Keeping ISRS Within Reason

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Outline

- Background: case study and seismicity
- Very high ISRS demands
- Contributions to high demands
- Explicit modeling of components indicate significantly lower demands
- Recommendations for ISRS reduction and further study

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Case Study Building

- Proposed, large-scale facility for the Department of Energy
- At the Y-12 site in Oakridge, TN
- Rock site - resulting project spectra with high energy content in upper frequency (>10 Hz) ranges.

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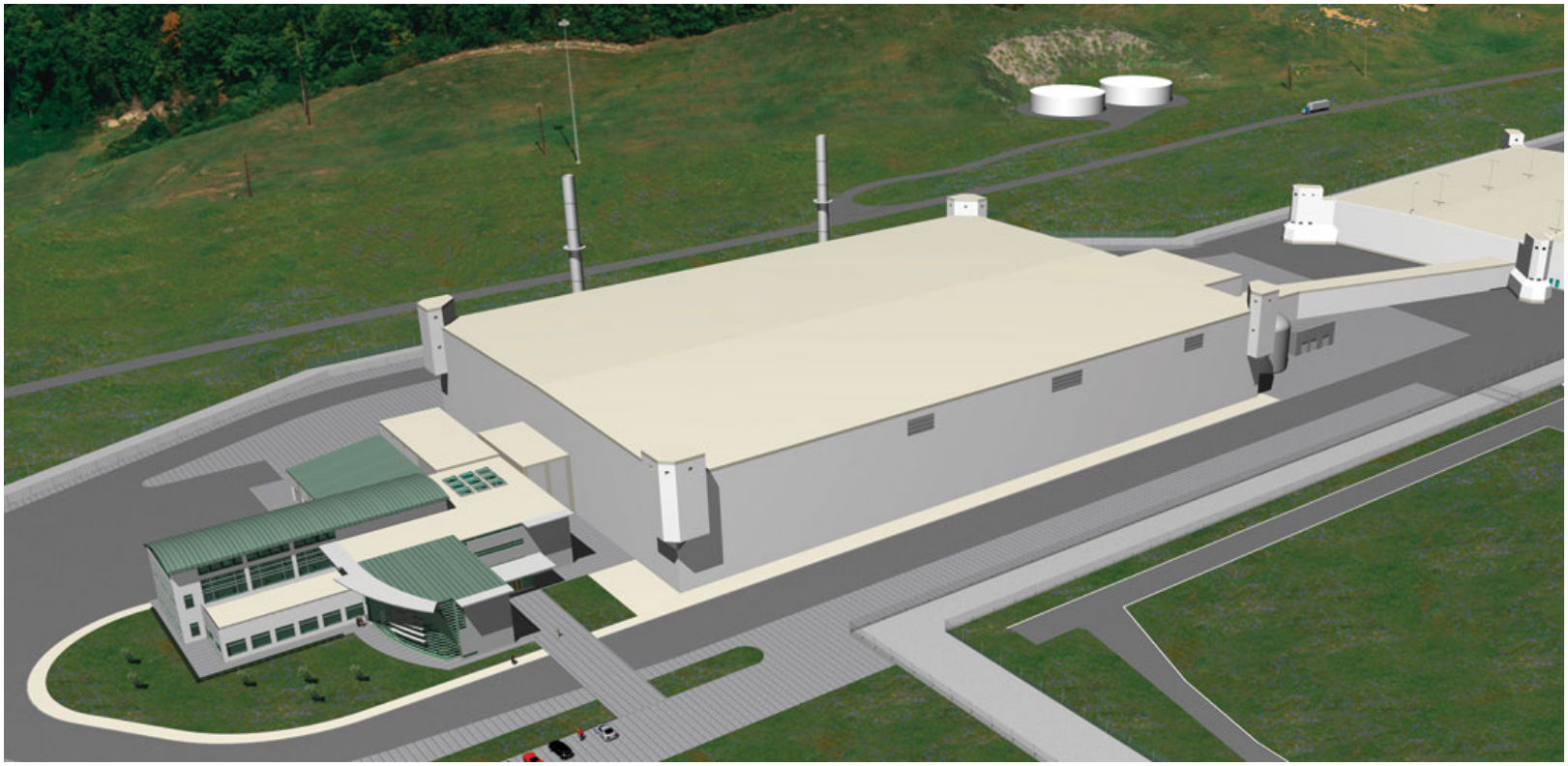
Case Study Building



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Case Study Building

- Heavily Reinforced Shear Wall Building
- 80’ tall by 300’ x 500’ in plan
- Formed slabs spanning to steel beams and girders supported on steel columns and concrete walls
- Roughly 350,000 SF with three levels
- Utility grid below roof originally designed with hangers at 10’ in both directions

