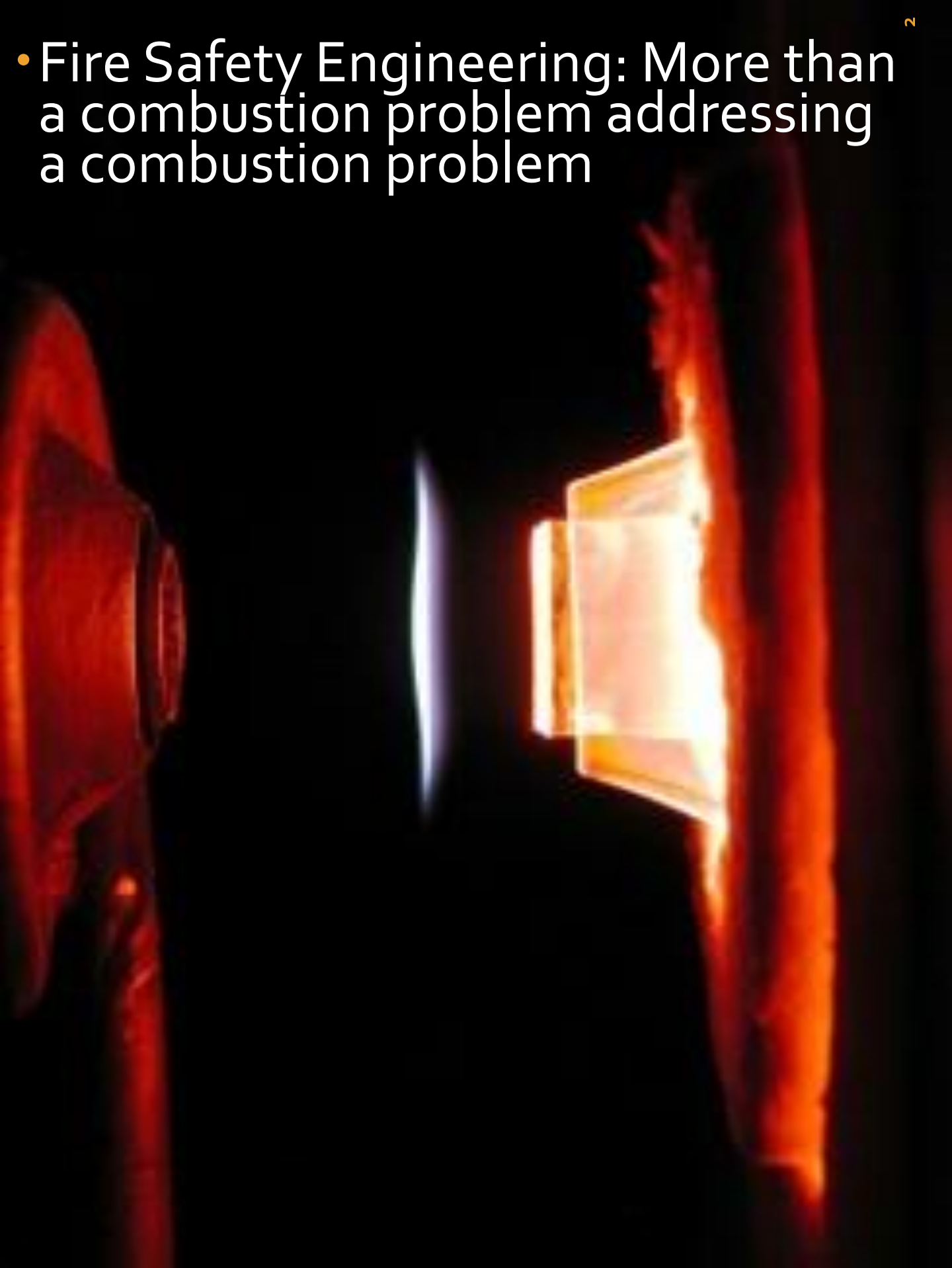
Introduction to Fire Safety Engineering

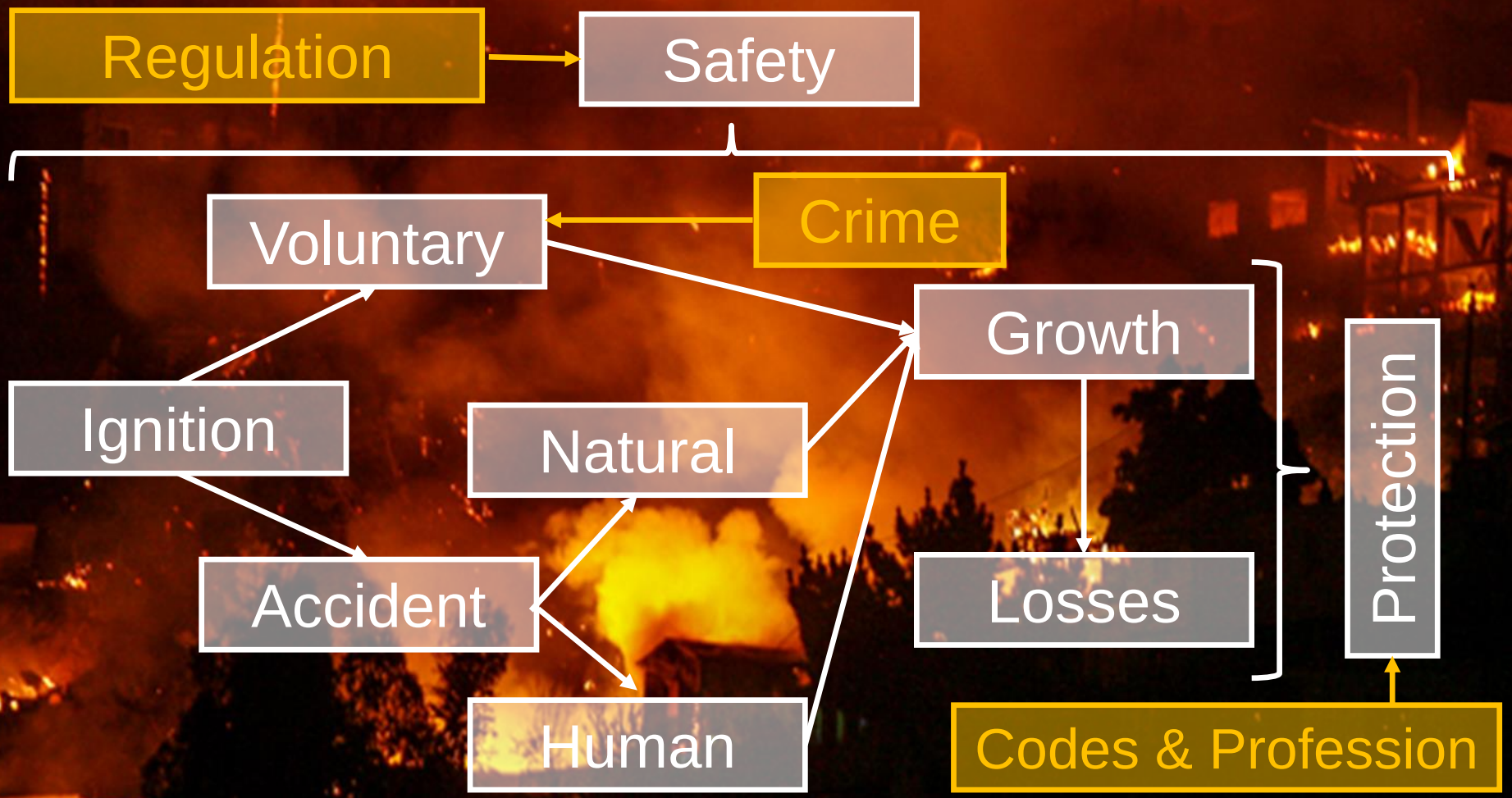
José L. Torero
A. James Clark School of Engineering, The University of Maryland, USA

