Sharing an Uncertain World in 2017

Safe & Secure Nuclear Engineering in an Uncertain World

| Paul Smith | Arup |

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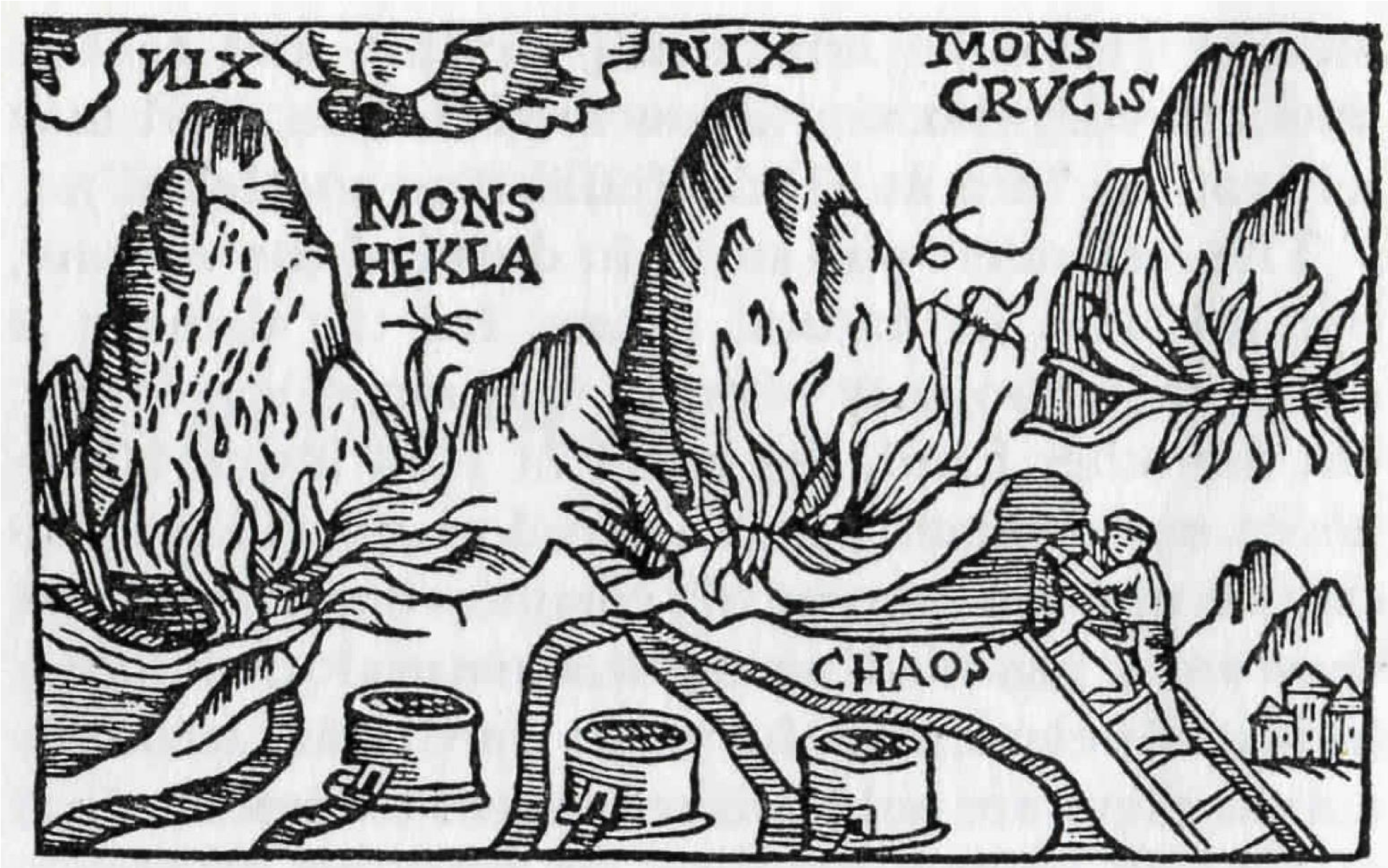
The World's Natural Hazards

7 Major Issues



From Olaus Magnus: Historia de gentibus septentrionalibus, 1555.

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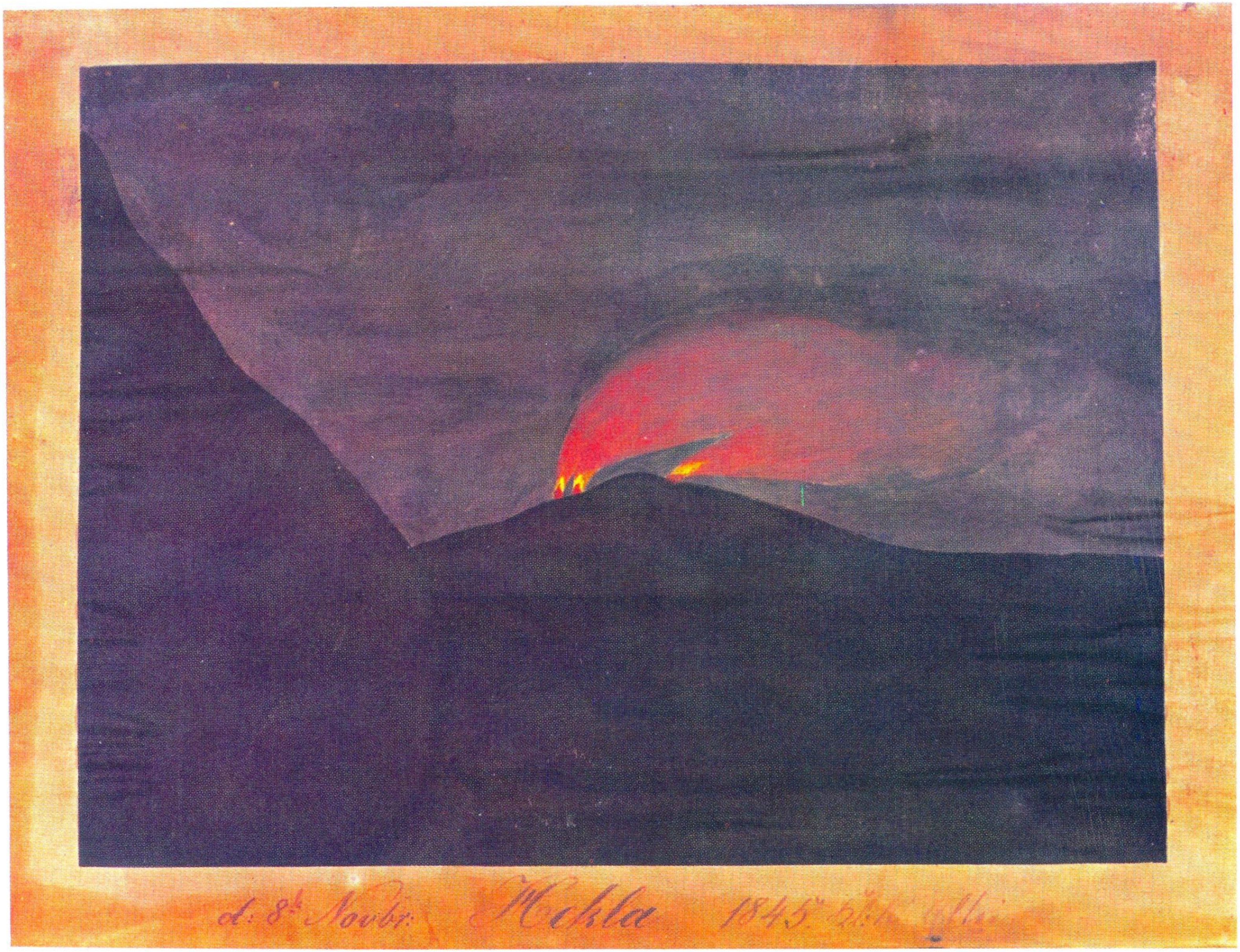
The risk from natural hazards is diverse, with the hazard-types ranging across:

- **Geomorphological;**
- **Geological;**
- **Climatological;**
- **Ecological;**
- **Astronomical;**
- **Biological; and,**
- **Man-Made scenarios.**



The 1845 Hekla Eruption by Danish physician A. S. I. Haalland;
National Museum of Iceland.

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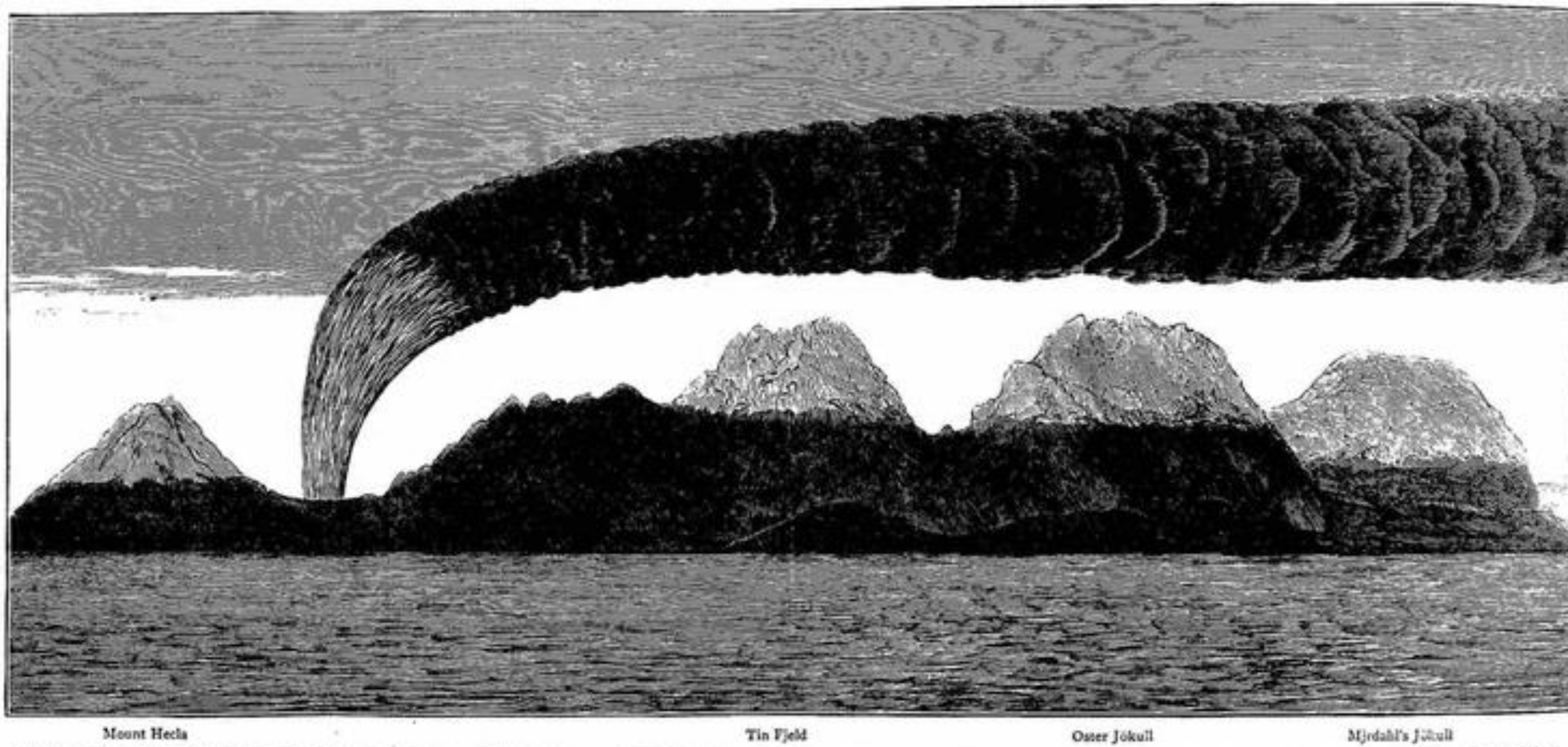