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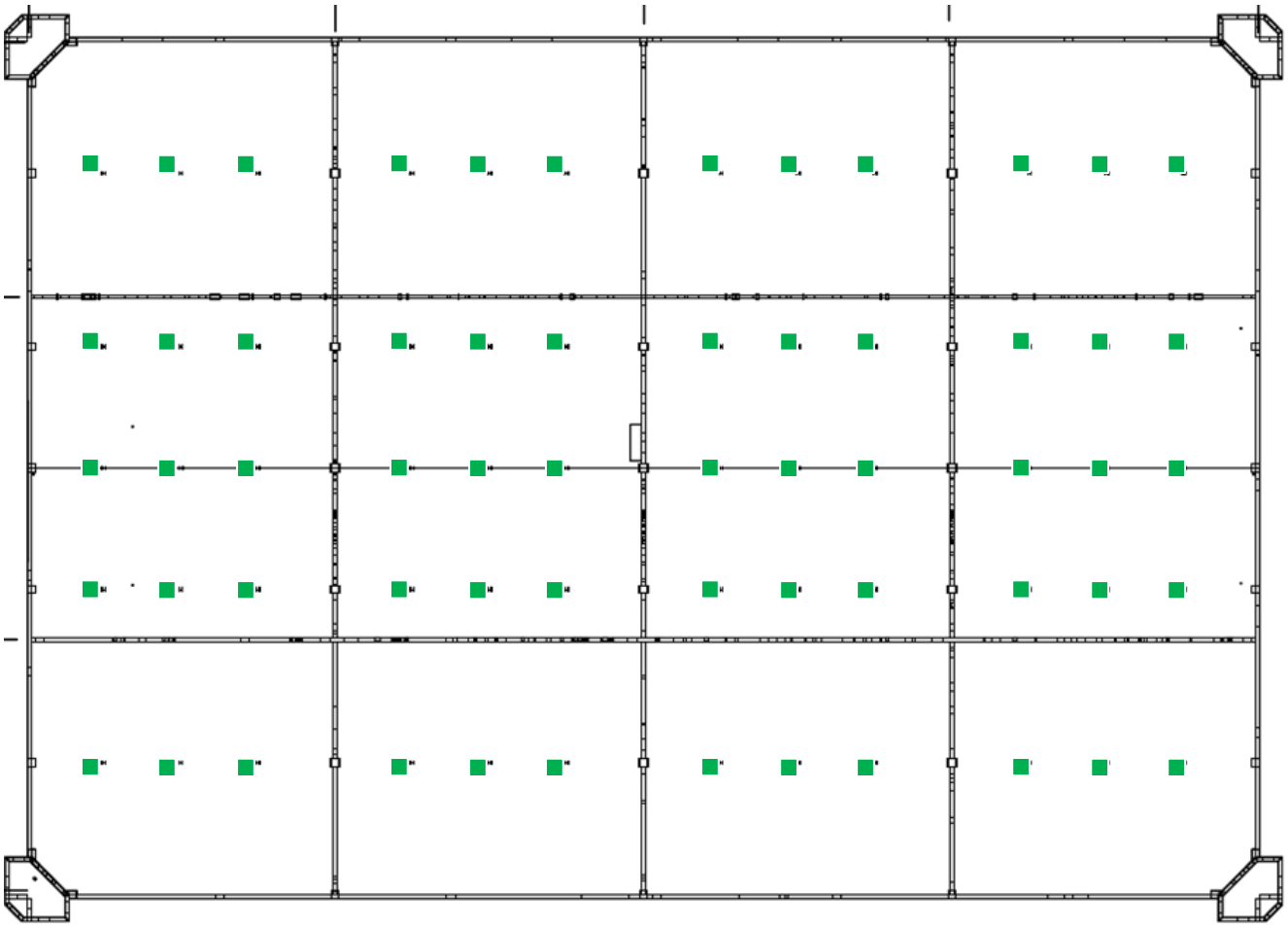
Building Layout



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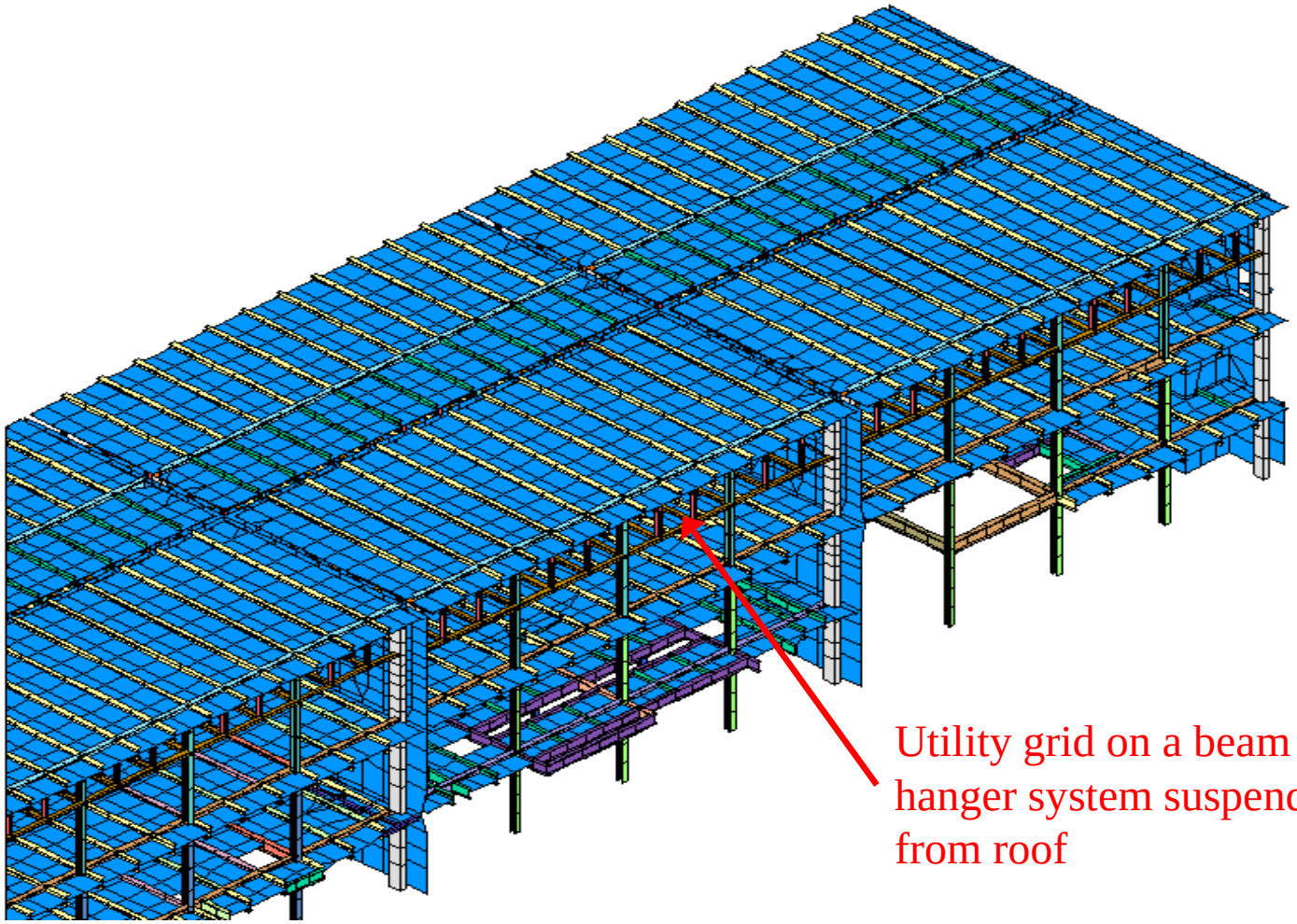
Utility Grid