- Fire Safety Engineering: More than a combustion problem addressing a combustion problem

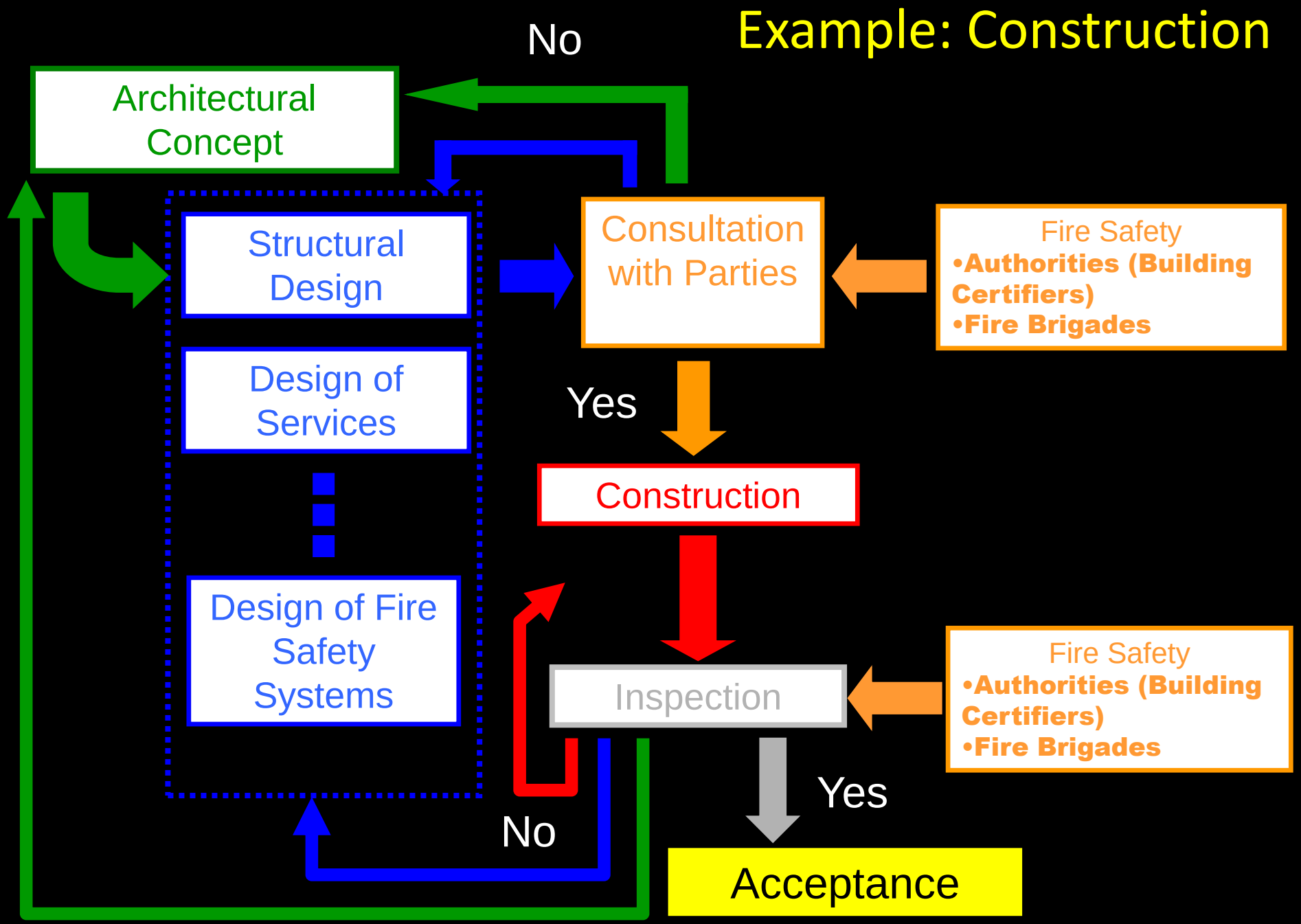


Fire

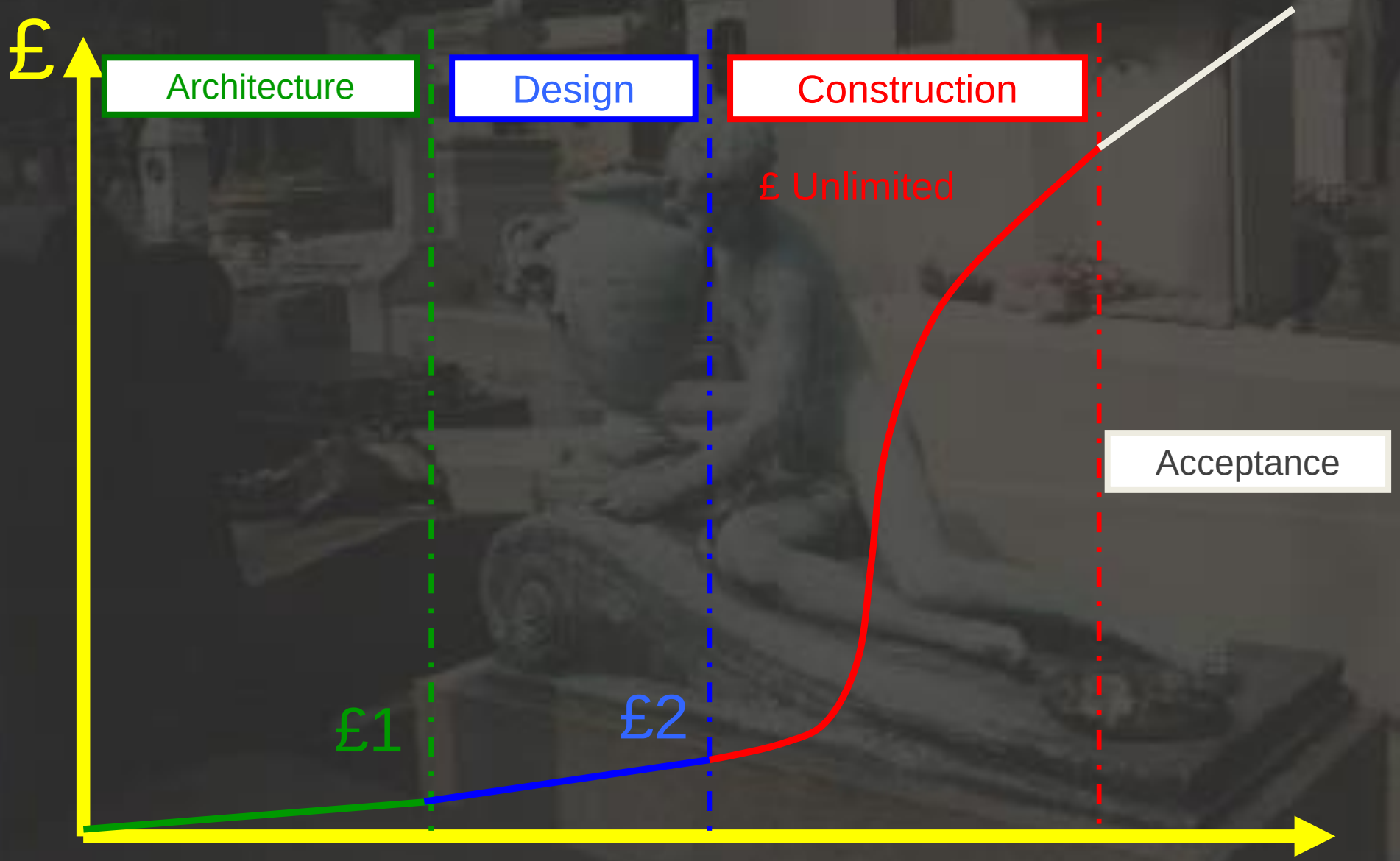
- Physical phenomenon that evolves in space and time – affect the wellbeing of people and property