THE ERUPTION OF MOUNT HECLA, ICELAND — SKETCHED FROM THE SOUTH-WEST ON BOARD THE DANISH MAIL STEAMER "VALDEMAR," MARCH 24, 1878

Eruption of Mount Hekla in 1845;
The Graphic, April 20th 1878, p 392.

Eruption column from Hekla in 1947 – 127 km away at 6.59 a.m. on 29th March, about 18 minutes after eruption began. Height of column is 27,000 m.
Hekla: A Notorious Volcano by Sigurdur Thorarinsson, 1970.

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Photo taken in early morning on the 5th March 2017
(Canon EOS 1DS II and Sigma 300mm f4 APO lens)

Photo taken at first sun rise on the 8th March 2017
(Canon EOS 1DS II and Sigma 300mm f4 APO lens)

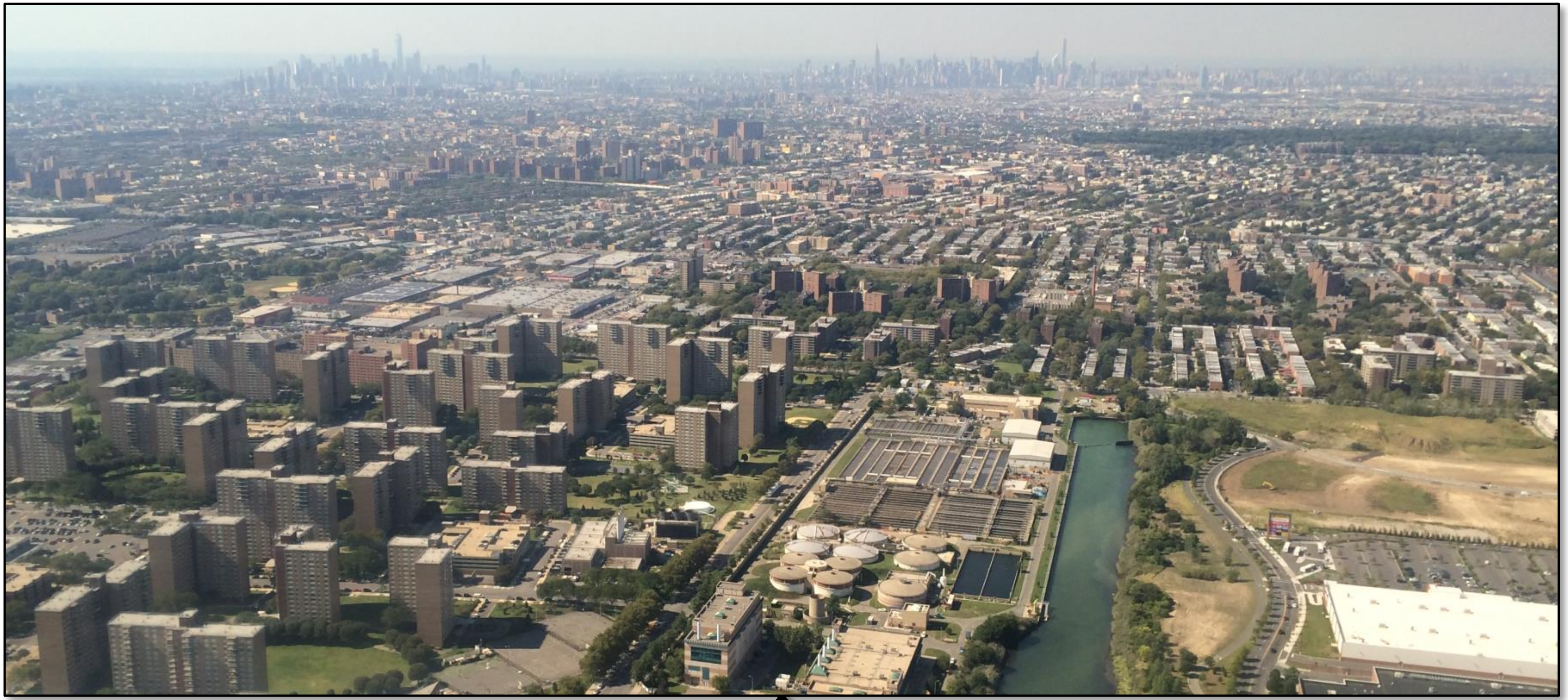
Seven major issues face us now and into the future as a society, in this century, and even beyond for subsequent centuries to come – for our children's children:

- **Population Density** *and its future increase relative to the planet's size;*
- **Economic Prosperity** *and the resultant personal wealth gap;*
- **Natural Resources** *diminishing without immediate alternatives;*
- **Devastating Natural Hazards** *with long-term periodicity;*
- **Pollution and Waste** *dangers resulting from industrialization;*
- **Climate Change** *causing sea rise, extreme storm weather events, drought; and,*
- **Political Will & Longer Term Strategy** *to mitigate and defend against future hazard-shock events.*

Now Reality

Our Man-Made Structural Fabric

New York's Structural Fabric - NYC



Single Building

Collection of Buildings

System of Buildings

New York's Structural Fabric is Adjacent to the Coastline

New York's Structural Fabric is Adjacent to the Coastline

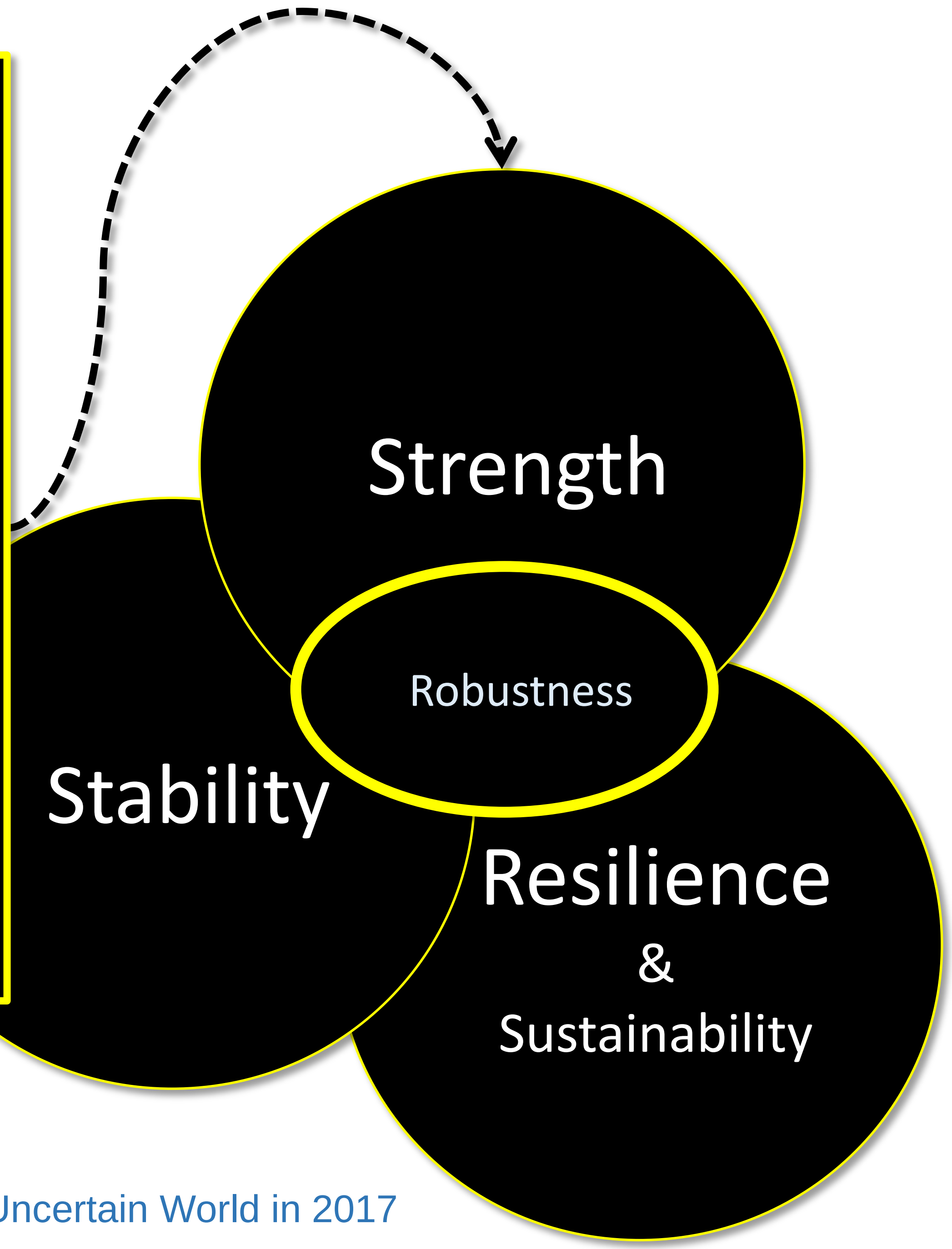
NYC and all US Eastern Seaboard Cities are Vulnerable

