwest Seismic Network, and Gifford Pinchot National Forest were receiving hundreds of press inquiries and holding multiple press briefings each day (Driedger and others, 2008). To manage the intense media and public interest and allow space and time for each agency to focus on other aspects of the response, Gifford Pinchot National Forest staff worked with CVO and the Washington State Emergency Management Division to establish a Joint Information Center (Driedger and other, 2008; Frenzen and Matarrese, 2008). This response was the VSC's first experience with the ICS since it was codified in 2004 (Federal Emergency Management Agency [FEMA], 2008). In the following weeks, the Joint Information Center became the focal point for information distribution and media interactions; several USGS staff members served as subject-matter experts to support the non-scientific staff brought into the Joint Information Center from various agencies to respond to public and media enquiries. The Joint Information Center was able to rapidly escalate and deescalate as the intensity of the response changed. In addition, Joint Information Center staff were able to quickly adapt to their new roles because the roles were well-defined and came with training materials. Scalability of response structure and well-defined roles, both prime tenets of the ICS, strongly influenced the design of the two management structures in the plan described herein.

The response by CVO seismologists highlights a discrete example of the challenges faced during the 2004–2008 eruption. Because pre-eruption unrest began with an intense earthquake swarm, most initial media inquiries were directed to seismologists. As a result, seismologists first focused on interpreting seismicity and responding to media requests, and it wasn't until several days after the start of unrest that seismologists began to plan for installation of new monitoring equipment. As a CVO field crew installed the first ever broadband seismometer at Mount St. Helens (Moran and others 2008a), the first explosion of the eruption occurred, forcing crews to evacuate and not return for four days. That four-day window turned out to be the most seismically vigorous of the entire 2004–2008 eruption. Had seismologists not been overwhelmed by media enquiries during the first few days, new seismometers would have likely been installed earlier, resulting in better seismic recordings from which to monitor, study, and learn about the 2004–2008 eruption. This experience informed two key aspects of the VSC plan: (1) the importance of expanding the observatory response structure before individuals become overwhelmed in their usual roles and (2) the importance of pre-defining roles in an observatory response structure so that key opportunities are not missed and the scope of responsibilities for each role is manageable.

Photograph of Hawaiian Volcano Observatory scientist Patricia Nadeau making gas measurements at Haleama`uma`u crater, Hawai'i, inside Kīlauea's summit caldera. U.S. Geological Survey photograph by Tamar Elias, December 21, 2020.

Photograph of lava overrunning a roadway in the Leilani Estates, Hawai'i, during the 2018 eruption of Kīlauea. U.S. Geological Survey photograph, May 5, 2018.

Kīlauea, 2018

As described by Neal and others (2019) and Williams and others (2020), the complexity of the 2018 Kīlauea eruption rapidly exceeded the HVO response capacity. The response necessitated full-time (24 hours a day, 7 days a week) scientific presence and monitoring at both the summit caldera and the lower East Rift Zone eruption site (where lava erupted in a series of more than 20 fissures for 3 months), intense international media inquiry responses, real-time hazard assessments and monitoring as lava flows in the lower East Rift Zone destroyed over 700 homes, and adjusting to the loss of the HVO building, damaged by earthquakes at the summit (Neal and others, 2019; Patrick and others, 2020; Williams and others, 2020). In addition, the President declared a major disaster for the State of Hawai‘i on May 11, 2018 (Federal Register, 2018), 11 days after magma began migrating down-rift to the lower East Rift Zone eruption site. This declaration resulted in an influx of support personnel to Hawai‘i from the U.S. Federal Emergency Management Agency (FEMA) and other Federal agencies. The rapid increase in county, State, and Federal agencies involved in the response brought an increased need for USGS subject-matter experts to serve continuous rotations at emergency operations centers in Hilo, Hawai‘i, and Honolulu, Hawai‘i. Combined with full-time monitoring, scientific, and outreach responsibilities, the overall scope of the response exceeded HVO’s response capacity on multiple fronts. As a result, many staff members from other observatories were brought in to assist.

Experience gained by VSC staff during the 2018 Kīlauea eruption response considerably influenced the VSC plan. Perspectives of others involved in the response, both inside and outside the VSC, were captured in two surveys distributed during and after the eruption (Williams and others, 2020). Commonly reported challenges included staff burnout, concerns about lost scientific opportunities, and confusion over roles and responsibilities. As the eruption unfolded, the benefit of having a response plan in place to define the response management structure, the functions and positions needed during a response, and the roles and responsibilities for those positions became increasingly apparent.

Incident Command System

During large-scale responses, USGS volcano observatories must change out of necessity from relatively non-hierarchical management structures, where individual staff members are mostly autonomous and can have multiple roles, to more hierarchical management structures, where staff members work in explicitly defined roles. Since large-scale responses do not happen often, such transitions have occurred primarily on an improvised basis. As a result, confusions have arisen from lack of practice and experience with complex, dynamic, and unfamiliar situations. Confusions have also arisen from the arrival of external staff who have sometimes been unfamiliar with local staff, local operation procedures, and (or) their explicit responsibilities (Williams and others, 2020).

Such experiences are not unique to large-scale responses at volcanoes. In the United States, the ICS was formed following repeated, large-scale emergency responses that suffered from organizational and management challenges. One disaster that was influential in the development of the ICS was a series of 770 fires that broke out across parts of California over a 17-day period in 1970, resulting in the tragic loss of 16 people and the destruction of over 700 structures (Stambler and Barbera, 2011). The scale of these fires quickly exceeded the State of California's fire-fighting resources, prompting a request to the Federal Government for assistance and the subsequent arrival of multiple Federal agencies to help with the response. An after-action review by the U.S. Forest Service and other responding agencies found that problems in the response stemmed from (1) confusion caused by different terminologies, organizational structures, and operating procedures used by various response agencies, and (2) inadequate mechanisms at inter-agency levels for coordinating and managing competing resource demands and for establishing consistent resource priorities.

These problems caused several California State agencies to design a scalable response structure that eventually became the ICS. Over the next several decades, the ICS became a standardized system used across the United States for managing responses to wildfires, hurricanes, earthquakes, terrorist attacks, winter storms, and other types of hazards. The ICS was codified nationally in 2004 as part of the National Incident Management System (FEMA, 2008).

Several characteristics of the ICS enable emergency-response managers to be nimble in adjusting the scale of a response as a situation dictates, characteristics directly relevant to the organization of a large-scale response at domestic volcanos. These include the following traits (FEMA, 2018a):

- *Modular organization*—The ICS can be used to manage both small-scale responses involving only a few responders and large-scale responses involving hundreds or thousands of responders. Organizational scaling is conducted through a pre-established hierarchical structure with many well-defined roles and tailored training materials. At the start of a crisis, only a few roles may be filled, whereas at the peak of a crisis, most or all may be filled. Assessments of the number of responders needed to manage a particular crisis are made regularly, as often as every 24–48 hours.
- *Manageable span of control*—In the ICS, no supervisor is responsible for more than seven or fewer than three people; with a recommended ratio of one supervisor to five supervisees. These ratios stem from lessons learned about the number of people that can be effectively managed by one person during emergency responses, particularly in situations where safety and accountability are a top priority. If these ratios are not met or exceeded, personnel are either added or subtracted and the management structure adjusted accordingly to bring the supervisor's span of control back within manageable bounds.

Despite many positive attributes, the ICS is not a perfect system. For example, Donahue and Tuohy (2006) observed that large-scale emergencies often involve confusion or a lack of awareness about the roles of different agencies, each of which may be using their own version of the ICS. Donahue and Tuohy (2006, p. 6) also noted that staff from different agencies participating in the ICS at an emergency operations center

> "…are usually liaisons who lack decision-making authority, aren't respected, and/or don't get along with each other."

However, we argue that difficulties described by Donahue and Tuohy (2006) result less from the ICS structure itself and more from the implementation of ICS during specific responses. This highlights a key lesson for the VSC—even with a perfectly designed response plan, responses may suffer from the same problems described by Donahue and Tuohy (2006) unless the plan is (1) well-socialized among all who may participate in a response, (2) regularly tested through procedures like scenario-based tabletop exercises, and (3) carried out by response teams that trust one another.

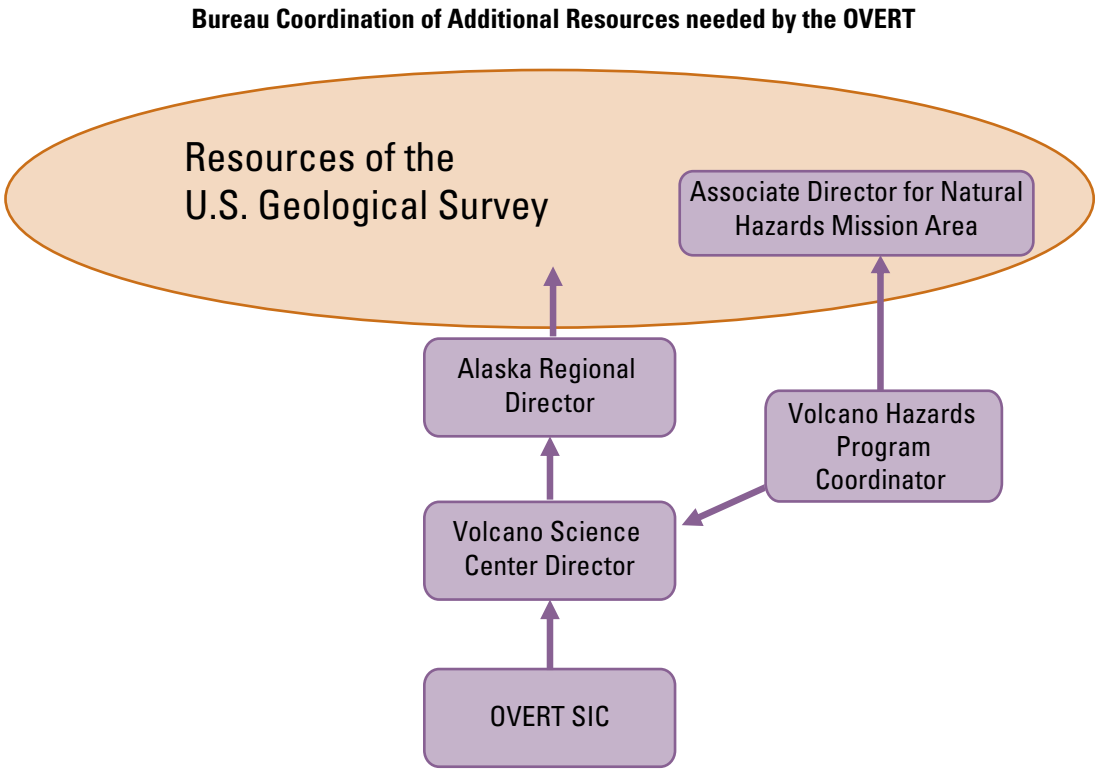


Figure 2. Diagram showing relationships between U.S. Geological Survey (USGS) response structures at the volcano observatory, science center, and regional or national USGS levels during large volcanic events. As needs increase, the response scales upward from the volcano observatory to the USGS Volcano Science Center (VSC) to regional and national level leadership. The four primary accountable managers (designated by the "Primary role" circles) are the observatory Scientist-in-Charge (SIC), VSC Director, the USGS Alaska Regional Director, and the USGS Volcano Hazards Program Coordinator. The relationships between the SIC, VSC Director, and USGS Alaska Regional Director follow the normal, non-response-mode chain of command. The VSC Director also works with the USGS Volcano Hazards Program Coordinator (who in turn works with the Department of the Interior [DOI] and USGS headquarters [HQ]) and the USGS Office of Communications and Publishing (OCAP), although without a chain-of-command relationship. USGS Alaska Regional Director coordination occurs regardless of the volcano's geographic location because the VSC organizationally lies within the Alaska Regional Office. The USGS Alaska Regional Director's role as the VSC line manager makes them familiar with the VSC, observatory operations, and responses to significant volcanic unrest and (or) eruptions. Green and orange arrows emphasize that, although communication must occur in both directions (green arrows), the primary focus at all levels must be providing the necessary support and resources (such as people, equipment, and funding) to the responding observatory (orange arrows).; Admin, VSC Administrative Team; DOI, Department of the Interior.

The Volcano Science Center Response Plan for Significant Volcanic Events

The plan described herein is designed to guide USGS volcano observatories as a volcanic event transitions from being manageable within the existing observatory structure to exceeding the response capacity of the responding volcano observatory in one or more areas. This plan also describes the ideal organizational alignment of the observatory, VSC, and other groups withing the USGS during a significant volcanic event so that all staff are effectively supporting the responding observatory and its SIC. The organizational structure shown in figure 2 is an idealized representation of how the three organizational levels relate to each other within the USGS during a response. The SIC leads the VSC's responsibilities and is equivalent to the Incident Commander in the ICS framework.

The plan features two integrated response structures for managing and carrying out operations within the VSC during a crisis: the Observatory Volcanic Event Response Team (OVERT) and the Center Volcanic Event Response Team (CVERT). Defining a USGS-wide management structure is outside the scope of this plan; instead, chapter 1000.1 of the USGS Manual defines the policies, functions, and responsibilities of the USGS Emergency Management Program for the entire USGS (U.S. Geological Survey, 2019). This USGS-wide program would become involved in any significant response (as occurred during the 2018 Kīlauea eruption) and would interface with the CVERT to provide executive direction, oversight, and support to the OVERT.

The next two sections describe the OVERT and CVERT management structures, as well as the roles and responsibilities of individual positions within each structure.

Photograph of Hawaiian Volcano Observatory Scientist-in-Charge Tina Neal speaking at a community meeting held during the 2018 eruption of Kīlauea, Hawai'i. U.S. Geological Survey photo by Ben Gaddis, May 30, 2018.

The Observatory Volcanic Event Response Team

Volcanic events can follow diverse trajectories with uncertain timelines and levels of impact. No two volcanic events are exactly alike, requiring observatories to be flexible and adaptive during all responses. However, many core activities and functions are common to large-scale responses, as reflected in the OVERT organizational structure shown in figure 3. OVERT structures will vary in detail between observatories; each observatory has unique aspects of their area of responsibility that may make some OVERT positions unnecessary (for example, a Facilities Coordinator might not be required for a response to a remote eruption in Alaska), whereas other positions may need to be filled by multiple people (for example, multiple people may need to work under the Remote Sensing Lead for that same eruption). Some observatories also have existing response plans and structures that have been developed in coordination with formal observatory partners. In such instances, those response structures should take precedence. However, if the response overwhelms existing response structures, the SIC of the responding observatory, in consultation with the VSC Director, may elect to transition into the OVERT structure.

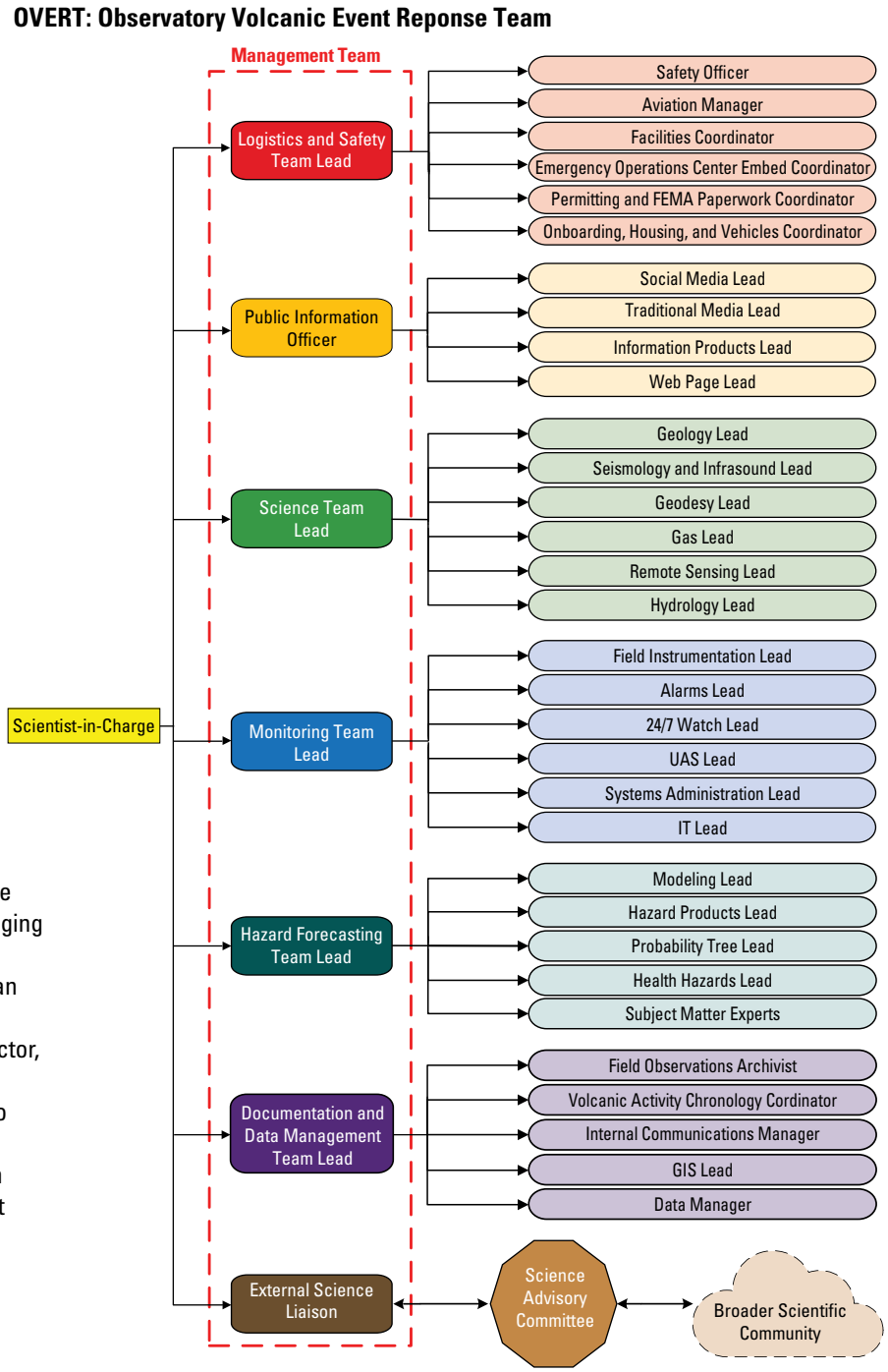


Figure 3. Diagram of the Observatory Volcanic Event Response Team (OVERT) that shows the organizational structure for managing USGS-led science responses to significant episodes of unrest and eruption at U.S. volcanoes. The structure is scalable and can be adapted as needed by the local Scientist-In-Charge (SIC), in consultation with the USGS Volcano Science Center (VSC) Director, to meet the needs of the responding observatory. Solid arrows represent OVERT chain-of-command relationships that define to whom individuals within the OVERT report. Positions within the red dashed box comprise the OVERT Management Team, which is managed by the SIC. FEMA, Federal Emergency Management Agency; 24/7, 24 hours per day, seven days per week; UAS, Unoccupied Aviation Systems; IT, information technology; GIS, geographic information system.

Key Principles

The OVERT concept and structure reflect several key principles. Chief amongst these principles is that the SIC of the responding observatory is the primary person responsible for managing USGS-wide involvement as it pertains to the scientific and local emergency response. As the response escalates and the VSC, other groups within USGS, and (or) other Federal agencies become involved, all other entities, including those from other agencies and the broader scientific community, must work in support of the SIC's response leadership efforts. The CVERT, described in the section "The Center Volcanic Event Response Team (CVERT)," supports the SIC and OVERT by providing oversight, staffing, equipment, and other resources as needed. Additionally, the CVERT coordinates efforts from within the USGS and other Federal agencies and keeps USGS leadership informed.