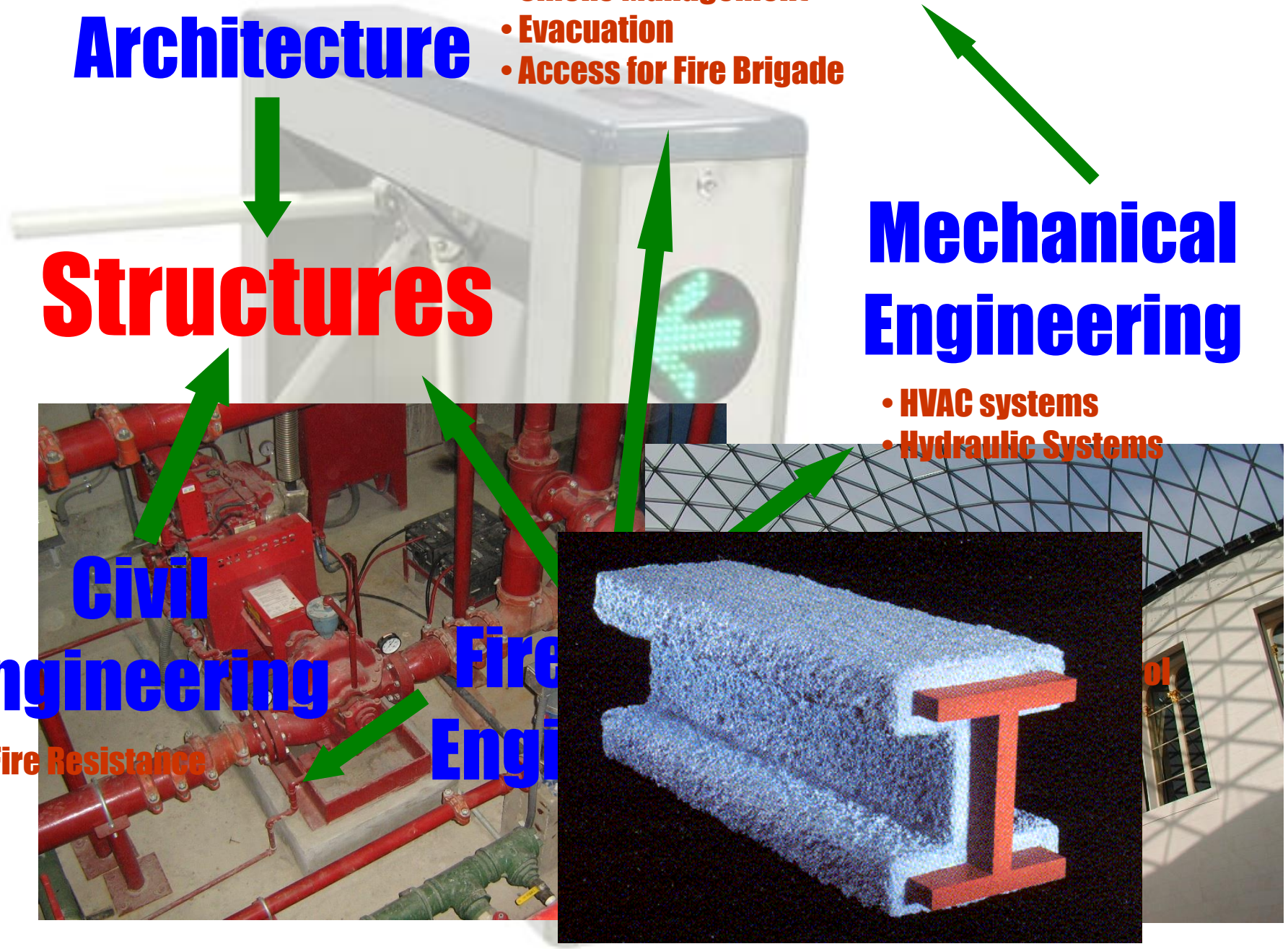
Example: Construction



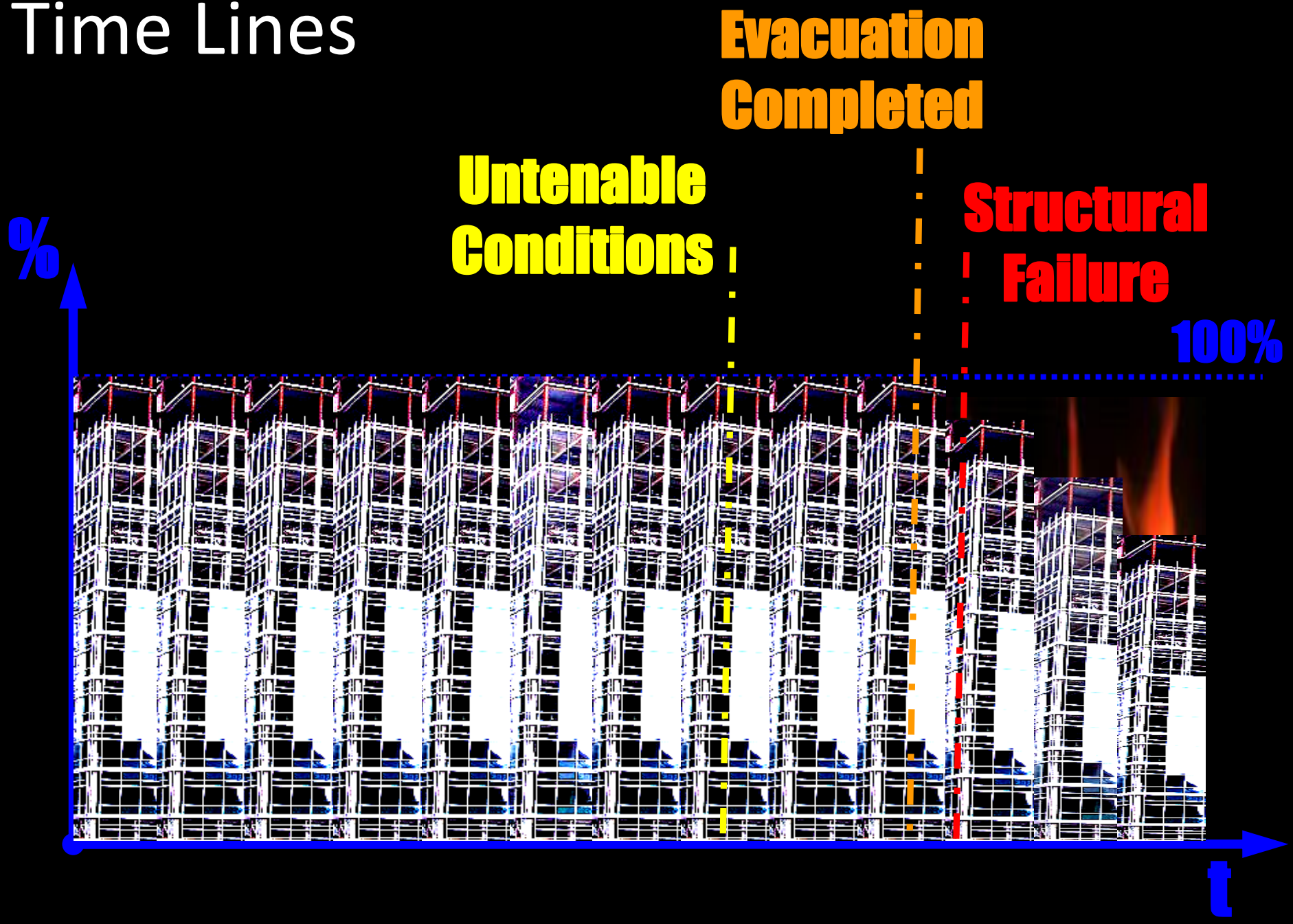
The Cost of Error



- Affects every aspect of building design



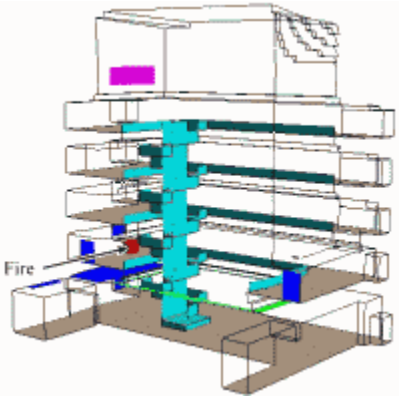
Time Lines


Evacuation Completed
Untenable Conditions
Structural Failure
%
100%
t

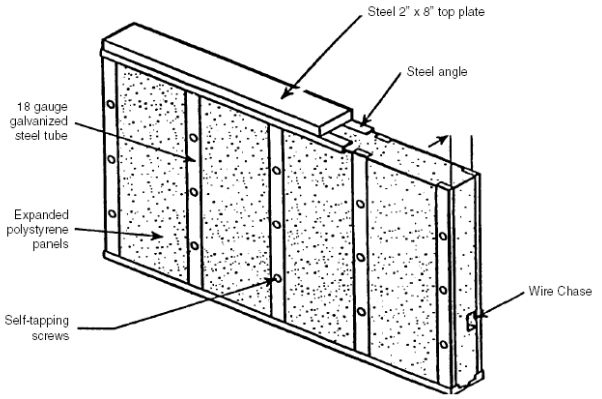
Fire Safety Strategies

- Prescriptive Design
- Performance Based Design

Life Safety

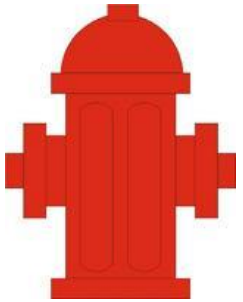


Compartmentation

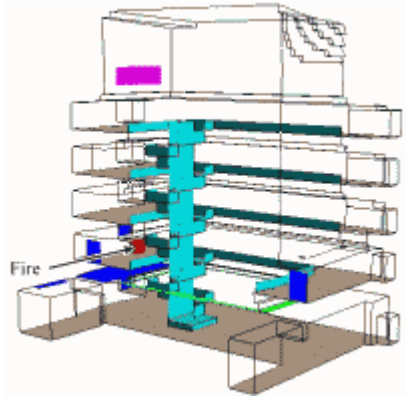