Parts of the System	Possible Vulnerable Parts of the System to Risk of Loss
Physical	Structural – Buildings, Infrastructure, Facilities, Networks, Supplies, Services
Natural	Resources – Water, Materials, Fuel, Minerals, Renewables, Energy
Human	Victims – Deaths, Lost, Permanent Harm, Viruses, Disease
Social	People – Community, Well Being, Solidarity, Happiness
Economic	Business – Industry, Science, Technology, Production, Jobs, Wealth
Political	Rulers – Governance, Leadership, Democracy, Law, Policy, Institutions
Security	Peace and Stability – Home, Abroad, World, War, Criminality, Terrorism

Holistic Integrity

Robustness of the man-made Structural Fabric requires high Holistic Integrity of the:

- Buildings
- Facilities
- Infrastructure
- Networks
- Services
- Supplies



Resilience

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Sustainability

Design Objectives:

- Sustainable Basis to Design
- Low Energy Construction Methods
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- Consider the People Under Stress
- Account for Socio-Technical Needs
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Resilience

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Resilience

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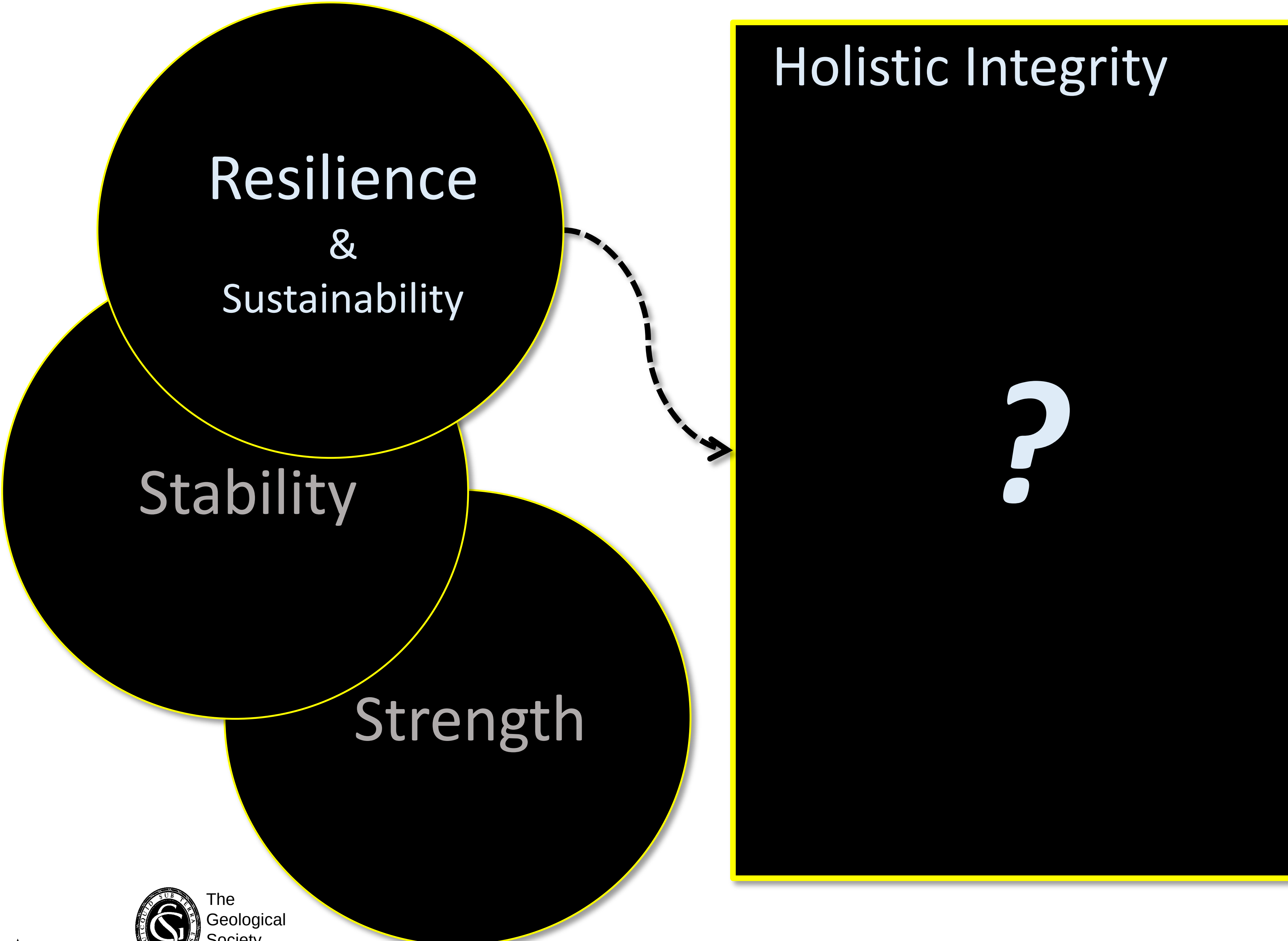

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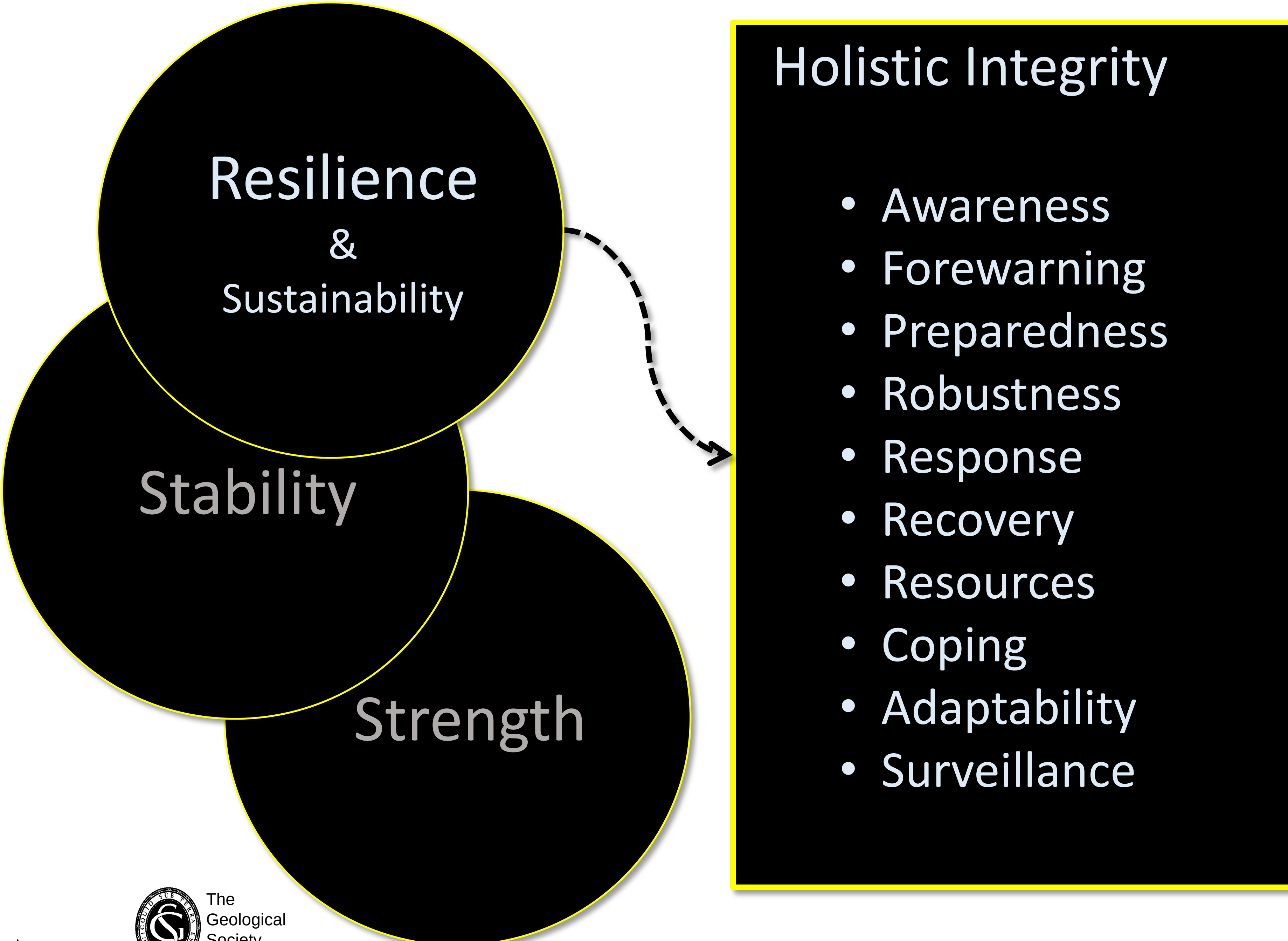

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Resilience

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Sustainability

Holistic Integrity:

