Toward a Lunar Building Code

Development of Seismic Design Criteria for Lunar Infrastructure

Presenter: Nerma Caluk, Ph.D.

SOM

Space Resources Roundtable 2026
SKIDMORE, OWINGS & MERRILL

Regolith as Construction Material

Integration of Robotic Construction

Moonquakes

Foundation Systems

Lunar Building Standards

Regolith as Construction Material

Integration of Robotic Construction

Moonquakes

Foundation Systems

Lunar Building Standards

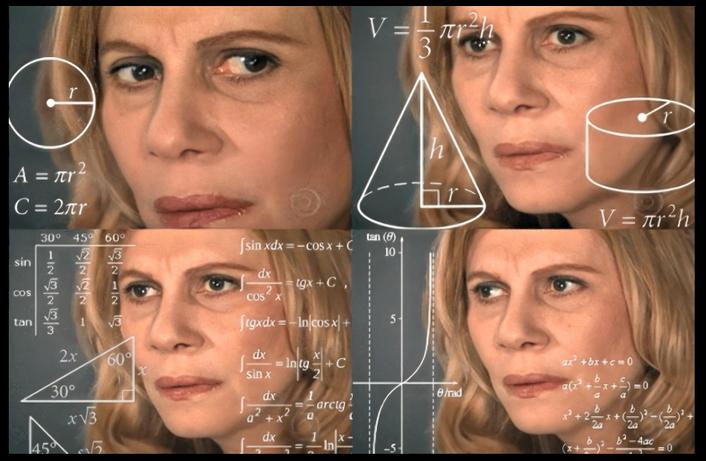
Seismic Design on the Earth

Decades of Terrestrial Recorded Data & Experiments

Design Criteria & Target Performance

Seismic Design on the Moon

Limited Lunar Recorded Data & Experiments



Seismic Design on the Moon

Limited Lunar Recorded Data & Experiments

Foundational Guidelines & High-Uncertainty Frameworks

ASCE - ASD - Space Engineering and Construction Technical Committee
Lunar Infrastructure Engineering, Design, Analysis, and Construction Guidelines
Lunar Structural Loads

ASCE | AEROSPACE
AMERICAN SOCIETY OF CIVIL ENGINEERS

American Society of Civil Engineers (ASCE)
Aerospace Division (ASD)

Technical Committee on
Space Engineering and Construction (SEC)

Lunar Infrastructure Engineering Design, Analysis, and Construction (LIEDAC) Guidelines