Structure

Response



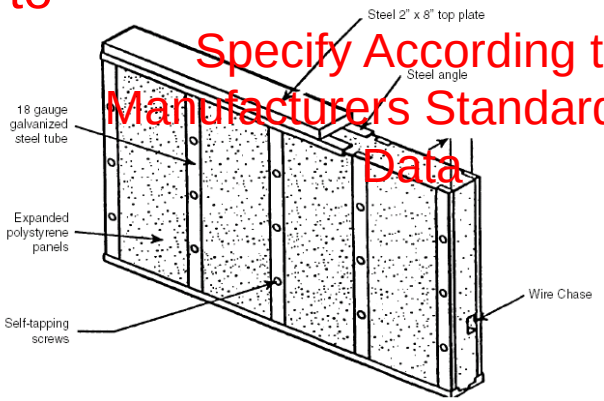
Life Safety



Common Sense

Compartmentation

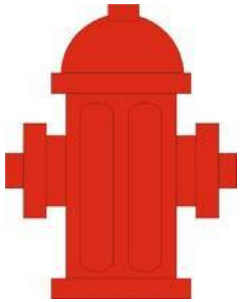
Locate According to manufacturers Specifications



Specify According to Manufacturers Standard Test Data

Structure

Response

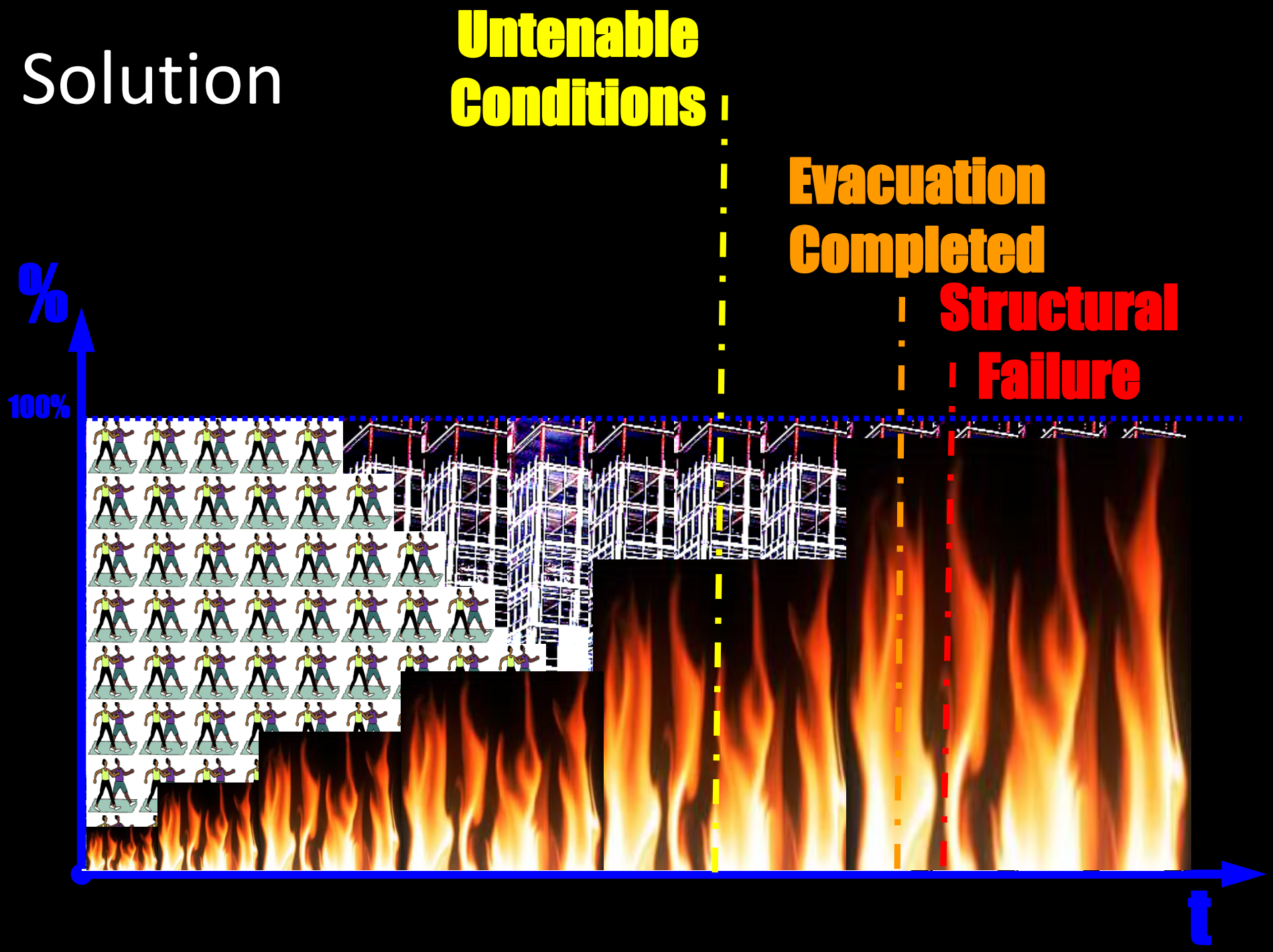


Common Sense

Define according to simple rules (Common Sense)

Common Sense

Solution


Untenable Conditions
Evacuation Completed
Structural Failure
%
100%
t

Can the same rules be applied?