- Engineering Design Objectives
- Engineering Design Principles
- Engineering Design Options
- Flexible and Adaptable
- What If? Stress-Testing
- “360” Holistic Awareness
- Whole Systems Thinking Mind-set
- Merging Disciplines as System
- Socio-Technical Systems (Society)
- Use Established Risk Analysis
- Ensure Coping Capability
- Before, During and After Events
- Focused Subjective Qualification
- More Specific Quantification
- New Standards & Practice
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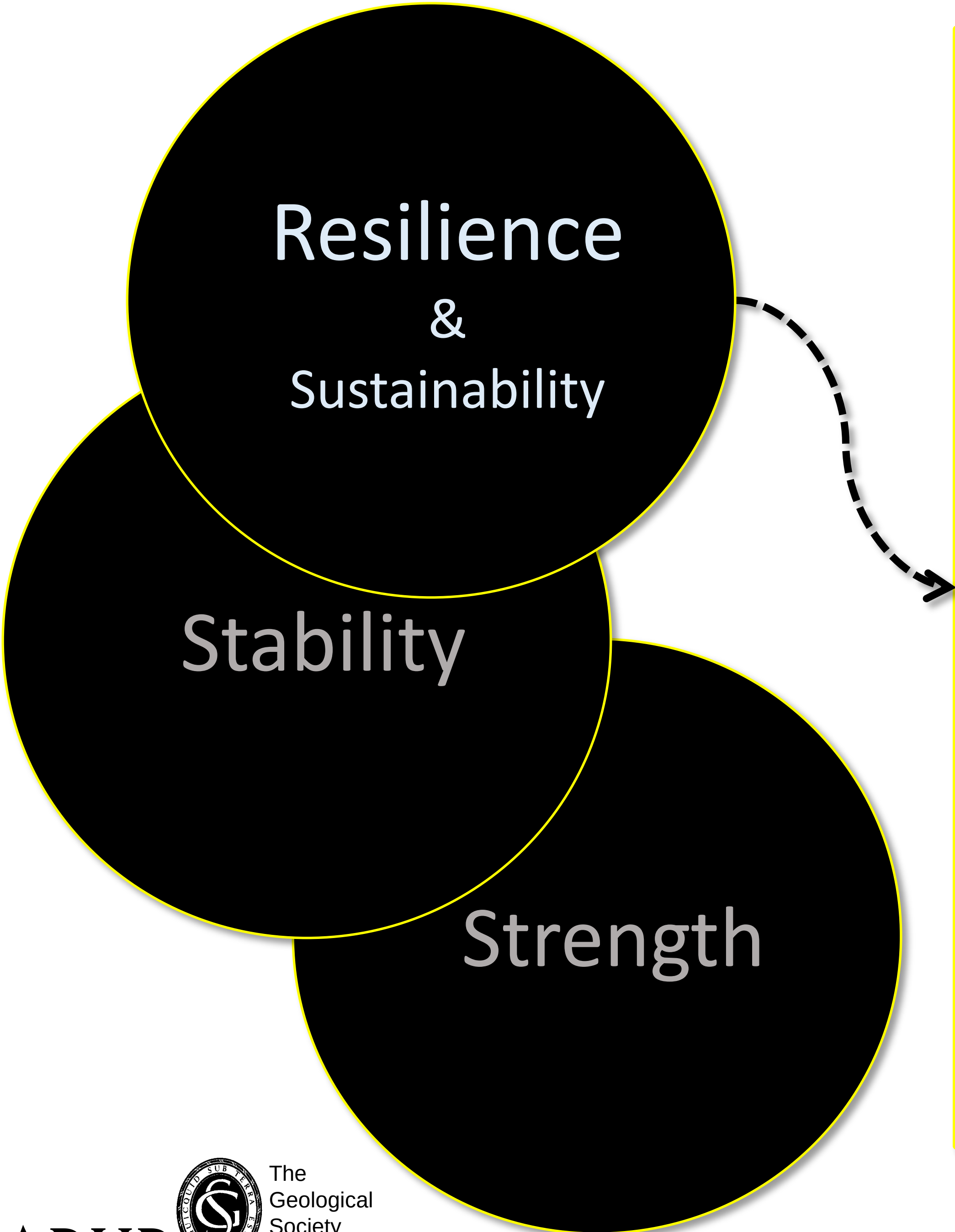

Holistic Integrity Test:

- Awareness
- Forewarning
- Preparedness
- Robustness
- Response
- Recovery
- Resources
- Coping
- Adaptability
- Surveillance

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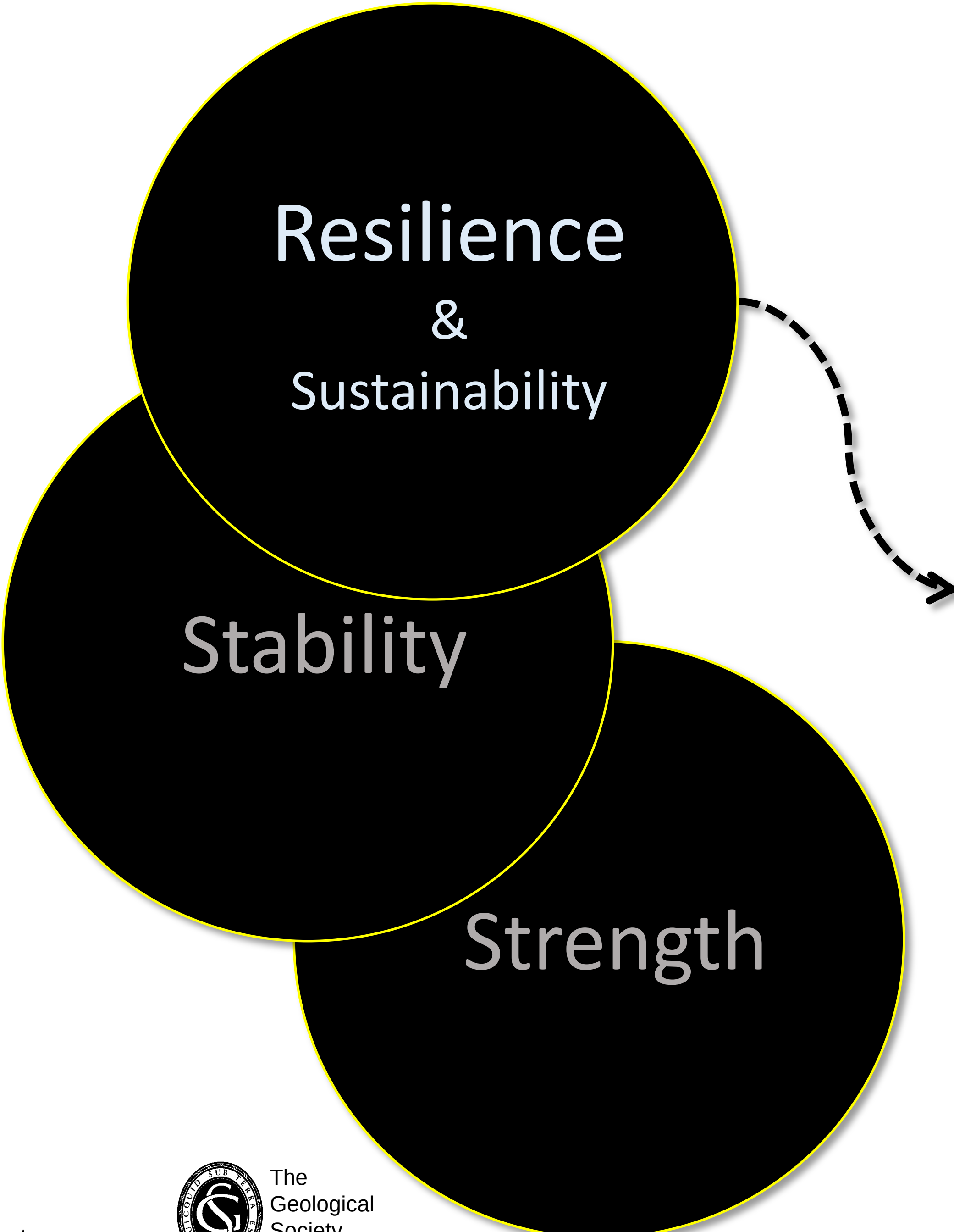
Holistic Integrity

Showing we can Cope with Hazard-Shock Events



Holistic Integrity Test:

- Awareness
- Forewarning
- Preparedness
- Robustness
- Response
- Recovery
- Resources
- **Coping**
- Adaptability
- Surveillance

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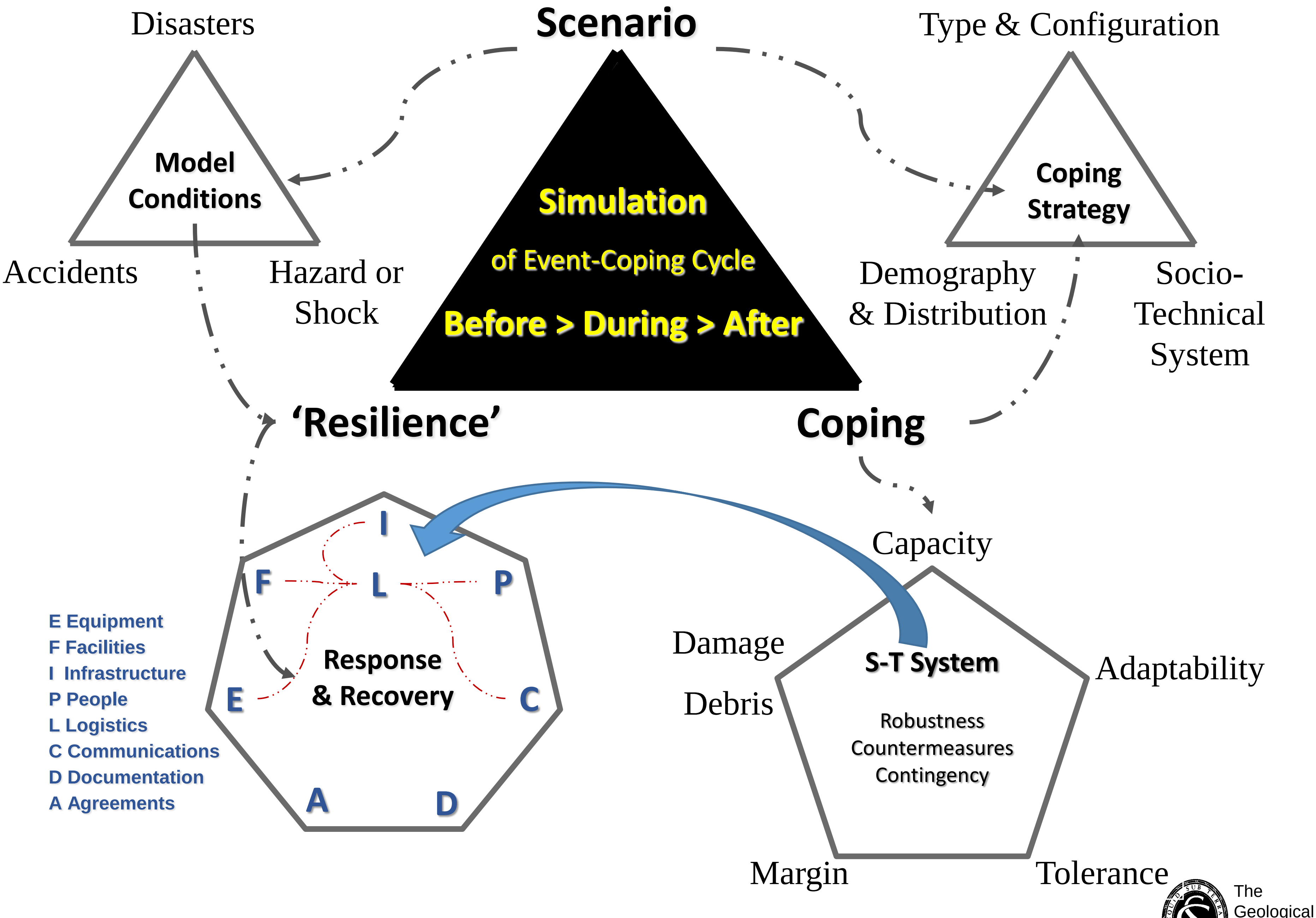

