## KECK COMBINED STRONG-MOTION/BROADBAND OBS

WHOI Ocean Bottom Seismograph Laboratory

### W.M. Keck Foundation Award to Understand Earthquake Predictability at East Pacific Rise Transform Faults.

- In 2006, the W.M. Keck Foundation awarded funding to Jeff McGuire and John Collins to determine the physical mechanisms responsible for the observed capability to predict, using foreshocks, large (Mw ~6) transform-fault earthquakes at the East Pacific Rise, and to gain greater insight into the fundamentals of earthquake mechanics in general.
- Achieving this objective required building 10 OBS of a new and unique type that could record, without saturation, the large ground motions generated by moderate to large earthquakes at distances of less than ~10 km.

### W.M. Keck OBS: Combined Broadband Seismometer and Strong-Motion Accelerometer

- The broadband OBS available from OBSIP carry a broadband seismometer whose performance is optimized to resolve the earth's background noise, which can be as small as 10<sup>-11</sup> g r.m.s. in a bandwidth of width 1/6 decade at periods of about 100 s. Thus, these sensors are ideal for resolving ground motions from large distant earthquakes, necessary for structural seismology studies.
- Ground motions from local, moderate to large earthquakes can generate accelerations of up a g or more, which would saturate or clip these sensors. Currently, there are no sensors (or data-loggers) that have a dynamic range to resolve this ~220 dB range of ground motion.
- To overcome this limitation, we used Keck Foundation funding to build 10 OBS equipped with both a conventional broadband seismometer and a strongmotion accelerometer with a clip level of 2.5 g. The combination of sensors makes these new *Keck OBS* capable of recording ~220 dB of ground motion.

### The Keck OBS: Combined Broadband/Strong-Motion Accelerometer OBS



### The NSF-Funded QDG Experiment

These 10 Keck OBS were deployed on an NSF-funded seismic field experiment to study the mechanical processes that control both seismic and aseismic fault slip at the Quebrada, Discovery and Gofar transform faults that offset the East Pacific Rise between -5° N and -3° N. The field work had passive (i.e. earthquake monitoring) and active (recording airgun shots) components. The passive component involved the deployment of 10 Keck OBS, 20 broadband OBS, and 10 short-period OBS, while the active-source part involved 17 deployments of short-period OBS.

# The QDG Experiment

The first local observations of the end of a oceanic transform seismic cycle Quebrada, Discovery, Gofar Fault System



### Earthquake epicenters at the Gofar Transform Fault.



Earthquake epicenters at the Gofar Transform Fault. The bathymetry map shows 21,919 events occurring August–December 2008 (black dots) and located with a double-difference scheme. Foreshocks on September 10–12, aftershocks on September 18–20, and swarm events on December 7-8 are shown in yellow, red, and cyan, respectively. OBS locations are shown by the white triangles (seismometer only) and white stars (seismometer plus strong-motion sensor). The epicenter of the largest (M5.2) aftershock, and the centroids of the 2008 M<sub>w</sub> 6.0 and 2007 M<sub>w</sub> 6.2 earthquakes are shown as large brown, orange, and blue circles respectively. OBS G04, G06, G08 and G10 are labeled below their symbols.



Mw 6.0 event recorded by OBS 1 km from fault.



Peak ground accelerations in units of g generated by the Mw 6.0 earthquake as recorded by the accelerometers on the Keck OBS. The earthquake epicenter is indicated by the red star. The rupture length of this event is 25-30 km.

### Broadband Seismometer versus Strong-Motion Accelerometer



The response of the broadband seismometer (top 3 traces) and strong-motion accelerometer (bottom 3 traces) on station G06 to the Mw 6.0 event at 01:41 UTC. The rupture length of this event is 25-30 km. The seismometer saturates/clips and remains saturated and off-level for approximately 20 hours. In contrast, the accelerometer channel does not saturate and records the aftershock sequence accurately.

### Broadband Seismometer versus Strong-Motion Accelerometer. Ctd.



A close-up of the previous figure, showing in more detail the aftershock sequence missed by the broadband seismometer because of saturation.

### Broadband Seismometer versus Strong-Motion Accelerometer. Ctd.



Another example of the value of the strong-motion sensor. The response of the seismometer (top 3 traces) and accelerometer (bottom 3 traces) on station G04 to the Mw 4.0 event at ~16:31 UTC and at a distance of a few kilometers. The seismometer saturates/clips and remains saturated for ~10 minutes. In contrast, the accelerometer channel does not saturate and records the aftershock sequence accurately.

### **Publications (QDG Experiment)**

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### The 2011-2015 Cascadia Initiative Community Experiment

The Cascadia Initiative (CI) was an NSF-funded (both EAR and OCE) onshore/offshore seismic and geodetic experiment that addressed questions ranging from megathrust earthquakes to volcanic arc structure to the formation, deformation, and hydration of the Juan de Fuca and Gorda plates.

The offshore component consisted of four 9-12 month deployments of up to 70 OBS each. The 10 WHOI Keck OBS were deployed in each of the 4 years of the CI. In addition to providing broadband seismic and long-period pressure data, the accelerometers on the Keck OBS allowed on-scale recording of regional earthquakes that saturated conventional OBS.



### 2015-01-28 Mw 5.7 Mendocino event

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Vertical-component seismograms (BHZ) and accelerograms (BNZ) for the Mw 5.7 Mendocino event. From top to bottom, epicentral distances are 0.04°, 0.13°, 0.14°, 0.16°, 0.19°, 0.23°, 0.24°, and 0.31°. The seismometer channel (BHZ) clips at the short distances, but the accelerometer does not.