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018

Compliance vs. Profession

- Limited to conventional buildings
  - Conventional is less and less frequent
  - Construction has evolved faster than codes
  - Construction has evolved faster than our capacity to train authorities/engineers/fire service
- Codes can only be used as a tool for the competent professional

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018


QueenslandRail
CENTRAL STN
QueenslandRail
BOMBARDIER

The Objectives

$$t_e <<<< t_f$$

$$t_e <<<< t_s$$

$$t_s \rightarrow \infty$$

Summary

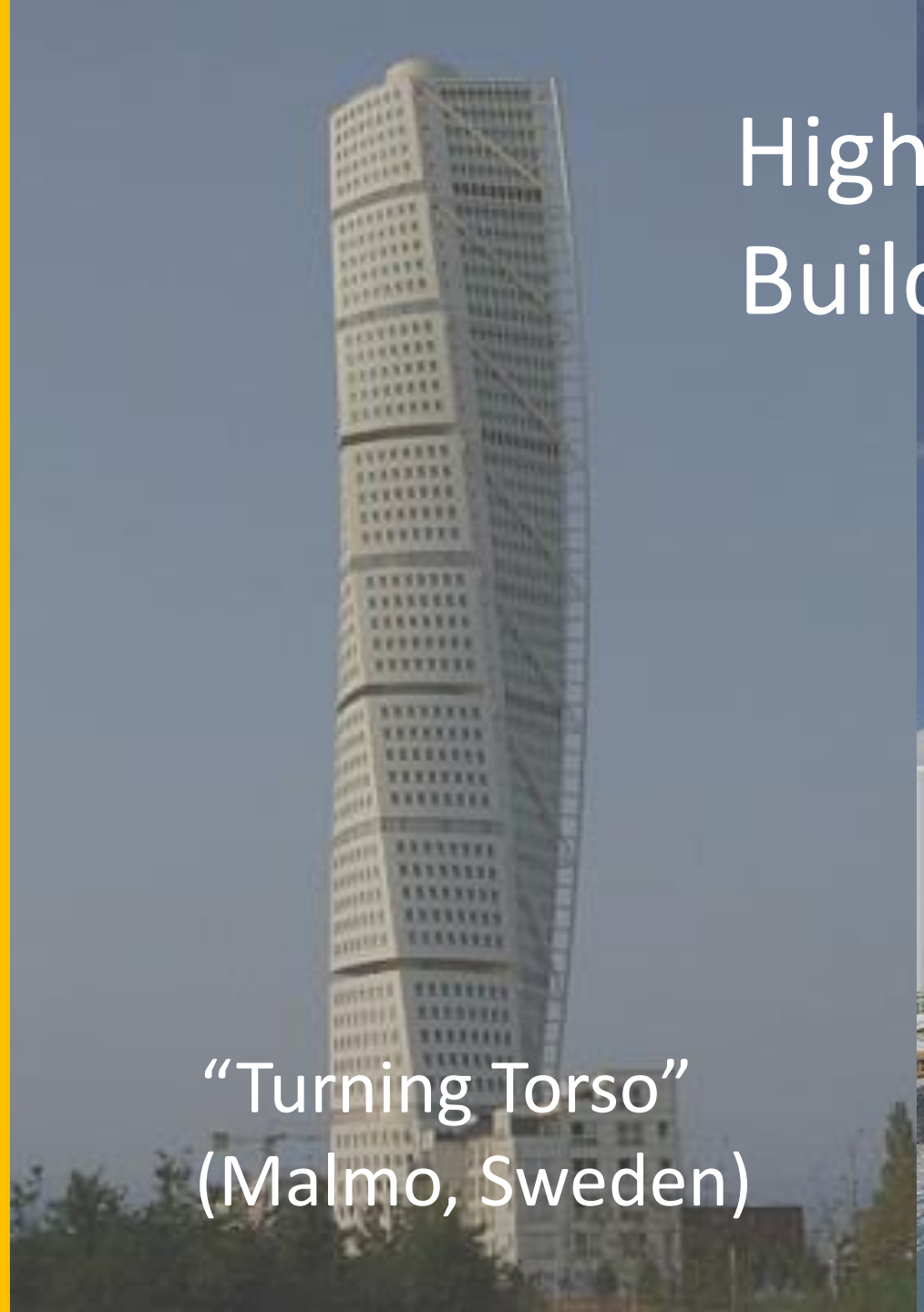
- Fire Safety Engineering is a complex field that interacts with all other disciplines in the construction process
- Codes and Standards (classic practises) are viable only for simple buildings – complex buildings require higher level engineering

Example

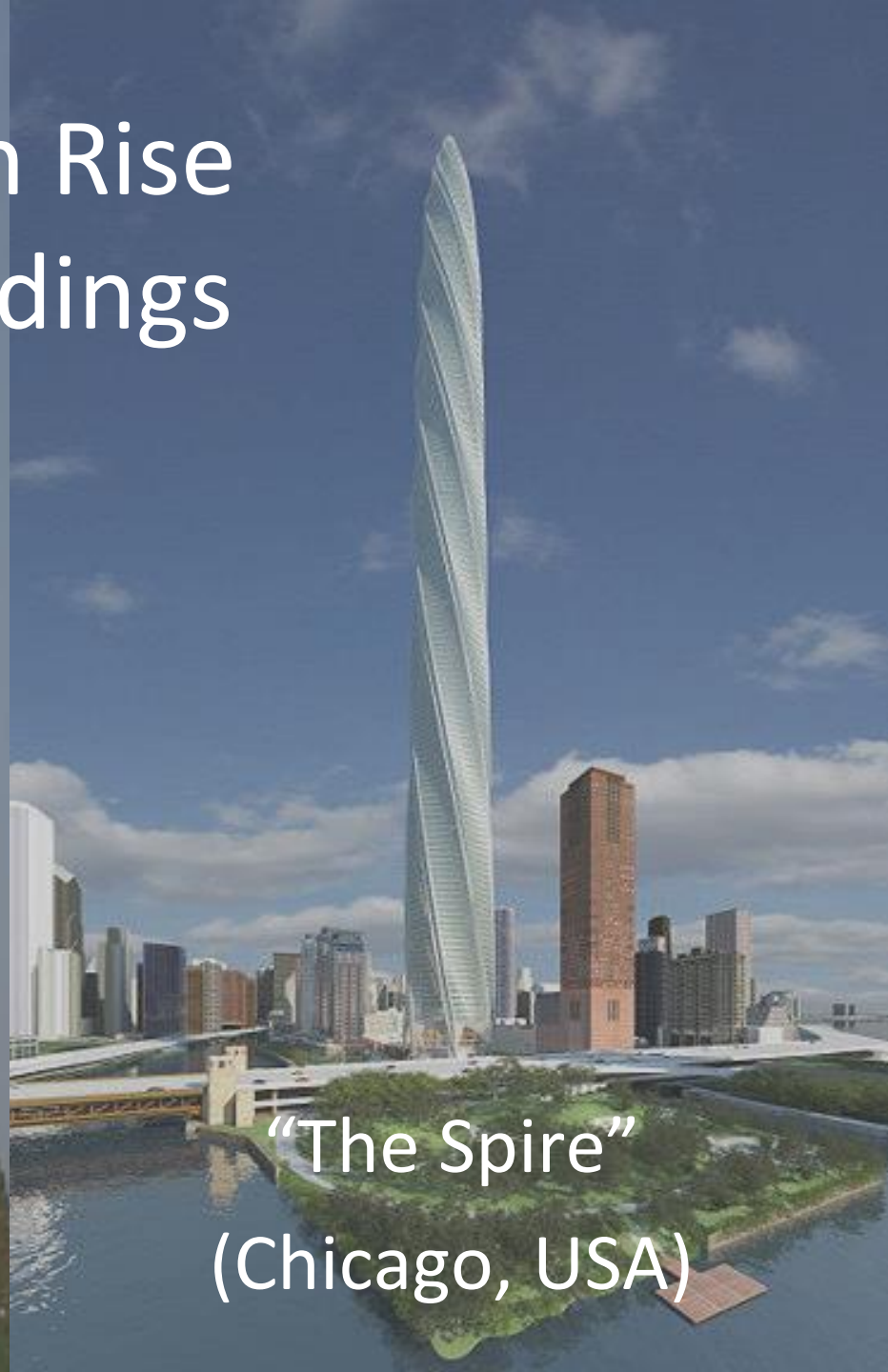
- Santiago Calatrava
  - Architect
  - Date of Birth: July 28th, 1951
  - Gold Medal AIA, USA
  - Grand Medaille D'Or Academie d'Architecture, Paris, France
  - Il Principe e l'Architetto, Italy
  - Sir Micha Black Medal, Royal College of Art, UK
  - Gold Medal IStructE, UK
  - Premio Principe de Asturias, Spain
  - More than 10 Honorary Doctorates