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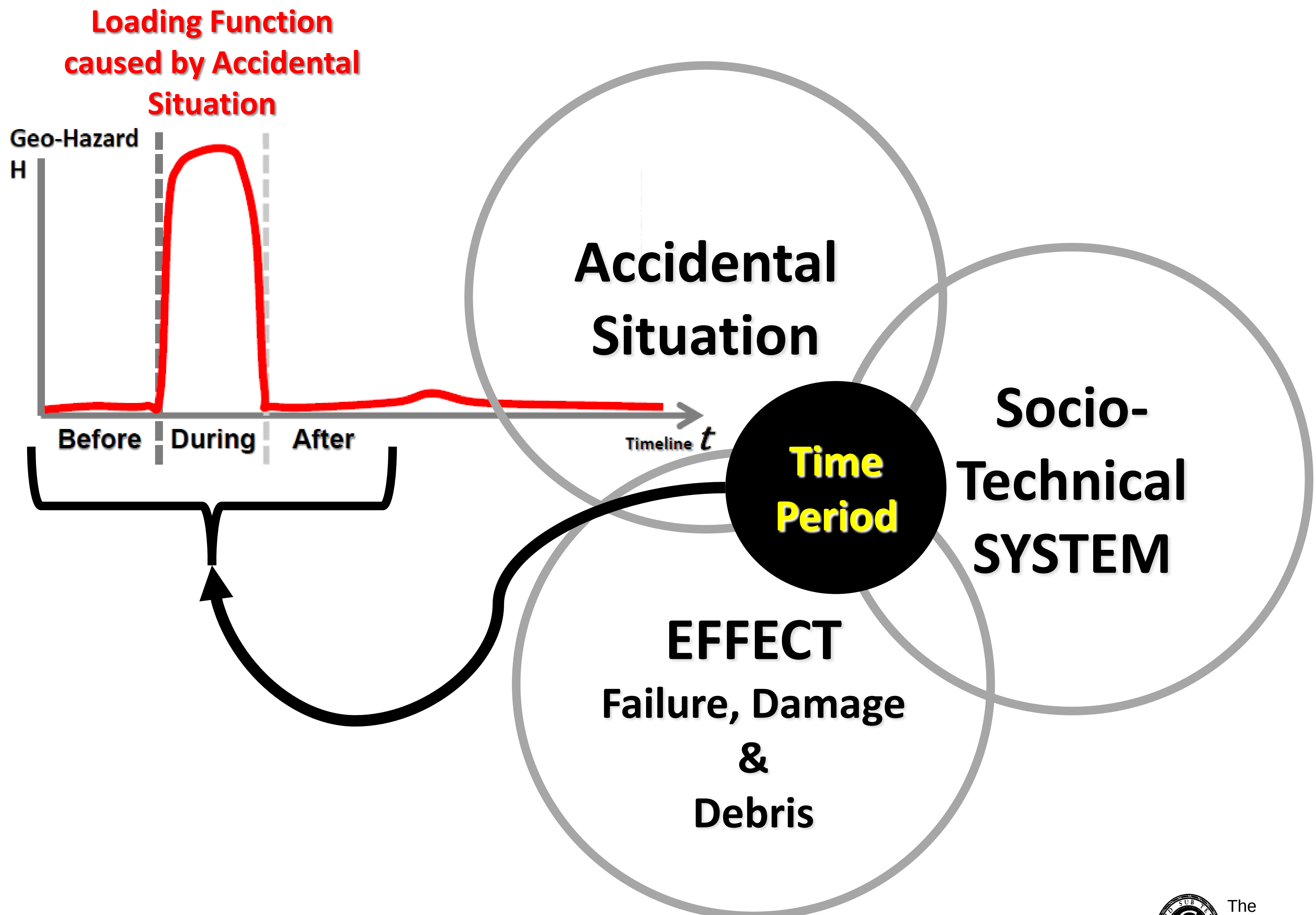
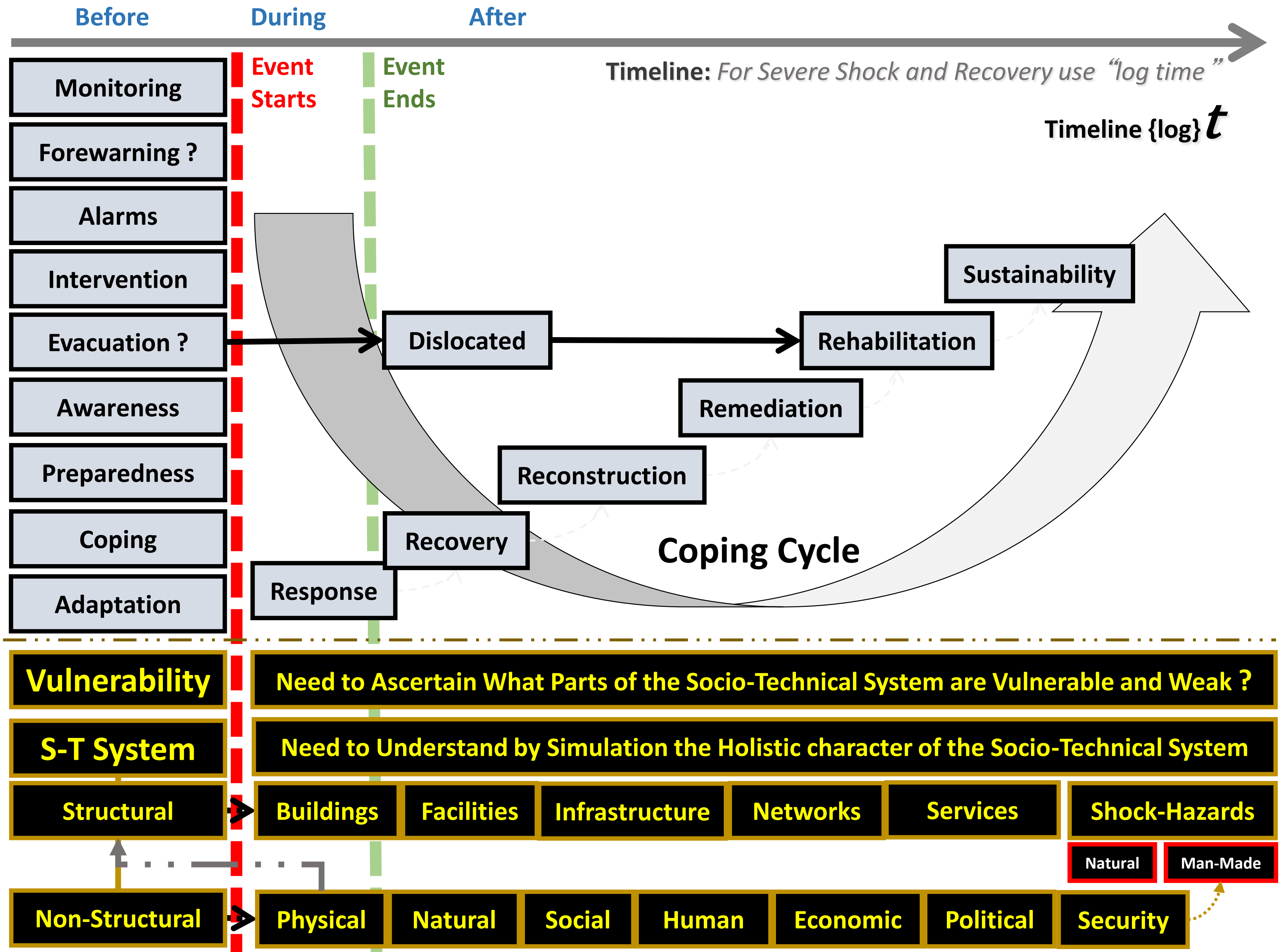
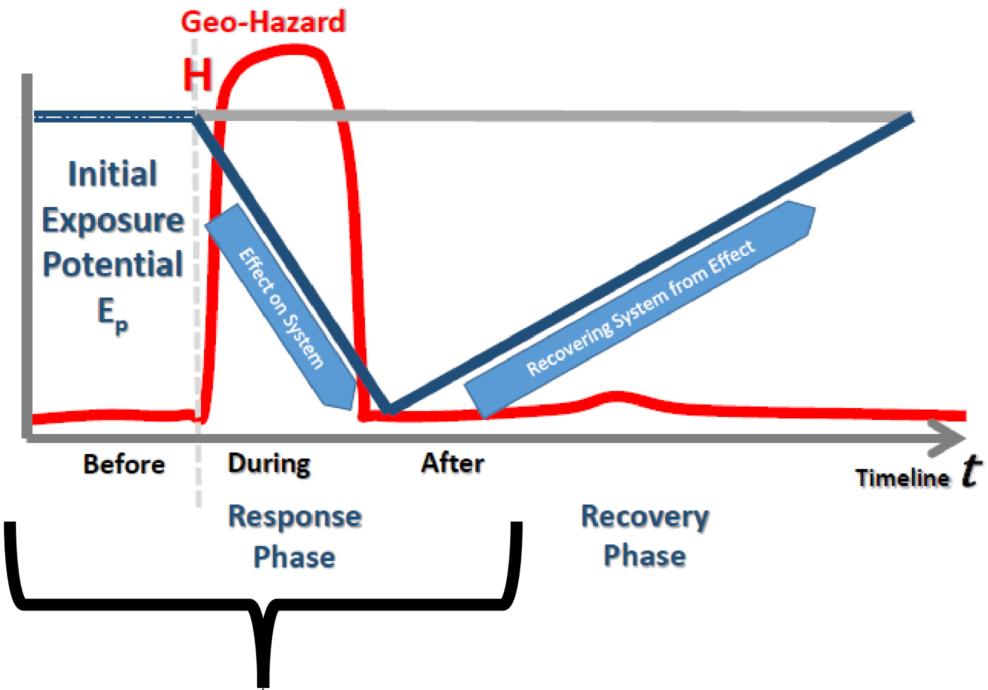
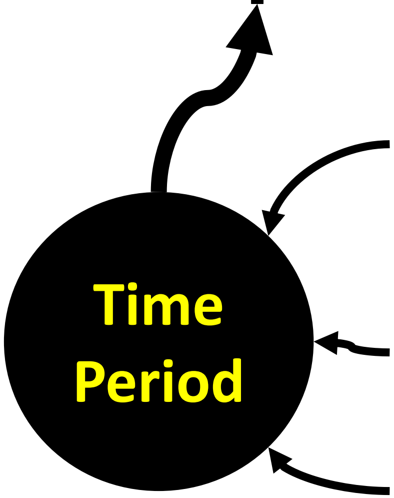

