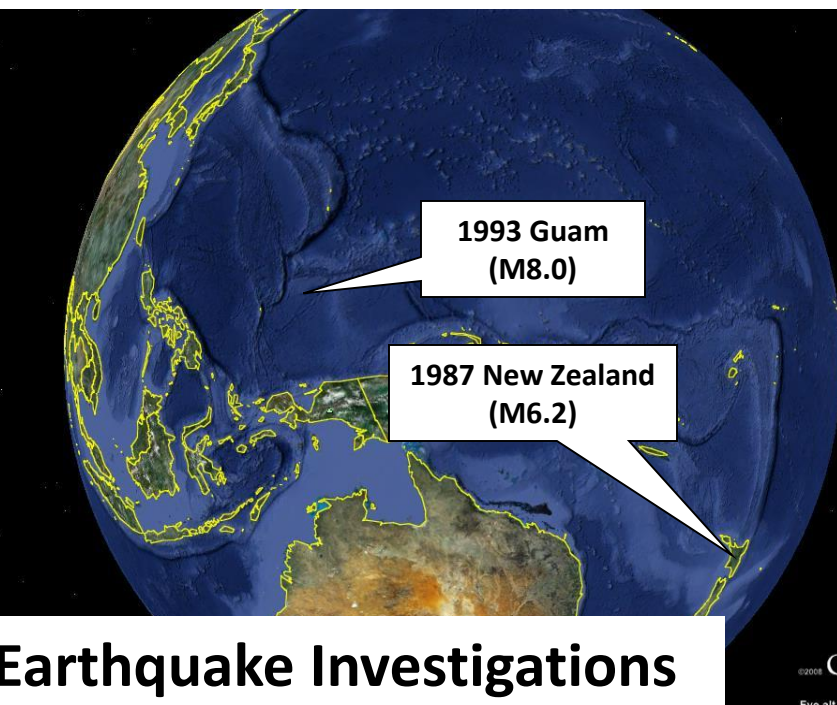
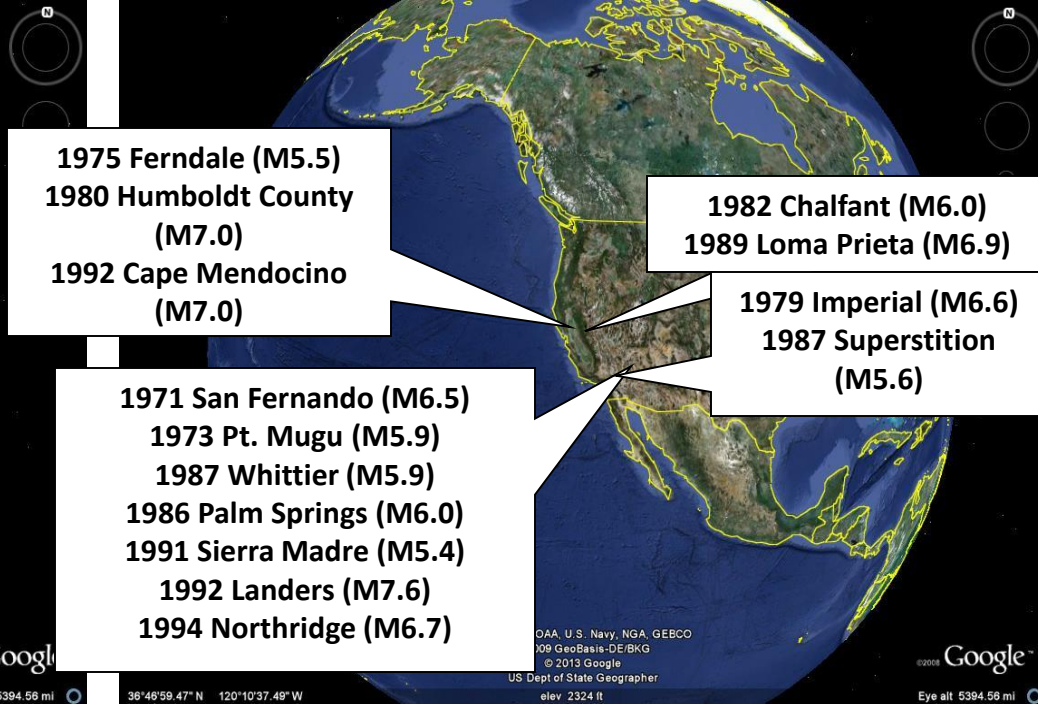
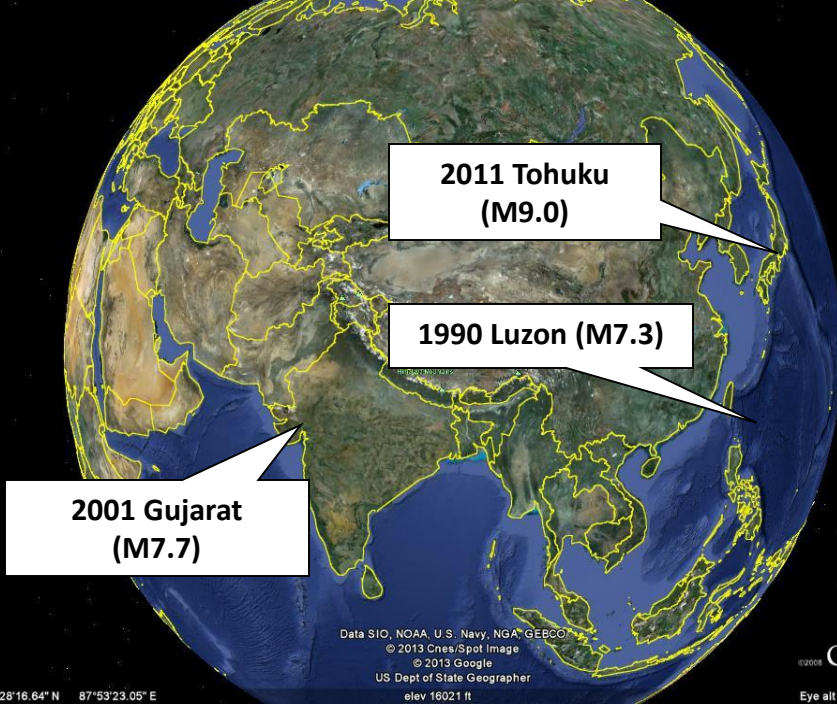