Photo credit: Suzanne DeChillo/™©The New York Times

High Rise Buildings



"Turning Torso"
(Malmo, Sweden)



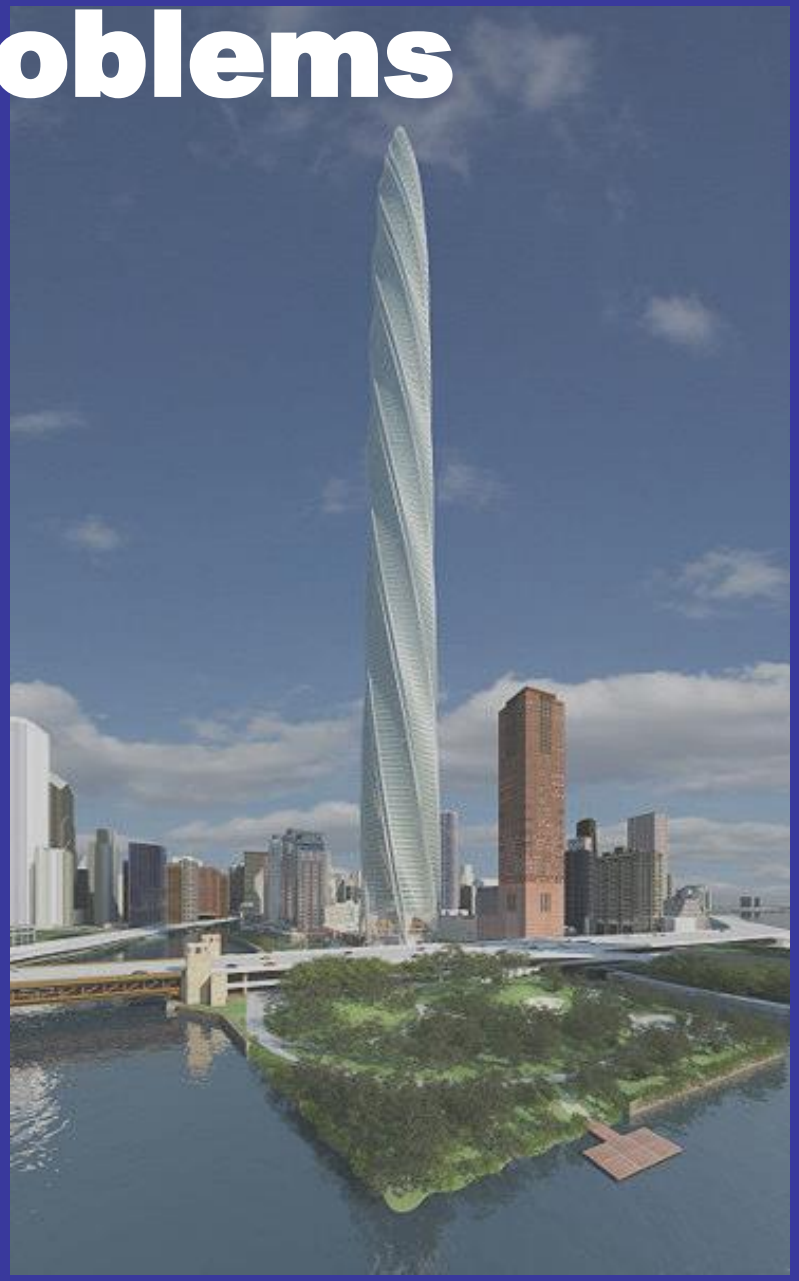
"The Spire"
(Chicago, USA)

Fire Safety Strategies

- Evacuation
  - Detection
  - Alarm
  - Displacement away from the fire
  - Crowd management
- Compartmentalization
  - Slows fire growth
  - Minimizes smoke spread
- Response
  - Automatic (fire suppression)
  - External
  - Internal
- Structural Integrity