Another key principle of the OVERT structure, guided by the ICS's "Manageable span of control" concept (see "Incident Command System" section), is that no single person manages more than seven or fewer than three people. If either of those bounds are exceeded, then the OVERT structure is expanded or contracted to accommodate the expanding or shrinking scope of responsibilities for one or more OVERT positions. Implementing this concept successfully requires a greater emphasis on chain-of-command operations than is typical at USGS volcano observatories. Although VSC staff always work in a chain-of-command system, most staff have the flexibility to determine work priorities and day-to-day activities during non-crisis times. As a response intensifies, the OVERT hierarchical chain-of-command structure becomes increasingly necessary to (1) minimize confusion over decision-making authority and responsibility for specific tasks, (2) mitigate staff burnout related to overwhelming workloads, and (3) centralize response command and control so as to ensure all parts of the OVERT are functioning in harmony. Staff occupying OVERT positions work under temporary assignments with temporary chain-of-command relationships; once staff rotate out of these positions, they return to their normal supervisory structures. The OVERT Management Team (red dashed box in figure 3), which manages centralized command and control, is collectively responsible for some or many of the functions (depending on the scale of the response) normally handled by the SIC during non-crisis times.

Photograph of lava entering the Pacific Ocean at Kapoho Bay, Hawai'i during the 2018 eruption of Kīlauea. U.S. Geological Survey photograph, June 4, 2018.

This hierarchical structure should not be the only, or even primary, means of communication within the OVERT. In our experience (amplified by the 2018 Kīlauea and Mauna Loa 2022 responses), frequent communications across the OVERT are critical for an effective response. Communications should include regular OVERT Management Team meetings, all-staff meetings (ideally daily during peak parts of the crisis) led by the SIC or SIC delegate, smaller group meetings, posts to internal logs, intra-OVERT sharing of talking points, and regular information exchange and discussion through internal communication platforms.

Photograph of helicopter retrieving a sling load of gear following installation of a new volcano monitoring station at Mount Rainier, Washington. U.S. Geological Survey photograph by Seth Moran, September 21, 2022.

Initially, the SIC should populate the OVERT with VSC staff and formal cooperators who have necessary experience, training, and access to various OVERT resources (for example, observatory log systems). VSC staff interested in serving in specific OVERT roles should be familiar with the position responsibilities and have sufficient experience, training, skills, and abilities to fulfill the duties of a specific role. Those assigned to OVERT roles should consider their duties to be the main priority for the duration of the assignment and report to, and take assignments from, their OVERT superior. However, anyone serving in an OVERT role also needs to keep their formal supervisors informed of their activities and status on a regular basis.

A benefit of a predefined response-management system like the OVERT is that it can serve as a checklist for responding SICs to consider as a response escalates. The importance of checklists for improving performance and outcomes has been repeatedly demonstrated in fields such as aviation and medicine (Gawande, 2009). Newhall and others (2021), who argue that volcano observatories can similarly benefit from a checklist-based approach, provided a detailed checklist covering a wide variety of pre-, syn-, and post-crisis activities. Many OVERT roles shown in figure 3 (described in the OVERT "Key Roles" section) encompass parts of their syn-crisis checklist. Newhall and others (2021, p. 513) also described an additional element in their pre-crisis checklist as establishing a

> "...crisis response plan by and within the observatory, including support for backup or relief (and potentially, also assigning responsibilities for each item in this checklist)."

Designing and testing observatory-specific versions of the OVERT would help observatory SICs to incorporate this checklist element.

Another benefit of predefined response management is that people outside the USGS volcano observatory system can receive training to serve in one or more OVERT roles. This aspect can be particularly helpful when the VSC lacks sufficient expertise to fill a specific OVERT role, such as when responses remain at critical levels for many months or when simultaneous, large-scale responses temporarily exceed the capacity of the VSC to fully respond. A logical starting point is to look to other parts of the USGS (for example, the Natural Hazards Mission Area, other science centers in the USGS region in which a particular volcano lies, or the USGS Office of Communications and Publishing) for qualified people with necessary clearance and access to observatory resources to serve in OVERT roles. In some cases, people outside the USGS may serve in OVERT roles; however, this would require significant preplanning to ensure proper credentials, training, and access are in place.

Key Roles

Crucial to the success of an OVERT-based system is having predefined, individual response roles. The following sections describe the general responsibilities of the roles identified in the OVERT organizational diagram (fig. 3). Although the scale and scope of response and response roles will vary from observatory to observatory and from crisis to crisis, these descriptions can serve as a checklist for SICs as they determine what roles may be needed before, during, or after future responses.

Scientist-in-Charge

The Scientist-in-Charge (SIC) of each volcano observatory is responsible for the oversight and management of all aspects of observatory operations. The scope of this position includes personnel management and evaluation, employee safety and morale, fieldwork and science prioritization, budget, resource and facilities management, hazard forecasts, alert-level changes, response preparedness, internal communications, establishing and maintaining relationships with external agencies and partner groups, and communicating with the public. During a volcanic crisis, the SIC is additionally responsible for (1) working with the VSC Director to provide information to USGS and (or) DOI management, (2) ensuring that adequate records of hazard-related discussions and decisions are maintained, (3) managing the OVERT, and (4) coordinating with the CVERT.

During non-crisis times, SIC responsibilities include the following duties:

- Serve as chief spokesperson for the observatory, including representing the USGS to county, State, and Federal agencies; Tribal nations; any other partner agencies; any emergency operations centers; the media; and the public.
- Determine whether formal alert levels should be changed.
- Generate and update observatory call-down lists for alerting external partners about any alert-level changes or significant events at a volcano. Such call-down lists could also be generated by the OVERT Public Information Officer, Science or Monitoring Team Leads, and (or) Alarms Lead (fig. 3).
- Coordinate science activities.
- Coordinate volcano-monitoring activities.
- Manage occupational health and safety programs in support of the well-being of all observatory staff.
- Ensure the timely release of hazard statements and products.
- Communicate frequently with observatory staff (including regular OVERT-wide staff meetings) to ensure situational awareness.
- Communicate regularly with the VSC Director to help inform senior leadership in the USGS and the DOI as needed.
- Track budgets and communicate the need for new resources (including staffing) to USGS headquarter as needed.

During a volcanic crisis, additional SIC responsibilities expand to include the following duties:

- Hold regular meetings with the OVERT Management Team (see positions in the dashed box in figure 3) to facilitate communication and ensure situational awareness across all branches of the OVERT.
- Track OVERT performance, including regular assessments about whether to expand or contract it.
- Ensure that other volcanoes in the observatory's purview continue to be monitored.
- Ensure that notes are taken during meetings where hazard-messaging and decisions are discussed and made.
- Manage other parts of the observatory that are not yet engaged in the response and (or) participating in the OVERT.

Although the SIC is accountable for all responsibilities listed above, they are not personally responsible for performing all or even many of them. All SICs delegate some part of their responsibilities to other staff in their observatory, even during quiet periods. As a volcano crisis develops and intensifies, the scope of the SIC's personal responsibilities can exceed their ability to adequately perform them. If the SIC becomes slow to react, slow to make decisions, and (or) difficult to reach because they are overwhelmed with certain tasks, it can negatively affect the efficacy of a response. Before this happens, the SIC should begin planning for the delegation of some of their responsibilities.

Any delegation of responsibility must also be accompanied by delegation of decision-making authority. Without decision-making authority, delegation of responsibilities will do little to improve response efficiency. The use of the OVERT Management Team can enable the SIC to delegate in a minimally disruptive manner. By having predefined roles with clearly defined responsibilities and areas of authority, the OVERT Management Team concept provides the SIC a straightforward mechanism to implement and communicate changes in duties and authority to everyone involved in the response.

OVERT Management Team

The OVERT Management Team is composed of seven positions: Logistics and Safety Team Lead, Public Information Officer, Science Team Lead, Monitoring Team Lead, Hazard Forecasting Team Lead, Documentation and Data Management Team Lead, and External Science Liaison (fig. 3). The OVERT Management Team is analogous to the ICS Command Staff and General Staff, all of whom report to the Incident Commander (FEMA, 2018a). Each member of the OVERT Management Team reports directly to and receives directions from the SIC for

Photograph of U.S. Geological Survey Volcano Science Center scientists participating in a 2018 tabletop exercise organized and facilitated by the California Volcano Observatory. U.S. Geological Survey photograph by Jessica Ball, January 30, 2018.

Photograph of Cascades Volcano Observatory scientists Cynthia Gardner, Seth Moran, and John Pallister speaking to reporters at a press conference held during the 2004–2008 eruption of Mount St. Helens, Washington. U.S. Geological Survey photograph by Carolyn Driedger, September 28, 2004.

the duration of their assignment. The term "Team Lead" in these and other OVERT position names indicates that position is responsible for leading the activities of a group involved in the response. This leadership includes facilitating communication and decision-making among the team, coordinating and prioritizing activities, facilitating communicating requests from the OVERT Management Team and (or) SIC, and communicating group needs (such as additional people or resources) to the OVERT Management Team and (or) SIC.

The OVERT Management Team collectively handles many of the responsibilities normally shouldered by the SIC during non-crisis times. This shift happens as the SIC delegates responsibilities and decision-making authority by assigning people to OVERT Management Team roles. Those serving in OVERT Management Team positions should be reliable, independent decision-makers with the specific capabilities listed in each position description.

Ideally, the OVERT Management Team functions as the main mechanism for formally communicating needs and establishing priorities across the OVERT. Communication and prioritization tasks could include requests for additional staff and equipment, establishing OVERT-wide scientific and monitoring priorities, addressing safety and (or) logistics issues, and establishing daily field schedules The OVERT Management Team should hold regular meetings to ensure sufficient time to address all pressing issues, the frequency of which would depend on the requirements of the response. Our minimum recommended meeting frequency is daily, especially upon onset of a volcanic event (when crises often evolve quickly) and as the response peaks. All OVERT Management Team members and the SIC should be present for all meetings to ensure representation of all OVERT branches and to maximize decision-making efficiency.

The following seven sections describe the roles and responsibilities of each OVERT Management Team Lead position, as well as the positions overseen by each OVERT Management Team Lead.

Logistics and Safety Team Lead

The Logistics and Safety Team Lead will, in most instances, be the first OVERT Management Team position filled and can initially serve many roles in support of the SIC (see appendix 1 for an example of how this position's responsibilities can evolve as a crisis intensifies). The individual in this position should have good communication and organization skills as well as substantial experience with key aspects of observatory operations, including safety and aviation. Specific Logistics and Safety Team Lead responsibilities, and the responsibilities of other Logistics and Safety Team members, include the following duties:

- Oversight of the observatory's safety and aviation programs, ground-based field logistics, remote field offices (if used), vehicle fleet operations, onboarding and housing of incoming staff.
- Oversight of interactions between OVERT staff and any emergency operations centers established by other agencies to manage response activities.
- Manage individuals working in the following Logistics and Safety Team positions:

Photograph of Alaska Volcano Observatory seismologist, John Power, briefing workers at Trident Seafoods on the condition of Akutan Volcano. U.S. Geological Survey photograph take by Rod Rozier, March 17, 1996.

- *Safety Officer*—The person in this role manages the observatory's safety program and should have experience with safety management, familiarity with Federal workplace safety guidelines, and experience performing job hazards analyses. Specific responsibilities include (1) performing job-hazard analyses for specific field-related tasks (for example, fieldwork in areas exposed to volcanic gases), (2) establishing safety protocols and procedures (including for the physical and psychological safety of OVERT staff), (3) ensuring staff are sufficiently trained in safety protocols and procedures, (4) tracking and providing necessary safety gear, (5) ensuring OVERT staff have a mechanism for reporting safety issues, (6) maintaining emergency contact information for all OVERT staff, (7) developing and communicating emergency plans especially for field-related hazards (for example, evacuations plans in case of volcanic activity escalation), (8) ensuring all OVERT staff are aware of and follow check-in, check-out, and reporting procedures, (9) ensuring all OVERT staff are aware of the USGS Anti-Harassment Policy and Code of Conduct, including harassment reporting requirements and resources, and (10) serving as the primary point of contact for the USGS Alaska Region and VSC Safety Managers.
- *Aviation Manager*—The person in this role manages the observatory's aviation operations of helicopters and fixed-wing aircraft. The person in this role must have experience and training with aviation management, be familiar with the observatory's emergency response plan as it relates to aviation operations, and have good communication and organization skills. Specific responsibilities include (1) procuring aircraft and pilots with the appropriate Office of Aviation Services credentials, (2) ensuring all aviation operations follow Office of Aviation Services safety guidelines and regulations, (3) ensuring any OVERT staff involved in flight operations have the necessary aviation training and personal protective equipment, (4) working with the Science and Monitoring Team Leads to develop aviation priorities and flight plans, (5) filing flight plans with the local Federal Aviation Administration (FAA) office, land management agencies, and (or) ICS agencies managing air traffic in the vicinity of the response, (6) ensuring flight-following procedures are followed and keeping a log of all activities during flight operations, (7) coordinating OVERT aviation operations with the Unoccupied Aviation Systems (UAS) Lead (in the Monitoring Team), and (8) managing field-communication systems and protocols, including ensuring that all field-based staff have redundant means of communicating back to the office (for example, cell phones, two-way radios, GPS-based two-way communication devices, and [or] satellite phones).

- *Facilities Coordinator*—The person in this role manages any remote field offices, including key access if needed for entering restricted areas or buildings. The person in this role must be familiar with General Services Administration rules and regulations for various types of facilities (such as offices and warehouses) and have some experience with facility management and working with contractors, good organizational skills, and experience and skills with government paperwork.

- *Emergency Operations Center Embeds (EOC Embeds) Coordinator*—The Emergency Operations Center Embeds Coordinator manages any OVERT staff working at emergency operations centers operated by other agencies. Specific responsibilities include (1) working with the CVERT Staff Rotation Coordinator (SRC) to identify qualified USGS staff members to represent the USGS and the SIC in an emergency operations center setting (Emergency Operations Center Embeds should have taken ICS training course IS-100.C, "Introduction to the Incident Command System [FEMA, 2018b]"), (2) working with the Logistics and Safety Team Lead and SIC to define the roles and responsibilities of Emergency Operations Center Embeds, (3) working with the CVERT SRC to schedule Emergency Operations Center Embed rotations, (4) onboarding Emergency Operations Center Embeds, including ensuring that they are aware of how communications should occur between Emergency Operations Center Embeds, the SIC, and other parts of the OVERT, and (5) communicating regularly with Emergency Operations Center Embeds to ensure that they have an up-to-date scientific understanding of the volcanic unrest and (or) eruption, are aware of any specific messaging with respect to hazard assessments, are aware of general observatory activities, and have all their issues or questions addressed.

- *Permitting/FEMA Paperwork Coordinator*—The person in this role coordinates permitting activities with land-management agencies, including tracking all OVERT staff working in restricted areas and ensuring all staff are aware of and are following the terms and conditions of any permits. In addition, this role manages any paperwork related to reporting and (or) reimbursing expenses through FEMA in the event of a Federal disaster declaration. The person in this role should have good organization and communication skills, some experience with permitting, and experience and skills with government paperwork.

- *Onboarding, Housing, and Vehicles Coordinator*—The person in this role ensures that incoming staff can quickly adapt to their new role and are properly onboarded, have sufficient training, and have adequate housing. Specific responsibilities regarding incoming staff include ensuring that staff (1) are adequately onboarded both to the specifics of their role and the observatory's unique standard operating procedures, (2) have the proper training for their role, including consulting with the Aviation Manager and Safety Officer to establish a method for tracking training, (3) know check-in and check-out procedures and who to contact with questions, (4) are put in contact with the person to whom they will be reporting in the OVERT chart, (5) have their contact and emergency contact information added to the observatory's emergency contact list, (6) understand how to upload field observations, photos, videos, and any collected data within the observatory's data-management structure, and (7) have proper housing, a task that includes working with the CVERT SRC to ensure that staff serving graveyard or swing shifts have quiet and comfortable housing during the daytime. In addition, the person in this position manages the maintenance and operation of vehicles, including coordinating assigning vehicles to individual field parties. The person in this position must have good awareness of all VSC staff and their capabilities, good communication and organizational skills, and good awareness of local housing options. Additional responsibilities of the Logistics and Safety Team Lead include:

  - Establish field priorities and schedules in coordination with the Monitoring and Science Team Leads as well as the Aviation Manager and the Permitting/FEMA Paperwork Coordinator.

  - Support the wellbeing of all OVERT staff, including providing staff with stress-management resources (including stress-counseling resources within the DOI) and ensuring that all staff are aware of official hours-reporting requirements, are working reasonable schedules, and have time to rest and recover from their daily duties.

  - Hold regular meetings with all OVERT staff serving under the Logistics and Safety Team Lead to coordinate actions, facilitate Logistics and Safety Team communication, and ensure situational awareness of any issues that require prompt attention (such as staffing or resource needs).

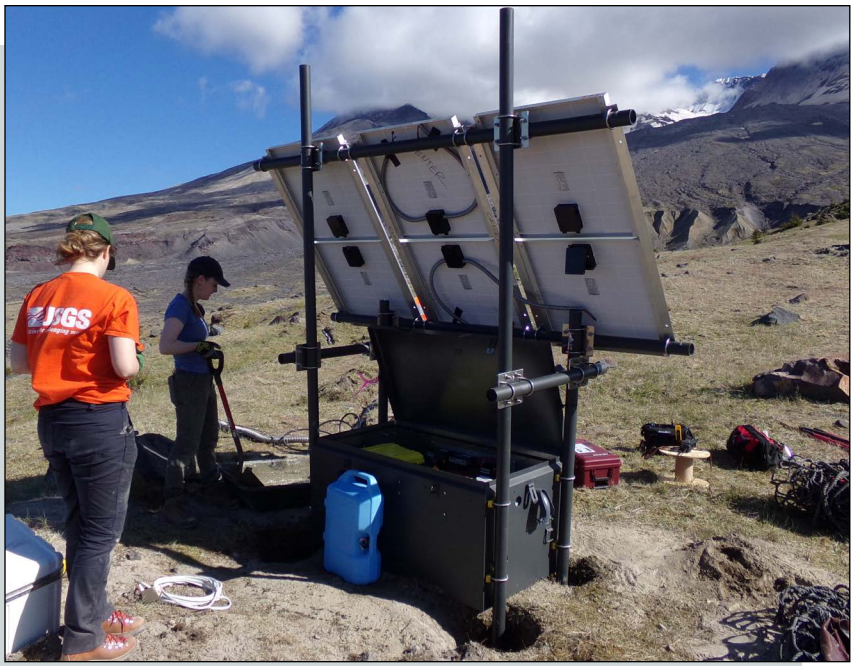
Public Information Officer

The Public Information Officer (PIO) will in most instances be the second OVERT Management Team position established, since providing information to the public and partner agencies is often one of the first aspects of a significant response that can overwhelm observatory capacities. The PIO should have substantial experience and skill in media relations and should be known and trusted by other groups and agencies involved in the response. The PIO consults with the SIC to manage the flow of information between the OVERT, partner agencies, the media, and the public (including formal information products for the USGS Hazard Notification System for Volcanoes [HANS]). If necessary, the PIO may establish a Public Information Team consisting of a Social Media Lead, a Traditional Media Lead, an Information Products Lead, and (or) a Web Page Lead. Individuals assigned to these roles are managed by the PIO for the duration of their assignment. Specific PIO responsibilities, and the responsibilities of other Public Information Team members, include the following duties:

- Hold regular meetings with the Public Information Team to establish public communication priorities, evaluate progress. These meetings ensure regular communication across the team for situational awareness about PIO-related activities and any issues that require prompt attention (such as staffing or resource needs).
- Manage hazard-related messaging across various media platforms.
  - Draft talking points for approval by the SIC or the SIC designate.
  - Ensure that talking points are thoughtfully and widely distributed.
  - Coordinate messaging with PIOs from other agencies as well as any established Joint Information Centers (for example, Driedger and others, 2008; Frenzen and Matarrese, 2008).
  - Coordinate the production of other information products as necessary (for example, coordinating the production of simplified hazard maps with the Hazard Forecasting Team Lead).
  - Serve as the primary OVERT point of contact for coordinating with the USGS Office of Communications and Publishing (OCAP).
- Manage individuals working in the following Public Information Team positions:
  - *Social Media Lead*—The person in this role works with the PIO and (or) SIC to determine rules for social media postings (for example, what can be posted by whom and when), coordinates social media staff rotations, and ensures all staff involved in social media follow USGS social media best practices, and coordinates social media efforts with other partner agencies.
  - *Traditional Media Lead*—The person in this role coordinates media interviews among OVERT staff, other USGS staff, and (or) other partner agencies, develops talking points in coordination with the PIO, tracks all media interactions, and coordinates press conferences as necessary (along with the USGS OCAP).
  - *Information Products Lead*—The person in this role coordinates information-product creation as needed for social media posts and web pages and (or) distribution to traditional media. These products can include seismicity maps, hazard maps, or conceptual models used to explain various phenomena. Activities of this position would likely overlap with the Hazard Products role in the Hazard Forecasting Team and (or) the Geographic Information System (GIS) Lead role in the Documentation and Data Management Team. The person in this role also works with the SIC, the relevant discipline specific leads in the Science Team, and (or) the 24/7 Watch Lead (in the Monitoring Team) to write, obtain reviews and approvals (where necessary) and transmit HANS information products as the situation warrants. The person in this role should have prior experience writing and transmitting HANS messages.
  - *Web Page Lead*—The person in this role manages the public-facing observatory website, ensuring the website is well-organized and updated multiple times per day with imagery, data plots, and hazard products as events warrant. This role works with other OVERT positions (including the Alarms and 24/7 Watch Leads in the Monitoring Team) to develop internal dashboards as an aide for those involved in real-time monitoring of volcanic activity.