Seismic Fragility Functions Based on Actual Earthquakes

Sam Swan

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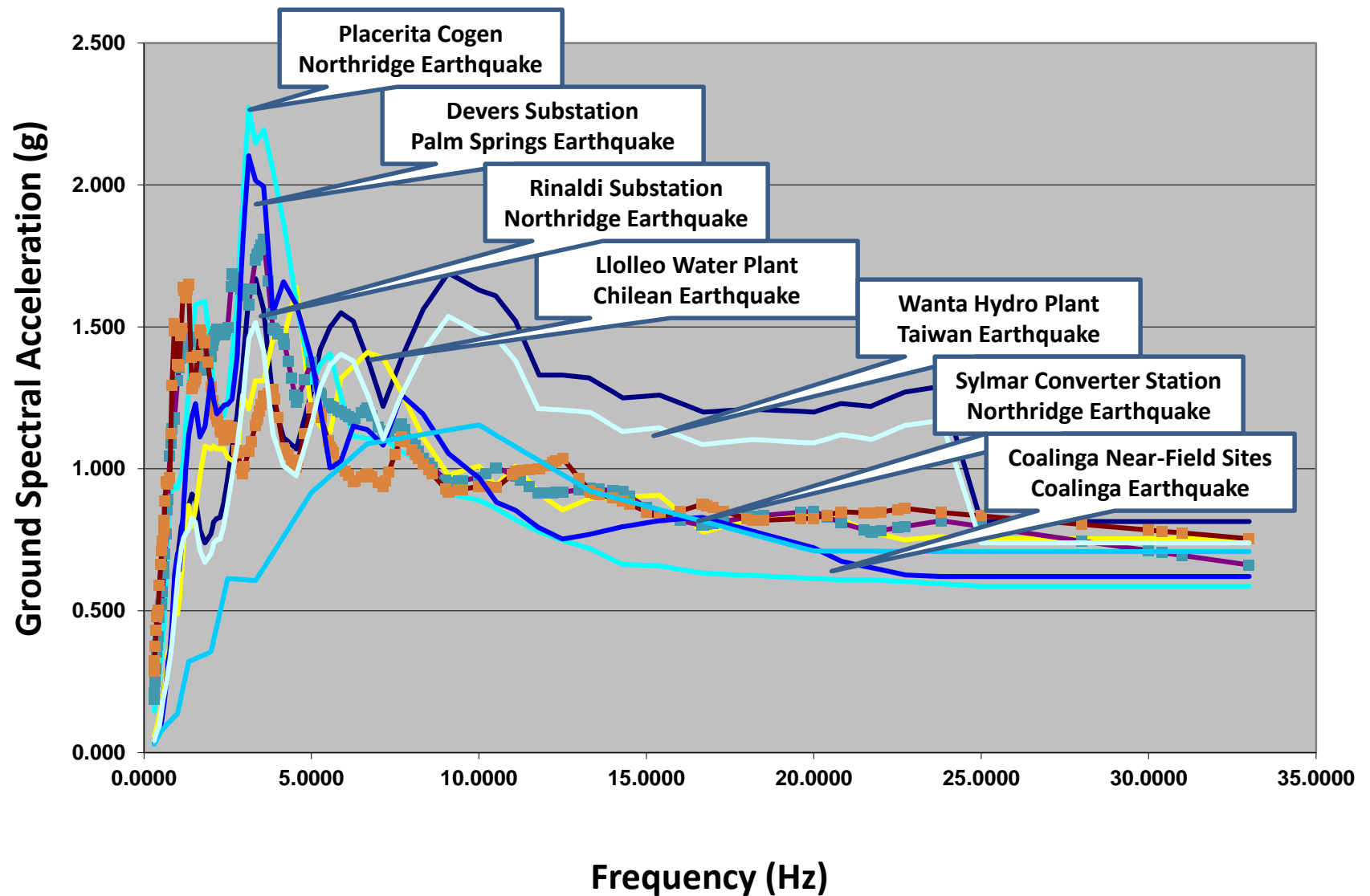