Loading Function
caused by Accidental
Situation
Geo-Hazard
H
Before
During
After
Timeline t
Accidental
Situation
Socio-
Technical
SYSTEM
Time
Period
EFFECT
Failure, Damage
&
Debris


Before
During
After
Event Starts
Event Ends
Timeline: For Severe Shock and Recovery use "log time"
Timeline {log} t
Monitoring
Forewarning ?
Alarms
Intervention
Evacuation ?
Awareness
Preparedness
Coping
Adaptation
Dislocated
Rehabilitation
Sustainability
Remediation
Reconstruction
Recovery
Response
Coping Cycle
Vulnerability
Need to Ascertain What Parts of the Socio-Technical System are Vulnerable and Weak ?
S-T System
Need to Understand by Simulation the Holistic character of the Socio-Technical System
Structural
Buildings
Facilities
Infrastructure
Networks
Services
Shock-Hazards
Natural
Man-Made
Non-Structural
Physical
Natural
Social
Human
Economic
Political
Security





Before:

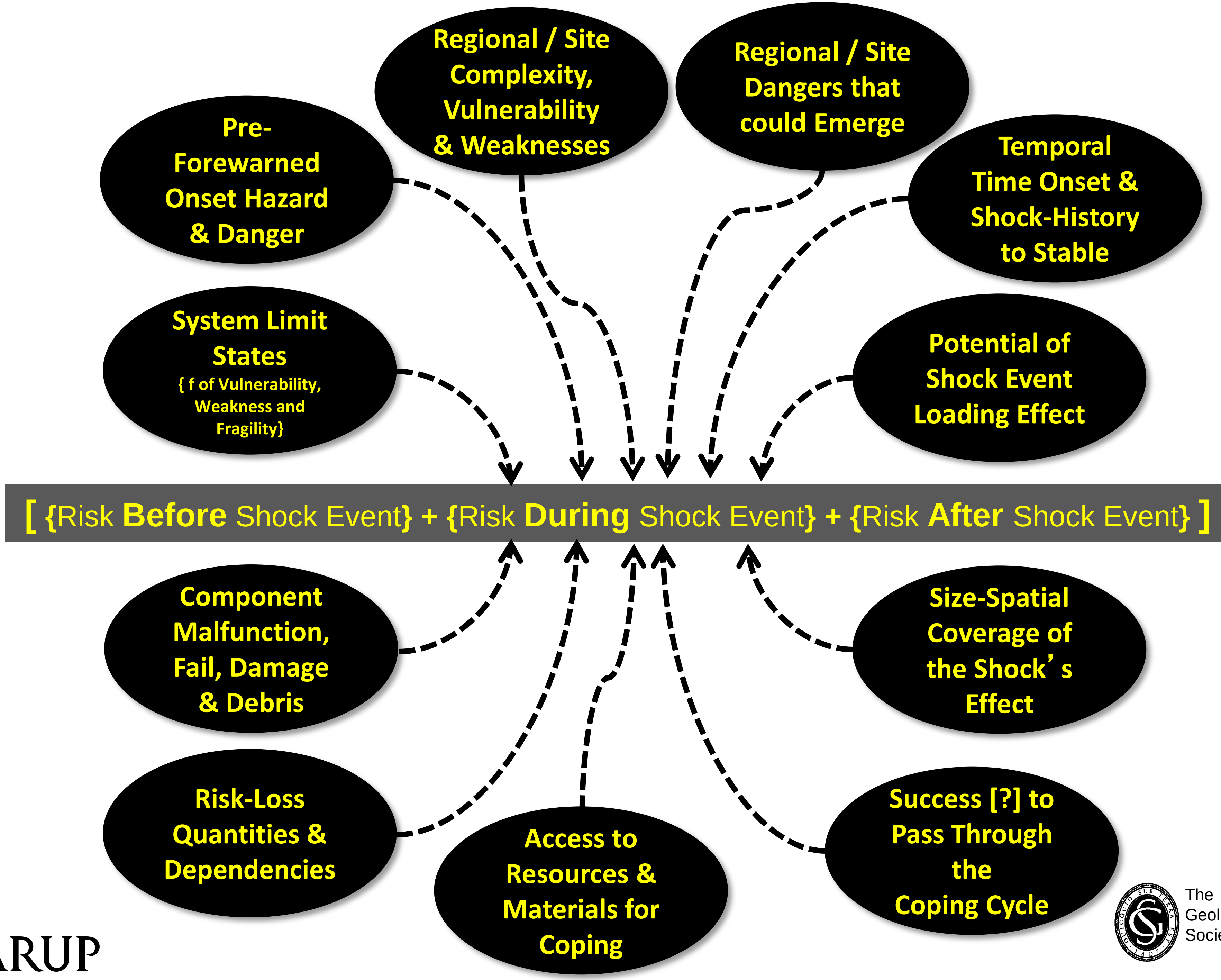
Projected Event Risk = $\{P_{rB} \times H_B \times E_P \times Z_P \times D_P\}^{BHSE}$

During:

Actual Event Scenario Risk = $\{P_{rD} \times H_D \times V_D \times T_D \times S_D \times F_O\}^{DHSE}$

After:

Post-Event Loss-Risk = $\{P_{rA} \times H_A \times V_A \times T_A \times S_A \times R_A\}^{AHSE}$



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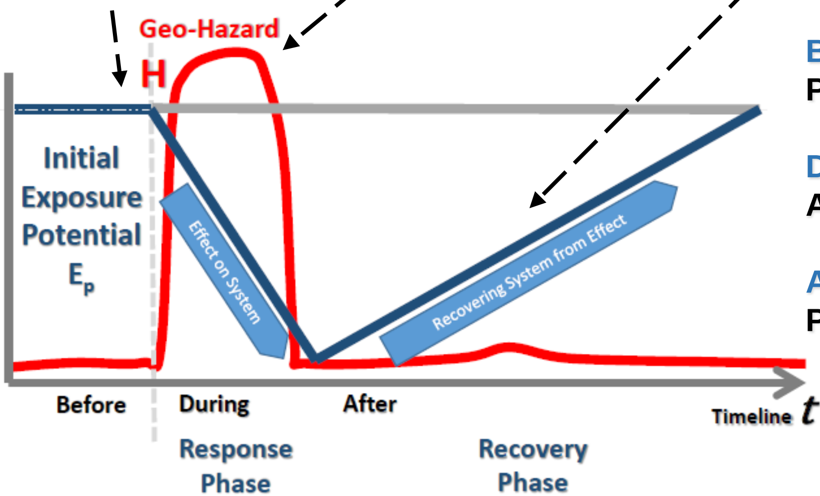
HIT Level 3
Objective Quantification

$\{P_{rD} \times H_D \times V_D \times T_D \times S_D \times F_O\}^{DSE}$

$\{P_{rB} \times H_B \times E_P \times Z_P \times D_P\}^{BSE}$

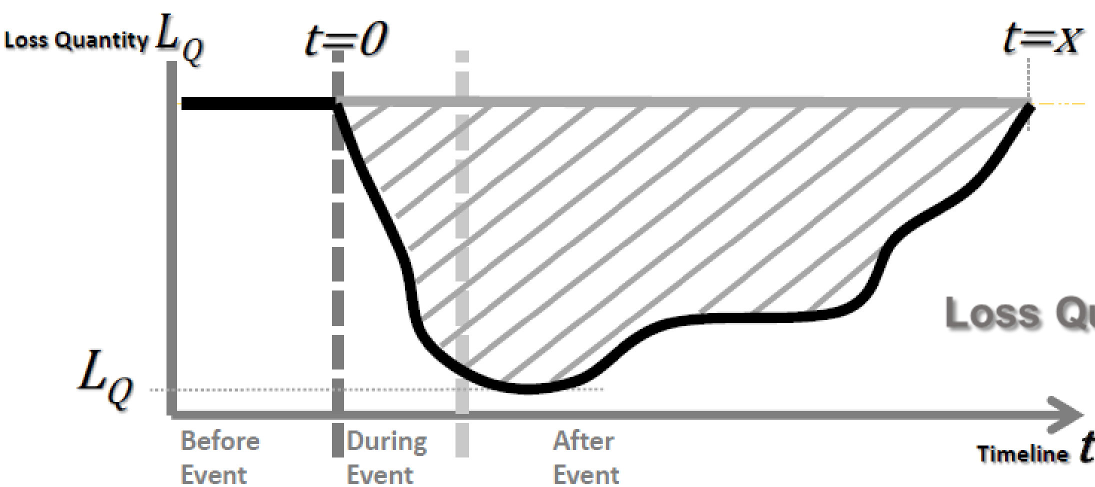
$\{P_{rA} \times H_A \times V_A \times T_A \times S_A \times R_A\}^{ASE}$



Before:
Projected Event Risk = $\{P_{rB} \times H_B \times E_P \times Z_P \times D_P\}^{BHSE}$

During:
Actual Event Scenario Risk = $\{P_{rD} \times H_D \times V_D \times T_D \times S_D \times F_O\}^{DHSE}$

After:
Post-Event Loss-Risk = $\{P_{rA} \times H_A \times V_A \times T_A \times S_A \times R_A\}^{AHSE}$



Loss Quantity: $\int_{t=0}^{t=x} L_Q\,(t)\,dt$

- Awareness
- Forewarning
- Preparedness
- Robustness
- Response
- Recovery
- Resources
- Coping
- Adaptability
- Surveillance

HIT Level 1 and 2
Expert Qualification

Are you?

Is your?

Are you?

System's Exposure Potential?

HIT Level 3
Objective Quantification

Actual Damage & Loss?

Likelihood for Response & Recovery?

Coping Capability?