Science Team Lead

A critical aspect of any response is collecting scientific data in support of short- and long-term hazard assessments and forecasts, as well as in support of research to improve the understanding of volcanic systems and processes. In the OVERT system, the SIC delegates responsibility for coordinating the observatory's science response to the Science Team Lead and External Science Liaison (see the "External Science Liaison" section). The Science Team Lead coordinates the observatory's scientific efforts, including assembling the Science Team itself, which is composed of discipline specialists who establish scientific priorities and ensure coordination of scientific efforts within and across disciplines. The Science Team lead generally does not participate in field work or other observatory activities, especially at the peak of the crisis, to ensure that they have the time necessary to focus on science priorities. The Science Team Lead should have substantial scientific expertise relevant to the ongoing eruptive crisis, be familiar with the broader scientific community's priorities in volcanology research, have good communication skills, and be able to facilitate frequent, multidisciplinary scientific conversations across the OVERT. The specific responsibilities of the Science Team Lead include the following duties:



Photograph of Cascades Volcano Observatory scientists Emily Bryant and Rebecca Kramer performing maintenance at a volcano monitoring station on the slopes of Mount St. Helens, Washington. U.S. Geological Survey photograph by Tami Christiansen, June 16, 2021.

- Establish and communicate the science priorities for the observatory's response, including priorities for field access, and ensuring that these scientific activities are supported and executed in a timely manner.
- Identify OVERT staff to serve as subject matter experts upon request by the Hazard Forecasting Team Lead.
- Evaluate science proposals from other USGS staff outside the responding observatory (including from the VSC) that would require field access, observatory staff support, or other observatory resources. Evaluations should focus on the importance of the proposed activity for public safety, whether data collection for the proposed activity is time-critical (as would be the case for ephemeral phenomena associated with the eruption, like ash and seismicity), and whether observatory resources exist to support the activity. Evaluations should be relayed to the SIC for a final decision.
- Coordinate with the External Science Liaison on the following duties:
    - Establish overarching science priorities.
    - Streamline communication between OVERT scientists and the broader scientific community.
    - Provide input to the Scientific Advisory Committee (if established) to facilitate evaluation of proposals from the broader scientific community (see the "Scientific Advisory Committee" section).
- Hold regular meetings with the Science Team to establish OVERT scientific priorities, evaluate progress, ensure situational awareness about scientific activities across the Science Team, and address any issues that require prompt attention (such as staffing, resource, permitting, or logistics needs).
- Establish and manage the Science Team, which consists of discipline-specific leads (Science Leads), to coordinate scientific activities within and across different disciplines. The Science Leads should have good communication skills and be experienced in their respective fields. In addition, they should have some response experience, direct work experience with the restless or erupting volcano, or both.

The following positions outline the duties of discipline-specific Science Leads.

Geology Lead—This role establishes geologic science and fieldwork priorities, including (1) coordinating ash, lava, and (or) tephra sample collection and analyses, (2) identifying and providing prioritized tasks for geologic observers for any observational flights, (3) coordinating with the UAS Lead (in the Monitoring Team) to establish geologic priorities for UAS flights, (4) coordinating with the Field Observations Archivist (in the Documentation and Data Management Team) to ensure that any imagery collected during observational flights or fieldwork is annotated and archived, (5) coordinating with the Field Instrumentation Lead (in the Monitoring Team) to install and maintain webcams and or other instrumentation, (6) coordinating with the CVERT SRC to establish field-team rotations as necessary, including identifying geologists from outside the home observatory who can assist with field work, and (7) coordinating geologic sampling protocols across the OVERT, including those for field technicians, geophysicists, and other non-geologists with regular field access. Additional duties of the Geology Lead include the following:

- Coordinate sample analysis, prioritizing those with potential to produce information that can feed into forecasts, hazard products, and other aspects of the response.
- Report any results to the Science Team, at OVERT staff meetings, or both.
- Ensure that any geologic data collected during the response are archived and made publicly available in a reasonable timeframe.
- Coordinate with the Hazard Forecasting Team Lead as necessary to address any questions about geologic hazards.
- Coordinate with the External Science Liaison to arrange for sample distribution with the broader scientific community if sufficient samples are available.
- Coordinate with the Alarms Lead (in the Monitoring Team) to implement lightning- and (or) webcam-based alarms as necessary.
- Establish a response structure for the geology team, as appropriate, to ensure that all necessary tasks are being accomplished, that there is clarity in the scope and responsibility of each role on the team, and that there is adequate staffing on the team to accomplish all tasks.

Seismology/Infrasound Lead—This role establishes seismic and infrasound science and fieldwork priorities, including campaign-style experiments and installing and (or) upgrading new instruments to improve real-time monitoring. This role manages the processing and result reporting of seismic and (or) infrasound data to the Science Team and (or) OVERT at staff meetings. This position is responsible for maintaining a response structure for the seismic and infrasound team, as appropriate, to ensure that all necessary tasks are being accomplished, that the scope and responsibility of each role on the team is clear, and that the team is staffed adequately to accomplish all tasks. Additional duties of the Seismology/Infrasound Lead include the following:

- Generate summaries of seismic and infrasound observations for OVERT staff meetings, log posts, social media, and internal reports.
- Report any results to the Science Team.
- Coordinate with the information technology (IT) Lead (in the Monitoring Team) to ensure robust real-time data processing.
- Coordinate with the Alarms Lead (in the Monitoring Team) to implement seismic and infrasound alarms.
- Coordinate with regional seismic network partners and (or) the USGS National Earthquake Information Center, as appropriate.
- Coordinate with the Field Instrumentation Lead (in the Monitoring Team) to establish field priorities for installing and maintaining seismic and infrasonic monitoring sites, including ensuring that site metadata are updated as soon as crews return from the field.
- Ensure that seismic and infrasound data (both telemetered and campaign) are archived and made publicly accessible in a reasonable timeframe.
- Coordinate with the 24/7 Watch Lead (in the Monitoring Team) and the Geodesy Lead to establish a 24/7 geophysical watch rotation as necessary.

Geodesy Lead—This role establishes geodetic science and fieldwork priorities, including campaign-style measurements and real-time monitoring instrumentation. This role manages the processing and result reporting of geodetic data to the Science Team and (or) OVERT at staff meetings. This position is responsible for maintaining a response structure for the geodesy team, as appropriate, to ensure that all necessary tasks are being accomplished, that the scope and responsibility of each role on the team is clear, and that the team is staffed adequately to accomplish all tasks. Additional duties of the Geodesy Lead include the following:

- Coordinate interferometric synthetic aperture radar (InSAR) analyses with the broader InSAR community as necessary.
- Coordinate with the Field Instrumentation Lead (in the Monitoring Team) to establish field priorities for maintaining and installing geodetic monitoring sites, including ensuring that site metadata are updated as soon as crews return from the field.
- Coordinate with the Alarms Lead (in the Monitoring Team) to implement geodetic alarms (for example, tilt) as necessary.
- Ensure that telemetered and campaign Global Navigation Satellite System (GNSS) data are archived and made publicly accessible in a reasonable timeframe.
- Coordinate with the 24/7 Watch Lead (in the Monitoring Team) and the Seismology/Infrasound Lead to establish a 24/7 geophysical watch rotation as necessary.

Gas Lead—This role establishes science and fieldwork priorities for measuring gas emission rates and gas geochemistry, including facilitating the sampling of fumaroles, springs, wells, and (or) lakes, as appropriate. This role manages the processing and reporting of gas emission-rate and chemistry data to the Science Team and (or) OVERT at staff meetings. This position is responsible for maintaining a response structure for the gas team, as appropriate, to ensure that all necessary tasks are being accomplished, that the scope and responsibility of each role on the team is clear, and that the team is staffed adequately to accomplish all tasks. Additional duties of the Gas Lead include the following:

- Coordinate with the Field Instrumentation Lead (in the Monitoring Team) to establish field priorities for the installation and maintenance of gas-monitoring equipment, including ensuring that site metadata are updated as soon as crews return from the field.
- Ensure that any gas emission-rate and chemistry data collected by field crews, monitoring instruments, or both are archived and made publicly available in a reasonable timeframe.

Photograph of Hawaiian Volcano Observatory scientist Janet Babb giving a media briefing during the 2018 eruption of Kīlauea, Hawai'i. U.S. Geological Survey photograph, May 14, 2018.

Remote Sensing Lead—This role establishes science priorities for the acquisition and processing of satellite-, fixed wing, and (or) helicopter-based remote sensing data. This role manages the processing and reporting of remote sensing data to the Science Team and (or) OVERT at staff meetings. This position is responsible for maintaining a response structure for the remote sensing team, as appropriate, to ensure that all necessary tasks are being accomplished, that the scope and responsibility of each role on the team is clear, and that the team is staffed adequately to accomplish all tasks. Additional duties of the Remote Sensing Lead include the following:

- Coordinate remote sensing activities across the OVERT.
- Coordinate with other groups in the USGS (for example, the Advanced Systems Center) and outside the USGS to ensure adequate tasking of satellite resources relevant to the response.
- Communicate with colleagues from the National Air and Space Administration (NASA), the National Weather Service, and the broader science community, in coordination with the External Science Liaison, to ensure mutual understanding of messaging and priorities.
- Ensure that any remote sensing related data collected by the remote sensing team during the response are archived and made publicly available in a reasonable timeframe.
- Coordinate with the Alarms Lead (in the Monitoring Team) to implement satellite-based ash-detection and hot spot detection alarms as necessary.
- Coordinate with the 24/7 Watch Lead (in the Monitoring Team) to establish a remote sensing watch rotation if necessary.

Photograph of Hawaiian Volcano Observatory Scientist-in-Charge Jim Kauahikaua giving a media interview near the summit of Kīlauea, Hawai'i. U.S. Geological Survey photograph, January 2011.

Hydrology Lead—This role establishes science and fieldwork priorities for installing and maintaining any hydrologic monitoring equipment (for example, lahar-detection stations, streamgages, or webcams), including ensuring that site metadata are updated as soon as crews return from the field. This role manages the processing and reporting of remote sensing data to the Science Team and (or) OVERT at staff meetings. This position is responsible for maintaining a response structure for the hydrology team, as appropriate, to ensure that all necessary tasks are being accomplished, that the scope and responsibility of each role on the team is clear, and that the team is staffed adequately to accomplish all tasks. Additional duties of the Hydrology Lead include the following:

- Coordinate with the Hazard Forecasting Team Lead as necessary to address any questions about hydrologic hazards.
- Coordinate with the Field Instrumentation Lead (in the Monitoring Team) to establish field priorities for installing and maintaining any hydrologic monitoring equipment (for example, lahar-detection stations, streamgages, or webcams), including ensuring that site metadata are updated as soon as crews return from the field.
- Coordinate with the Alarms Lead (in the Monitoring Team) to implement hydrologic alarms (for example, lahar detection) as necessary.
- Collaborate with hydrologists from other USGS science centers and (or) other agencies (for example, the National Weather Service) as necessary.

Monitoring Team Lead

Data from real-time and near real time monitoring systems support situational awareness of the status of unrest or eruption. These data also inform reliable and timely forecasts, alerts, and warnings. Monitoring systems have wtoring networks; experience in project management; some understanding of IT networking; and good communication and organization skills. Specific responsibilities of the Monitoring Team Lead include the following duties:

- Ensure adequate monitoring is in place and data telemetry from remote instrumentation is robust.
- Identifies where additional monitoring resources are required, including instrumentation and personnel to monitor, analyze, and report on statuses and trends.
- Ensure that alarm capabilities are robust, including by developing new alarm capabilities as needed.
- Implement OVERT's monitoring priorities, including real-time field-based monitoring networks, UAS activities, alarm implementation, real-time data watch rotations, and IT activities necessary to support monitoring and alarming.
- Establish and manage task-specific Monitoring Leads as necessary.

Photograph of Cascades Volcano Observatory scientists participating in a daily staff meeting during the 2004–2008 eruption of Mount St. Helens, Washington. U.S. Geological Survey photograph by Carolyn Driedger, October 1, 2004.

The following positions outline the duties of task-specific Monitoring Leads.

Field Instrumentation Lead—This role leads and establishes a response structure for the Field Instrumentation Team to ensure that all necessary tasks are accomplished, the scope and responsibility of each role on the team is clear, and the team is adequately staffed to accomplish all tasks. This role also coordinates with discipline-specific Science Leads to establish field priorities for new real-time monitoring instrumentation. This coordination may involve regular attendance in Science Team meetings but would generally not include managing campaign-style equipment, a responsibility of discipline-specific Science Leads. Additional responsibilities of the Field Instrumentation Lead include the following duties:

- Assemble daily status reports for the monitoring network.
- Oversee the maintenance of field instrumentation, as needed.
- Coordinate with the Permitting/FEMA Paperwork Coordinator (in the Logistics and Safety Team) to fulfill permitting requirements for monitoring sites.
- Coordinate with the Aviation Manager (in the Logistics and Safety Team) to establish priorities for aviation supported monitoring fieldwork requiring aviation support.
- Coordinate requests for additional instrumentation from other parts of the VSC with the CVERT Associate Center Director for Monitoring Networks.
- Manage field-engineering staff involved in installing and maintaining monitoring-network stations, including the following tasks:
- Ensure that checklists are created as necessary to guide instrumentation installations in crisis conditions.
- Coordinate with the CVERT SRC to establish staff rotations as necessary.
- Coordinate with the Safety Officer (in the Logistics and Safety Team) to ensure all staff have the proper safety equipment and training.
- Coordinate with the Seismology/Infrasound, Geodesy, Geology, and Gas Leads (in the Science Team) to ensure monitoring-station metadata are kept up to date.

Alarms Lead—This role implements real-time alarms in coordination with the IT Lead and the Geodesy, Seismology/Infrasound, and other discipline-specific Science Leads in the Science Team, as appropriate, and ensures that alarms are robust and well-integrated into observatory functions. Additional responsibilities of the Alarms Lead include the following duties:

- Develop protocols for responding to alarms (for example, when to alert the SIC or others).
- Coordinate alarm-threshold modification with discipline specialists as needed.
- Troubleshoot false and (or) missed alarms.
- Manage the list of OVERT positions that receive automated alerts.
- Coordinate with the 24/7 Watch Lead, the Web Page Lead (under the PIO), and relevant discipline-specific Science Leads (on the Science Team) to develop automated visualization tools that support situational awareness across the OVERT structure.

24/7 Watch Lead—This role establishes internal call-down lists to be used for rapidly contacting specific OVERT positions as well as protocols for initiating call downs (both would need approval from the SIC). This role ensures that all watch-team observations are recorded in an observation log or other archiving mechanism and that 24/7 watch members are properly trained. Additional responsibilities of the 24/7 Watch Lead include the following duties:

- Coordinate with the Seismology/Infrasound, Geodesy, and (or) Remote Sensing Leads (in the Science Team) to establish and schedule staffing for 24/7 watch rotations to monitor real-time data.
- Coordinate with the Alarms Lead, the Web Page Lead (under the PIO), the IT Lead, the Systems Administration Lead, and relevant discipline-specific Science Leads to develop automated visualization tools that support situational awareness across the OVERT structure.

UAS Lead—This role manages UAS operations in coordination with the Aviation Manager (in the Logistics and Safety Team), including procuring UAS, mission tasking, and developing and filing flight plans. This role ensures that all UAS team members receive proper training and all UAS operations follow USGS, Office of Aviation Services, and FAA safety guidelines and flight protocols. Additional UAS Lead responsibilities include the following duties:

- Work with the CVERT SRC to establish UAS flight-team rotations, including incorporating UAS-trained staff from other USGS science centers and (or) DOI bureaus as necessary.
- Coordinate with the Science Team Lead to establish UAS priorities. This coordination may include attending Science Team meetings.
- Coordinate UAS data collection and archival with the Data Manager (in the Documentation and Data Management Team).
- Coordinate OVERT UAS operations with other non-USGS groups that have UAS assets to ensure that science objectives are met.
- Coordinate the establishment of real-time UAS feeds to the observatory and (or) emergency operations Centers, if practicable and desirable.

Systems Administration Lead—This role provides system administration support for desktops, laptops, and other computer resources required by OVERT staff. This support primarily includes troubleshooting issues with software systems used by the OVERT, including databases for storing monitoring data, databases for storing images, observation logging systems, and collaboration platforms.

Information Technology (IT) Lead—This role provides dedicated IT networking support for real-time monitoring stations and associated telemetry systems. Additional responsibilities of the IT lead include the following duties:

- Ensure that monitoring data are available from any VSC location to allow for 24/7 monitoring outside the local observatory structure.
- Coordinate with the VSC Associate Director for IT and the USGS Office of Enterprise Information to address any internet and (or) telecommunications reliability issues and challenges.

Photograph of news media personnel gathered at the Castle Lake viewpoint near Mount St. Helens, Washington. U.S. Geological Survey photograph by Larry Mastin, October 5, 2004.

Hazard Forecasting Team Lead

In addition to providing verbal guidance and situational awareness to authorities, the SIC and observatory staff may also need to prepare formal or informal hazard assessments during the response. This need could arise quickly; to manage the observatory's hazard-forecasting activities, the SIC will likely need to choose a Hazard Forecasting Team Lead early in a crisis response. This person should have substantial experience in hazard assessments, producing various hazard-related products, or both.

Specific Hazard Forecasting Team Lead responsibilities, and the responsibilities of other Hazard Forecasting Team members, include the following duties:

- Manage individuals working in the following Hazard Forecasting Team positions.

Modeling Lead—The person in this role coordinates hazard-related modeling efforts across the OVERT, including ashfall models, lava-flow and lahar-inundation models, and physics-based models for interpreting observations from monitoring networks, geologic data, and other sources. This coordination should also involve the Science Team Lead to ensure the latest data are being incorporated into physics-based models. The person in this position should have modeling experience and good communication skills.

Hazard Products Lead—The person in this role is responsible for coordinating the production and release of hazard-related products such as maps, graphics for various audiences, and reports. The person in this role should have some graphic-design experience as well as experience presenting volcano hazard information to a variety of audiences,

Probability Tree Lead—The person in this role leads probability-tree discussions, including identifying scientists to serve on probability-tree panels. The person in this role should have good communication skills and experience participating in and (or) leading probability-tree exercises.

Health Hazards Lead—The person in this role coordinates the response to potential health hazards such as vog (volcanic air pollution) and ash ingestion. The person in this role should have expertise with various health hazards associated with volcanic activity and should also have the skills to work and communicate with a wide variety of external agencies.