Utility grid on a beam and hanger system suspended from roof

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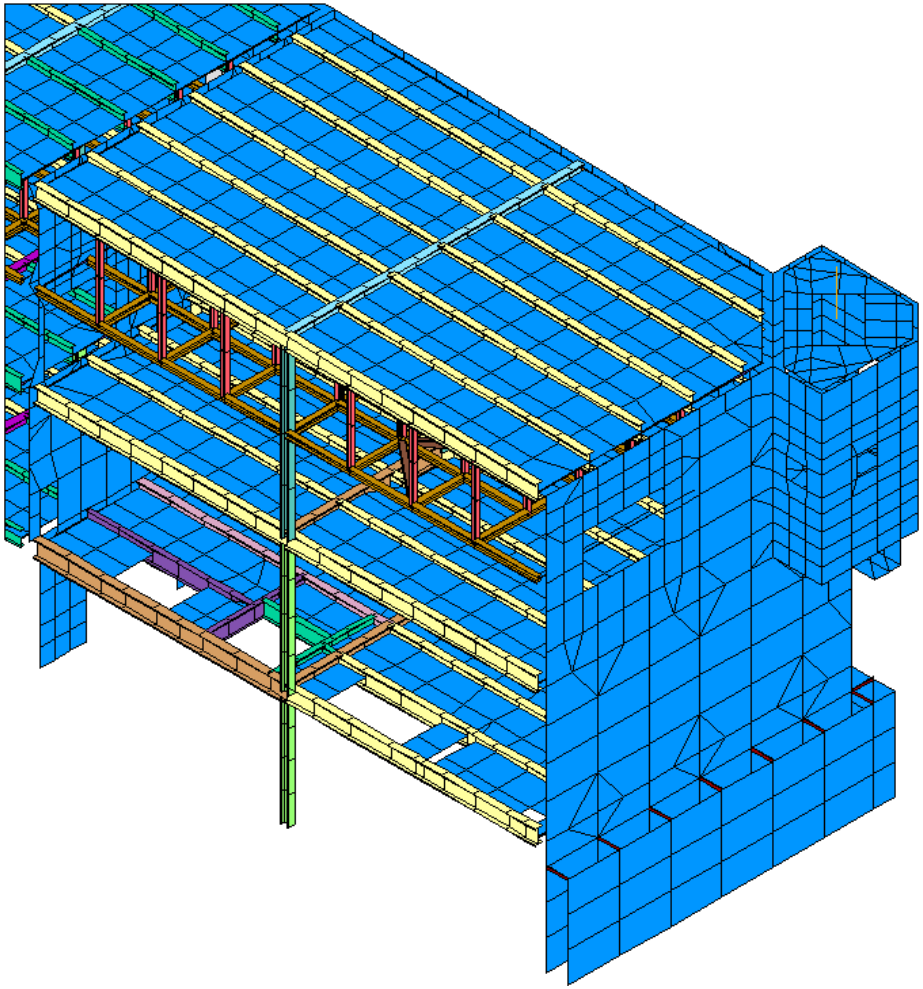
Utility Grid

- A full utility grid eliminated the use of diagonals in a potentially very congested space.