Earthquake Investigations

Some of the Data Sites

	0.60 – 0.80g	0.50 – 0.60g	0.40 – 0.50g	0.35 – 0.40g	0.30 - 0.35g	0.25 – 0.30g	0.20 – 0.25g	0.10 – 0.20g
	Onagawa	Anjar	Manzanillo	Trinidad	Oxiqim	Fertimex	Piti	Valdivia
	Horcones	Madhapar	Takuan	Watson Waste	Con Con	Sicartsa	Guam Water	La Villita
	Constitucion	20 Micron	Watkins	Metcalf	Guam Sewage	Guam Diesels	Orote Point	El Infiernillo
	Licancel	Ballapur	Centerville	Cool Water	Watson Telco	Petacalco	Cabras	Ugama
	Trupan	Bagio Teleco	Valley Steam	El Centro	Mitsubishi	Adak	Las Ventanas	Harmon
	Nueva Aldea	Bata Shoes	Palco	Green Giant	Lipton	Santa Teresa	Rapel	Tanguisson
	Olive View	Soquel	Great West	Cool Water	Moss Landing	San Mateo	San Manuel	Pasadena
	Sylmar	Coalinga Water	Pitchess	San Luis	Castaic	Cardinal	Cabanatuan	Ormond
	Rinaldi	Pleasant Valley	Placerita	Santa Cruz Tel	Mingtan	EPRI HQ	Monte Vista	Hunters Pt
	Arco Cogen	Watson Water	UCSC	Seagate	Kosekoy	Burbank	Gates	Mesquite
	LLoleo	Changuinola	Santa Cruz H2O	Gilroy	National	Glendale	Kettlemen	Poterero
	Getty	Techi	Andapazari	Humboldt	Pakayama	Drop IV	Dededo	Del Amo
	Shell Water	Wanta	Ticor	Sanwa	Renca	Newberry	Yigo	Grand Central
	Union Oil	NZ Distillery	SCE HQ	Commerce	Tienlun	Whakatane	Mirassou	Lone Star
	Shell Tanks	Edgecumbe	SCE Dispatch	Kawerau	San Martin	Matahina	Puente Hills	Laguna Verde
	Whitewater	Moin	Caxton	Cal Fed	Rinconada	Hi Head	Mesa	Cachi
	Devers	White Trout	Alhambra	Wells Fargo	San Antonio	Pfizer	Center	Nu Cemento
	Olinda	Painted Hills	Soyopango	Rosemead	Rio Acehuate	Goodrich	Lighthype	SEGS

Ground Motion Response Spectra from Database Sites



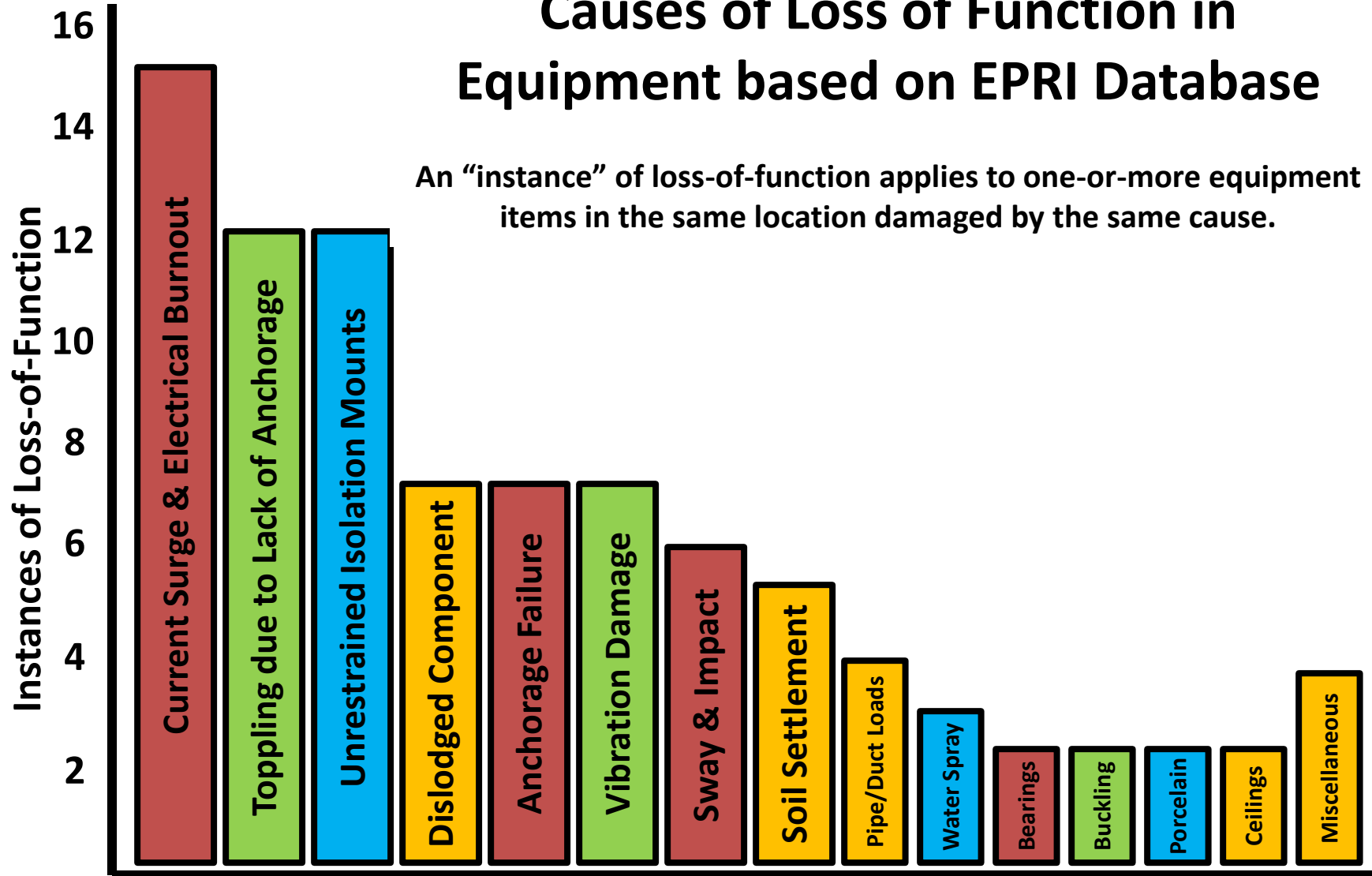
The Most Important Information Comes from Failure