Part 2 – Lunar Structural Loads

1

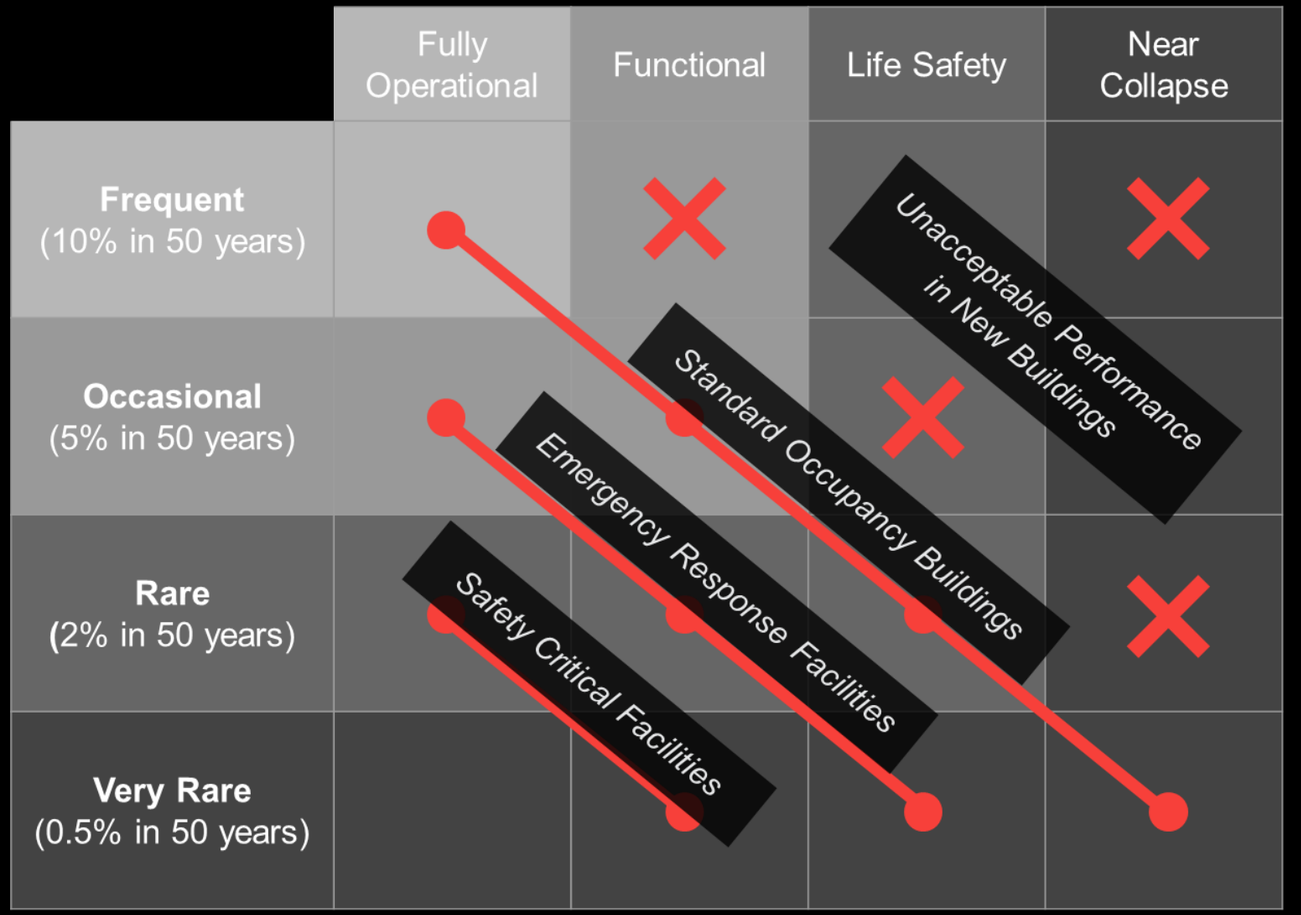
Terrestrial Approach

Standard Occupancy Building

- Inelastic Behavior – Allowed to Deform and Yield
- Energy Dissipation - Controlled Damage
- Primary Objective - Life Safety

High-Importance & Essential Facilities

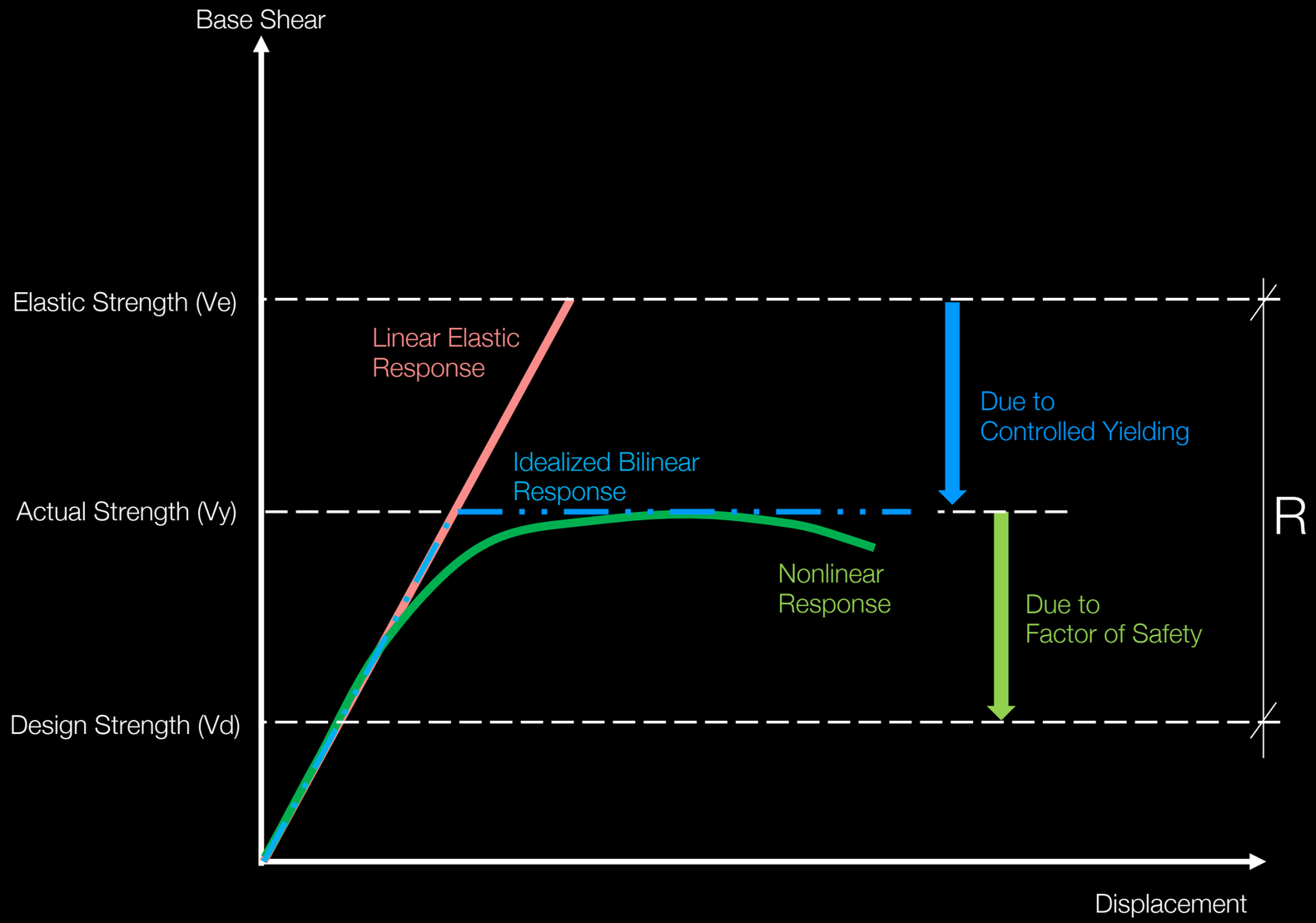
- Shifted Performance Targets
- Operational Continuity



