What Does Validation Look Like?

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Questions

- What does validation mean?

- What gets validated?

- Who decides if it's validated?

- Where is the boundary between earthquake simulations and engineering practice?

The Three V's — Verification, Validation, and Value-Added

- **Verification**

  Does the software do what we claim it does?

- **Validation**

  Is the software a sufficiently accurate model of reality so that we can rely on it in a given application?

- **Value-Added**

  Is the software sufficiently better than alternative approaches, so that its usage is worth the cost?

Applications of Dynamic Rupture

"It is difficult to make predictions, especially about the future."
— Old Danish Proverb

Dynamic rupture could be applied in various ways:

- Generate a representative suite of synthetic seismograms.

- Determine the probability distribution of some ground motion parameters (*e.g.* peak intensity, spectral content, duration).

- Estimate the probability of some discrete event (*e.g.* probability of exceeding some design limit, probability of a fault-to-fault jump).

To validate the use of dynamic rupture, we need to say how it is applied, and how faithful to reality the simulation needs to be, and in what way the simulation needs to be faithful to reality.

What Gets Validated?

- Dynamic rupture as an abstract concept?

    No — You can't use an abstract concept in an application.

- A dynamic rupture code?

    No — A dynamic rupture code is not stand-alone. You need to supply lots of other ingredients — fault geometry, friction law, velocity model, initial stress.

- A dynamic rupture *platform*?

    Almost — A platform would combine one or more dynamic rupture codes with all the other ingredients needed to do runs. But you still need to know how to apply it — there are good ways and bad ways to use a platform.

- Platform + Workflow?

    Yes — If you identify all the ingredients *and* how they are to be applied, then you have something that could be validated.

Who Decides If It's Validated?

Ultimately, the users decide. *If users are convinced that dynamic rupture is a reliable technique for their application, then we can say it's validated.*

Users will come to accept dynamic rupture in different ways and at different times:

- Some engineers (*early adopters*) are ready to use dynamic rupture right now.

- Some may want to see peer-reviewed journal articles.

- Some may want to see acceptance within the engineering community.

Many large structures in California are now designed using *performance-based engineering*. The engineer must prove that the building will perform well in an earthquake, and then the proof is evaluated by a review panel of engineers. So dynamic rupture (or any new technique) cannot be used until it is well-enough accepted to pass review.

What Tests Would Convince the Users?

Ask them!

What characteristics do our simulations need to share with real earthquakes?

- Agreement with GMPEs?

- Spectrum?

- Reproduce past earthquakes, with carefully-tuned parameters and initial conditions? (Doesn't tell us how to choose parameters to simulate future earthquakes.)

- Other tests we haven't thought of?

There are alternatives to dynamic rupture:

- GMPEs.

- SCEC Broadband Platform.

- NGA West database of ground motion recordings.

Value proposition: We need to demonstrate that dynamic rupture is "better" than alternatives.