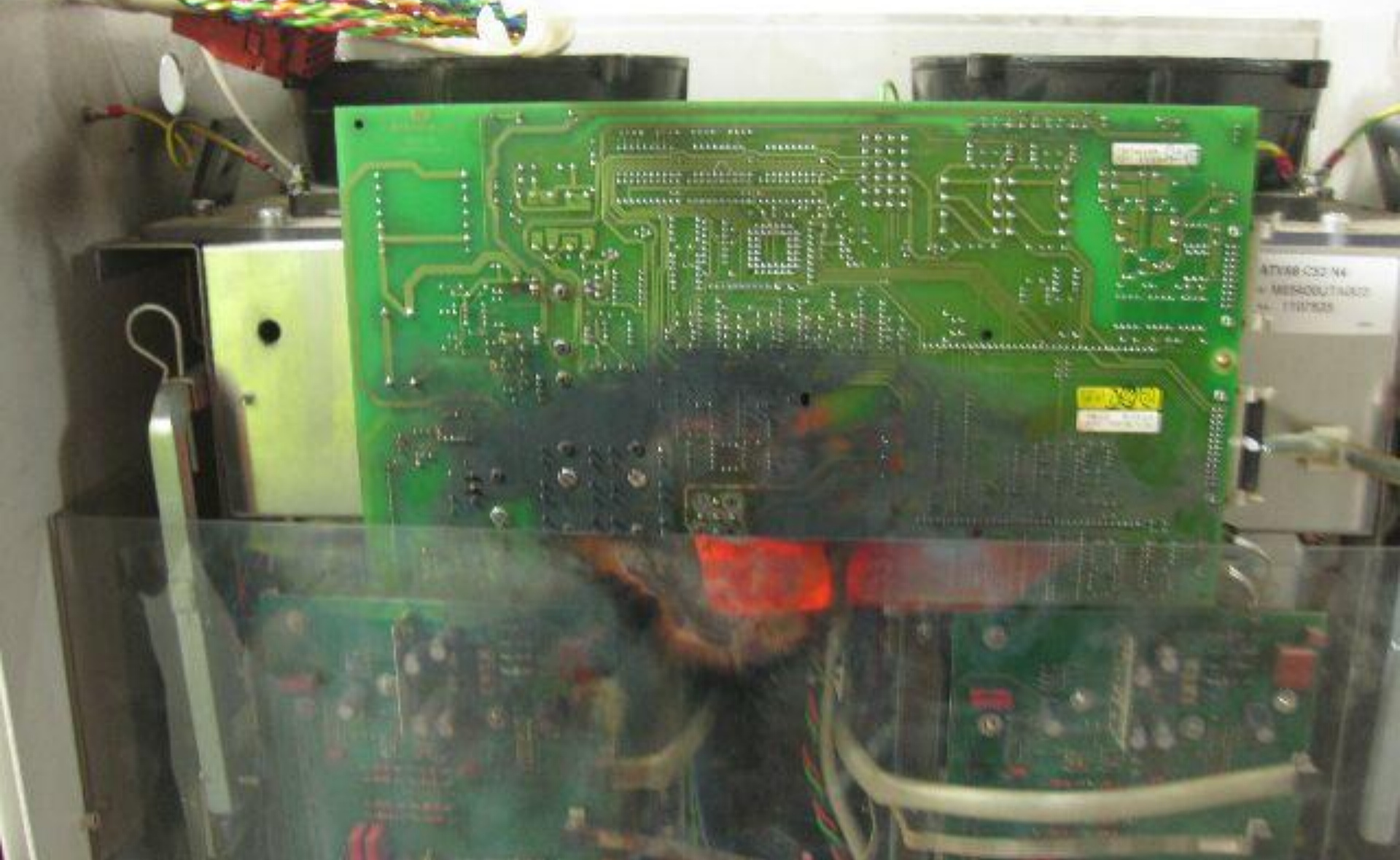


Overall earthquake failure rate for some 22 categories of mechanical, electrical & electronic equipment: 2 – 3% , i.e., on the order of 100 failures of out ~4,000 items of equipment. Perhaps half of failures might apply to nuclear plant equipment installations.

