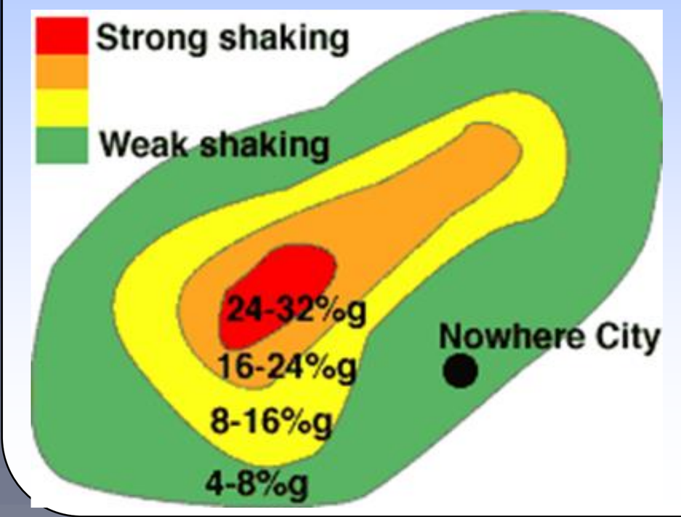

Errors in Seismic Hazard Assessment are Creating Huge Human Losses

1558 Natural Hazards James Bela

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Be Prepared for
The Unpredictable Largest Earthquake

Abstract

"What *can* happen!" *vs* "What is *most likely* to happen?

The current practice of representing earthquake hazards to the public based upon their perceived likelihood or *probability* of occurrence is proven now by the global record of actual earthquakes to be not only *erroneous* and *unreliable,* but also too deadly! More than 700,000 people have now lost their lives (2000 - 2011), wherein 12 of the World's Deadliest Earthquakes have occurred in locations where *probability-based* seismic hazard assessments [*psha*] had predicted only *low* seismic hazard.

Unless Seismic Hazard Assessment [SHA] and the setting of minimum earthquake design safety standards for buildings and bridges are based on a more realistic *deterministic* recognition of "what can happen," rather than on what mathematical models suggest is "most likely to happen," such future huge human losses can only be expected to continue!

The actual earthquake events that did occur were at or near the maximum potential-size event [Maximum Credible Earthquake or MCE] that either: (1) already had occurred in the past; or (2) were geologically known to be *possible.* Haiti's M 7 earthquake, 12 January 2010 (with > 222,000 fatalities) meant the dead could not even be buried with dignity. Japan's catastrophic Tohoku earthquake, 11 March 2011; a M 9 ***Megathrust*** earthquake, unleashed a *tsunami* that not only obliterated coastal communities along the northern Japanese coast [Fig. A], but also claimed > 20,000 lives. This *tsunami* flooded nuclear reactors at Fukushima, causing 4 explosions and 3 reactors to melt down.

But while this history of *Huge Human Losses* due to erroneous and misleading seismic hazard estimates, *despite its wrenching pain, cannot be unlived; if faced with courage* and a more realistic deterministic estimate of "what is possible, "*it need not be lived again!*" *

An objective testing of the results of *global* probability-based seismic hazard maps against *real* occurrences has never been done by the GSHAP team [Global Seismic Hazard Assessment Program, as part of the U.N. International Decade for Natural Disaster Reduction UN/IDNDR, late 1990s] - even though the obvious inadequacy of the GSHAP maps could have been established in the course of a simple check before the project completion.

EPA Photo image

Figure A

Tsunami damage (complete destruction) in M 9 Tohoku, Japan Megathrust earthquake 11 March, 2011.

Too Generous to a Fault?

Is reliable earthquake safety a Lost Art?

Earthquake Name and (Region)	Date	M	Intensity Difference (ΔI_0)	Death Toll
Tohoku or Sendai (Japan)	March 11, 2011	9.0	III (+3.2)	~ 20,000
Southern Qinghai (China)	April 13, 2010	7.0	II (+2.1)	2,698
Port-au-Prince (Haiti)	Jan. 12, 2010	7.3	II (+2.2)	222,570
Padang (Southern Sumatra, Indonesia)	Sept. 30, 2009	7.5	II (+1.8)	1,117
Wenchuan (Sichuan, China)	May 12, 2008	8.1	III (+3.2)	87,587
Yogyakarta (Java, Indonesia)	May 26, 2006	6.3	= (+0.3)	5,749
Kashmir (Northern India – Pakistan border region)	Oct. 08, 2005	7.7	II (+2.3)	~ 86,000
Nias (Sumatra, Indonesia)	March 28, 2005	8.6	III (+3.3)	1,313
Sumatra-Andaman (Indian Ocean Tsunami Disaster)	Dec. 26, 2004	9.0	IV (+4.0)	227,898
Bam (Iran)	Dec. 26, 2003	6.6	= (+0.2)	~ 31,000
Boumerdes (Algeria)	May 21, 2003	6.8	II (+2.1)	2,266
Bhuj (Gujarat, India)	Jan. 26, 2001	8.0	III (+2.9)	20,085