- Work with the SIC, Science Team Lead, and others to identify a subject matter expert in each discipline relevant to the Hazard Forecasting Team's probability-tree discussions, hazard assessments, and hazard products. Subject matter experts may not serve in this role full time (for example, a geology subject matter expert could also be in the OVERT Science Team) because the need for subject matter expert s could, at times, be short-lived. The intent in making the subject matter expert a separate OVERT position is to indicate the importance of the Hazard Forecasting Team having access to relevant subject matter experts whenever the need arises.

- Engage with the USGS OCAP and (or) USGS Office of Science Quality and Integrity to determine expeditious and policy-compliant avenues for office publication of hazard assessments and other types of hazard-based reports and products. Ideally, this work would involve the Information Products Lead under the PIO, if that position has been filled,

- Hold regular meetings of the Hazard Forecasting Team to establish hazard-forecasting priorities, evaluate progress, and ensure situational awareness about hazard-forecasting activities across the entire team, as well as awareness of issues that require prompt attention (such as staffing needs).

- Work with the SIC, Science Team Lead, and PIO to write hazard reports, including responses to hazard-based questions from partner agencies, USGS headquarters, the DOI, FEMA, and (or) other groups.

Documentation and Data Management Team Lead

Thoroughly documenting observatory activities as events unfold is another critical function during a response. Documentation includes chronologies of the event itself, records of observatory activities (for example, staff meetings, actions taken in response to specific events, probability-tree conversations, and staffing records), searchable archives of observations (written and verbal, photos, and videos), including those from outside the observatory (for example, reports from pilots, the media, or the public), and records of any hazard-based conversations. In addition, response staff often need assistance with data management for newer types of monitoring data (for example, UAS and lidar data) since such datasets can be large and often have no preestablished archive or repository. The USGS adheres to the Findable, Accessible, Interoperable, and Reusable standards for scientific data management and stewardship (Wilkinson and others, 2016) and prioritizes disseminating government-collected data as widely as possible when policy considerations allow.

In the OVERT system, the SIC delegates responsibility for managing response-related documentation and data-management activities to the Documentation and Data Management Team Lead. The person occupying this position should have strong organizational skills, experience with crisis responses and (or) maintaining chronologies, experience managing large datasets, and awareness of USGS rules and regulations (such as Survey Manual 600.6, "Implementation and Administration of Section 508 of the Rehabilitation Act"). Specific responsibilities of the Documentation and Data Management Team Lead include the following duties:

- Ensure that response documentation (for example, field reports, chronologies, photos, or videos) is maintained in easily searchable and secure platforms, and that all USGS staff adhere to proper reporting and archival procedures.
- Ensure that datasets with no established archival path and (or) are large and difficult to manage are archived in an accessible format in a timely manner.
- Ensure that observatory and OVERT staff can access the data they need to perform their job functions.
- Hold regular Documentation and Data Team meetings to coordinate actions, facilitate communication within the team, and ensure situational awareness of any issues that require prompt attention (such as staffing or resource needs).
- Establish and manage task-specific Documentation and Data Management positions as necessary.

Photograph of Alaska Volcano Observatory Scientist-in-Charge Tom Murray monitoring activity at Augustine Volcano, Alaska, during its 2006 eruption. U.S. Geological Survey photograph by Rick Wessels, February 3, 2006.

The following positions outline the duties of task-specific Documentation and Data Management Team members.

Field Observations Archivist—This role establishes and maintains an archive of field observations, photography, and videography. People serving in this role should have good organizational skills as well as experience working in the field. Additional responsibilities of the Field Observations Archivist include the following duties:

- Ensure imagery has the proper metadata.
- Ensure that staff submit field-based observations to a predesignated location (for example, an observatory-wide logging system or a centralized internal collaboration platform).
- Coordinate with Volcanic Activity Chronology Coordinator (in the Documentation and Data Management Team) and the Geology Lead (in the Science Team).

Volcanic Activity Chronology Coordinator—This role compiles and maintains a chronology of unrest and (or) eruption. People in this role should have good organizational and writing skills (including an ability to distill lots of information into succinct formats) along with some response experience. The person in this position would likely work closely with the Field Observations Archivist and the Geology Lead (in the Science Team).

Internal Communications Manager—This role establishes and (or) manages internal communication platforms, including managing platform access, particularly by non-USGS response workers. People serving in this role should have good communication and organizational skills as well as substantial experience with the specific communication platform being used during a response.

Photograph of Steamboat Geyser in Yellowstone National Park erupting on May 23, 2022. Dead and downed trees can be seen in the foreground. Photograph courtesy of Mara Reed, University of California at Berkeley.

Geographic Information System (GIS) Lead—This role oversees all GIS related activities during a response. The person in this role should be and expert practitioner of GIS analysis with experience using widely available GIS platforms, an understanding of standard resources for metadata (for example, Station Information System [Yu and others, 2017], Earthscope, and the USGS Volcano Monitoring Instrumentation Databases), an understanding of the USGS data-release system, and good communication skills. Additional responsibilities of the GIS Lead include the following duties:

- Develop a central repository for ground-based metadata (for example, station locations or sample locations), spatial and (or) chronological data (for example, ground observations, remote sensing imagery, aerial images, or thermal maps), and hazard-related model outputs (for example, lava-flow inundation or ash-fall forecasts).
- Create visual products (for example, GIS layers or maps) to facilitate the situational awareness and scientific understanding of everything occurring at the volcano and surrounding area for OVERT staff, partner agencies involved in the response, and (or) the public.
- Maintain communication with GIS managers of partner agencies and administer GIS online groups for accessing and (or) distributing GIS data among VSC staff and partners.
- Establish a workflow for rapid approval of GIS-based products (for example, maps) for distribution to partner agencies and the public.

Data Manager—This role manages any datasets with no established archival path and streamlines the USGS approval process for any data releases. People serving in this role should have experience managing large datasets, including experience publishing datasets via the USGS ScienceBase system and other repositories. Additional responsibilities of the Data Manager include the following duties:

- Coordinate with the IT Lead (in the Monitoring Team) to establish pathways for automatic archival.
- Facilitate dataset access for OVERT staff.

Photograph of Alaska Volcano Observatory scientists Jordan Lubbers (top left), Matt Loewen (bottom left), and Hannah Dietterich (right) examining a tephra site in a drainage on the south flank of Kanaga Volcano, Alaska, during fieldwork in the central Aleutians. Photograph by Abigail Nastan, Alaska Volcano Observatory and Alaska Division of Geological and Geophysical Surveys, August 28, 2023.

External Science Liaison

The External Science Liaison coordinates communication between the observatory and the broader scientific community, including interfacing with a Science Advisory Committee (or SAC; see the "Science Advisory Committee" section) if one is formed. The person in this position should have substantial scientific expertise relevant to the ongoing eruptive crisis and be at least somewhat known to the broader scientific community. In addition, the External Science Liaison should have excellent communication skills, including patience for the many conversations they will need to have with the observatory, OVERT staff, and members of the broader scientific community. Specific responsibilities of the External Science Liaison include the following duties:

- Coordinate discussions about scientific priorities, requirements, and needs between the OVERT and the broader scientific community, ideally through a SAC (for example, Fischer and others, 2021; Cooper and others, 2023) established by the SIC and other scientists. This work could include the following tasks:
    - Coordinate observatory and other USGS involvement in evaluating proposals from external scientists.
    - Bring SAC approved proposals to the SIC for consideration.
    - Inform the broader scientific community about the status of the volcano, its monitoring networks, observatory resources, and talking points, as appropriate.
- Coordinate with the Science Team Lead and participating in Science Team meetings to keep situational awareness of OVERT scientific activities.

The External Science Liaison may receive a large number of requests for information and (or) proposals from the broader scientific community, as indicated by recent community-based tabletop exercises (for example, Fischer and others, 2021) and recent responses (for example, the 2020–2021 Kīlauea responses; Cooper and others, 2023). For that reason, the SIC should be prepared to assign a group of people to this role to spread out responsibilities. For example, one External Science Liaison could manage the internal evaluation component for proposals submitted to the SAC, while another could manage coordination with the broader scientific community (including providing periodic updates).

Photograph of California Volcano Observatory scientists load gas measurement equipment on a boat for fieldwork on Paoha Island in Mono Lake, California. U.S. Geological Survey photograph by Andy Calvert, March 2021.

Cross-OVERT Relationships and Communications

Although the OVERT describes a vertical chain-of-command system with formal reporting and tasking pathways, cross-OVERT communication is essential to its success. It is impossible to anticipate every necessary cross-OVERT interaction; however, in addition to regular, OVERT-wide staff meetings, the following are the most likely to be needed:

Monitoring and Science Teams—These two groups have the collective responsibility of determining and implementing field priorities and monitoring strategies. The Monitoring and Science Team Leads should hold regular meetings (ideally daily during the peak of a crisis), bringing in other members of the two teams as appropriate.

Modeling Lead and Discipline-Specific Science Leads—The Modeling Lead is part of the OVERT Hazard Forecasting Team, but they could have just as easily been placed in the Science Team. Their placement in the Hazard Forecasting Team reflects how modeling results often feed directly into hazard-based products and forecasts. Additionally, the Science Team Lead in a fully engaged OVERT may already have the maximum seven people reporting to them. Given the importance of modeling for interpreting scientific data, however, the Modeling Lead needs to be in close contact with discipline-specific Science Leads. This contact ensures that the Modeling Lead has the latest data to work with, that they can contribute to conversations about fieldwork and data-gathering priorities, and that the discipline-specific Science Leads are aware of the Modeling Team's latest understanding of eruption drivers and mechanisms. The Hazard Forecasting and Science Team Leads should facilitate such coordination and communication.

Hazard Forecasting and Science Team Leads—At varying times through the course of the response, the Hazard Forecasting Team will need to bring in subject matter experts, sometimes at short notice, for expertise relevant to various forecasting efforts. The Science Team is the most likely branch of the OVERT to have individuals who can serve as subject matter experts. The Hazard Forecasting Team Lead should identify subject matter expert in coordination with the CVERT SRC before requesting them through the Science Team Lead. Changing reporting and tasking relationships for subject matter experts from the Science Team to the Hazard Forecasting Team, will likely make these relationships more complicated since subject matter experts may only serve in that role for a few hours or days before returning to their Science Team roles. The Hazard Forecasting and Science Team Leads must maintain close communication to ensure that staff serving as subject matter experts aren't overtasked and that they smoothly transition between the two teams.

UAS Lead and Aviation Manager—UAS operations are placed under the UAS Lead, separate from the Aviation Manager, because (1) UAS operations don't involve the same types of risks and procedures associated with fixed-wing and helicopter-based operations and (2) UAS operations, which can be staffed entirely by trained USGS personnel (including UAS pilots), can be complex enough during a crisis to warrant a separate OVERT position to manage the program. However, UAS are flown in the same airspace as fixed-wing aircraft and helicopters, so the UAS Lead and the Aviation Manager must coordinate closely to determine daily flight schedules.

Science Team Lead and External Science Liaison—These two positions collectively encompass the entirety of an observatory's scientific response to a volcano crisis. Therefore, the Science Team Lead and External Science Liaison must communicate regularly to coordinate activities and identify collaborations between observatory staff and the broader scientific community. The Monitoring Team Lead can also be part of these conversations, particularly for proposals requiring monitoring resources (for example, staff-member time, equipment, and field access).

Training OVERT Replacements During Extended Responses

Mitigating staff burnout during an extended response requires management to intentionally and proactively identify and train replacements for individual OVERT roles. The need for qualified replacements is particularly true for the SIC and OVERT Management Team positions, which have multiple time-critical responsibilities with little room for on-the-job training. The SIC must work with the CVERT SRC to identify replacements for OVERT Management Team positions, including arranging for a minimum 1–2-day overlap period to ensure an orderly transition. The VSC Director, in turn, must identify a replacement SIC; logical candidates include current SICs from other observatories or former SICs. Once a replacement is identified, the SIC of the responding observatory should include their replacement in all communications and decisions starting several days before the role transfer. When planning staff rotations for other OVERT positions, the SIC and (or) the relevant OVERT Management Team members should work closely with the CVERT SRC.

Activating and Deactivating the OVERT

The SIC should consult with the VSC director to determine how and when to transition from the normal observatory organizational structure to the OVERT structure. At the start of a crisis, most OVERT functions may not be needed (for example, the Onboarding, Housing, and Vehicles Coordinator) or may only be needed part-time (for example, the Geology Lead if initial unrest is only seismic). Individuals will likely fill multiple OVERT roles initially; for example, a seismologist might be involved in field-monitoring activities, a full-time watch, the science response, and responding to media requests. However, as a response escalates, more OVERT positions will become necessary. As the number of positions increase, OVERT management should clarify and (or) limit the scope of responsibilities for individual staff members (including the SIC) to mitigate staff confusion, burnout, and (or) underperformance.

Once the OVERT is implemented, decisions to expand and contract the OVERT should also include input from the OVERT Management Team. The SIC, the OVERT Management Team, and the VSC Director should have regular discussions (ideally daily, especially during the peak of a crisis) about the necessary scale of the OVERT and whether staffing levels should be expanded, maintained, or contracted to meet current needs. Appendix 1 provides an example of how an OVERT might expand during the initial stages of a volcanic crisis. The next two sections describe several indicators that may signal that OVERT implementation, expansion, contraction, or deactivation is warranted.

Photograph of Hawaiian Volcano Observatory scientist Steven Fuke conducting maintenance on a volcano monitoring station on the southwest flank of Kīlauea. U.S. Geological Survey photograph by Patricia Nadeau, September 2021.

Potential Indicators for Implementing or Expanding the OVERT

The SIC should consider having qualitative indicators in mind when deciding whether to implement and (or) expand the OVERT structure. One key indicator is observing or hearing (from supervisors or observatory staff) that one or more staff members are working long hours and becoming overwhelmed. Knowing this may require the SIC to proactively reach out to staff to solicit input, since individuals are typically highly motivated to work long hours at the start of a crisis and may not realize they are overcommitted until well after they start experiencing burnout symptoms.

Additional factors that could indicate the need to implement and (or) expand the OVERT include:

- Increases in severity of volcanic unrest or alert-level status,
- Infrastructure and (or) populations exposed to volcanic hazards,
- Response fatigue and (or) insufficient staffing resources decreasing the capacity of the local observatory and its cooperators to effectively respond,
- High level of interest from the public, media, and (or) broader scientific community interest,
- Accessibility of the volcano (more accessible volcanoes will attract greater interest, both from the public and the broader scientific community),
- Establishment or expansion of emergency operations centers or other outposts by responding agencies,
- Likelihood or issuance of a Presidential disaster declaration,
- Significant requests for data and (or) hazard evaluations from the USGS, DOI, partner agencies, Tribes, and (or) local emergency and land managers, and
- High degree of interest from the broader scientific community.

Potential Indicators for Contracting and (or) Deactivating the OVERT

Given the effect of an OVERT structure on resources and staff, the SIC and the OVERT Management Team should also be proactive in recognizing the need to contract and (or) deactivate the OVERT, including developing a step-down plan while still in peak-response mode. Factors that could indicate the need to contract and (or) deactivate the OVERT include:

- An extended pause in the eruption and (or) an extended decline in unrest levels,
- A decrease in alert-level status,
- Decreased need for active response activities and information gathering in the field,
- Decreased level of public or media interest,
- Decreased number of data and (or) hazard evaluation requests from the USGS, DOI, partner agencies, Tribes, and (or) local emergency and land managers,
- Contraction or termination of other agency's ICS centers, and
- Termination of a Presidential disaster declaration.

Internal communication among all response staff about any contraction of the OVERT should take place before the contraction occurs to effectively transition between roles and responsibilities.

Photograph of California Volcano Observatory scientist Genna Chiaro taking rock samples at Crater Mountain, a Holocene lava dome at Mono Craters, California. U.S. Geological Survey photograph by Andy Calvert, May 2024.

Science Advisory Committee

As occurred during the eruptions of Mount St. Helens in 1980–1986 and 2004–2008 and the eruption of Kīlauea in 2018, the broader scientific community can have intense interest in performing scientific activities at an erupting volcano and (or) participating in an eruption response. This interest can be challenging for the responding observatory and external scientists; observatory staff may be overwhelmed by the response and have little latitude for interacting with external scientists, whereas external scientists may become frustrated with the lack of correspondence from observatory staff during the response. To maximize scientific returns and minimize such frustrations, the SIC may wish to establish a Science Advisory Committee (SAC) to help the observatory communicate with the broader scientific community during a response. There are two primary roles served by the SAC in support of the SIC and the response: (1) facilitate two-way communication between the observatory and the broader scientific community to promote awareness of ongoing scientific activities and the observatory is aware of the community's interests and capabilities and (2) evaluate proposals from the broader scientific community for gathering data or samples that require immediate physical access to the volcano and logistical and scientific support from the responding observatory.

The SAC should include scientists from a variety of volcano-relevant disciplines. Ideally, some of these scientists would have familiarity with the volcano. SAC members should declare conflicts of interest and recuse themselves from evaluating any proposals in which they are either participants or have a vested interest. Lastly, the SAC should include one or more representatives from the responding observatory (including the External Science Liaison at minimum) to provide perspective on the observatory's needs, activities, and resources.

Because the SAC serves two-way communication and proposal-evaluation roles normally performed by the SIC, the SIC should define the specific responsibilities of the Science Advisory Committee. We recommend that the SIC choose a scientist to serve as the Science Advisory Committee Chair and then work with the SAC Chair and the External Science Liaison to clearly define other members and roles of the SAC. An additional recommendation, from recent experiences with the SAC model during the 2020–2022 Kīlauea eruptions (Cooper and others, 2023), as well as CONVERSE tabletop exercises in 2020 (Fischer and others, 2021) and 2022 (Lin and others, 2023), is that the scope of the SAC should not be so expansive that it overburdens individual SAC members, observatory staff serving as External Science Liaisons, or other OVERT staff. A final recommendation, from experience during the 2020 Kīlauea eruption, is that SICs should consider forming standing SACs before unrest begins in order to facilitate a rapid transition to volcano-specific SACs once unrest begins.

OVERT Interactions with External Agencies Using the Incident Command System

Although the OVERT and ICS structures are similar in several important respects, the OVERT is not an ICS. Substantial aspects of the OVERT, such as the Science, Monitoring, and Hazard Forecasting Teams, do not correspond directly with ICS structures used in emergency operations centers or other outposts. However, several OVERT positions will likely substantially interact with ICS structures used by other agencies during a response. VSC experiences during the 2004–2008 Mount St. Helens, 2018 Kīlauea, and 2022 Mauna Loa eruptions provide some guidance as to the nature of OVERT and ICS interactions during a significant response. This section describes potential pathways for interactions between OVERT and external groups that use the ICS organizational structure. ICS positions that will likely interact with one or more OVERT positions include the following (fig. 4):

Incident Commander—The Incident Commander is responsible for setting priorities, determining objectives and strategies for meeting those objectives, approving incident action plans, authorizing information releases, and coordinating activities across all parts of the ICS. The SIC is the most likely OVERT position to interact with the Incident Commander, but at times, the Incident Commander may request meetings with other OVERT staff, including the Hazard Forecasting Team Lead, Subject Matter Experts, the PIO, or Emergency Operations Center Embeds.

Public Information Officer—The ICS PIO has many of the same responsibilities as the OVERT PIO. During a response, the OVERT PIO works closely with ICS PIOs, as well as PIOs from other involved agencies, particularly if a Joint Information Center and (or) other interagency efforts to coordinate media engagement are established.

Situation Unit (Planning Section)—The Situation Unit, organizationally housed in the Planning Section under the ICS PIO, is responsible for collecting, maintaining, and displaying incident status information for the Incident Commander and their staff. OVERT staff serving as Emergency Operations Center Embeds will likely interact closely with the Situation Unit, as was the case during the 2018 Kīlauea eruption. Such engagement will help Planning Section staff evaluate information about the volcano, particularly since most people serving in ICS positions will have little to no experience with volcanoes or volcano crises.