Causes of Loss of Function in Equipment based on EPRI Database

An “instance” of loss-of-function applies to one-or-more equipment items in the same location damaged by the same cause.



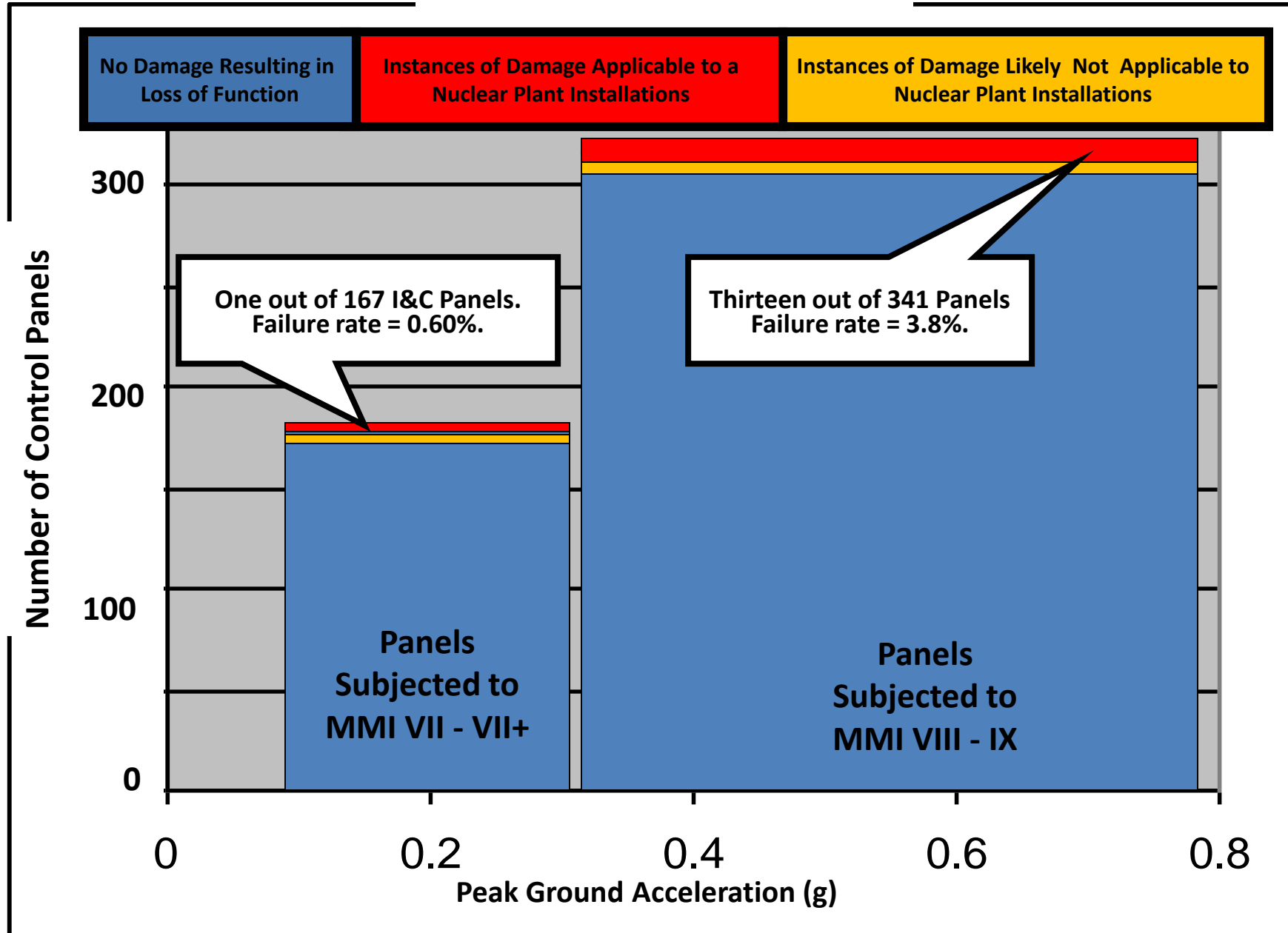