Table 1. Fatal Global Evidence of Recent Large and Catastrophic Earthquake Disasters

List of the top twelve *deadliest* earthquakes occurring during the period 2000 – 2011, and the corresponding Intensity (of shaking) Difference (**ΔI_0**) between the observed values **$I_0(M)$** and those predicted by the Global Seismic Hazard Assessment Program or GSHAP. **ΔI_0** is computed from the observed magnitude **M** and the maximum Peak Ground Acceleration (**PGA**) values given by GSHAP Maps around the observed epicenter:

$$\Delta I_0 = I_0(M)\ \text{[observed intensity]} - I_0(mPGA)\ \text{[GSHAP predicted intensity]}$$

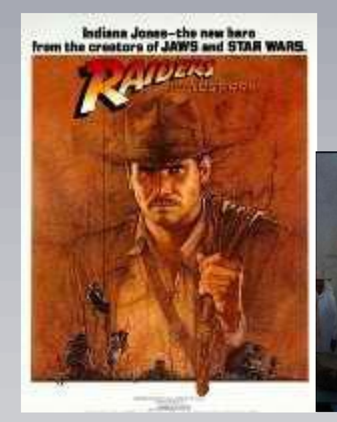
Roman numerals III (+ 3.2) give the *difference* in numerical values of macroseismic (felt and damage level) intensity. For 9 out of 12 events the GSHAP values severely *underestimated* the observed ones: $\Delta I_0 \geq$ II – IV (+ 2 - 4) intervals on the European Macroseismic Scale **(EMS).**

Summary: These data show that **seismic hazard** was largely *underestimated* by the Probabilistic Seismic Hazard Assessment (PSHA) in particularly five of the largest magnitude earthquakes of M 8 and above. And if we include the January 17, 1995 M 7 Kobe earthquake (5,502 killed, 36,900 injured and extensive damage) in the list, we see Japan was hit by two "surprises" in just the past 20 years.

(modified *after* Kossbokov and Nekrasova, 2010; and Panza, Peresan and La Mura, 2013.)

THIS IS ALL MY FAULT REALLY

What went Wrong?



In director Steven Spielberg's classic adventure movie, **Raiders of the Lost Ark** (1981), Indiana Jones (Indy) is confronted by a bedazzling *mega*-knife wielding Arab swordsman in a black robe. With the Arab apparently ready to "slice-and-dice" the seemingly doomed and out-knived Indy, to everyone's surprise and amusement, Indy calmly *unholsters* his gun and *blam!* . . . fells the menacing swordsman with one shot (generating the biggest laugh of the movie)!

Our sense of surprise comes from both the fact that: **(a)** "we didn't see it coming," and also **(b)** our sense of fairness *presumes* that Indy will rebuff and overcome the challenge with the same or similar hand-to-hand weaponry as his antagonist, perhaps his famous bullwhip.

Heh, heh, heh!

Over the last 11+ years, since the beginning of the year 2001, it has seemed to an ever - growing number of earthquake hazards' experts and professionals that a *global* epidemic of "maximum possible earthquake" events has overwhelmed similar seemingly defenseless populations, whose incomplete and really "incorrect" seismic hazard estimates had predicted only ***low*** (knife-wielding) earthquake-shaking seismic hazards (what was "most likely" or *probable*)–only to be blown away by the seismic equivalent of Jones' Smith & Wesson revolver (or in the example of the very largest unexpected human losses–such as in Haiti 2010, with human losses probably somewhere over 220,000 - a shotgun blast!). See *Table 1. Fatal Global Evidence of Recent Large and Catastrophic Earthquake Disasters (← left).*

"People count up the faults of those who keep them waiting."