Terrestrial Approach

Terrestrial Force Reduction

- Abundance of Data & Testing
- Allowance of Non-Linear Response
- Economic Reality



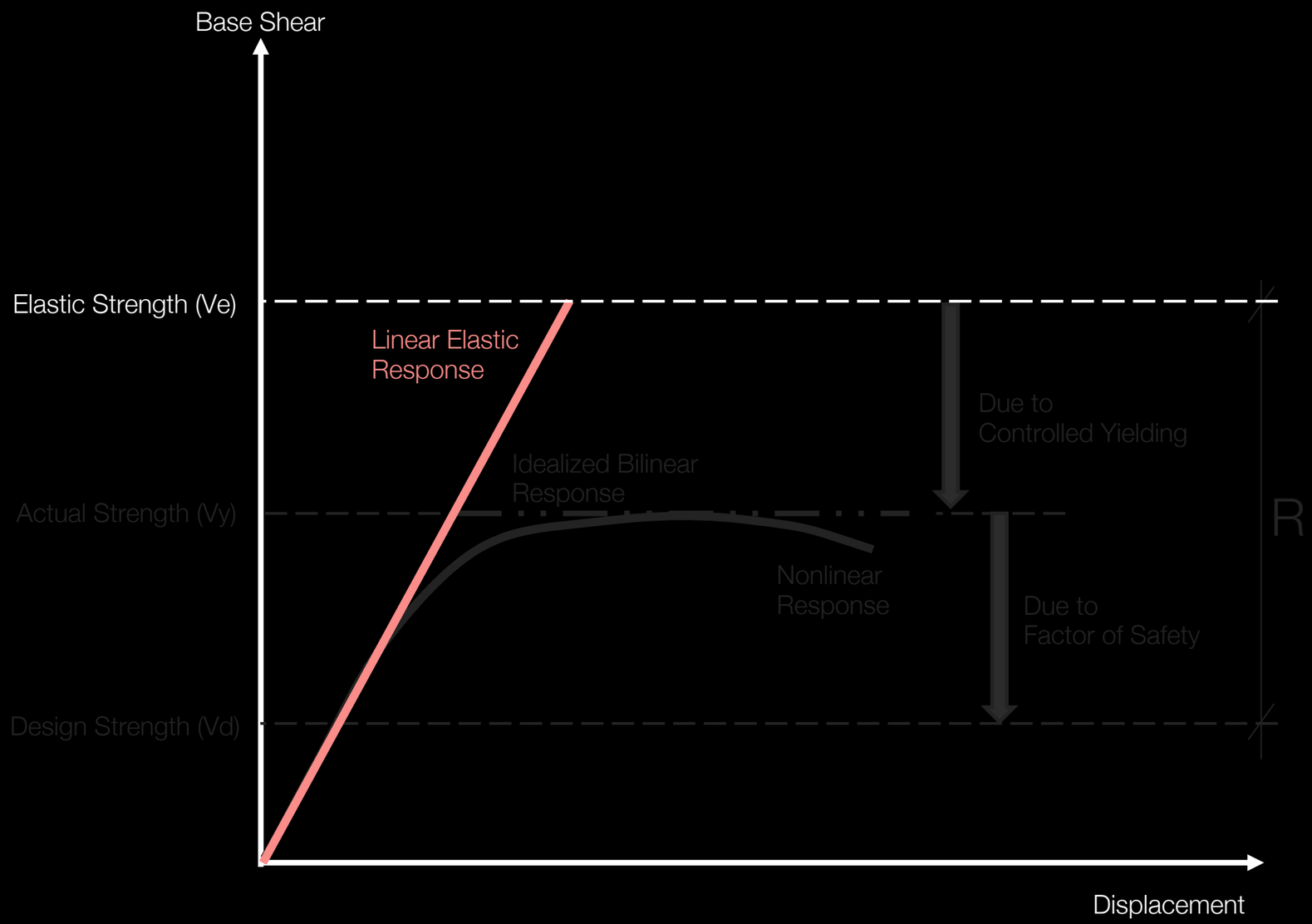
Terrestrial Approach

Terrestrial Force Reduction

- Abundance of Data & Testing
- Allowance of Non-Linear Response
- Economic Reality