**Most Common Earthquake Failure:
Current Surge Burn-Out:
Fifteen Instances of Failure**

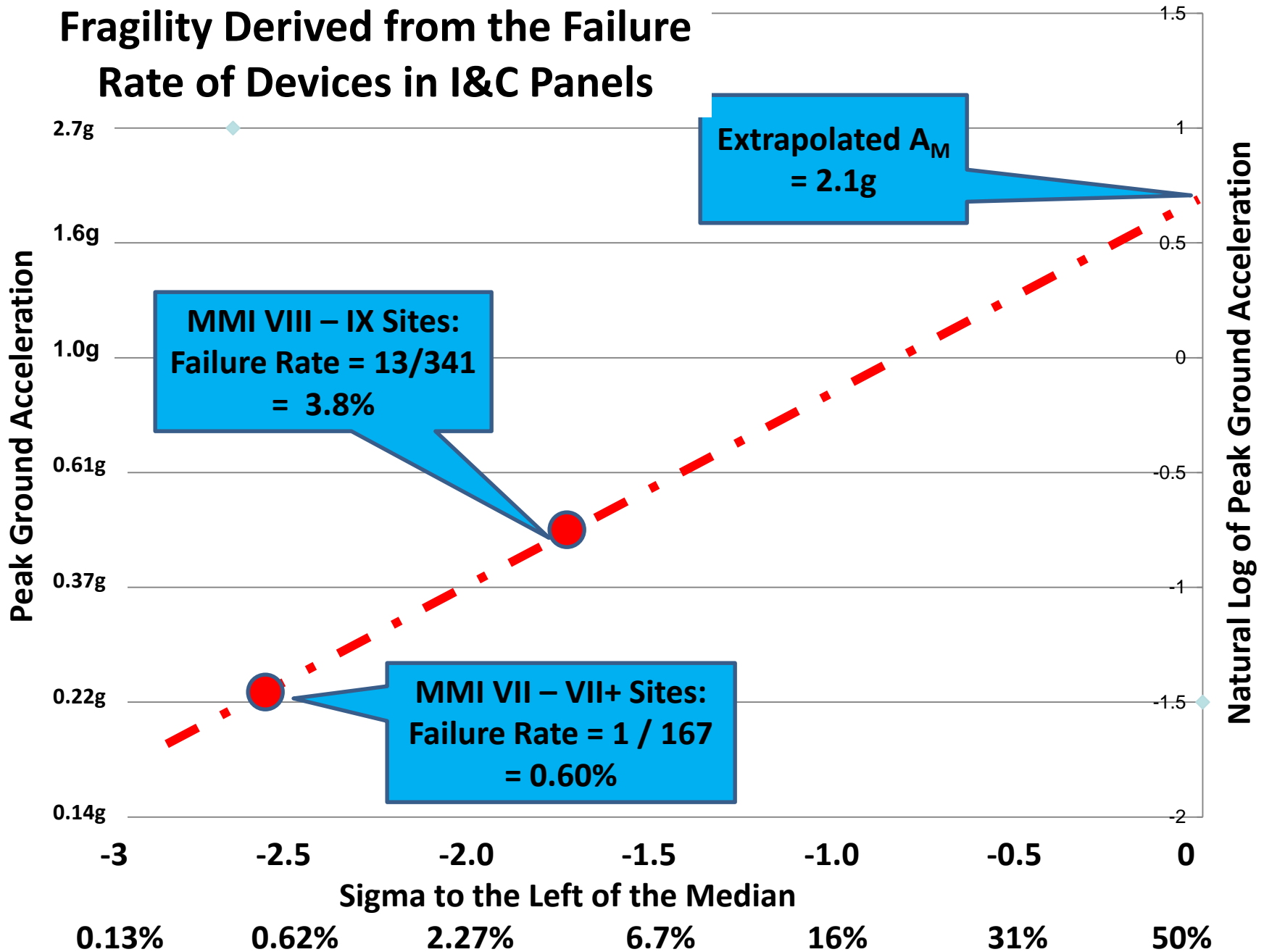


**Example Category
of SSC:
Instrument & Control
Panels**

Instrument & Control Panels

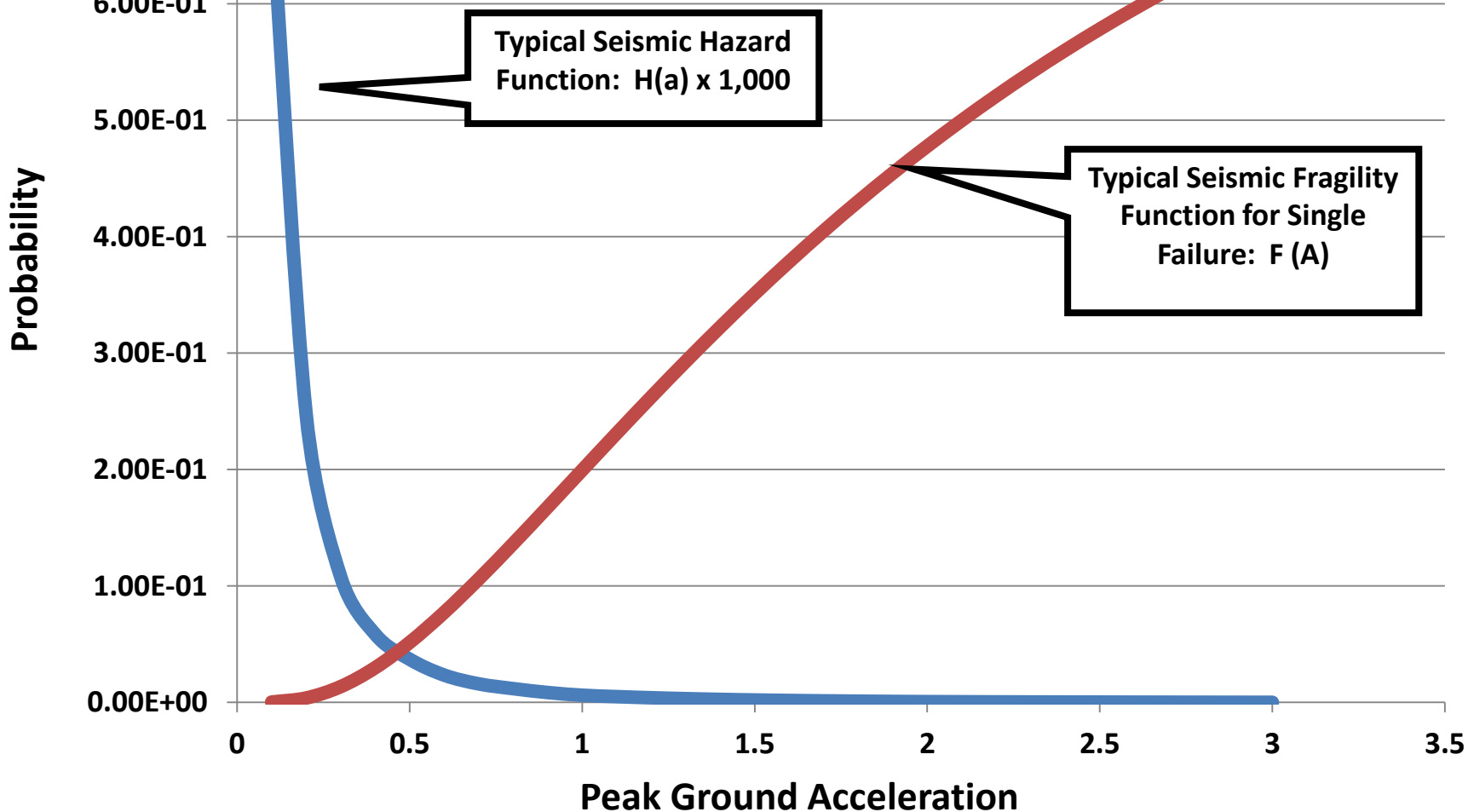