What happened? And why did this happen, not just *once*, but many, many times over just these last dozen + years? The late Nobel laureate in physics (1965) Richard Feynman, in dissenting from the official report following the 1986 Challenger Space Shuttle disaster, had made clear that he believed NASA had greatly ***underestimated*** the technological risks, when it had decided to launch on that cold January morning – despite warning not to do so. And throughout his distinguished career, Feynman liked to remind both himself and others:

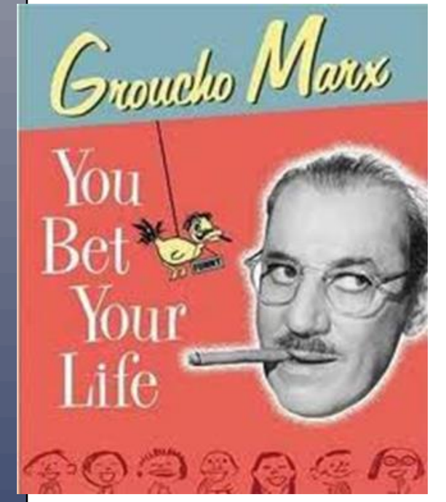
"It doesn't matter how *beautiful* your theory is; it doesn't matter how *smart* you are; if it doesn't *agree* with experiment, it's *wrong!*"

In the late 1990s, as a part of the U.N. International Decade for Natural Hazard Reduction UN/IDNDR Global Seismic Hazard Assessment Program (GSHAP), seismic hazard maps had been prepared. These maps portrayed earthquake hazards by map contours: showing the peak ground acceleration pga (as a fraction of g – the acceleration due to gravity) with a 10% *probability* of being exceeded in 50 years. An acceleration of 30% g (0.3 g) is about what one experiences making their way down the aisle of an airplane experiencing moderate turbulence, when one has to hold onto the seats in order to maintain their balance. Think of 30% g as a third of your mass trying to push you *sideways*.

Although the hazard maps only really actually represented the "likelihood" of earthquake shaking as a percentage of g (%g), or gravity, they were (as was similarly assumed in the Space Shuttle Challenger example) also most generally inferred as also categorizing the earthquake ***risk*** to populations as well. This was because, unlike a simple 50-50 flip of the coin (a clear-cut "yes" or "no"), there was a presumed 90% chance of their *not* being exceeded.

But although *hazard* and *risk* are often used interchangeably, it is not only useful, but also necessary, to distinguish the two. **Hazard** can be thought of as the chance (i.e., likelihood or *probability*) of something bad happening - regarding some physical phenomenon that can harm you. **Risk** reflects the *consequences* of that phenomenon, as may be seen in this simple Risk Equation:

Risk = Hazard (Threat) x Vulnerability x Value (Cost).



Say the *secret* word and win $100!

If I bet you **$5** a tossed coin will come up ***heads***, you might take that bet?

But if I then bet you **$10,000** that it comes up ***tails***, you *probably* wouldn't!

The *probabilities* are still the same . . .
but what has changed are the ***consequences!***

Wanna Bet???

Conclusions

The GSHAP maps were derived from *probabilistic seismic hazard analysis* or *psha*. These are in contrast to a deterministic (or scenario-derived) seismic hazard assessment, dsha, which considers the seismic effects from one maximum potential earthquake scenario (Indy's Smith and Wesson) on a specific fault source located near a population center. The *probabilistic* method determines the "expected effects of all seismic source volumes within the vicinity of the point of interest," by considering both their likelihood (periodicity of occurrence of individual fault sources) and their distances away from the site. It had been presumed that, since such *psha*-derived seismic hazard maps "are supposed to account for all possibilities," they could representatively "form the basis of the assessment of the seismic risk for critical facilities and for the population."

The most recent example where the PSHA method and maps did not successfully capture the occurrence of a major devastating earthquake was in the 11 March 2011 M 9 Tohoku earthquake in northeastern Japan. A cascade of "more bad things" followed the *megathrust* earthquake and its more deadly tsunami, culminating in the *radiation* or "silent enemy" unleashed by reactor core meltdowns at the Fukushima nuclear power plants. When consulting northeastern Japan's *probabilistic* seismic hazard map, the earthquakes occurred "in areas where they were least expected and no large earthquake happened in the regions marked red for danger."

"For a successful technology, *reality* must take precedence over public relations, for *Nature* cannot be fooled."

- Richard Feynman

Given the "errors in expected human losses due to incorrect seismic hazard estimates" revealed globally in these past performances of the **GSHAP** maps, we need to ask the following: (a) "Is reliable earthquake safety a *lost art?;"* and who and what were the **"Raiders of the Lost Art?**;" (b) Is "fatalism of the inevitable" (the belief that people cannot change the way events will happen and that especially bad events cannot be avoided) to remain the norm for explaining and accepting these *rare* but *deadly* events?; (c) Has our over-reliance on an *unsuccessful* technology (as "the standard method" for performing *seismic hazard analysis*) been directly to blame for such tragic results?; and (d) Has our "failure to warn" been the result of "the absence of information," or more simply and more directly . . . due to "the ***wrong*** information?"