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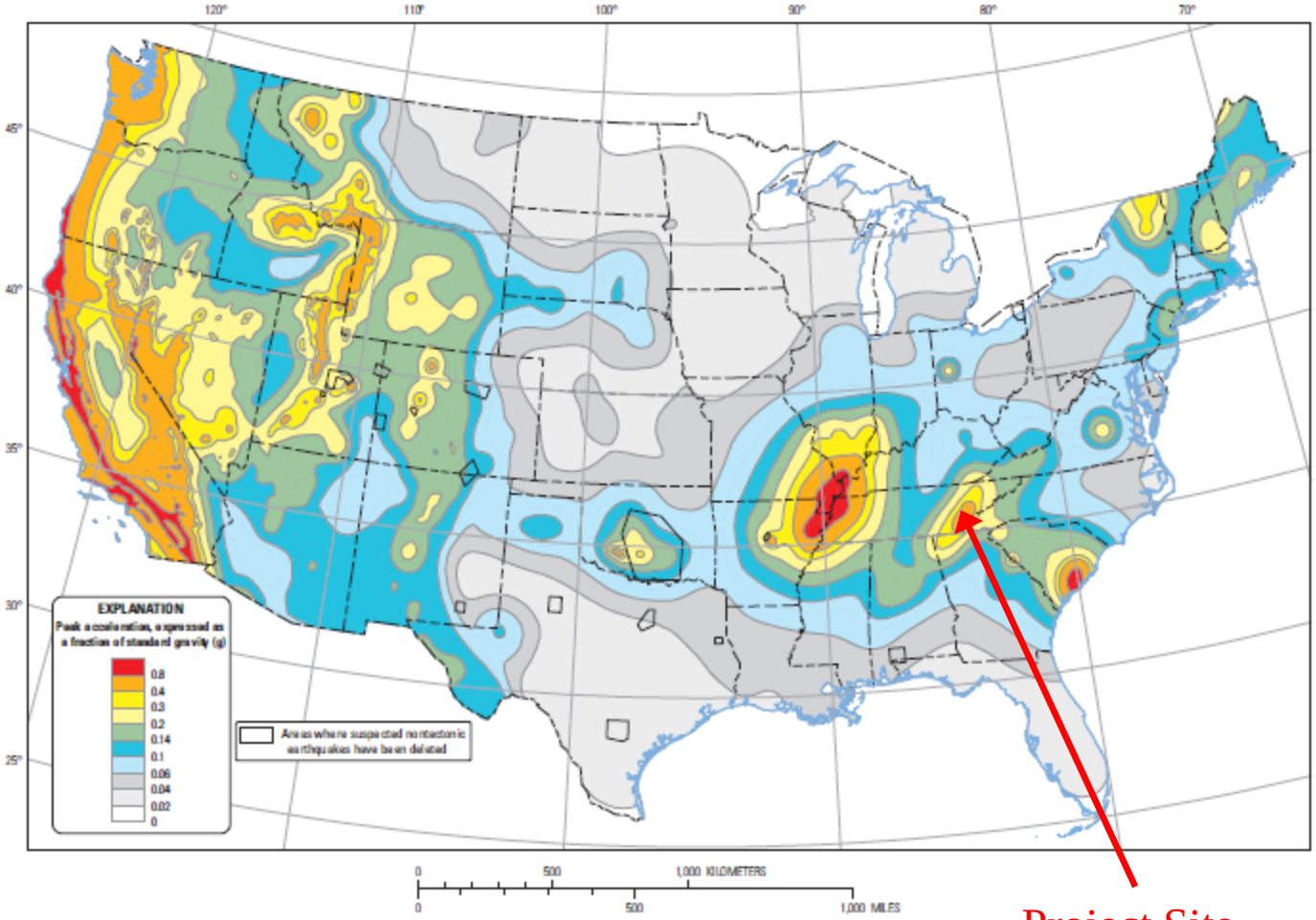
Seismicity (USGS MCE – 2%/50)



Project Site

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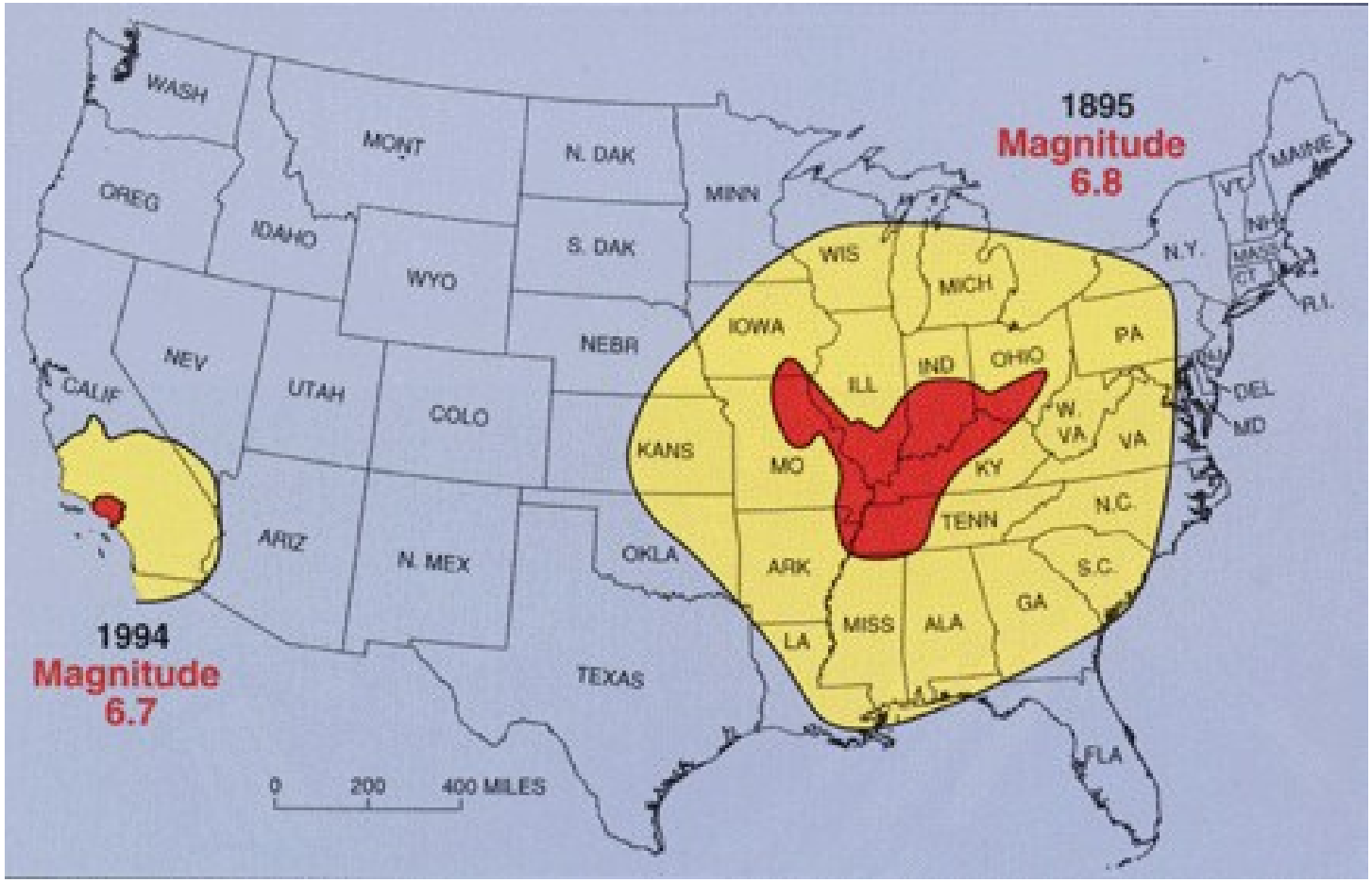
Seismicity (USGS)