Air Operations Branch (Operations Section)—The Air Operations Branch is part of the Operations Section, which is responsible for implementing and managing all tactical operations of the incident action plans established by the Planning Section and (or) Incident Commander. The Air Operations Branch can be responsible for managing aviation operations, the airspace over the incident, or both. In such instances, the OVERT Aviation Manager (in the Logistics and Safety Team), the UAS Lead (in the Monitoring Team), and (or) the Logistics and Safety Team Lead will likely interact with the Air Operations Branch for approval of OVERT flight plans for both crewed and uncrewed missions. These OVERT staff may also work with the Air Operations Branch to access aviation resources if the OVERT Aviation Officer is unable to procure such resources on their own.

Safety Officer—The ICS Safety Officer is responsible for identifying and mitigating hazardous situations and has the authority to halt any actions they deem to be unsafe. Since some OVERT staff will necessarily be working in hazardous areas during a response, the OVERT Safety Officer (and potentially other OVERT staff) will likely interact with the ICS Safety Officer regarding various safety-related issues.

Facilities Unit (Logistics Section)—The Facilities Unit is part of the Logistics Section. The leader of this unit is responsible for establishing, operating, and demobilizing temporary facilities used in support of a response. If OVERT staff need remote facilities for operational work during a volcano crisis, the OVERT Facilities Coordinator would likely interact with this ICS position.

Liaison Officer—The ICS Liaison Officer is the interface between the ICS and any local, State, Tribal, and Federal agencies, and (or) other groups that are assisting or cooperating in a response. Depending on the nature of a volcanic crisis, the SIC or the SIC's designate might interface with the Liaison Officer rather than the Incident Commander. The OVERT External Science Liaison serves a similar role as the Liaison Officer, albeit for the scientific community rather than for cooperating agencies.

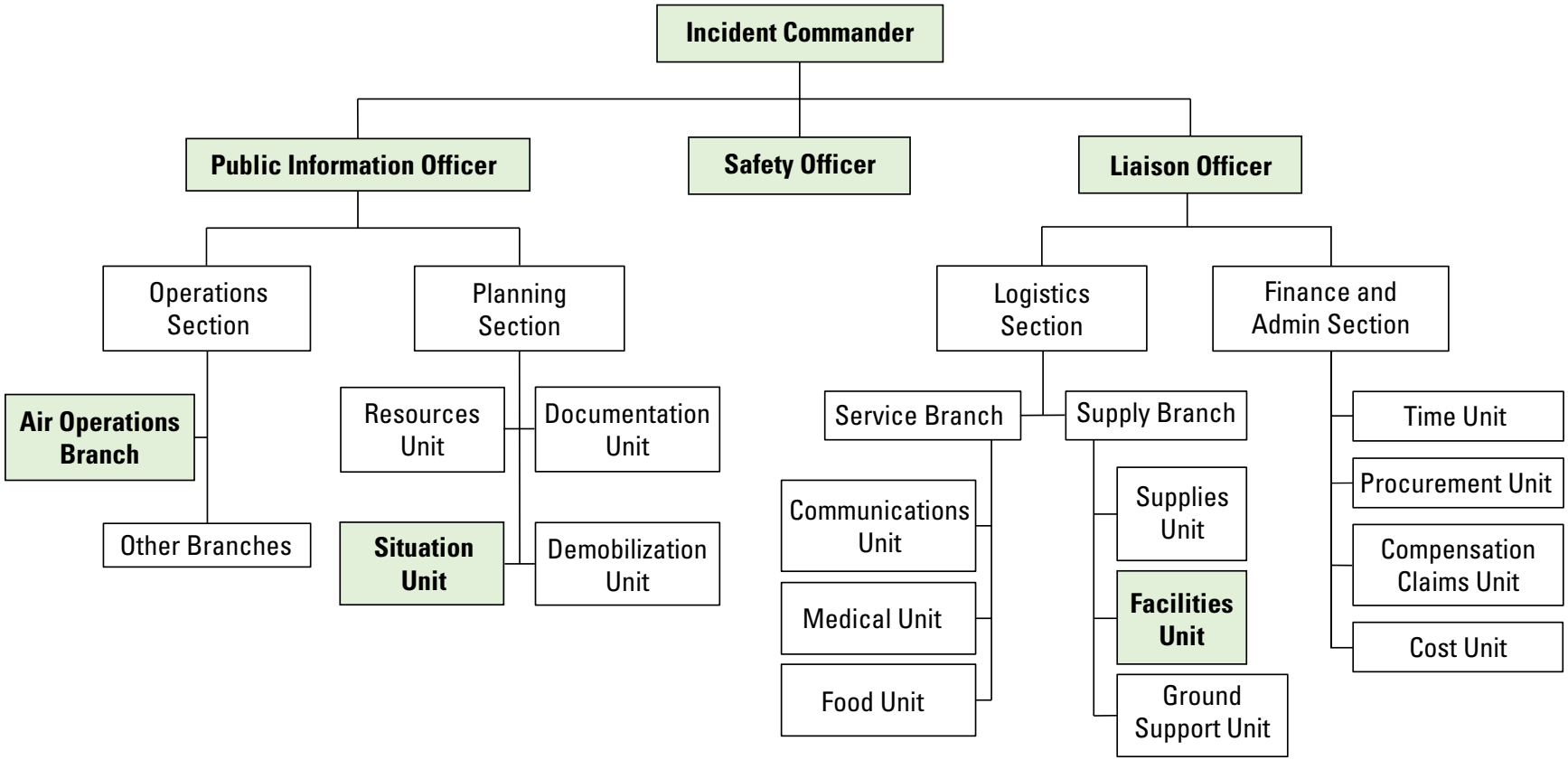


Figure 4. Diagram of the Incident Command System (ICS) organizational structure (Federal Emergency Management Agency, 2018). Green boxes indicate ICS positions with which the Volcano Science Center is most likely to interact during a significant response.

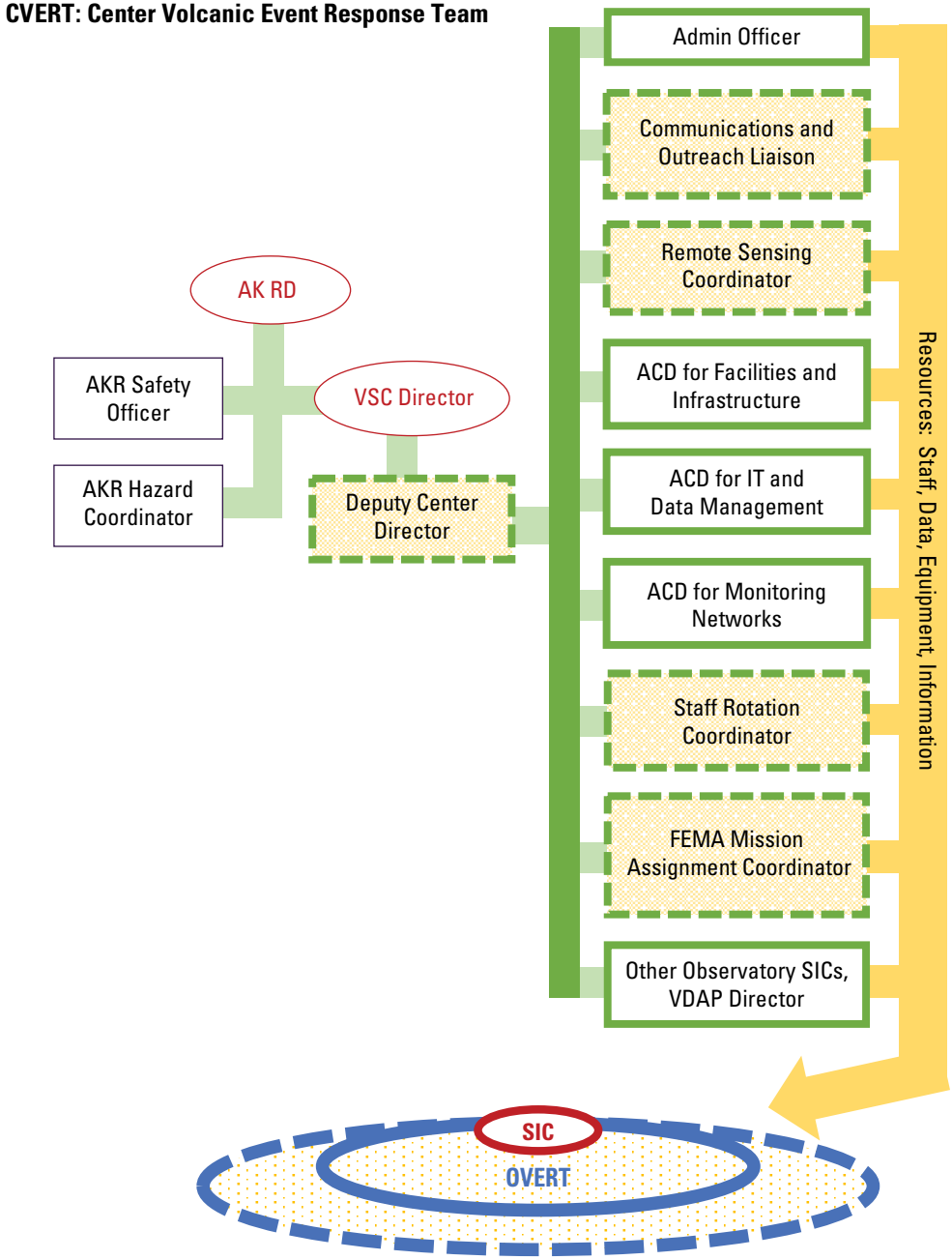
The Center Volcanic Event Response Team

A second VSC management structure for supporting a significant response is the Center Volcanic Event Response Team (CVERT; fig. 5). The primary role of the CVERT is to assist the VSC Director in managing VSC activities during a crisis response. As with the SIC and the formation of the OVERT, the VSC Director should proactively delegate progressively more of their responsibilities to CVERT positions as a response intensifies to continue effectively fulfilling their responsibilities. Once established, the CVERT serves several roles, including:

- Support the responding observatory by providing resources (including funding and staffing) and coordinating activities across the VSC.
- Coordinate activities with the USGS Volcano Hazards Program Coordinator.
- Ensure that regional and USGS leadership, including the USGS Office of Emergency Management, remain informed.
- Coordinate response activities with other USGS regions, mission areas, and science centers as they become involved in the response.
- Coordinate efforts and information sharing with other agencies at the regional and national level, both those internal and external to the DOI (for example, FEMA, the National Weather Service, or NASA).
- Respond to data requests from USGS headquarters, the DOI, and other Federal agencies.
- Facilitate high-level inter and intradepartmental communications in coordination with the responding SIC.
- Ensure sufficient situational awareness across the VSC, USGS, and other government entities.

A key difference between the OVERT and CVERT structures is that the CVERT always works in support of the responding observatory, whereas the response itself is managed at the OVERT level by the SIC. As a response escalates, the VSC Director may require the assistance of the USGS Alaska Region (in which the VSC administratively resides) to coordinate requests for resources and assist in responding to information requests to or from other groups within the USGS, the DOI, and other Federal agencies.

Photograph of Old Faithful geyser in Yellowstone National Park begins an eruption as visitors watch in the distance. U.S. Geological Survey photograph, September 2023.



CVERT Structure and Responsibilities

The CVERT is established and led by the VSC Director, who in turn is supervised by the USGS Alaska Regional Director. Once established, the CVERT, like the OVERT, should meet regularly with the VSC Director to lead meetings, establish agendas, and maintain records. Unlike the OVERT, most CVERT positions align with their respective existing positions and CVERT members retain their normal reporting structure. In contrast, the responding observatory's SIC has authority over OVERT staff while they are involved in the response, even if they come from another observatory. Given that half of the CVERT positions are aligned with the VSC's regular management structure (solid-outlined, colored boxes in figure 5), the main distinction between CVERT meetings and regular VSC management meetings is that CVERT meetings focus exclusively on response issues. In addition to existing VSC management positions, the CVERT can include other positions filled as necessary by the VSC Director (dash-outlined, colored boxes in figure 5).

As with the OVERT, clearly defining the roles and responsibilities of individual CVERT positions is critical for a successful response. Initially, the CVERT may consist entirely of existing VSC management positions, with the VSC Director delegating various tasks as collateral duties for people serving in these positions. The following nine sections describe the general responsibilities of existing CVERT positions (VSC Director, VSC Administrative Officer, VSC Associate Directors, and other SICs) and CVERT positions filled during a significant volcanic event (Deputy Center Director, Staff Rotation Coordinator, Remote Sensing Coordinator, FEMA Mission Assignment Coordinator, and Communications and Outreach Liaison; fig. 5).

Figure 5. Diagram of a generic U.S. Geological Survey (USGS) Center Volcanic Event Response Team (CVERT) structure. Solid-outlined boxes indicate existing positions; dash-outlined boxes indicate potential temporary, response-related positions; shaded boxes indicate positions within the USGS Volcano Science Center (VSC); circles indicate the primary positions responsible for the observatory, center, and region levels of the response. The CVERT assists the Observatory Volcanic Event Response Team (OVERT) and the Scientist-in-Charge (SIC), shown at the bottom of the diagram, in resource acquisition and interaction with other USGS groups, other DOI bureaus, and other government agencies. IT, information technology; FEMA, Federal Emergency Management Agency.

Volcano Science Center Director

The VSC Director manages personnel, operations, and budgets across the entire VSC. During a volcanic crisis, the VSC Director has three primary responsibilities: (1) coordinating and communicating regularly with the responding SIC to ensure they have the resources and support needed for a successful response, (2) coordinating response activities across the VSC, and (3) coordinating and communicating with higher levels within the USGS (including the USGS Alaska Region, USGS Volcano Hazards Program, and USGS Natural Hazards Mission Area) as well as other Federal agencies and working groups. Additional responsibilities of the VSC Director include the following duties:

Photograph of view looking south across the Newberry Volcano caldera, Oregon, towards the Big Obsidian lava flow (left of center) and Paulina Peak (right of center), with Paulina Lake in the foreground. U.S. Geological Survey photograph by Seth Moran, July 12, 2011.

- Communicate regularly with the responding SIC.
- Communicate regularly with the USGS Alaska Regional Director and the USGS Office of Emergency Management Coordinator.
- Coordinate the distribution of VSC resources in support of the responding observatory's efforts.
- Track response-related expenditures across the VSC.
- Work with the VSC Administrative Officer and administrative staff to ensure administrative policies are communicated, implemented, and (or) developed.
- Manage and document staff rotations from other parts of the VSC and groups outside the VSC in support of the response.
- Coordinate actions, messaging, and resource requests with the USGS Volcano Hazards Program Coordinator.
- Manage FEMA mission assignments and communicating with FEMA at the regional level in the event of a Presidential disaster declaration.
- Report to the USGS Emergency Management Coordinator and (or) to the DOI Watch Office, including daily Situational Reports.
- Provide briefings to other USGS offices and other Federal agencies.
- Ensure coordination of OVERT and (or) CVERT requests for resources from other groups within the USGS, as well as from other Federal agencies.
- Support or facilitate interagency efforts to collect remote sensing data for the OVERT.
- Keep records for meetings where policy- and (or) hazard-based decisions are discussed and made.
- Coordinate activities of the VSC Deputy Director and the VSC Associate Directors in support of the response.
- Establish CVERT positions (for example, the SRC) to coordinate VSC assistance to the OVERT.
- Facilitate regular CVERT meetings.
- Manage parts of the VSC not engaged in the response.

Volcano Science Center Administrative Officer

Employee safety, employee well-being, and the financial well-being of the VSC all require standard USGS and DOI business practices to be followed during a crisis. The VSC's Administrative Officer and VSC administrative staff play a pivotal role in helping VSC staff perform their duties while also ensuring that USGS and DOI policies are being followed. VSC's Administrative Officer responsibilities include the following duties:

- Track spending and personnel traveling in support of the response, as well as tracking employees working in the field as required by the UGSS Emergency Management Coordinator.
- Ensure that employees and supervisors follow VSC, USGS, and DOI rules and conventions regarding claiming and reporting extra hours, overtime, and hazard-duty pay.
- Facilitate rapid procurements of resources and property as necessary.
- Keep track of OVERT staff training and reporting training status to the SIC, CVERT SRC, OVERT Safety Officer, and (or) the USGS Emergency Management Coordinator upon request.
- Assist with travel arrangements for OVERT staff, including working with the OVERT Staff Housing Coordinator to coordinate housing arrangements for non-observatory OVERT staff.
- In the event of a Presidential disaster declaration, coordinate with the USGS Emergency Management Coordinator to ensure that FEMA mission assignments, overall expenditures, and other factors are appropriately instituted and tracked. If this task becomes too time consuming, the VSC Director may delegate this responsibility to a FEMA Mission Assignment Coordinator (see "Federal Emergency Management Agency (FEMA) Mission Assignment Coordinator" section).
- Coordinate with the USGS Office of Administration, which provides advice and oversight regarding administrative procedures and policies, including those on procurement; staff; time and attendance; facilities; and safety.

Volcano Science Center Associate Directors

As of 2023, the VSC management group includes three Associate Director positions. VSC Associate Directors oversee the VSC's monitoring networks, IT infrastructure and staff, and telecommunications and facilities functions. During a response, VSC Associate Directors may take on additional responsibilities on behalf of the VSC Director, including assisting with liaison duties to the USGS Offices of Enterprise Information, Management Services, Emergency Management, and Administration. VSC Associate Directors can also help ensure that the other USGS volcano observatories maintain functionality throughout a crisis. If necessary, a VSC Associate Director can also serve as Deputy Center Director or Acting VSC Director.

Other Scientists-In-Charge

SICs from other observatories can become involved in a response as needed to assist the responding SIC and VSC Director. SICs should be mindful of the potential for a crisis to provide professional-development opportunities for members of their staff and should, in coordination with the SRC, proactively approach individual staff members to gauge their interest in serving in one or more OVERT roles. Response tasks that other SICs can assist responding staff with include the following:

- Help the responding SIC fill OVERT roles until a SRC is assigned.
- Serve as or assisting the SRC.
- Connect staff in their observatory who are interested in serving in the OVERT with the responding SIC, the SRC, or both.
- Assist the OVERT PIO with media responses.
- Work with the OVERT Housing and Onboarding Coordinator to ensure OVERT staff from the SIC's observatory are trained, fully understand their roles and responsibilities, have adequate housing, and have the necessary safety equipment prior to starting their OVERT roles.
- Serve as Acting SIC for the responding observatory if the responding SIC needs time off.
- Serve as Deputy Center Director and (or) Acting VSC Director.

Deputy Center Director

If a crisis escalates to the point that the VSC Director requires assistance with assigned duties, some of their responsibilities can be delegated to the VSC Deputy Center Director. This position requires an overall awareness of VSC priorities, staffing, and business practices. Although the scope of responsibilities given to the Deputy Center Director depends on the situation and the person's skillsets, these responsibilities could include the following:

- Assemble and distribute daily Situational Reports.
- Lead CVERT meetings.
- Assist the responding SIC and (or) SRC with identifying staff to fill OVERT positions.
- Keep records of CVERT meetings, particularly those that involve discussions about hazard assessments and derivative products.
- Respond to data calls.
- Coordinate actions with various groups (for example, coordinating UAS activities among other USGS offices and DOI agencies).
- Represent the VSC Director in meetings and communications not related to the response.
- Maintain VSC business activities unrelated to the response.