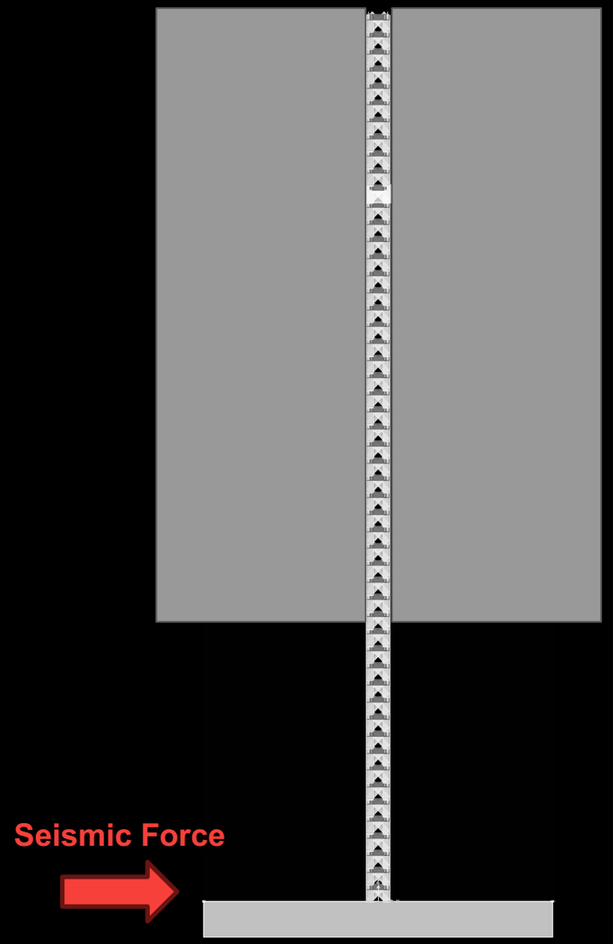
Lunar Linear-Elastic Approach

- Zero-Tolerance for Damage
- Serviceability Concerns
- Mission-Ending Serviceability Failure



Lunar Approach

Equivalent Lateral Force (ELF) Method



Step 1:
Calculate Total Base Shear Demand

Minimum Base Shear for Lunar Structures

$$V = 0.6 * I * W$$ *(Equation 6.5-1)*

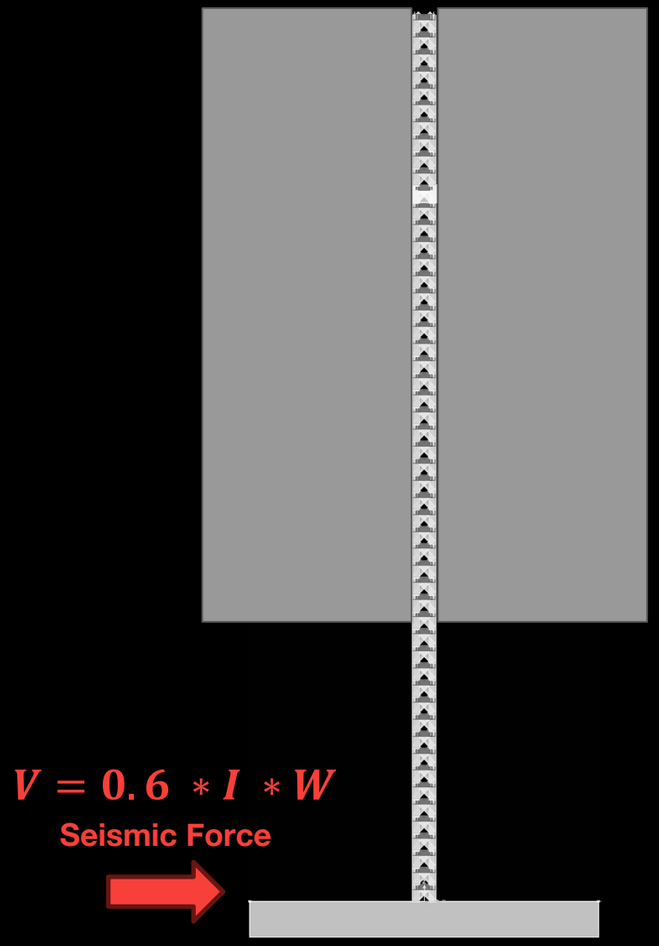
Table 1.6.2-1. Importance Factors by Risk Category of Buildings and Other Structures