Following each painful and tragic humanitarian loss, more and more earthquake professionals have been calling for a new way forward, saying: We should use **deterministic**, not *probabilistic*, seismic hazard maps to more realistically "estimate the risk to which the population is exposed due to large earthquakes."

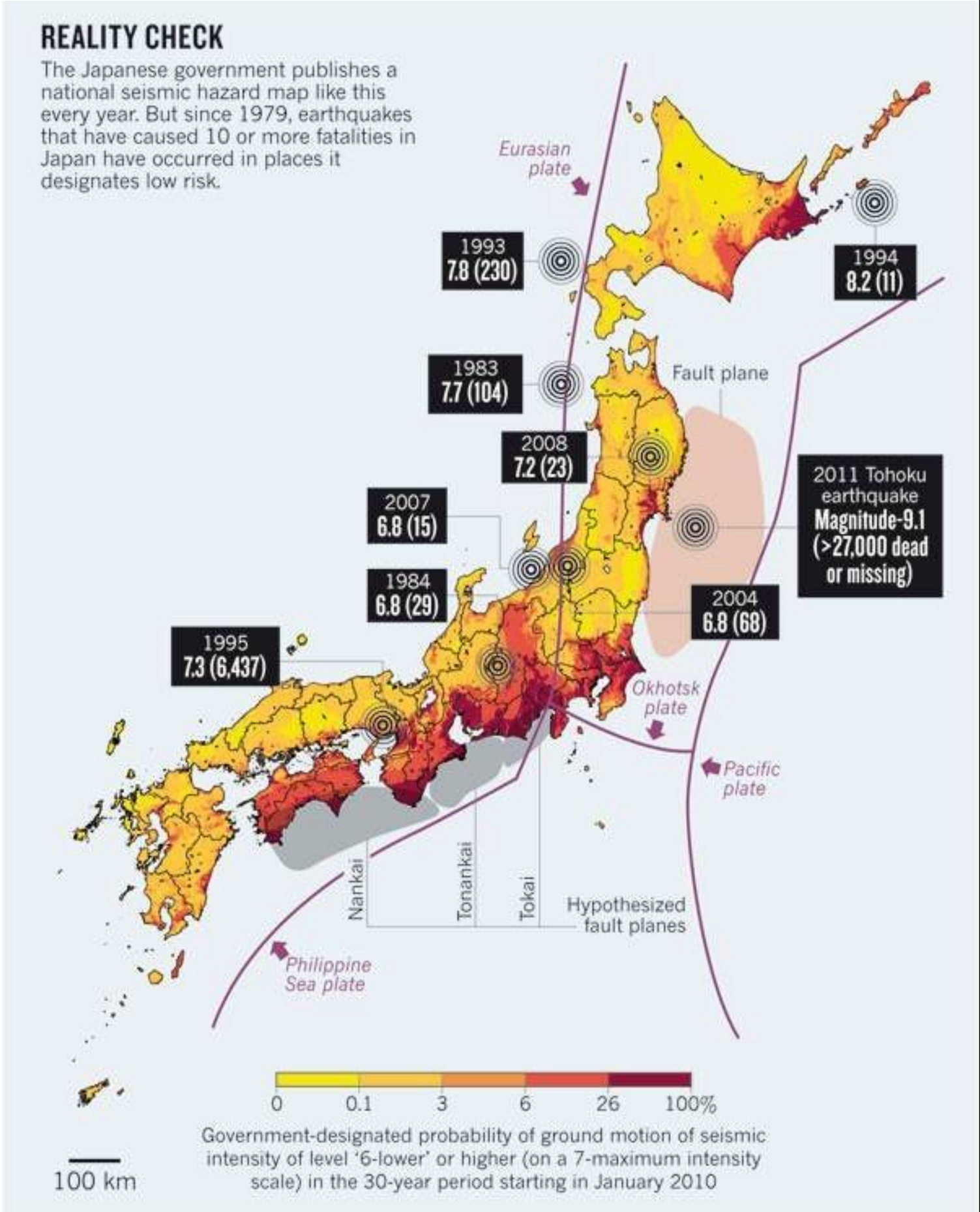
In ***deterministic*** or ***scenario*** seismic hazard assessment, the **bottom line** is the ~~**fault**~~ line! Design for what is ***possible***, and not just for what is ***probable!*** In any economic or cost-benefit analysis, consider the benefit of *avoiding* or ameliorating what *can* happen, not just what seems *most likely* to happen. "When considering two sites, A and B, prone to earthquakes with the same magnitude, say *M = 7*, given that all the remaining conditions are the same, the site where the recurrence is lower appears naturally preferable: nevertheless, parameters for seismic design must be equal at the two sites, since the expected magnitude is the same *(M = 7).*" *