Staff Rotation Coordinator

The initial OVERT staffing process should be managed at the observatory level by the SIC. However, as soon as outside staff are needed to support the responding observatory, the VSC Director should establish a Staff Rotation Coordinator (SRC) to manage staff rotations. Once established, any needs of the responding observatory for outside help should be coordinated through the SRC. The SRC's principal responsibilities are to (1) identify individual VSC members to fill specific OVERT roles as requested by the SIC, VSC Director, or an OVERT Management Team member, (2) maintain staff-rotation spreadsheets, including those for any shift-based rotations (for example, swing- or graveyard-shift field teams), (3) ensure that the SIC, the OVERT Management Team, the Onboarding, Housing, and Vehicles Coordinator, and the Safety Coordinator are aware of any new outside staff arriving to fill an OVERT role, and (4) ensure that OVERT staff have supervisory approval to serve in their roles. The SRC reports to the VSC Director but mostly works with the responding SIC and OVERT Management Team to identify and fill staffing needs. The SRC should work closely with the OVERT Onboarding, Housing, and Vehicles Coordinator to ensure that outside staff are fully trained and prepared for their OVERT roles before they arrive. The SRC can request specific staff from other observatories; however, the SRC must ensure that all outside staff receive approval from their supervisors and from the SIC to participate in the OVERT before travel arrangements are made. The SRC should also be mindful of inclusivity and equity to ensure fair access to opportunities across the VSC. The SRC keeps a master schedule of outside staff who have served OVERT roles and works with the SIC to identify staff to fill anticipated OVERT needs at least one week into the future. Additionally, the SRC is responsible for ensuring that incoming staff:

- Have the appropriate experience and training to perform the job to which they are assigned,
- Fully understand the roles and responsibilities of the job to which they are assigned,
- Are put in contact with the OVERT Safety Officer and Onboarding, Housing, and Vehicles Coordinator to receive safety and onboarding briefings,
- Have the necessary personal protective equipment to perform the job to which they are assigned (in consultation with the OVERT Safety Officer and Aviation Manager),
- Have schedules designed using best practices for swing or graveyard shifts (for example, see the publication "Plain Language about Shiftwork" by the National Institute for Occupational Safety and Health [Rosa and Colligan, 1997]), and
- Have access to housing with robust internet and, for those working swing and graveyard shifts, is quiet during daytime hours.

Remote Sensing Coordinator

As a volcanic crisis escalates, it may become important to access satellite resources from organizations like NASA, the USGS Earth Resources Observation and Science Center, or commercial sources not normally used in routine observatory operations. Although the OVERT chart contains a Remote Sensing Lead position, the VSC Director may determine that the level of interagency coordination required to access satellite assets warrants the establishment of a Remote Sensing Coordinator in the CVERT as well. Experience working with satellite data is a basic requirement for this position; therefore, the VSC Director will likely need to bring in VSC staff from outside the VSC management group to fill this position. Additional responsibilities of the Remote Sensing Coordinator include the following:

- Coordinate with the OVERT Remote Sensing Lead to ensure necessary data products are made available to OVERT staff.
- Serve as a liaison to the USGS Geographical Information Response Team, which is responsible for the coordination, communication, archiving, and accessibility of the geospatial data pertinent to an event response. Liaison work includes supporting the USGS Event Support Map and the Hazards Data Distribution System.
- Coordinate requests for geospatial information between the Geographical Information Resources Team and the OVERT.
- Coordinate with the USGS Advanced Systems Center, the USGS Earth Resources Observation and Science Center, NASA, other Federal agencies, and (or) commercial agencies for access to specific satellite resources.
- Manage the International Charter (an international protocol to make satellite data readily and freely available for use during a crisis or disaster).

Photograph of California Volcano Observatory geologist Wes Hildreth investigates a volcanic scoria deposit at Ubehebe Crater, California. U.S. Geological Survey photograph by Judy Fierstein, November 14, 2013.

Photograph of a Hawaiian Volcano Observatory geophysicist deploying a campaign GPS site on the Kīlauea caldera floor to measure changes in ground motion. The gas plume from the summit crater eruption is visible in the background. U.S. Geological Survey photograph by Andria Ellis on December 21, 2020.

Federal Emergency Management Agency Mission Assignment Coordinator

If a crisis escalates to the point that a Presidential disaster declaration is signed (as happened during the 2018 Kīlauea eruption), there may be funds available from FEMA to cover some of the VSC's response costs. In addition, FEMA may request that one or more VSC staff serve in specific mission assignments (which also happened during the 2018 Kīlauea eruption). Both circumstances may require the VSC to dedicate substantial time and effort to managing paperwork associated with requests for funding and reimbursements, tracking mission assignments, and fulfilling information requests from audits and data calls. The VSC Director can delegate these and related tasks to the FEMA Mission Assignment Coordinator. This position is not responsible for interacting with local FEMA officials onsite (that responsibility falls to the SIC, the USGS Emergency Management Coordinator or their designees, or both) nor FEMA officials at regional or headquarters levels (that responsibility falls to the VSC Director or their designees, in conjunction with the USGS Emergency Management Coordinator). Additional responsibilities of the FEMA Mission Assignment Coordinator include the following:

- Coordinate with FEMA and the USGS Emergency Management Coordinator.
- Complete paperwork required for FEMA mission assignments.
- Work with the VSC Director to identify OVERT positions or functions (for example, helicopter use, UAS use, or Emergency Operations Center Embeds) that may be eligible for cost recovery from FEMA.
- Work with USGS and DOI emergency-response personnel to facilitate observatory operations within the ICS system.
- Help other VSC management staff address continuity-of-operations issues and troubleshoot unanticipated challenges and policy questions.

Communications and Outreach Liaison

Although communications and outreach are primarily the domain of the responding observatory, the SIC, and (or) the OVERT PIO, the VSC Director is responsible for ensuring that communications and outreach throughout the center, USGS, and DOI are seamlessly integrated with the observatory's messaging and media strategy. The VSC Director may delegate these responsibilities to a Communications and Outreach Liaison. This Liaison works primarily with the USGS OCAP and equivalent DOI offices and is responsible for ensuring effective two-way communication between the OVERT (through the PIO, SIC, or both) and OCAP and other DOI agencies as needed. The position requires communications and outreach expertise and (or) experience working with OCAP, so the VSC Director will likely need to bring in VSC staff from outside the VSC management group to fill this position. Additional responsibilities of the Communications and Outreach Liaison include the following duties:

- Assist the OVERT PIO as necessary with media interviews, social media, and interactions with partner agencies.
- Coordinate with OCAP on any national-level messaging and external products.
- Coordinate participation with OCAP during formal ICS communication calls.
- Coordinate OCAP's interactions with the OVERT PIO staff.

Administrative Positions and their Coordination with CVERT

The CVERT also serves as a communication and coordination liaison between the VSC and higher levels in the USGS, particularly the USGS Alaska Region in which the VSC administratively resides. Although the plan herein does not prescribe how regional and USGS leadership staff act within the CVERT, the following five sections describe how specific positions might interact with the CVERT, as determined by experiences with the 2018 Kīlauea eruption. This information is intended to ensure awareness of these roles should a future crisis reach the same level of engagement.

Alaska Regional Director

The USGS Alaska Regional Director is the direct supervisor of the VSC Director and provides executive oversight of the response and communicates the resource needs of the VSC to the wider USGS. The Alaska Regional Director is also a member of the USGS Executive Leadership Team and, as such, is well-positioned to coordinate response-related activities involving other USGS regions or mission areas. Responsibilities of the Alaska Regional Director during a response may include the following duties:

- Coordinate the delivery of USGS resources to the OVERT and VSC in support of the response.
- Communicate information about the status of the response and any needed resources to the USGS Hazard Response Executive Committee, including members of the USGS Executive Leadership Team and the USGS Director's Office, and serve as a liaison to the USGS Hazard Response Executive Committee as needed.
- Lead CVERT meetings in place of the VSC Director as necessary.
- Consult with other USGS Regional Directors and USGS Mission Area Associate Directors to bring in experience and resources from other parts of the USGS as needed or as requested by the SIC, the VSC Director, or both in support of the response.
- Provide overall oversight of the response, including working as a gatekeeper to minimize external pressures on VSC and (or) OVERT staff.
- Assist the VSC Director in seeking additional funding.

Alaska Regional Safety Manager

During a response, the USGS Alaska Regional Safety Manager advises the VSC Director, VSC Administrative Officer, SIC, and OVERT Safety Officer regarding safety issues and employee accountability. This role can also be filled by a Safety Officer from another USGS region, especially if the responding observatory physically resides in that region, as was the case during the 2018 Kīlauea eruption. Additional responsibilities of the Alaska Regional Safety Manager during a response may include the following duties:

- Provide guidance and oversight to support the health and safety of employees involved in the response.
- Coordinate with safety officers from other USGS science centers or regions that have staff involved in the response.
- Coordinate with the Office of Aviation Safety and Survey aviation managers on behalf of the VSC.
- Interface with land management agencies and (or) the ICS to ensure situation-specific safety protocols and job-hazard analyses are in place, if required for OVERT staff to access the field area.
- Provide backup and support to the OVERT Safety Officer.

Alaska Regional Hazard Coordinator

During a response, the USGS Alaska Regional Hazard Coordinator assists the USGS Alaska Regional Director in maintaining a broad awareness of the response, interagency coordination issues, hazard implications, and variety of potential scenarios. In addition, this position is responsible for incorporating perspectives from other USGS hazard programs and lessons learned from after-action analyses of past responses to hazardous events within the Alaska Region and across the USGS. This position may act as the interface between the CVERT and the USGS Hazards Response Executive Committee. Lastly, this position may assist the VSC Director and Alaska Regional Director with developing strategies to support the OVERT and ensure the availability of regional, USGS-wide, other agency, and (or) allied academic scientific assets as needed.

Natural Hazards Mission Area Associate Director

The USGS Natural Hazards Mission Area Associate Director works at USGS headquarters in Reston, Virginia, and is a member of the USGS Executive Leadership Team. The USGS Natural Hazards Mission Area Associate Director provides executive-level oversight and coordination at USGS headquarters as a cochair of the USGS Hazard Response Executive Committee. The USGS Natural Hazards Mission Area Associate Director works in tandem with the USGS Alaska Regional Director to keep the USGS Hazard Response Executive Committee and the USGS Office of the Director informed, as well as brief the DOI Office of Communications, the National Security Council, the Office of Science, Technology, and Policy, and other executive-level Federal agencies and working groups. Additional responsibilities of the USGS Natural Hazards Mission Area Associate Director in support of the response may include the following duties:

- Provide executive oversight (along with the USGS Alaska Regional Director) in discussions with the USGS Office of Budget, Planning, and Integration to frame potential requests for additional funding in support of large responses.
- Support the Alaska Regional Director through formal and informal consultations.
- Work as a subject-matter expert with the USGS Volcano Hazards Program Coordinator and office staff to brief the USGS Director, other high-level USGS offices, the Secretary of the Interior, and the Assistant Secretary for Water and Science, as needed.

Volcano Hazards Program Coordinator

The USGS Volcano Hazards Program Coordinator is responsible for setting high-level priorities and allocating funding for USGS activities (including the VSC) in support of annual congressional volcano-hazards appropriations. During a response, the USGS Volcano Hazards Program Coordinator may need to (1) adjust budget allocations to support OVERT and CVERT activities, (2) work with the USGS Alaska Regional Director and Natural Hazards Mission Area Associate Director to address funding gaps, and (or; 3) help coordinate requests to the USGS Hazard Response Executive Committee or the USGS Budget Officer for extraordinary expenses, formal requests submitted as part of Disaster Supplemental legislation, or both.

Additional actions of the USGS Volcano Hazards Program Coordinator in support of the response may include the following duties:

- Work with the VSC Director, Alaska Regional Director, or both to provide high-level programmatic connectivity and coordination between (1) the OVERT and CVERT response structures, (2) Federal agencies such as the National Science Foundation, NASA, and the National Weather Service, and (3) other Federal agencies with resources and (or) responsibilities relevant to volcano crisis responses.
- Incorporate input from the VSC Director and Alaska Regional Director into funding requests made through the USGS Budget Office, congressional liaisons, or both.
- Assist the USGS Natural Hazards Mission Area Associate Director in their support of the response, including serving as a subject-matter expert at USGS headquarters and representing the VSC to the USGS Hazard Response Executive Committee, the media, and other information requesters.
- Provide guidance and coordination to international partners with whom the USGS Volcano Hazards Program has formal or informal agreements and who may have capabilities useful in a significant response.
- Provide input to the VSC Director regarding opportunities during the response for fulfilling objectives of the USGS Volcano Hazards Program strategic plan.

Photograph of view looking to the northeast of the 2016 eruption of Pavlof Volcano, Alaska, taken at an elevation of 20,000 feet by U.S. Coast Guard Lieutenant Commander Nahshon Almandmoss. Photograph courtesy of Nahshon Almandmoss, March 28, 2016.

CVERT Activation and Stand-Down

The VSC Director uses input from the responding SIC, the USGS Alaska Regional Director, and VSC management to determine when the CVERT is activated. Factors driving the decision to activate the CVERT include:

- Significant and sustained levels of volcanic unrest,
- A high probability of a significant eruption,
- Significant and (or) rapidly increasing public interest,
- An increase in formal alert levels that is anticipated to prompt a significant interagency response,
- A high potential for significant effects to communities, infrastructure, or both,
- Issuance (or likelihood of issuance) of a Presidential disaster declaration,
- Requests for additional staff from the SIC of the responding observatory,
- Activation of the International Charter for satellite resources in support of the response,
- Increased need for coordinating interagency actions, both within the USGS and in the DOI, in support of the response,
- Accessibility of the potential affected area (more accessible areas likely require a larger response structure), and
- Significant data and reporting requests from USGS headquarters, the DOI, FEMA, and (or) other Federal agencies.

The VSC Director also determines when to scale back or deactivate the CVERT. Factors driving this decision include:

- An extended plateau, diminishment, or pause in eruptive activity at the surface,
- A significant and extended decline in various unrest indicators (for example, seismicity, deformation, or degassing),
- A decrease in formal alert levels,
- Diminishing levels of resource requirements (especially staffing) by the responding observatory,
- Waning public interest, and
- Declining data and reporting needs from USGS headquarters, the DOI, FEMA, and other Federal agencies.

Photograph of view of Mammoth Mountain lava dome complex overlooking Horseshoe Lake, California. U.S. Geological Survey photograph by Jennifer Lewicki, August 4, 2019.

Closing Thoughts

No plan can cover all possible contingencies, and we fully expect that those managing the response to the next significant volcanic event in the United States will need to modify one or more aspects of the Observatory Volcanic Event Response Team (OVERT) and Center Volcanic Event Response Team (CVERT) response structures described herein to meet the needs of that response. In addition, we fully expect that each USGS volcano observatory will modify the OVERT structure to fit their specific operating conditions and staffing structures as they develop and (or) revise observatory-specific response plans. However, we note that the OVERT and CVERT response structures reflect many lessons learned from past responses at U.S. volcanoes. As such, these response structures should serve as a starting point for observatory Scientists-in-Charge and USGS Volcano Science Center (VSC) Directors as they plan for future responses to significant volcanic events. Of greatest importance, however, is that each observatory has their own internal response plans in place, plans that are periodically tested through tabletop exercises and regularly discussed with observatory staff and cooperators to ensure broad familiarity and acceptance of how the observatory will operate the next time it has to respond to a significant volcanic event.

Acknowledgments

We would like to thank Aimee Devaris, Keith Knudsen, and Anna Stull for their very helpful comments and discussions that sharpened our thinking and presentation. In addition, we are grateful to Michelle Coombs and Mike Poland for providing us with similarly thoughtful comments. We are also grateful to Joe Bard for providing the graphic used in figure 1. Many people provided feedback to us as this plan took shape starting in 2018. In particular, we would like to acknowledge Joe Bard, Andy Calvert, Michelle Coombs, Hannah Dietterich, Julie Donnelly-Nolan, Andi Ellis, Ken Hon, Peter Kelly, Matt Loewen, Jake Lowenstern, Kendra Lynn, Jon Major, Maggie Mangan, Emily Montgomery-Brown, David Phillips, Mike Poland, Tom Sisson, Wes Thelen, Alexa Van Eaton, Jacky Verna, Kristi Wallace, Heather Wright, and others for thought-provoking conversations and (or) written communications about various aspects of the Observatory Volcanic Event Response Team (OVERT). We are grateful for the patience and constructive feedback from those who participated in the 2022 Mauna Loa response (including the 50 people who submitted anonymous responses to an after-action survey), which was the first large-scale eruption response led by the U.S. Geological Survey to use a version of the OVERT system described in this plan. Lastly, we want to thank the more than 100 VSC staff who participated in a two-day virtual tabletop exercise in April 2023 that was designed, in part, to test the OVERT system—the dedication and comradery they showed during the exercise, along with the detailed notes taken by many groups (including nascent response plans) not only helped improve this plan in ways both small and large but also demonstrated that the United States is in good hands whenever the next significant event happens at a U.S. volcano.

Photograph of U.S. Geological Survey Unoccupied Aircraft System (UAS) pilots performing a routine inspection of a UAS system prior to a flight at the summit of Kīlauea, Hawai'i, during its 2018 eruption. U.S. Geological Survey photograph by Patricia Nadeau, June 2018.

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Photograph of steam vents along the Yellowstone River near the Mud Volcano thermal area, Yellowstone National Park. U.S. Geological Survey photograph by Pat Shanks, June 1, 2015.

Appendix 1. An Example of OVERT Implementation

To illustrate how the Observatory Volcanic Event Response Team (OVERT) system could be implemented during a volcano crisis response, this appendix describes a five-stage unrest-to-eruption scenario accompanied by OVERT diagrams for each stage. Although the scenario is for a generic "Volcano X," it presumes that Volcano X is accessible with nearby infrastructure vulnerable to eruption-related hazards. Because of the accessibility and infrastructure exposure, the eruption of Volcano X will lead to a (1) high level of public and media interest early in the unrest sequence, (2) a high level of interest from the broader scientific community in performing scientific investigations over the course of the eruption, and (3) the formation of one or more emergency operations centers s by land management agencies, Tribes, local communities, and (or) State emergency-management officials.

Stage One—Seismic Unrest Begins

Scenario—A seismic swarm begins at Volcano X, which has a network of seven collocated seismic and GNSS real-time monitoring stations, two of which also have infrasound sensors and one of which has a webcam with a decent view of the summit. After two days, over 50 volcano-tectonic earthquakes are located beneath the summit at depths of 2–3 kilometers (km; the largest of which has a local magnitude [M_L] of 2.1), and hundreds of additional events have occurred that are too small to locate. Although this increase in activity is a significant departure from the usual 1–2 located earthquakes per day at Volcano X, it has experienced similar swarms in the past, including 5 years ago; such swarms generally dissipate after several days. Social media posts by the X Volcano Observatory (XVO) about the seismicity have generated some interest and one media inquiry.

OVERT Structure—Response needs are minimal (fig. 1.1). The two resident XVO seismologists jointly serve as the Seismology/Infrasound Lead and take responsibility for monitoring seismicity (including checking seismicity several times per day) and providing analyses and interpretations to the Scientist-In-Charge (SIC). To address communication needs, the SIC creates an internal, collaborative communication channel to facilitate response related discussions and provide daily XVO-wide updates. The SIC identifies a geologist with Volcano X expertise to serve as the Geology Lead, who provides context for interpretations and begins thinking about possible unrest and eruption scenarios. The SIC also identifies an XVO staff member to serve as a Public Information Officer (PIO). This staff member, who has ample outreach experience and training in U.S. Geological Survey (USGS) communications policies and procedures, leads the production and distribution of social media posts, facilitates interactions with traditional media outlets, and coordinates the production of Hazard Notification System for Volcanoes (HANS) messages, as warranted. Collectively, these three positions plus the SIC make up the OVERT Management Team. The team occasionally reaches out to other XVO scientists for checks on non-seismic data streams, but otherwise there are few responsibilities to manage and all OVERT duties are part-time.