Accidental Design Situations

Extension of Design Situations with Climate Change Effects

Consequence Class 3

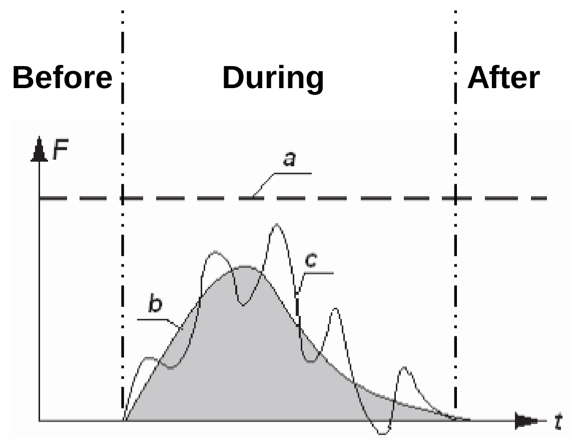
B.4 Methods of Risk Analysis

HIT Level 2
Expert Qualification

Qualitative Risk Assessment

Holistic Integrity Test (HIT)

- Robustness
- Awareness
- Forewarning
- Preparedness
- Response
- Recovery
- Resources
- Coping
- Adaptability
- Surveillance



Key :
a : equivalent static force
b : dynamic force
c : structural response

Figure 1.1

EUROPEAN STANDARD
EN 1991-1-7
(Reference 30)

HIT Level 3
Objective Quantification

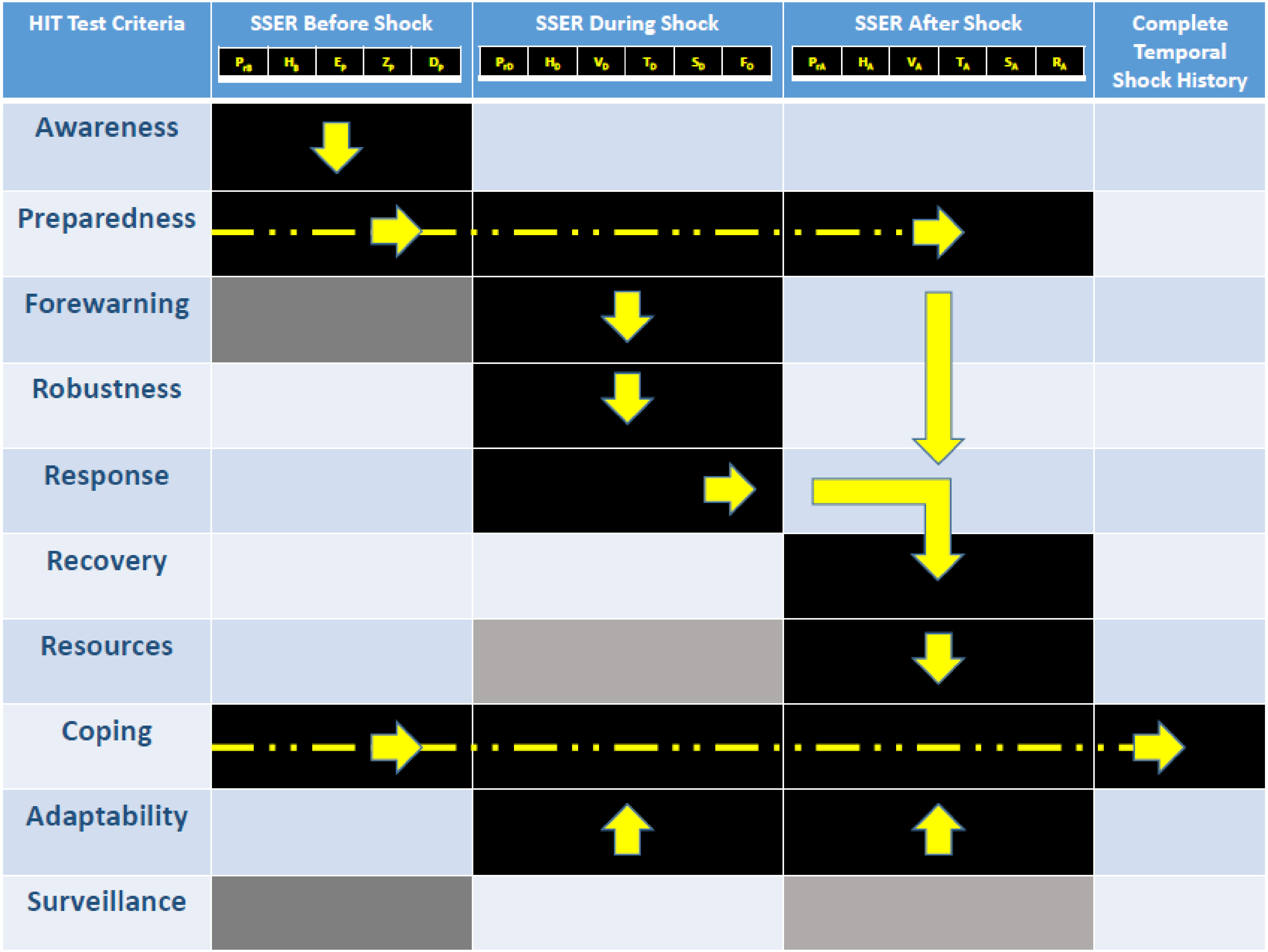
Quantitative Risk Analysis (QRA)

Arup's Severe Shock Event Risk (SSER) Equation

Before
$P_{rB} \times H_B \times E_P \times Z_P \times D_P$

During
$P_{rD} \times H_D \times V_D \times T_D \times S_D \times F_O$

After
$P_{rA} \times H_A \times V_A \times T_A \times S_A \times R_A$


HIT Test Criteria
SSER Before Shock
P_{rB} H_B E_P Z_P D_P
SSER During Shock
P_{rD} H_D V_D T_D S_D F_D
SSER After Shock
P_{rA} H_A V_A T_A S_A R_A
Complete Temporal Shock History
Awareness
Preparedness
Forewarning
Robustness
Response
Recovery
Resources
Coping
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Holistic Integrity Test:

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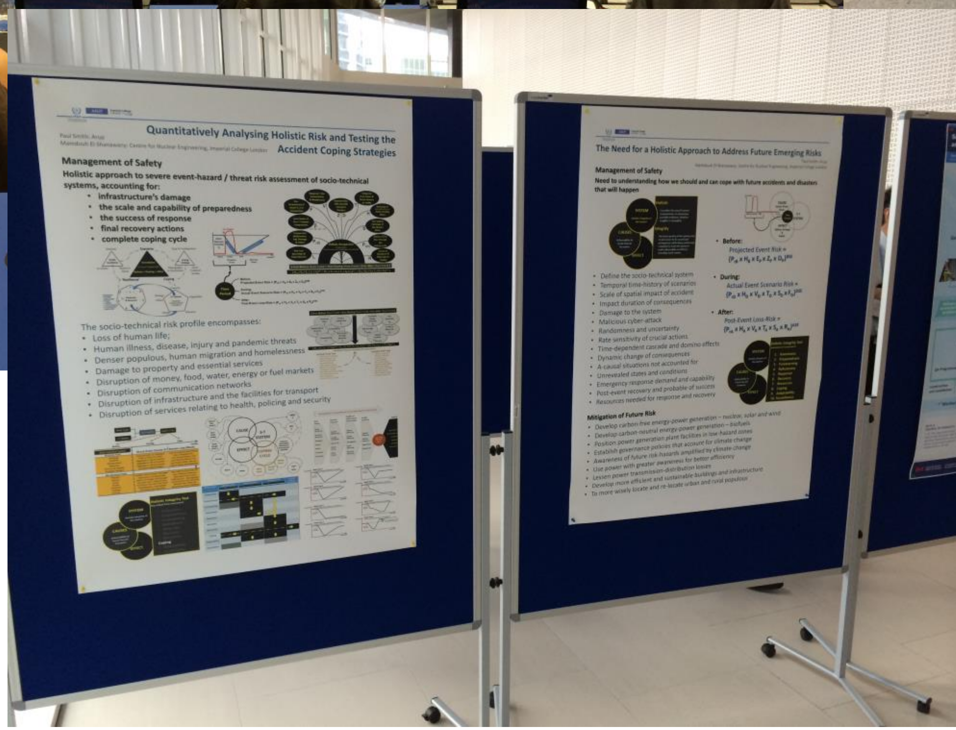

IAEA
International Atomic Energy Agency

14th IAEA–FORATOM Management System Workshop

Nuclear Power

Energy Supply to the Structural Fabric

Nuclear Power?

- **Can be and is a reliable energy supply;**
- **Carbon-free power supply;**
- **Practiced, experienced people and knowledge;**
- **Potential long period of use;**
- **Engineering well established;**
- ***.... But ….***

Further development is needed for future Nuclear Power to be accepted:

- **Reduced Capital and Operating Cost;**
- **Shorter Time for Build and Construction;**
- **Modular Design and Engineering;**
- **Simpler Design and Safety;**
- **Much Better Hazard Withstand; and**
- **Holistic Integrity & Coping Capability.**

Accident Risk to Nuclear Power Plants specifically concentrates on:

- **Protecting against Engineering Failure;**
- **Protecting against Human Error;**
- **Withstanding Earthquake;**
- **Withstanding Flood and Tsunami;**
- **Withstanding Storm Winds;**
- **Withstanding Aircraft Crash;**
- **Secure and Safe against Terrorism.**