The **PSHA** methodology (a derived mathematical model), despite its dominance today as "the standard method" for performing seismic hazard assessments and analysis is fundamentally flawed: it is a complicated numerical creation without any strong physical realities in earthquake science and earthquake physics. And it uses a *dimensionless* number, the probability in one year, incorrectly as a dimensional (or per yr) "annual frequency" term related to earthquake ground motions, with which it estimates a so-called earthquake return period. This is equivalent to tossing that coin (*fifty-fifty* probability mentioned previously) . . . and *forgetting* that a **Heads** *or* **Tails** can happen at any time!

Quite simply, psha has consistently failed to disclose "what is possible," in preferential deference to what its methodology [or maybe *mythology*] concludes to be "most likely" or probable. However, because large earthquakes (which are the most damaging and the most deadly) are by their very natures "rare events," the *probabilities* surrounding them are not very *reliable.* Indeed, for protecting public safety, "sometimes it's good to know just how big your zero is!" The **DSHA** methodology, which has a long history of successful use in California *bridge* and *building* design, can *consistently* alert at risk populations to "what is possible" – for this ultimately determines their true earthquake *risks* and, more importantly, their true chances for *survival!*

American poet and novelist Maya Angelou (1928 - 2014) has captured both the essence and the lessons from these GSHAP maps' failures:

"History, despite its wrenching pain, cannot be unlived, but if faced with *courage*, need not be lived again."



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And *"that,"* says Indiana Jones, "depends on how *reasonable* we're all willing to be."

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[IBC-12.13 FIGURE 1613.3.3.1 (1)(2)(3)(4)(5)(6)_.doc]

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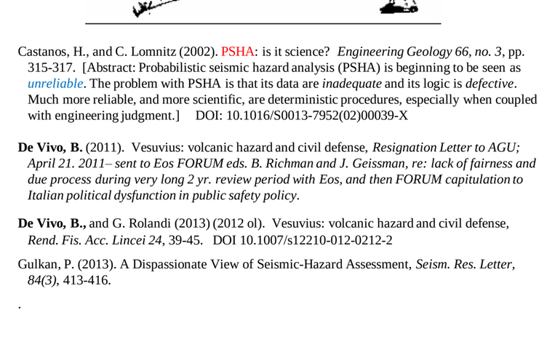
"To be sure of hitting the target, *shoot first*, and call whatever you hit the target."



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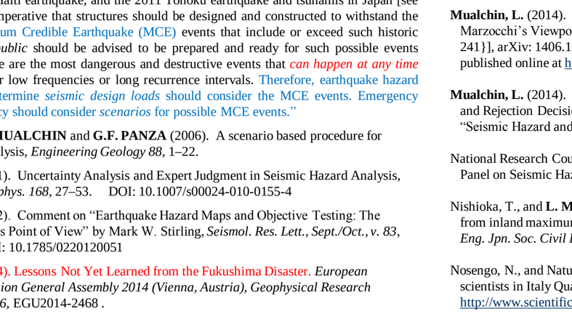

"In view of the devastation produced by large earthquakes and associated phenomena exemplified by the 2004 Sumatra earthquake and tsunamis, the 2008 Wenchuan earthquake in China, the 2010 Haiti earthquake, and the 2011 Tohoku earthquake and tsunamis in Japan [see *Table 1*] , it is imperative that structures should be designed and constructed to withstand the largest or Maximum Credible Earthquake (MCE) events that include or exceed such historic events; and the *public* should be advised to be prepared and ready for such possible events *beforehand.* These are the most dangerous and destructive events that *can happen at any time* regardless of their low frequencies or long recurrence intervals. Therefore, earthquake hazard assessment to determine *seismic design loads* should consider the MCE events. Emergency management policy should consider *scenarios* for possible MCE events."

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"We have nothing to fear but *shear* itself."
"We're all *subducting* in this together."
"Do not look back in anger, or forward in fear, but around in *awareness.*"

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