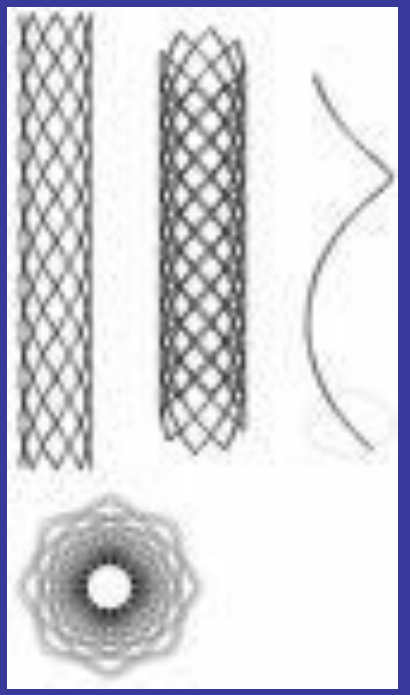
What are the Problems

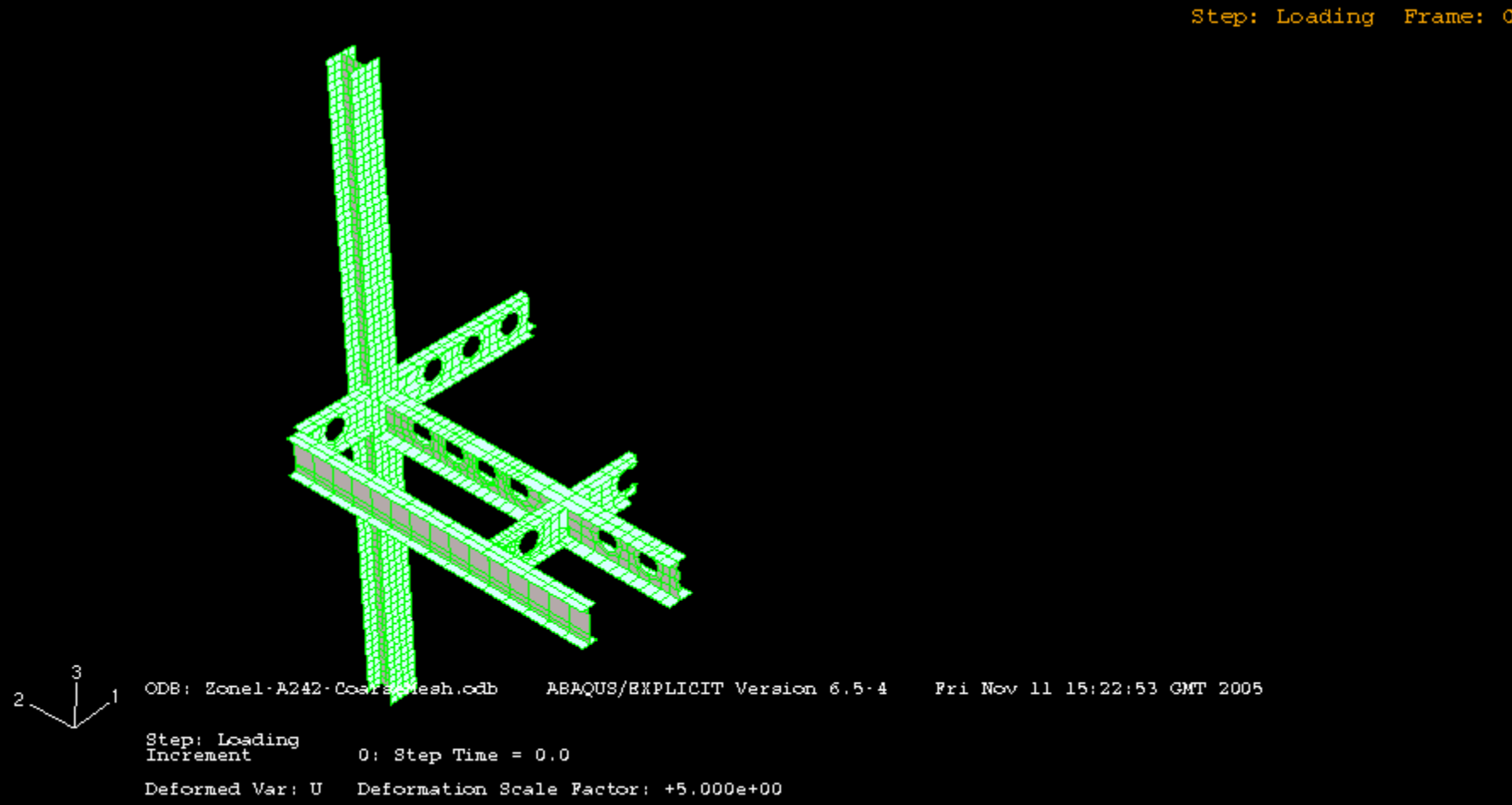
- **Compartimentation**
- **Structural**



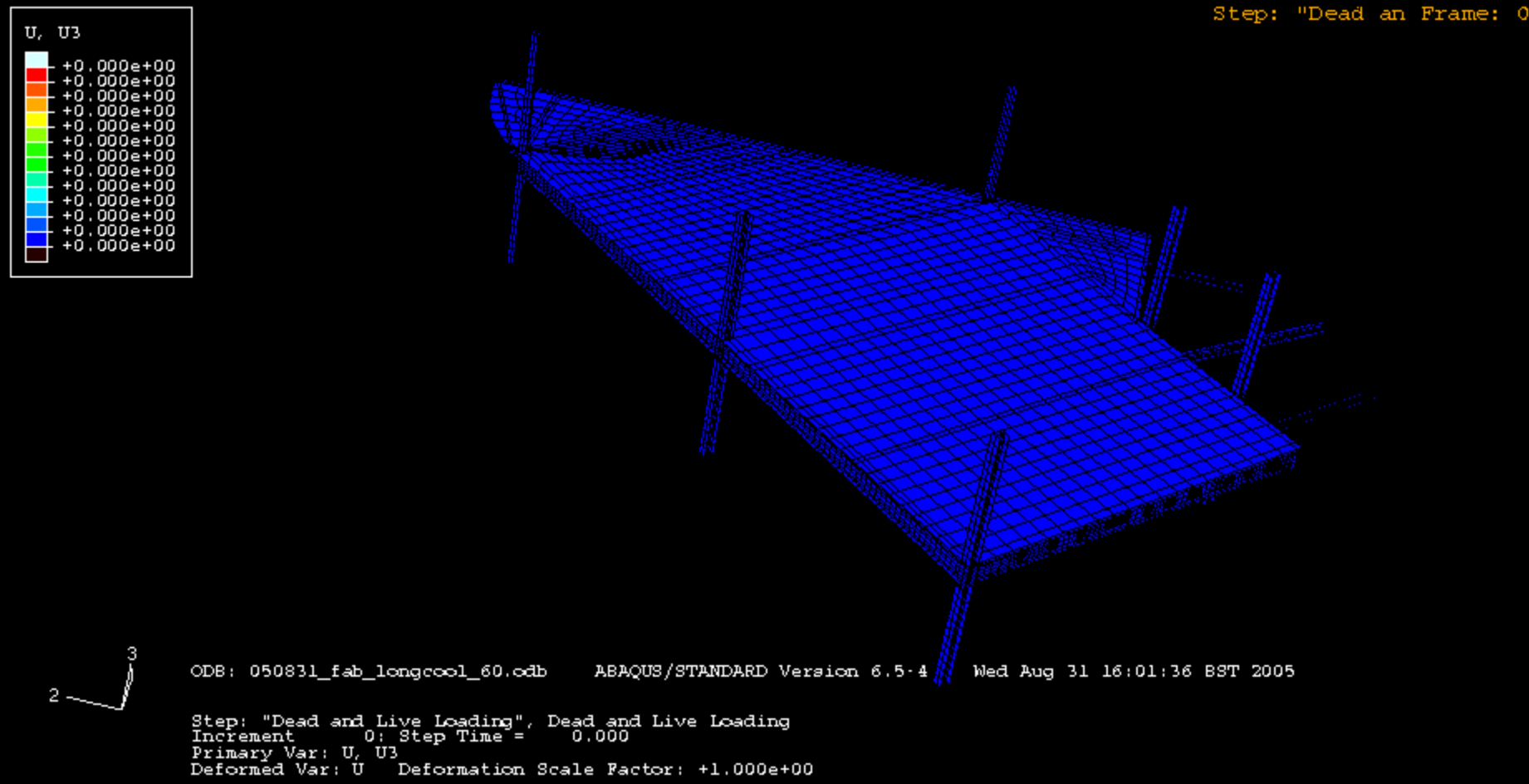
Dia-Grid

- **Allows for unusal deformations that have the potential to break compartimentation**