Fragility Derived from the Failure Rate of Devices in I&C Panels

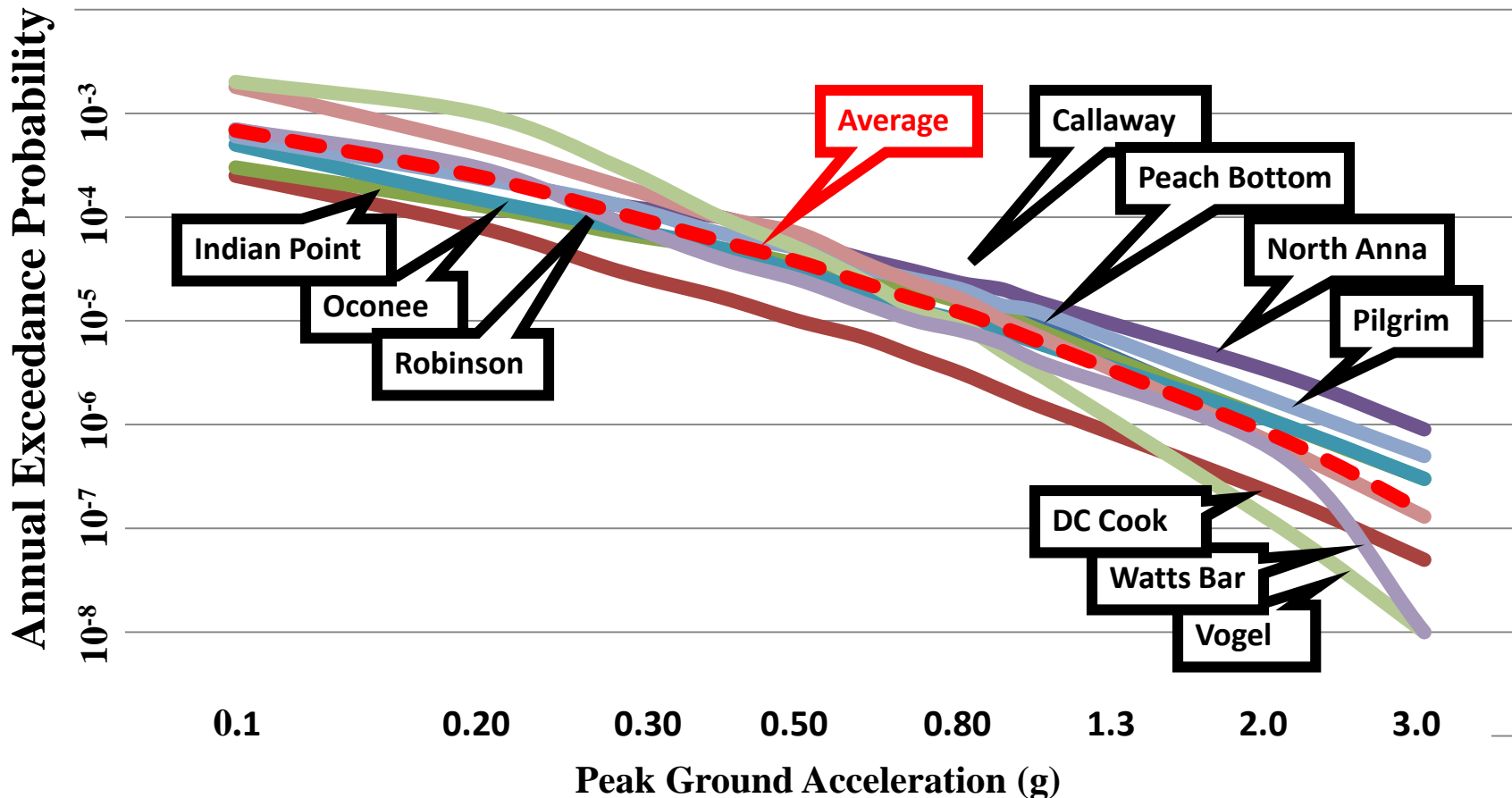


The Contribution to Core Damage Frequency (CDF) of any SCC is the Convolution of the Site Seismic Hazard Function and the SSC