Considerations for Future Generation IV Nuclear Power Plants

Design Objectives

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- Low Energy Construction Methods
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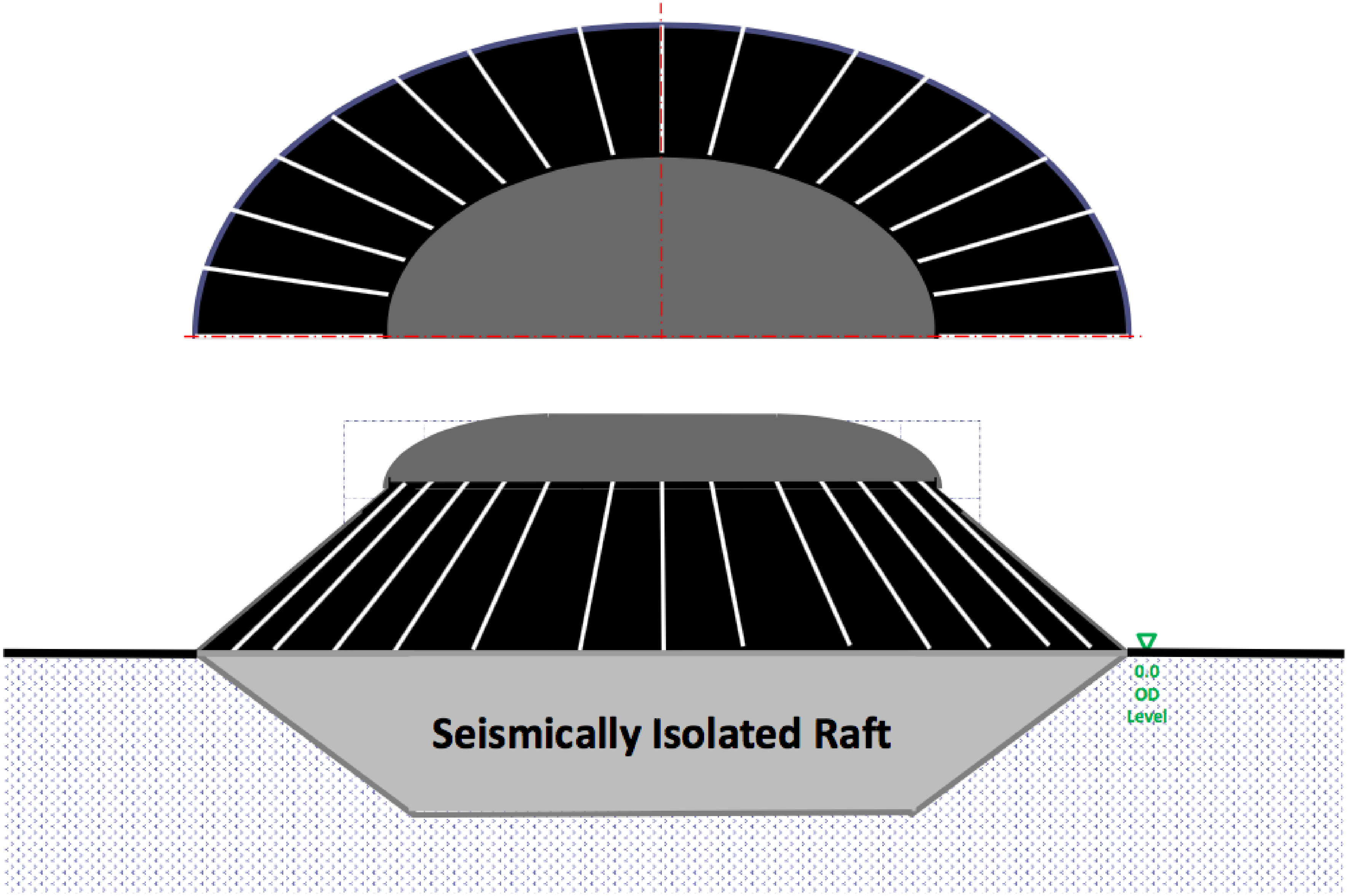
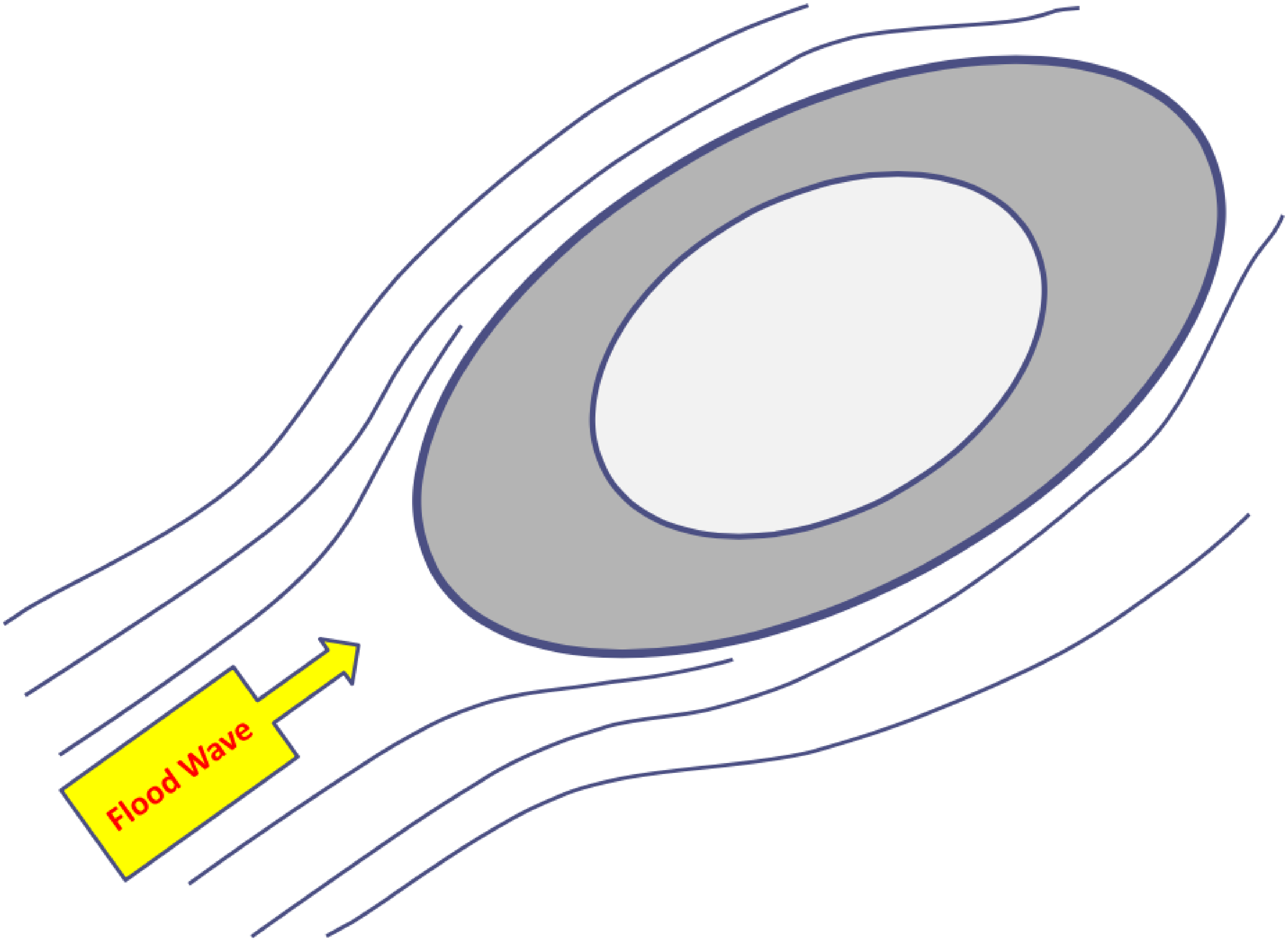
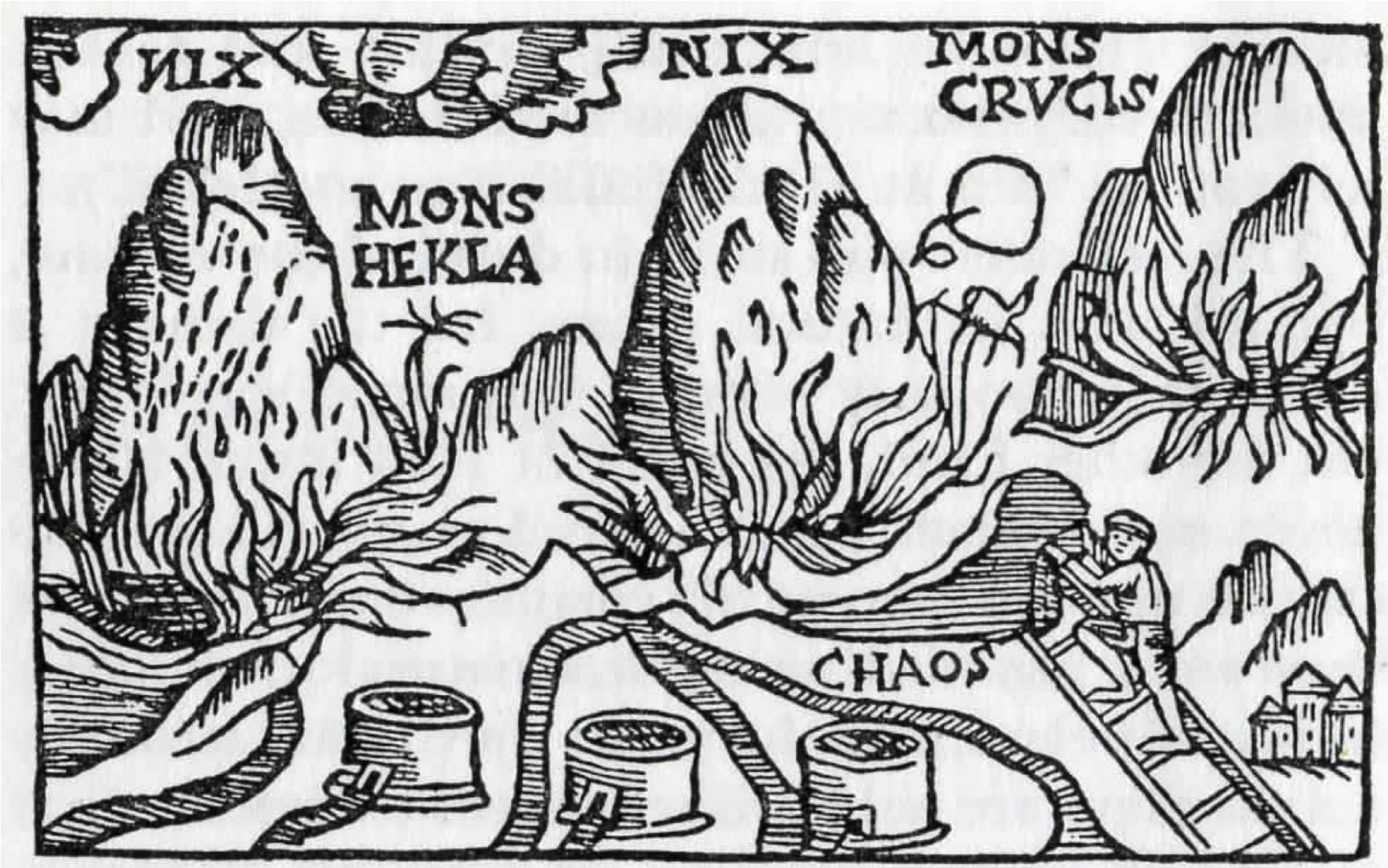

Seismically Isolated Raft
0.0
OD
Level


Flood Wave



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Nuclear Engineering
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Thank You

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Society