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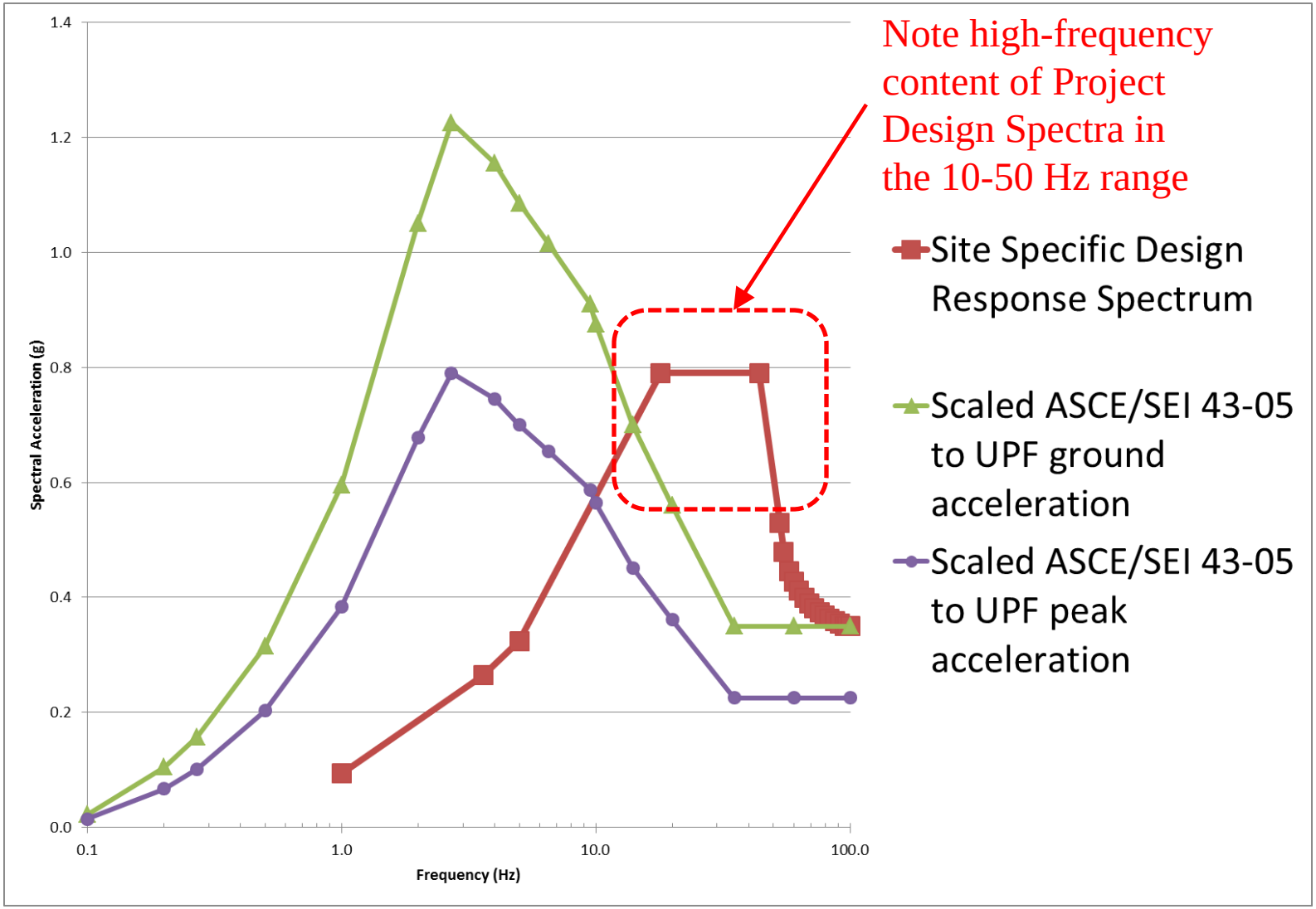
ASCE vs Project Design Spectra