Risk Category	Importance Factor, *I*
I	1.00
II	1.25
III	1.50

$W - effective\ seismic\ weight$

Lunar Approach

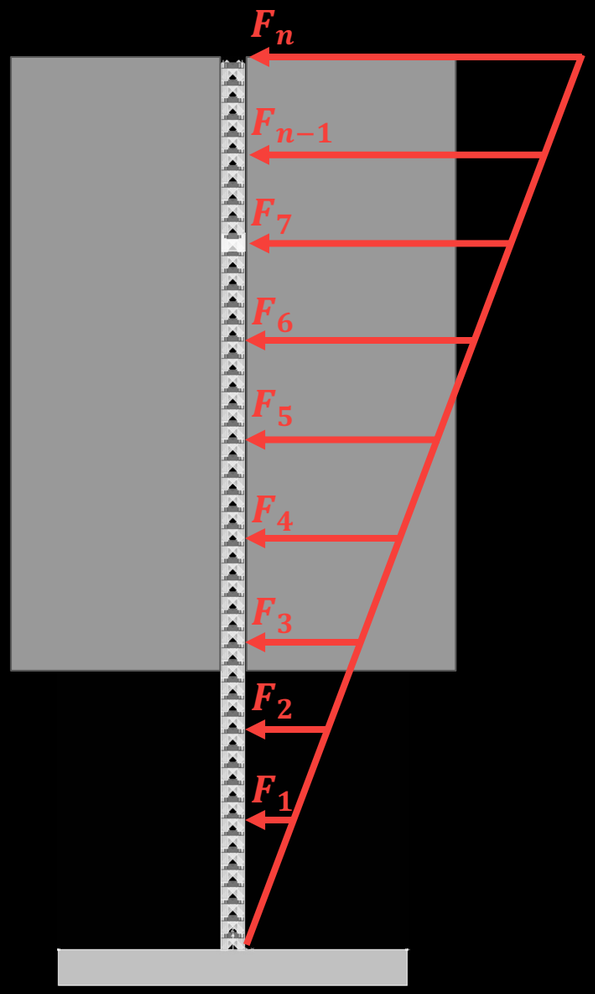
Equivalent Lateral Force (ELF) Method



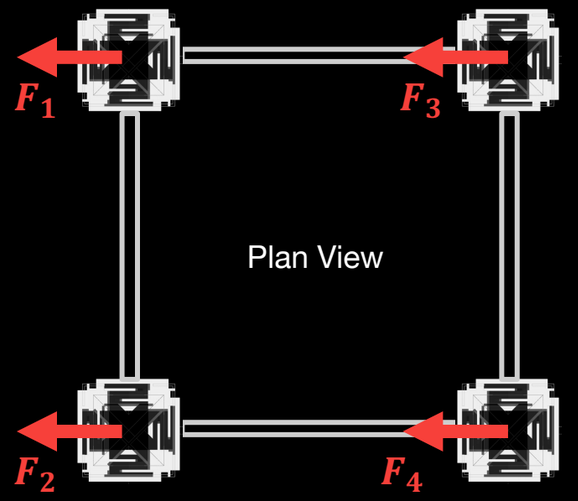
$$V = 0.6 * I * W$$

Seismic Force

Step 1:
Calculate Total Base Shear Demand



Step 2:
Vertical Distribution of Seismic Force



Step 3:
Horizontal Distribution of Seismic Force

Lunar Approach

Response Spectrum

Risk Category I

Buildings & other structures that represent a low hazard to human life in the event of failure

Risk Category II

Buildings & other structures that represent a sustained hazard to human life in the event of failure

Risk Category III

Buildings & other structures designated as Essential Facilities

Lunar Approach

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Table 6.4.2-1. Assignment of Moonquake Hazard Levels by Risk Category (LIEDAC Lunar Structural Loads)

Risk Category	Probability of Exceedance	DBM Hazard	MCM Hazard	Design Intent
I	10%	Mean	95th Percentile (Optional)	DBM ensures life safety MCM evaluation optional
II	5%	Mean	95th Percentile	DBM ensures life safety MCM verifies collapse prevention
III	2%	Mean	95th Percentile	DBM ensures life safety under extreme events MCM verifies collapse prevention under extreme events