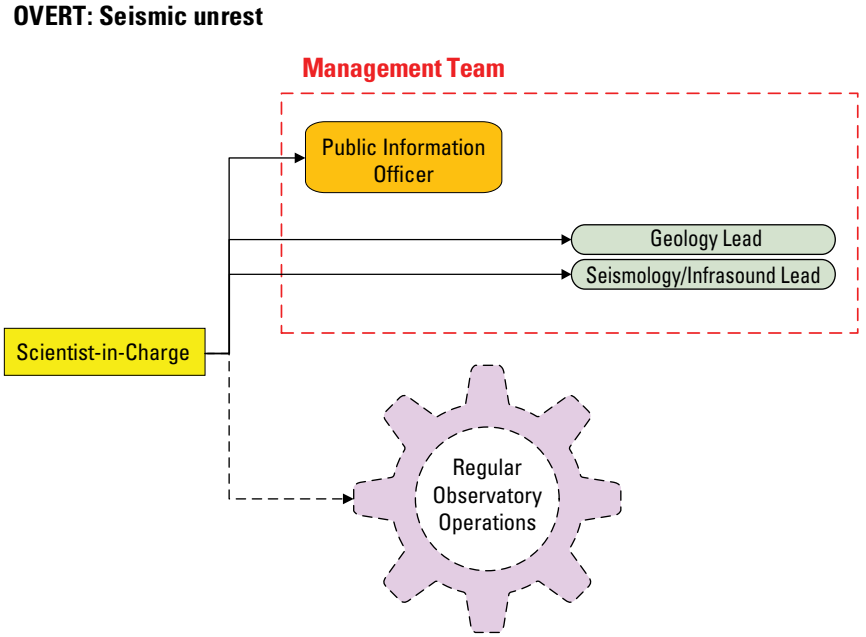


Figure 1.1. Diagram of the Observatory Volcanic Event Response Team (OVERT) response structure for stage one of the Volcano X unrest-to-eruption scenario. At this stage, the OVERT Management Team essentially consists of anyone involved in the response, totaling four people.

Stage Two—Seismicity Intensifies

Scenario—A week after the start of seismic unrest, the seismic swarm suddenly intensifies; earthquakes occur every 5–30 minutes, both as isolated events and in spasmodic bursts, including a M_L 3.0 (the largest event to date). Several hundred earthquakes have now been located below the summit at depths of 1–3 km. Most are volcano-tectonic events, but in the last day, the two XVO seismologists report that they have identified a few small low-frequency events. The duration and intensity of the swarm now exceed all prior swarms recorded at Volcano X. No deformation has been recorded on XVO's GNSS network, and no steam or other signs of unrest have been observed at the surface. In response, XVO issues an Information Statement, which generates several media inquiries, as well as a noticeable uptick in views and shares of XVO's daily social media posts. XVO begins planning to install additional real-time monitoring stations to bring the Volcano X network into compliance with the National Volcano Warning System Level 4 monitoring-network standard (12–20 seismic and GNSS stations within 20 km of the summit; Moran and others, 2008b), including a real-time gas-monitoring station. The observatory also performs its first overflight to make visual observations and take gas measurements.

OVERT Structure—Increased public and local media interest begin to overwhelm the PIO. To address this, the SIC and PIO identify three XVO staff with the appropriate experience to serve as Social Media, Traditional Media, and Web Page Leads; after receiving approval from their supervisors, these three leads begin reporting to the PIO (fig. 1.2). Duties for these roles are part-time for now, but the SIC notes that they could quickly become full-time roles if unrest further intensifies. The PIO's role shifts to managing these three staff positions, continuing to coordinate writing HANS products, including draft messages for raising the alert level, and coordinating with the USGS Office of Communication and Publishing (OCAP) and PIOs from other agencies and groups to address growing media and public interest.

Given the substantial demands on the two XVO seismologists, the SIC assigns one of them to be the Seismology/Infrasound Lead and counsels the other to rest for the time being so they will be ready to rotate into that position if unrest continues intensifying in the coming weeks. To relieve the Seismology/Infrasound Lead of some of their responsibilities, the SIC establishes a Monitoring Team to both manage field installations and monitor various data feeds. The positions in this Team include the following:

- Field Instrumentation Lead—This position manages the procurement, testing, and assembling of equipment for new real-time seismic, GNSS, and gas-monitoring stations, as well as field crews to perform the installations.
- Alarms Lead—This position develops and (or) maintains alarms that use real-time seismic data.
- Permitting Coordinator—This position manages the permitting process for the new stations. Note that this is a different title from the OVERT "Permitting/FEMA Paperwork Coordinator" chart in figure 3; since there is no FEMA paperwork yet, the SIC opts to refer to this position simply as the "Permitting Coordinator," thereby illustrating the intended flexibility of the OVERT system.

Since these three positions meet the minimum threshold for expanding the OVERT management structure, the SIC identifies an XVO staff member with substantial management and field experience to serve as the Monitoring Team Lead.

In response to the intensifying unrest, the SIC expands the number of discipline-specific Science Leads to include a Geodesy Lead to monitor GNSS data and assist with planning new installations, a Gas Lead to coordinate gas overflights and assist with the assembly, testing, and deployment of real-time gas-monitoring equipment, and a Geology Lead with substantial field experience working on Volcano X to serve as a subject-matter expert and begin thinking about field priorities in case unrest intensifies further. The SIC also identifies a staff member with substantial eruption forecasting experience to serve as a Probability Tree Lead and manage emerging probability-related discussions, which are just starting within XVO. Although the discipline-specific Science Leads are part-time roles (except for the Seismology/Infrasound Lead), the SIC elects to bring on a senior XVO scientist to serve as the Science Team Lead and coordinate XVO's scientific activities and priorities.

The SIC begins holding daily meetings with the OVERT Management Team, which now consists of the SIC, the PIO, and the Science and Monitoring Team Leads. The SIC also institutes short, daily staff meetings to ensure all XVO staff have an up-to-date understanding of the state of Volcano X. Other than these staff meetings, the XVO staff not serving roles in the OVERT or taking part in the full-time monitoring-data watch continue performing day-to-day activities and have little to no engagement in the response. During a daily phone call, the VSC Director tells the SIC that between managing the nascent OVERT, the Management Team, and their day-to-day XVO responsibilities, the SIC has a lot of on their plate. The VSC Director expresses concern that the SIC could quickly find themselves overwhelmed if unrest intensifies any further.

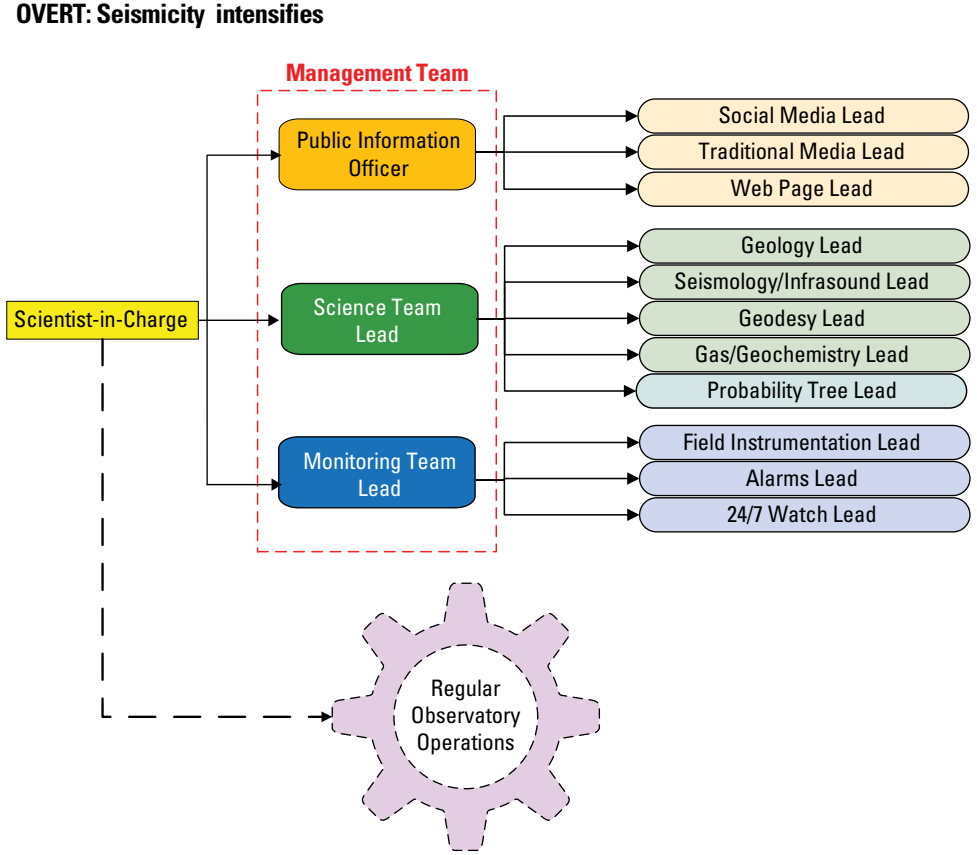


Figure 1.2. Diagram of the Observatory Volcanic Event Response Team (OVERT) response structure for stage two of the Volcano X unrest-to-eruption scenario. At this stage the OVERT Management Teams consists of the Public Information Officer and the Science and Monitoring Team Leads. Fifteen people fill OVERT staff roles on at least a part-time basis. In addition to the formal OVERT roles reflected on this chart, additional X Volcano Observatory staff are involved in around-the-clock monitoring watch shifts.

Stage Three—Unrest intensifies, XVO Changes Alert Level to Advisory/Yellow

Scenario—Two days after the M_W 3.0 event, the Geodesy Lead reports that two GNSS stations located on Volcano X's edifice have trendlines barely above the noise threshold, indicating uplift. Observers on an overflight the evening before found no evidence of surface deformation, anomalous steaming, or other signs of activity. However, the Gas Lead notes that a rapid overnight analysis of gas data collected during the overflight found elevated levels of carbon dioxide (CO_2). Seismicity has not intensified any further, but it also hasn't diminished, and the Seismology/Infrasound Lead notes that the percentage of low-frequency earthquakes is increasing.

In response to the detection of surface deformation and CO_2 emissions, the SIC changes the alert level status (Gardner and Guffanti, 2006) to ADVISORY/YELLOW. XVO receives many local and national media inquiries in the hours following the status change, and the XVO website is visited millions of times in the 12 hours following the alert-level change. The U.S. Forest Service (USFS), the land-management agency for Volcano X, is also overwhelmed by media enquiries; they begin discussions with the SIC and other partner agencies about forming a Joint Information Center (Frenzen and Matarrese, 2008; Driedger and others, 2008). The USFS also requests that the SIC provide them with an updated hazard map for Volcano X and an estimate of the likelihood that Volcano X will erupt. XVO accelerates plans to install additional real-time monitoring stations and begins instituting daily overflights to make visual observations, measure ground-surface temperatures, and measure gas concentrations.

OVERT Structure—The PIO branch of the OVERT is now fully engaged (fig. 1.3) and the PIO is in regular contact with the USGS OCAP, as well as PIOs from other agencies. All other members of the PIO branch are working full-time:

- The Social Media Lead has established a rotation of three XVO staff with experience writing social-media posts in a government context. These workers take day-long shifts where they are primarily responsible for generating social-media posts and responding to comments.
- The Traditional Media Lead has worked with OCAP to develop a system for tracking interview requests and has also developed a network of XVO staff, as well as others within the VSC, to give interviews as needed.
- The Information Products Lead is fully engaged, providing graphics for use in social-media posts and on the Volcano X web page. They are also responding to requests from the USFS and partner agencies for updated hazard maps and supporting graphics. In addition, the PIO asks the Information Products Lead to coordinate the writing of HANS products with the relevant Science Leads.
- The Web Page Lead has revamped the Volcano X website so that it shows real-time data as well as photos and videos from the field. They are working with the XVO information technology (IT) staff to ensure that the Volcano X website can withstand substantial increases in internet traffic.

The Science Team Lead begins holding daily meetings with the four discipline-specific Science Leads and other scientists engaged in the response to identify scientific priorities for hazard assessment and data gathering. All discipline-specific Science Leads are now working full-time and have brought in other discipline specialists from XVO. These additional specialists to assist in day-to-day work and to develop plans in the event that unrest leads to eruption. With the detection of surface deformation and CO_2, the SIC also recognizes the need for a person to lead the OVERT's modeling efforts. Lacking such expertise on their staff, the SIC asks the VSC Director if a modeling expert from another observatory can serve as the Modeling Lead. This request triggers the VSC Director to identify an SIC from another observatory to prepare to serve as the Center Volcanic Event Response Team (CVERT) Staff Rotation Coordinator (SRC) should the need arise.

The SIC also recognizes that in all the excitement, they have started to lose track of the exact sequence of unrest. To ensure that an accurate record of Volcano X's activity is available to the SIC and the rest of the observatory, the SIC identifies a scientist with response experience to serve as the Volcanic Activity Chronology Coordinator. Rather than fill a new OVERT Management Team position, the SIC places them and the Modeling Lead in the Science Team.

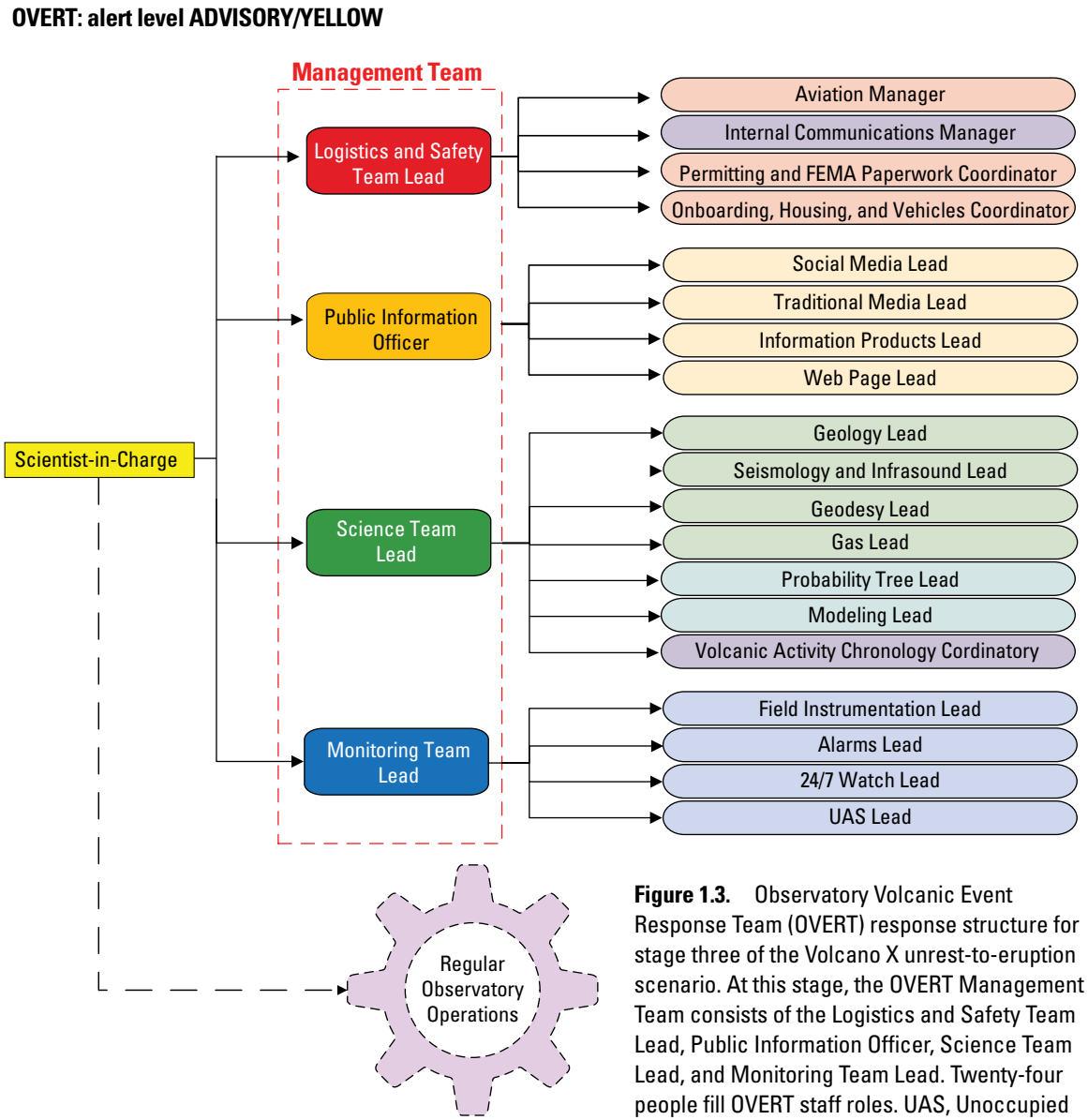


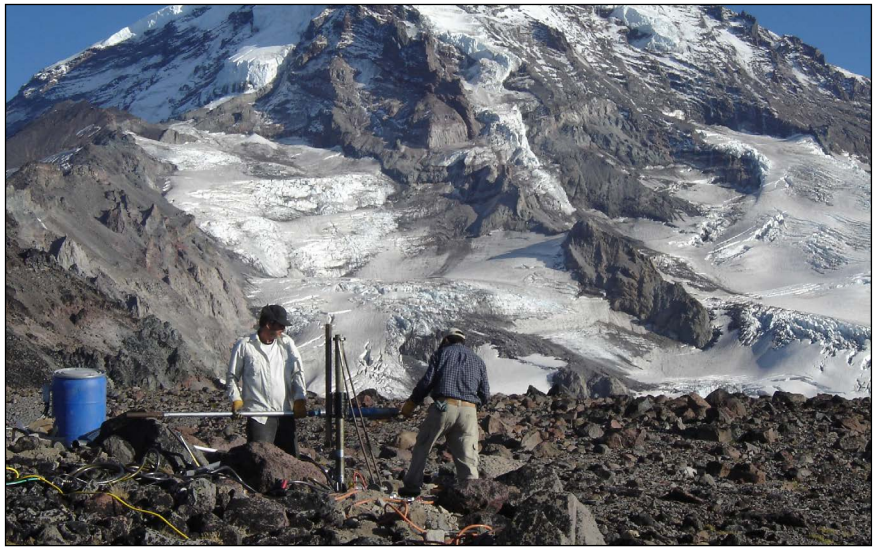
Figure 1.3. Observatory Volcanic Event Response Team (OVERT) response structure for stage three of the Volcano X unrest-to-eruption scenario. At this stage, the OVERT Management Team consists of the Logistics and Safety Team Lead, Public Information Officer, Science Team Lead, and Monitoring Team Lead. Twenty-four people fill OVERT staff roles. UAS, Unoccupied Aviation Systems; 24/7, twenty-four hours per day, seven days per week.

In consultation with the VSC Director and their OVERT Management Team, the SIC identifies five additional positions that are now required. These include the following roles:

- The commencement of daily flight operations requires a staff member with significant experience and training in aviation management needs to serve as the OVERT Aviation Manager and manage the observatory's daily flight operations.
- The need to document changes at the surface using techniques like structure from motion photography requires a staff member with active Unoccupied Aviation Systems (UAS) certification and substantial experience operating and (or) managing UAS flights needs to serve as the OVERT UAS Lead. Their tasks include coordinating with other local agencies and groups with UAS assets to ensure efficient use of airspace and UAS resources.
- With plans to install new monitoring equipment triggering permitting discussions with the USFS, a person with good writing and communication skills as, well as permitting experience with various land-management agencies, needs to serve as the Permitting Coordinator.
- The increased use of vehicles by staff working on the volcano and anticipation of VSC staff from other observatories coming to work at XVO requires a staff member with good organizational and communication skills, good familiarity with internal operations at the observatory, and good connections to the community in which XVO resides needs to serve as the Onboarding, Housing, and Vehicles Coordinator.
- Increase internal communication withing XVO requires a staff member with good organizational and communication skills, as well as experience establishing and (or) managing internal communication platforms, needs to serve as the Internal Communications Manager. They will establish and maintain an internal, collaborative communication channel for the response.

The SIC places the UAS Lead in the Monitoring Team; however, recognizing that the other new positions warrant establishing a new OVERT branch, the SIC identifies an experienced staff member to serve as the Logistics and Safety Team Lead. The SIC places the Aviation Manager, Internal Communications Manager, Permitting Coordinator, and Onboarding, Housing, and Vehicles Coordinator under the Logistics and Safety Team Lead.

The OVERT Management Team now consists of the SIC, the PIO, and the Science, Monitoring, and Logistics and Safety Team Leads. The SIC continues to hold daily OVERT Management Team and staff meetings to ensure OVERT-wide situational awareness and to facilitate rapid decision-making as the need arises. Many XVO staff not serving roles in the OVERT are also starting to become engaged in the response through performing fieldwork, taking part in around-the-clock watches, speaking with the media, or working with discipline-specific groups to develop plans for the coming days and weeks. Many continue to perform their day-to-day activities, but at a reduced level. The VSC Director tells the SIC during their daily phone call that the SIC is doing a great job of delegating, but that they remain concerned that the SIC could still become quickly overwhelmed. The VSC Director encouraged the SIC to continue asking for help and develop plans now for further delegation should the need arise.