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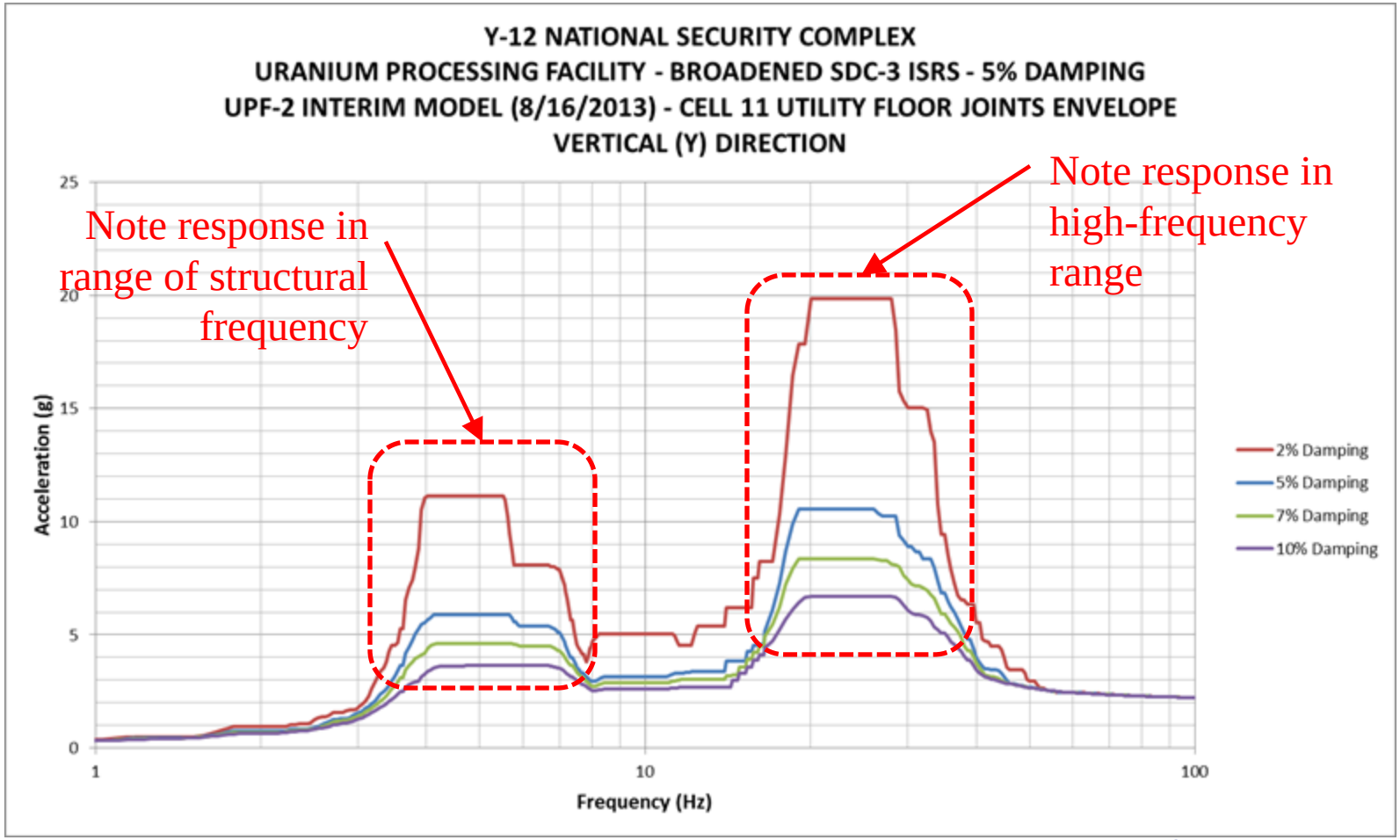
ISRS Results for Hanger System

Broadened ISRS:



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ISRS Results for Hanger System

- North-South:

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	10.94	14.35	12.25	7.94	11.37	9.502	10.35	10.42	16.38	12.63	9.87	8.38
90th percentile (g)	7.88	8.09	8.80	7.13	8.88	8.01	8.77	8.84	12.36	9.28	6.89	6.33

Max: 29 g

90th percentile: 16 g

- East-West:

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	12.97	11.65	10.76	21.35	29.09	13.77	11.40	15.04	22.74	9.26	12.56	12.67
90th percentile (g)	8.42	9.17	8.25	9.64	10.09	9.66	10.35	10.04	15.54	7.23	9.73	8.80

Max: 26 g

90th percentile: 14 g

- Vertical:

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	15.02	15.38	11.71	14.59	26.24	18.25	16.27	16.32	15.76	16.69	12.39	17.42
90th percentile (g)	10.97	12.26	8.75	10.69	10.42	10.77	12.01	11.23	10.82	13.95	9.34	13.81

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Contributions to high ISRS

Project requirements necessitated increasing wall thickness from 18” to 30”, resulting in significantly higher horizontal and vertical stiffness and resulting accelerations transferred up from the rock site.

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Mitigate with Structural Changes

Structural modifications

- Beam/Girder systems spanning to columns and walls
- Replace wide-flanged hangers with HSS tube sections with vertically slotted bolt connections

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Results of Beam/Girder system

- North-South:

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	14.18	57.22	50.40	45.71	24.65	20.23	14.91	18.60	14.49	10.55	10.25	10.76
% change	130%	399%	411%	576%	217%	213%	144%	179%	88%	84%	104%	128%
90th percentile (g)	12.42	20.50	29.53	29.62	20.54	18.98	13.67	17.23	12.52	8.74	8.47	9.96
% change	158%	253%	336%	415%	231%	237%	156%	195%	101%	94%	123%	157%

Average increase of 205%

Average increase of 195%

- East-West:

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	15.45	33.59	11.93	30.77	19.62	17.43	16.99	16.26	29.14	15.90	10.22	17.14
% change	103%	218%	102%	211%	75%	96%	104%	100%	185%	95%	82%	98%
90th percentile (g)	8.47	17.99	6.27	20.01	10.15	10.52	10.01	11.44	9.60	7.48	5.45	8.13
% change	77%	147%	72%	187%	97%	98%	83%	102%	89%	54%	58%	59%

Average decrease of 94%

- Vertical:

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	32.87	34.12	74.52	45.71	11.78	11.38	11.07	12.82	10.52	8.90	12.94	7.93
% change	390%	372%	903%	474%	117%	118%	107%	128%	68%	123%	133%	90%
90th percentile (g)	23.85	19.77	61.22	29.62	11.10	10.88	10.57	11.83	9.69	7.64	10.39	6.91
% change	283%	216%	742%	307%	110%	113%	102%	118%	62%	106%	107%	79%

HSS vs. wide-flange hangers

- North-South

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	26.04	20.54	20.78	24.31	21.23	21.99	17.17	18.03	25.22	5.80	17.96	25.60
% change	114%	86%	78%	143%	56%	77%	41%	75%	124%	41%	68%	145%
90th percentile (g)	13.23	14.18	13.46	17.60	15.21	14.99	14.78	15.34	16.18	5.69	12.78	17.21
% change	69%	126%	97%	129%	61%	62%	63%	77%	102%	60%	66%	146%

- Vertical

Average decrease of 88%

ISRS Peak comparison	Cell											
	1	2	3	4	5	6	7	8	9	10	11	12
Maximum (g)	19.93	24.17	21.17	27.52	21.09	23.16	17.95	24.46	27.45	4.81	16.83	26.71
% change	55%	126%	98%	173%	42%	65%	32%	53%	122%	18%	46%	119%
90th percentile (g)	14.12	16.63	17.23	24.34	15.93	16.50	11.75	19.08	20.96	4.71	11.56	22.73
% change	40%	108%	83%	157%	33%	49%	22%	43%	117%	20%	33%	148%

Average decrease of 71%

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Are the calculated ISRS correct?