Lunar Approach

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Lunar Approach

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Lunar Approach

Response Spectrum – Horizontal Ground Motion

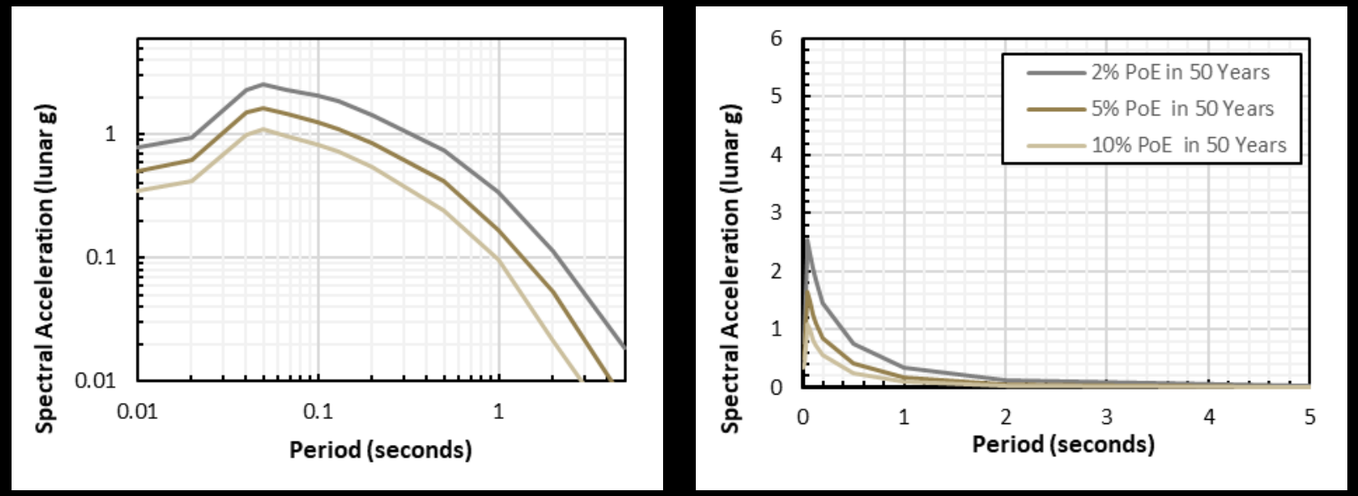


Figure 6.6-1. DBM Response Spectra for Mean Uniform Hazard, in log-log (left) and linear (right) scale (LIEDAC Lunar Structural Loads)

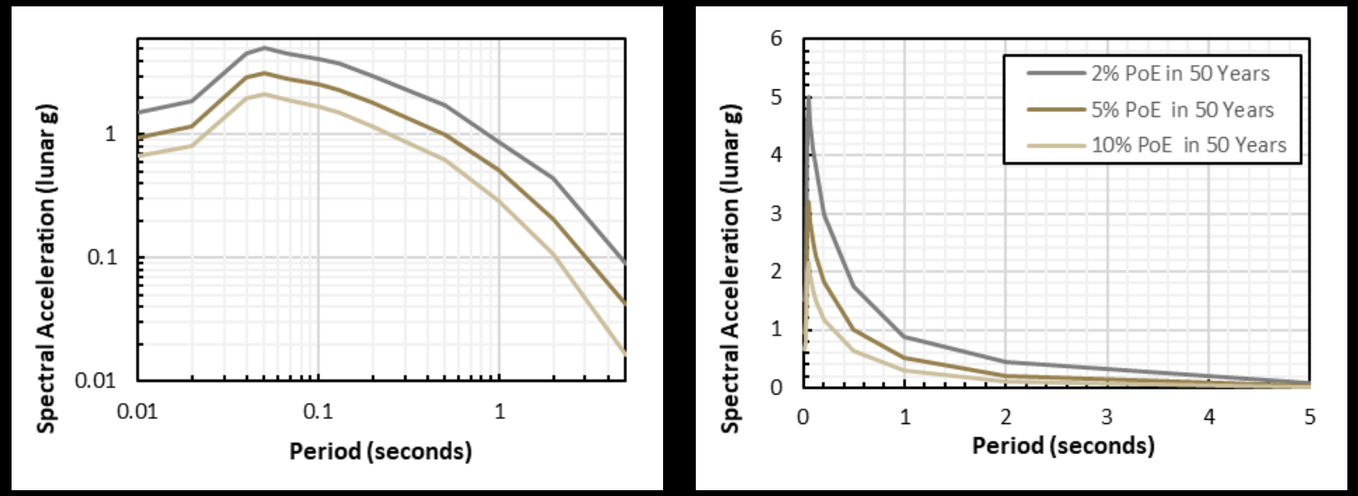


Figure 6.6-2. MCM Response Spectra for 95th Uniform Hazard, in log-log (left) and linear (right) scale (LIEDAC Lunar Structural Loads)