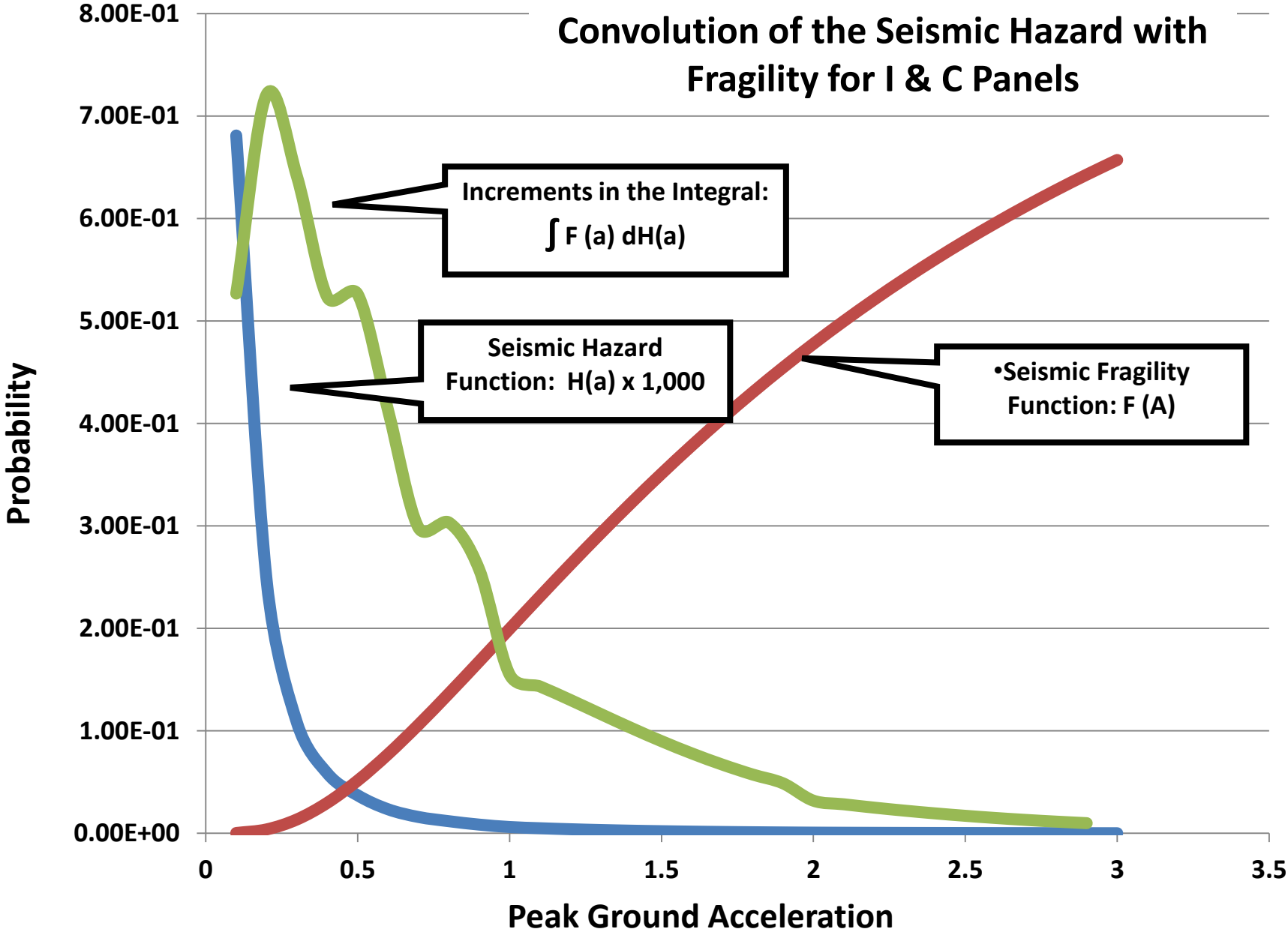
$$\text{Fragility Function: } \int F(a) dH(a)/da da$$



Seismic Hazard Functions for the Ten Nuclear Plant Sites Rated by the NRC as Priority 1



Convolution of the Seismic Hazard with Fragility for I & C Panels



Observations & Conclusions

- For seismic fragility functions, $F(a)$, anchored to actual earthquake experience, the contribution to the convolution integral, and hence the contribution to core damage frequency, is minor above $\text{PGA} \approx 1.0g$.
- Only $F(a)$ in the range of about $0.20g - 1.0g$ is of importance. This is the range where fragility is shaped by failure rates observed in actual earthquakes, and the range of representation by the earthquake database.

“The problem is we don’t design nuclear plants to withstand earthquakes; we design them to withstand finite element analysis.”

-- Enrico Fermi, 1939