Our study:

- Explicit modeling of SDOF masses at each hanger
  - Lumped masses at mid-span between mid-height of hangers
  - Lumped masses at mid-height of hangers
- Single cell
- Input motion: the response history motions of the cell walls from the overall model

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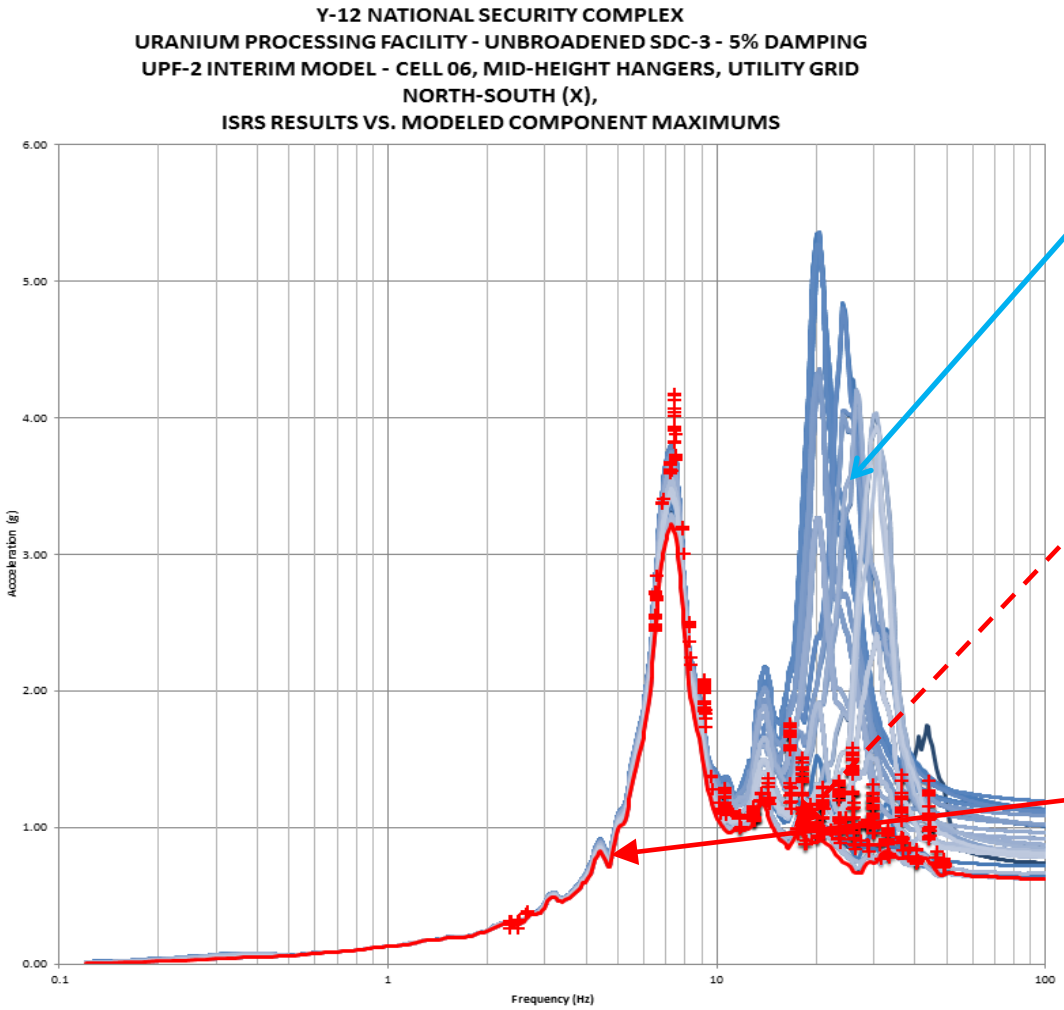
Explicit modeling of Components



ISRS at each hanger

Markers represent peak accelerations from each lumped mass

Solid line represents response spectrum generated by wall input motion

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Direct Reduction of ISRS

- Proposed by Reed, Kennedy and Lashkari [Reed et al, 1993]
- Results in a direct reduction of Project Design Spectra used for ISRS