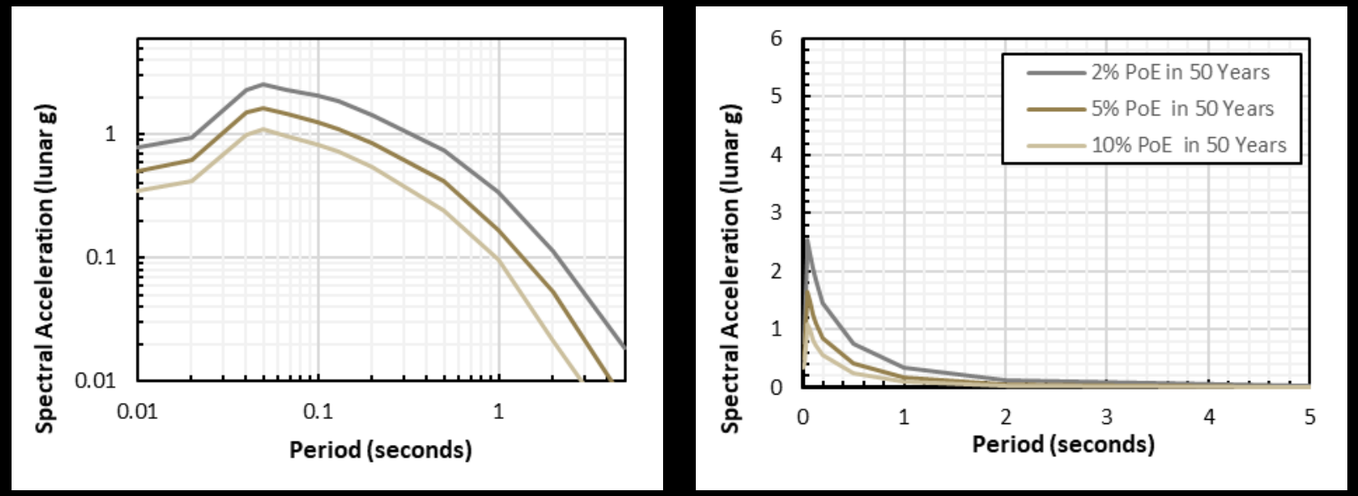
Lunar Approach

Response Spectrum – Vertical Ground Motion

$$\frac{H}{V} \approx 1.5$$

$$S_{a,v}(T) = \frac{2}{3} S_{a,h}(T)$$

Section 6.11: Vertical Ground Motions for Seismic Design (LIEDAC Lunar Structural Loads)



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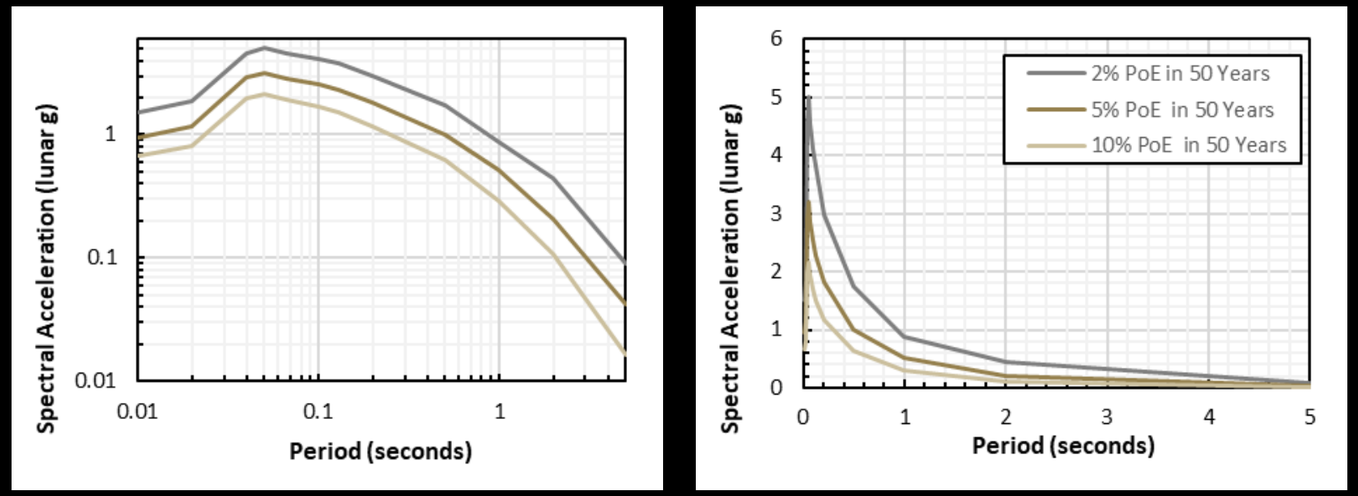


