iMUSH methods and goals

What is iMUSH?

- iMUSH ("**i**maging **M**agma **U**nder **S**t. **H**elens") is a project to improve volcano monitoring and aims to save lives by learning more about the underground feeder system that supplies magma to Mount St. Helens (MSH).
- The project will collect new data, via minimum-impact temporary instrument deployments, to produce high-resolution images of the Earth beneath Mount St. Helens. The scientists will integrate these images with existing geologic datasets to develop improved models of the Mount St. Helens magma systems.
- The deployments will collect ***magnetotelluric (MT)***, ***passive-source seismic*** and ***active-source seismic data,*** details below.
- Such a large-scale and multidisciplinary integrated approach has rarely been attempted at volcanoes due to expense and difficult logistics, but is critical for forming a high-resolution three-dimensional model of the Earth to the necessary depth of 60 miles.
- Our integrated approach will produce a state-of-the art high-resolution image that will allow unambiguous interpretations and improved understanding of the volcano's inner workings, which will help us do more effective above-ground monitoring of Mount St. Helens.

Who is iMUSH?

- iMUSH is a group of University and government researchers who came together specifically to work on this project at MSH.
- Researchers come from the University of Washington, Oregon State University, Lamont-Doherty Earth Observatory, Rice University, and the U.S. Geological Survey. Additional students and scientists from other universities, as well as local volunteers, will participate in the fieldwork.
- iMUSH is funded by the National Science Foundation's GeoPRISMs and Earthscope programs, and the USGS will contribute in many ways.

Why do this at Mount St. Helens?

- ***Assessing Hazards:***
    - Mount St. Helens (MSH) erupted twice in the last 35 years and has been the most active volcano in the Cascade Range over the last 2000+ years.
    - The better we understand its underlying magmatic system and how it relates to activity at the top of the volcano, the more accurate will be our interpretations of future signs of unrest.
    - More accurate interpretations of unrest may help us save lives in the future, both at Mount St Helens and other volcanoes around the world.
- ***State-of-the-art volcano imaging:***

    - At MSH we have a rare opportunity to create a state-of-the-art image of an active volcanic system from "source to surface," something that has not been achieved elsewhere.
    - Because it has been so well studied and well monitored, and recent eruptions are carefully characterized, we have a good basic understanding of how MSH works. Such an understanding is required to go to the next level and address questions like:
        - Where is magma stored under MSH?
        - By what chemical and physical process does the solid rock melt and rise in the volcano?
        - How much magma lies beneath MSH?
        - Can we see where magma is being created?
        - How do local earthquakes relate to the MSH magmatic system?
        - How does the regional geologic structure change in the vicinity of nearby volcanoes such as Mount Adams and Mount Rainer?
- ***<u>Relatively easy access:</u>***
    - Experiments such as iMUSH are rare because volcanoes are in difficult places to work.
    - Although not easy, the existing regional resources around MSH present a unique opportunity to perform complex field-based imaging experiments at an active volcano.

How is iMUSH going to be implemented?

- We are proceeding with a carefully planned experiment designed to have minimal impact on the environment and people in the MSH area.
- A limited amount of magnetotelluric (MT) fieldwork will start in the summer of 2013 in areas adjacent to and west of Gifford Pinchot National Forest. The full phase of seismic and magnetotelluric fieldwork within Gifford Pinchot National Forest will begin in the fall of 2013 or perhaps later, after a full NEPA (National Environmental Policy Act) analysis has been completed by the USFS.
- The three fieldwork-based components of iMUSH will be implemented in different ways:
    - ***<u>Passive- (or "natural-") source seismic:</u>***
        - Involves a total of 70 sites over a ~60 x 60 mile area centered on MSH.
        - Seismic recordings of local earthquakes, remote large earthquakes, and other types of events, as made on the 70+ sites, will form the primary dataset for several different types of imaging analyses.
        - 33 sites are in the Gifford Pinchot National Forest, 7 of which are inside the MSH National Monument.
        - Equipment at all sites will be installed in 2014, starting in the spring as sites become accessible.
        - Equipment will be in place for two years, then removed in the summer of 2016.
        - Each site will have a seismometer, an Action-Packer-type enclosure with electronics and batteries, and most will have a solar panel.

  - Solar panels, if used, will be placed on the ground or on top of the enclosure and positioned so as to not be easily visible from nearby roads.
  - Ground disturbance will come primarily from seismometer burial:
    - A ~3'-diameter hole will be dug 3' deep to house the seismometer.
    - The seismometer will be placed on a small concrete pier at the base of the hole and buried with sand.
    - A ~1'-diameter plastic corrugated pipe will be placed around the seismometer to protect it from water.
    - The top of the plastic pipe will be buried so it is not visible.
    - A short cable will run from the seismometer to an equipment enclosure either in a shallow trench (and buried) or along the surface & covered by rocks.
  - Here is an example of a monitoring site from a previous, solar-powered, passive experiment in the Olympic Mountains. Some sites will be powered only by batteries, thus will look the same without the solar panel.

- ***<u>Magnetotelluric (MT):</u>***
  - Involves a total of 150 sites spread across an area approximately 125 miles from north to south by 110 miles east to west. This area includes Mt. Adams and Mt. Rainier.
  - 82 of these sites are on Gifford Pinchot land, including 2 inside the MSH National Monument
  - First sites occupied in the late summer of 2013, last in fall of 2014
  - Each site will be occupied typically for no more than 1 day

- Each monitoring site will look similar to the below photo when occupied.

- Each site will involve very little ground disturbance. Compact battery powered magnetotelluric (MT) instrumentation is used. A recording device is typically placed in the center of an array that consists of 4 wires extending from the data receiver in each of the four cardinal points of the compass, to a distance of 50 meters. These wires are connected to a small sensor that picks up electric signals. A sensor that picks up magnetic signals is also connected to the data recorder via a cable and is placed near the center. In order to provide a stable installation for these sensors, they are buried about 2 feet beneath the surface of the ground. A GPS antenna is left above ground level to provide accurate system time signals.

- A typical installation will look similar to the site in this photo:

- ***Active-source seismic:***
  - Involves a total of 6,800 seismometer sites spread across a 100 by 100 mile area, and the emplacement/ignition of 24 1,000-2,000-lb charges in 80'-deep boreholes.
  - 50% of the instruments and 8-14 boreholes are on Gifford Pinchot land, including ~1500 instrument sites and possibly 3 boreholes inside the MSH National Monument
  - The active-source experiment is scheduled for mid-July to mid-August, 2014.
  - Active sources and seismometer installations/retrievals will happen at the same time.
  - Each instrument site will be occupied for 3-4 days.
  - Each instrument site will have a small seismometer buried 3-6" below the surface attached to a soda-can-sized battery-operated recording unit (see picture below)
  - Active sources will be used at night, when cultural noise is low.
  - The detonations produce the effect of a magnitude ~1-2 earthquake. They can be felt ~200 yards from the source, and can be heard to ~1000 yards.
  - Detonation sites will be located in areas of already-disturbed ground such as clear cut areas, quarries or gravel pits, garbage dumps, etc., and will be selected so as to ensure no disturbance to local groundwater or biological resources.
  - Typically the ground at the source point is undisturbed except for the effects of drilling the borehole. Source sites are cleaned following the experiment.