"Rupture to Rafters"
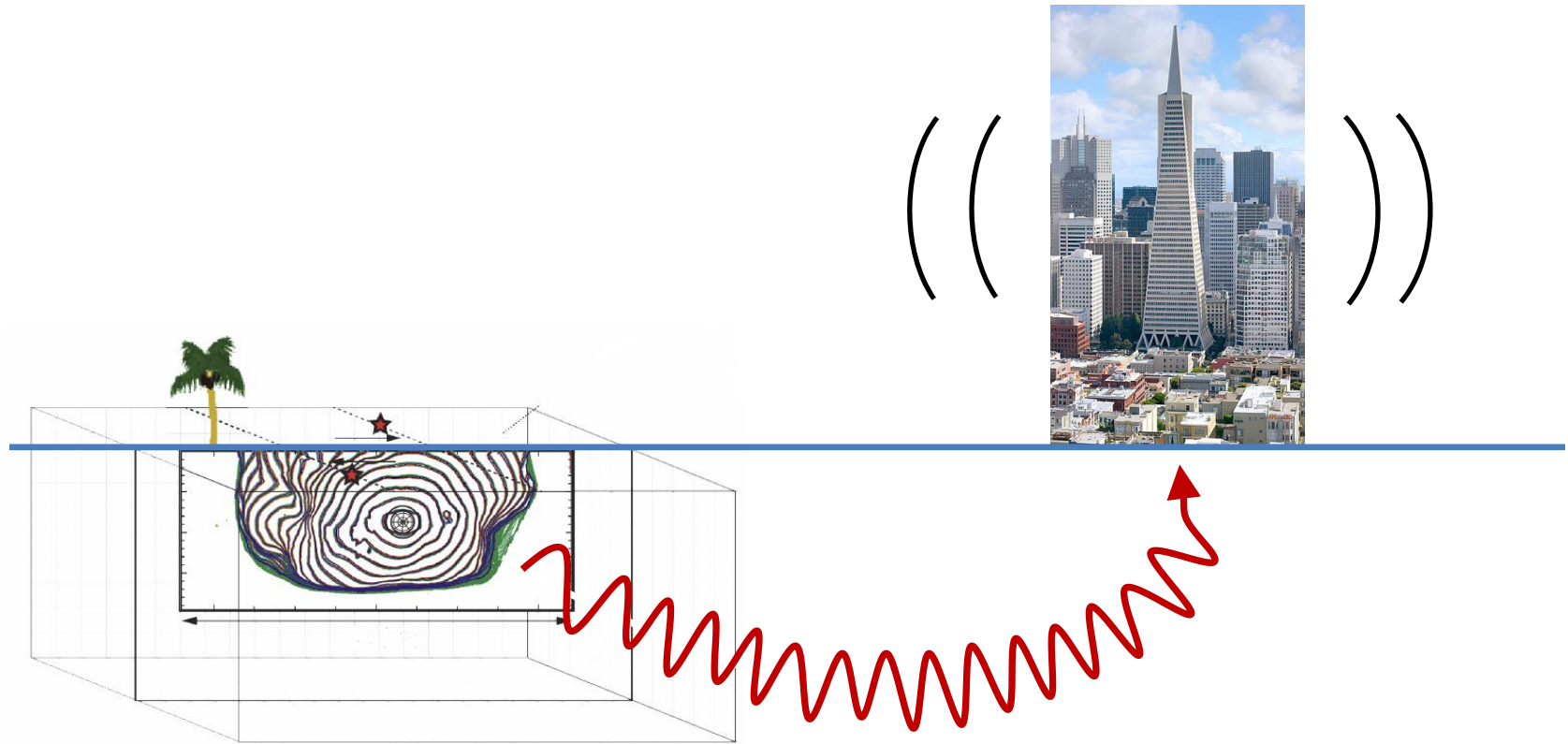
One possible application is a "rupture to rafters" simulation that includes nucleation, rupture propagation, seismic waves, site effects, *and* the shaking of the building and the effects of that shaking on the building systems?

This simulation cannot, and *should not*, all be done with a single code.

Boundary Between Earthquake Simulation and Engineering Practice

Engineers have code for simulating the behavior of structures and sites. They want us to provide inputs to their codes, so we need to define the *boundary* between earthquake simulations and engineering.

Possible boundaries for ground motions:

- Maybe motions at the Earth's surface.

- Large structures have deep foundations, so maybe engineers want motions at the base of the foundation.

  o Good for us, removes some low-velocity surface layers that dynamic rupture code can't handle well.

- Engineers may have models for site complexity and building interactions. So maybe they want motions at a hypothetical, "standard" site.

Conclusions: What Does Validation Look Like?

I think two big things need to happen for us to validate dynamic rupture:

1. There needs to be a lot more contact with engineers (and maybe other potential users):

   - Determine what products users want (waveforms, spectra, probabilities), and how they will be used.

   - Specify the boundary where our job ends, and their job begins.

   - Determine what makes a simulation "good enough" to be used.

   - Figure out how to demonstrate that "goodness" in a way that is convincing to users.

2. We need to move in the direction of a dynamic rupture platform with a defined workflow:

   - The platform would combine one or more dynamic rupture codes with other codes and datasets that are needed to run the simulations.

   - The workflow would define how to use the platform in the desired applications.