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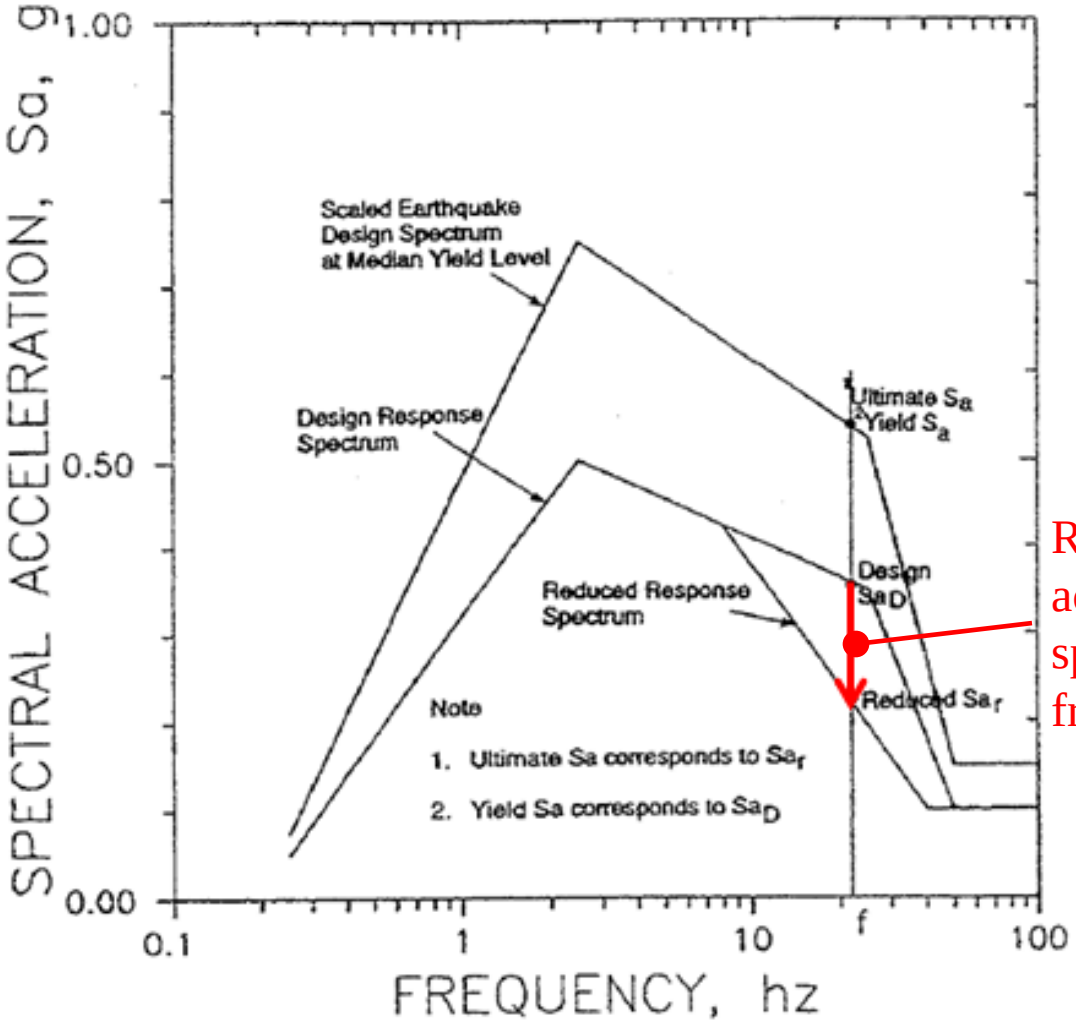
Spectral Acceleration Reduction

- [Reed, Kennedy and Lashkari, 1993]



Reduction of spectral accelerations specifically in the high frequency range

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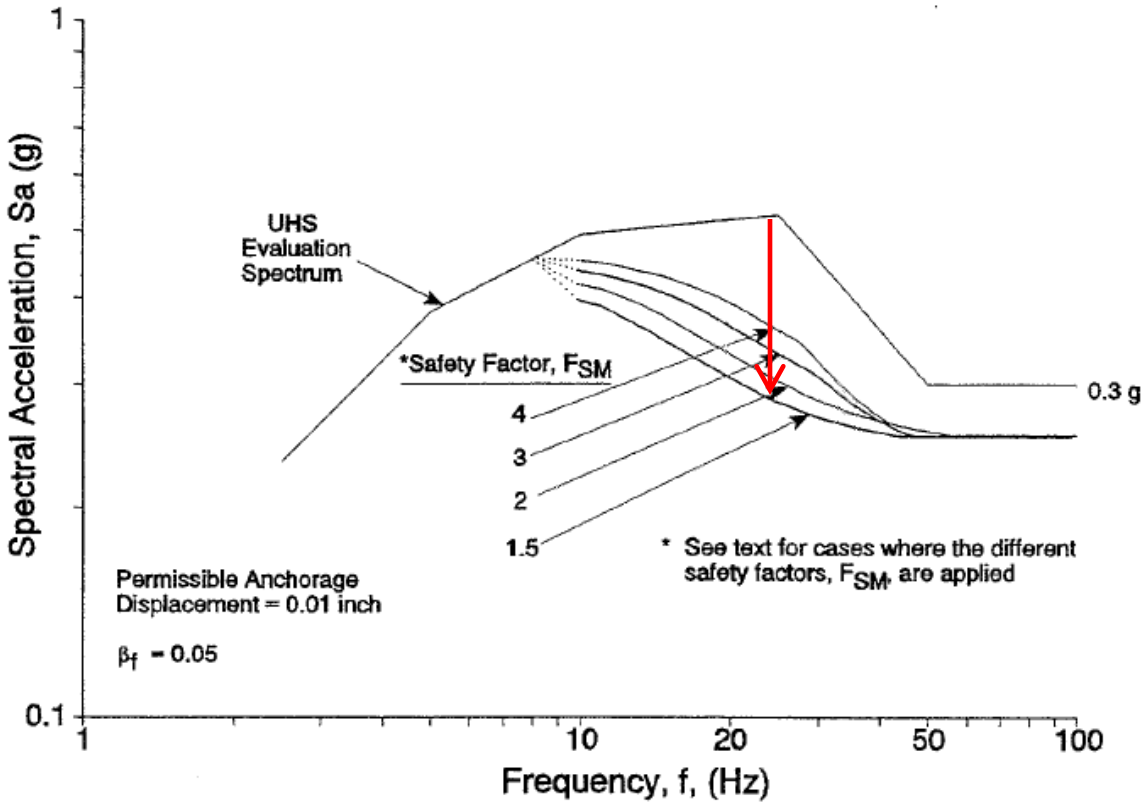
Example of Sa Reduction



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Conclusions

- Reduction of ISRS through structural design can be partially effective; however, peak accelerations are still significant.
- Recommendations:
  - Reduction of ground motions used to generate ISRS [Reed et al, 1993]
  - Also recommend further studies on component isolation
  - Obtain regulatory buy-in to procedures

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Questions?

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