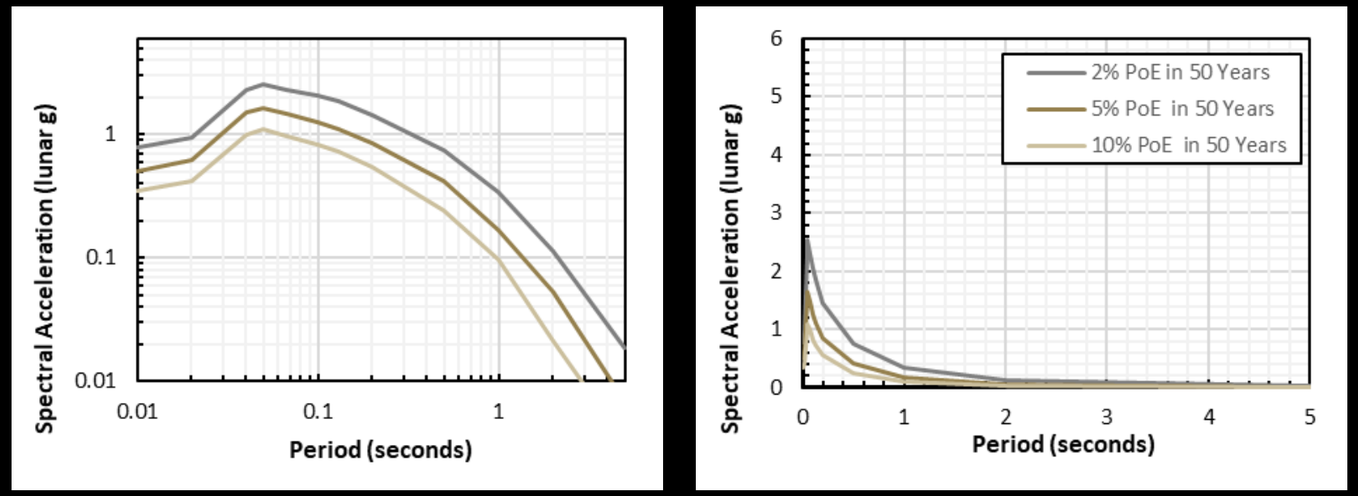
Figure 6.6-2. MCM Response Spectra for 95th Uniform Hazard, in log-log (left) and linear (right) scale (LIEDAC Lunar Structural Loads)

Lunar Approach

Response Spectrum – Site-Specific Analysis

Site-Specific PSHA

- Probabilistic Seismic Hazard Analysis
- Poisson process model over 50-year design life
- Characterized Uncertainty:
  - Seismic Source Model
  - Ground Motion Model
- SA values for DBM and MCM ≥ 80% of standard guideline-table values



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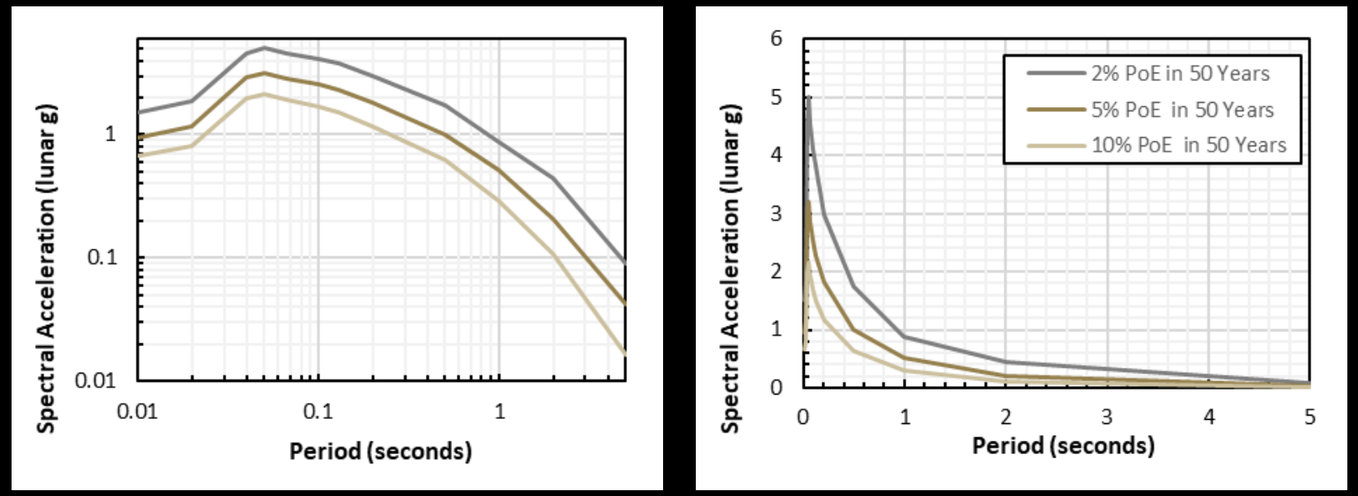

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Conclusion

Engineering the First Lunar Building Code

Core LIEDAC Approach

Risk Category Allocation (I, II, III)

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Moonquake Hazard Levels (DMB/MCM)

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Elastic Force Demand Evaluation (R = 1.0)

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Base Shear Verification

Path Forward

- Characterizing Structural Material & Cyclic Testing
- Defining Structure Response Factors
- Advancing Geotechnical Site-Specific Knowledge
- Ground Motion Model Refinement

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