Photograph of Cascades Volcano Observatory scientists Gene Iwatsubo and Mike Lisowski installing a volcano monitoring station at Mount Rainier, Washington. U.S. Geological Survey photograph by Seth Moran, September 8, 2008.

Stage Four—Unrest intensifies, XVO Changes Alert Level to Watch/Orange

Scenario—In the week following XVO's move to the Advisory/Yellow alert level, deformation trends have slowly accelerated, and caron dioxide (CO_2) emissions have progressively increased, with sulfur dioxide (SO_2) detected for the first time during an overflight two days ago along with the first visible steam plumes. Observers on an overflight yesterday afternoon reported smelling SO_2 and observing ground cracks at the summit, with infrared cameras recording temperatures as high as 100 degrees Celsius in some of the cracks. Overnight, a real-time gas-monitoring station installed two days ago near the summit started detecting high levels of both CO_2 and SO_2, with a CO_2 to SO_2 ratio of roughly 15:1. Also overnight, members of the 24/7 watch rotation reported a significant intensification in seismicity, which now features an even mix of volcano-tectonic and low-frequency earthquakes occurring every 2–3 minutes, some as large as M_w 3.0. XVO overflights are now occurring twice per day, and field crews are a constant presence near the volcano.

Increased seismicity, deformation, CO_2 emission rates, ground cracks observations, and the appearance of SO_2 leads the SIC to change the alert level status for Volcano X to WATCH/ORANGE. In the hours and days after the alert-level change, both XVO and USFS receive hundreds of local and national media inquiries. In addition, the USFS reports that members of the public have started camping near the volcano and requests assistance from XVO in determining areas around Volcano X where access should be restricted. To manage the intense public interest, the USFS establishes an ICS at their local headquarters ~50 km from Volcano X, including a Joint Information Center to manage the increased media inquiries. The USFS requests that a member of XVO be stationed at their ICS full-time to assist ICS staff with situational awareness. In addition, the State Emergency Management Agency (SEMA) establishes their own ICS at their headquarters ~250 km from Volcano X and asks that a member of XVO be stationed there part-time. Both the USFS and SEMA request that the SIC provide them updated estimates of the likelihood that Volcano X will erupt and the likelihood that an eruption will affect specific locations, including a visitor's center located ~10 km from the volcano and several hydroelectric dams located 30–50 km downstream along drainages stemming from the volcano. The USFS also reports concerns over airspace usage around Volcano X, including a close call involving an XVO overflight and a UAS drone operated by an unknown party. In response, the FAA issues a Temporary Flight Restriction that only allows flight operations within 50 km of Volcano X approved by the Incident Commander of the USFS ICS. In addition to increased public interest, the change in Alert Level results in the SIC receiving communications from external scientists interested in deploying instruments and performing other fieldwork at Volcano X.

Photograph of California Volcano Observatory geologist Lauren Harrison sampling a lava flow next to the Whitney Glacier on Mount Shasta, California. U.S. Geological Survey photograph by Andy Calvert, June 2023.

OVERT Structure—The SIC recognizes that the OVERT must be rapidly expanded both to meet current demands and to prepare for future needs should Volcano X begin erupting (fig. 1.4). With only 35 staff in XVO, the SIC requests permission from the VSC Director to bring in staff from other observatories to fill targeted roles and (or) to provide relief to XVO staff. The VSC Director contacts the other observatory SIC identified in stage three to fill the SRC role and grants them permission to start arranging for outside staff requested by the XVO SIC to travel to XVO. These external staff become involved in the response on the condition that they first receive permission from their supervisor and (or) SIC before making travel arrangements. The VSC Director also asks the SRC to develop a spreadsheet for tracking the arrival, departure, and response activities of non-XVO staff to be shared with the XVO SIC, OVERT Management Team members, and the USGS Emergency Management Coordinator. The VSC Director also asks the SRC to be in close contact with the Onboarding, Housing, and Vehicles Coordinator to ensure incoming staff are properly onboarded and have adequate housing. Lastly, the VSC Director and the XVO SIC work with the SRC to identify VSC staff to fill specific OVERT roles.

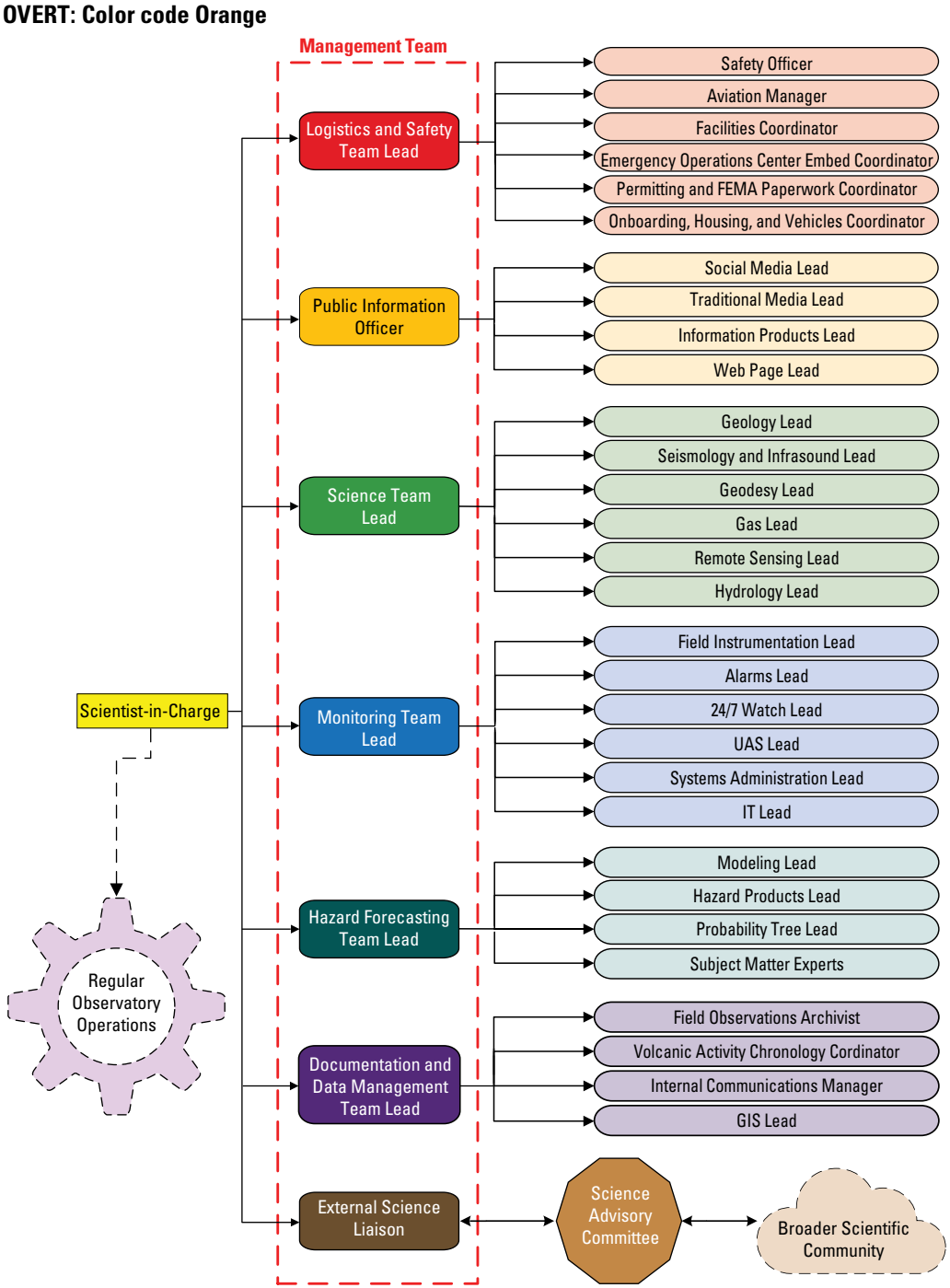


Figure 1.4 Observatory Volcanic Event Response Team (OVERT) response structure for Stage Four of the Volcano X unrest-to-eruption scenario. At this stage the OVERT has almost doubled in size relative to Stage Three, with 37 people filling OVERT staff roles. Other staff involved in the response but not indicated in this figure include field engineers, discipline-specific scientists, and those involved in rotations established for 24/7 watches and U.S. Geological Survey Emergency Operations Center Embeds. The number of people required at this stage of the response would exceed the staffing levels of any single USGS volcano observatory and would necessitate bringing in staff from other observatories and (or) observatory partners to help. UAS, Unoccupied Aviation Systems; 24/7, twenty-four hours per day, seven days per week.

The SIC next holds a meeting with the OVERT Management Team and SRC to identify staffing needs and revise the OVERT management structure to accommodate the new OVERT positions. The OVERT Management Team identifies ten new OVERT positions that are now needed, all of which are approved by the SIC. Recognizing that the additional OVERT positions will exceed the span of control of some of the current OVERT Management Team members, the SIC asks the OVERT Management Team for recommendations for VSC staff capable of serving in three new OVERT Management Team positions:

- A Hazard Forecasting Team Lead with good communication skills and experience with eruption responses to manage various efforts related to forecasting and providing assessments for various types of hazards
- A Documentation and Data Management Lead with good organizational skills to establish and manage systems for documenting the course of the eruption and any large datasets for which there is not an existing archival system
- An External Science Liaison with good communication skills and with significant scientific expertise to serve as the go-between between XVO and the broader scientific community

To follow OVERT management policy and make room in the Science Team for two additional discipline-specific Lead positions (Remote Sensing and Hydrology), the SIC shifts the Probability Tree and Modeling Leads from the Science Team to the newly formed Hazard Forecasting Team. The SIC also moves the Volcanic Activity Chronology Coordinator and Internal Communications Manager to the new Documentation and Data Management Team. With the OVERT restructuring, the SIC recognizes the need for delegation of responsibilities and requests that the SRC work with each OVERT Management Team Lead to identify VSC staff to fill each new OVERT position.

In coordination with the Logistics and Safety Team Lead, the SRC identifies a VSC staff member with experience managing USGS safety programs to serve as the Safety Officer. The SRC also identifies a VSC member with ICS training and (or) experience working in the ICS to lead a group of five VSC staff that will serve rotations as USGS Emergency Operations Center Embeds in the USFS and SEMA ICS posts. The SIC places both positions in the Logistics and Safety Team, the scope of which has expanded to the point that the Logistics and Safety Team Lead is now holding daily meetings to coordinate activities across the team.

In coordination with the Monitoring Team Lead, the SRC identifies a VSC staff member to provide dedicated systems administration support for the rapidly expanding number of monitoring data streams coming into XVO. The SRC also identifies a member of the VSC IT staff to serve as IT Lead and provide dedicated IT assistance to all those involved in the OVERT. With the influx of new staff members, the Monitoring Team Lead also begins daily team meetings. The Monitoring Team Lead also begins meeting daily with the Science Team Lead to coordinate activities and establish field priorities.

In coordination with the Hazard Forecasting Team Lead, the SRC identifies a VSC staff member with experience producing hazards maps and other hazards-related products to serve as the Hazard Products Lead. The Hazard Forecasting Team Lead also works with the SRC and the Science Team Lead to identify VSC scientists to serve as subject matter experts on their team. With the addition of the Modeling and Probability Tree Leads, the Hazard Forecasting Team has four members and begins holding daily meetings to establish priorities and coordinate activities across the Hazard Forecasting Team.

Lastly, in coordination with the Documentation and Data Management Lead, the SRC identifies a VSC staff members with substantial GIS expertise, including the production of map-based products that require access to various datasets, to serve as the GIS Lead. The SRC also identifies another VSC staff member with good organizational skills and fieldwork experience to serve as the Field Observations Archivist to collate and organize all field staff observations. With the addition of the Volcanic Activity Chronology Coordinator and the Internal Communications Mangers, the Documentation and Data Management Lead begins holding daily meetings with their four-person team to establish priorities and coordinate activities.

Meanwhile, the SIC, relieved that the staffing of the OVERT is in good hands, turns their attention to the increasing number of requests they are receiving from outside scientists. In coordination with the External Science Liaison and the VSC Director, the SIC identifies an external non-USGS scientist with good Volcano X familiarity, experience working with XVO scientists, and interdisciplinary teamwork experience to serve as chair of a Science Advisory Committee (SAC). The SAC collectively determines that its role will be to facilitate communications between the OVERT and the broader scientific community as well as advise the SIC's decisions about which broader scientific community proposals to provide resources to, if any. The SIC, External Science Liaison, and SAC Chair identify additional scientists to serve on the SAC, with the goal of having a wide variety of disciplines represented on the SAC.

The SIC continues to hold daily OVERT Management Team meetings to facilitate communication, coordination, and decision-making across the OVERT.

Stage Five—Eruption Begins, XVO Changes Alert Level to Warning/Red

Scenario—One week after the initial observation of ground cracks, Volcano X erupts. The eruption begins explosively with a plinian column that maintains its height for thirty minutes, producing an ash cloud that drifts toward downwind communities and disrupts air traffic routes. Pyroclastic density currents generated by the collapsing column flow down multiple flanks of the volcano, melting snow and ice, generating lahars, and destroying several monitoring stations. Within minutes of the eruption's onset, XVO raises the alert level to WARNING/RED. In the aftermath of the eruption, public safety inquires increase, with many community members expressing concerns about potential hazards from ingesting ash. Eruptions continue sporadically over the next week, and then intermittently over the next three months. A remote field office is established to give the many staff working in the field a place to store equipment, upload data and field observations, and coordinate field operations.

OVERT Structure—With most OVERT positions filled, only three additional roles are required now (fig. 1.5). In consultation with the VSC Director and SRC, the SIC identifies VSC staff members to serve as the Health Hazards Lead to coordinate the multi-agency response for addressing health-related concerns stemming from the eruption, Facilities Coordinator to establish and manage the remote field office, and Data Manager to manage the large datasets being generated by UAS operations. After almost a month of continual response, several staff members are reporting or demonstrating signs of burnout, including the SIC, who receives counsel from the VSC Director to take a few days off and delegate SIC duties to an SIC from another USGS observatory.

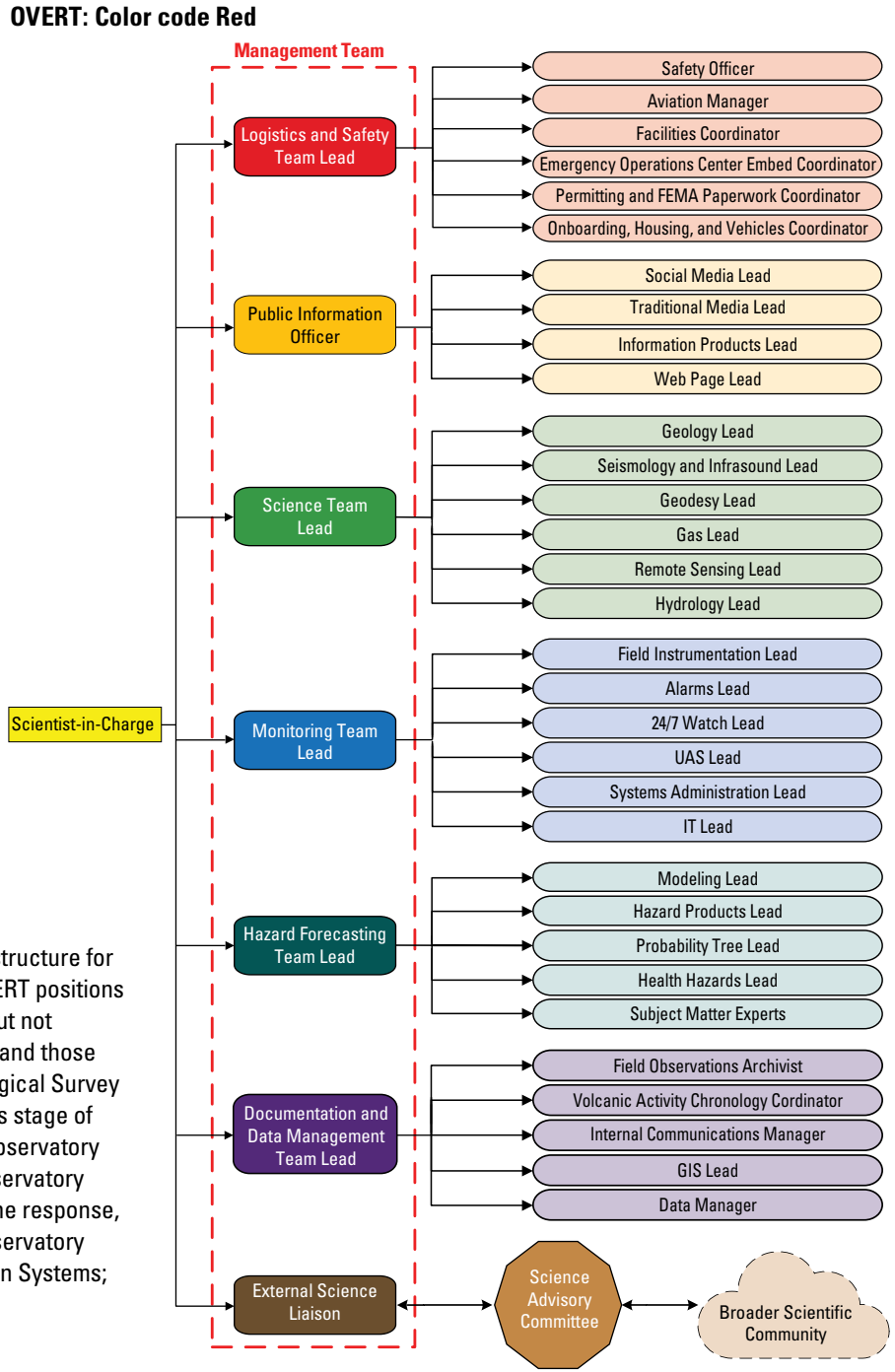


Figure 1.5 Observatory Volcanic Event Response Team (OVERT) response structure for Stage Five of the Volcano X unrest-to-eruption scenario. At this stage all OVERT positions are filled involving a total of 40 people. Other staff involved in the response but not indicated in this figure include field engineers, discipline-specific scientists, and those involved in rotations established for 24/7 watches, field work, and U.S. Geological Survey Emergency Operations Center Embeds. The number of people required at this stage of the response would exceed the staffing levels of any single USGS volcano observatory and would necessitate bringing in staff from other observatories and (or) observatory partners to help. Given that the Scientist-in-Charge will be fully engaged in the response, additional VSC staff may be required to help manage and support normal observatory options (these staff are not included in the OVERT). UAS, Unoccupied Aviation Systems; 24/7, twenty-four hours per day, seven days per week.

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Photograph of Alaska Volcano Observatory scientists conducting maintenance work at a volcano monitoring station with Redoubt Volcano, Alaska, in the background. Photograph courtesy of Jimmy Finney, July 30, 2023.

Front cover. Aerial photograph of lava fountaining from fissure 3 on the Northeast Rift Zone of Mauna Loa on November 29, 2022. U.S. Geological Survey photograph by Matthew Patrick.

Back cover. Photograph of U.S. Geological Survey scientists participating in a press conference along with (left to right) U.S. Senator Maria Cantwell, U.S. Representative Brian Baird, Secretary of the Interior Gale Norton (speaking), and U.S. Representative Greg Walden. This press conference was held in front of the Cascades Volcano Observatory in response to escalating unrest at Mount St. Helens prior to the onset of the 2004–2008 eruption. U.S. Geological Survey photograph by Eliot Endo, October 2, 2004.

Moffett Field Publishing Service Center
Manuscript approved March 7, 2024
Edited by Mitchell Phillips
Graphic design and layout by Kimber Petersen

ISSN 2330-5703 (online)
ISSN 1067-084X (print)
https://doi.org/10.3133/cir1518