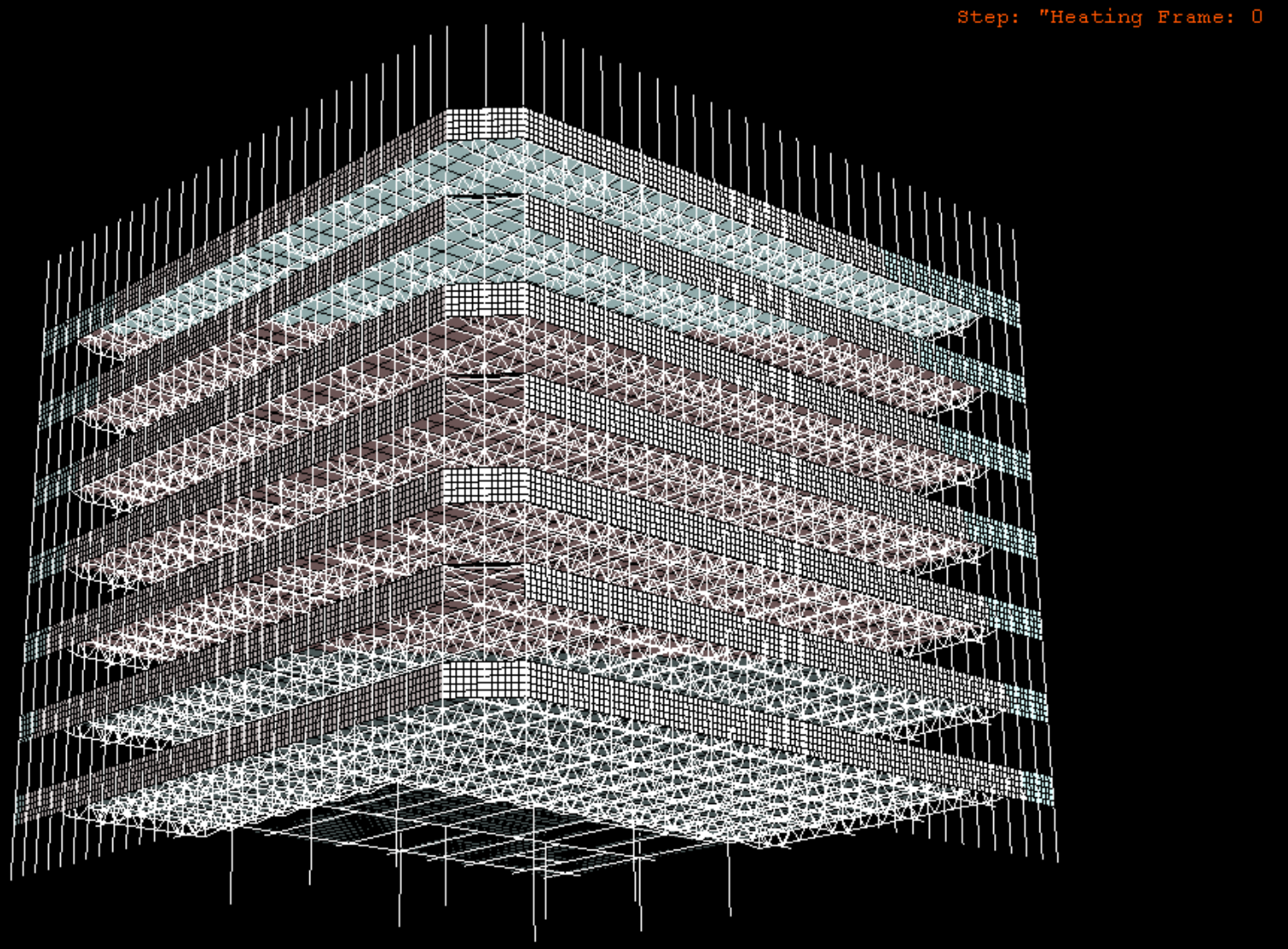



Step: Loading Frame: 0
3
2
1
ODB: Zone1-A242-Coarse_Mesh.odb ABAQUS/EXPLICIT Version 6.5-4 Fri Nov 11 15:22:53 GMT 2005
Step: Loading
Increment 0: Step Time = 0.0
Deformed Var: U Deformation Scale Factor: +5.000e+00

Detailed Models



Detailed Models



Allen Lambert Gallery (Canada)

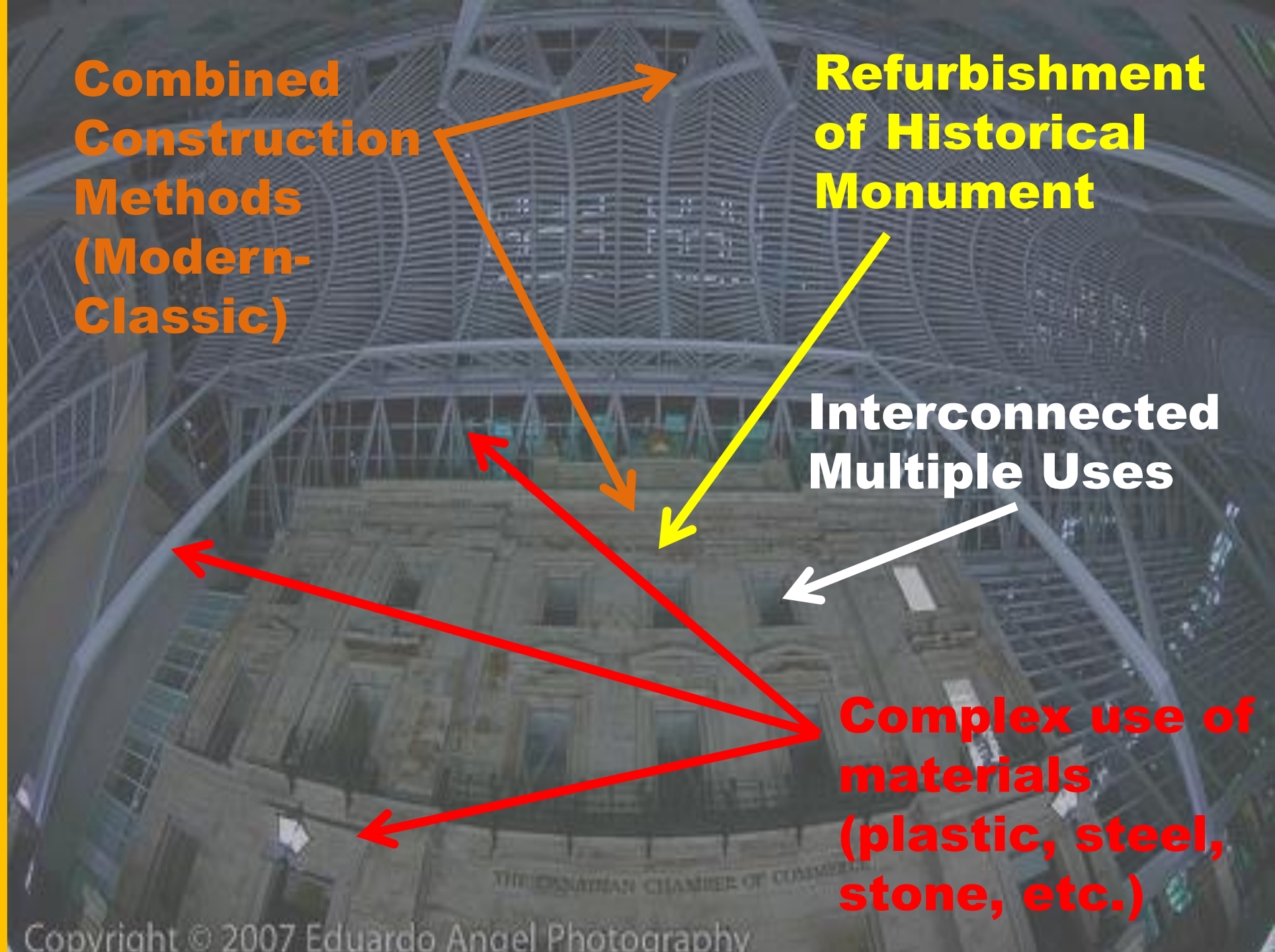
Unprotected structure

High Ceilings

- **Delayed detection**
- **Delayed sprinkler Activation**

Smoke Management

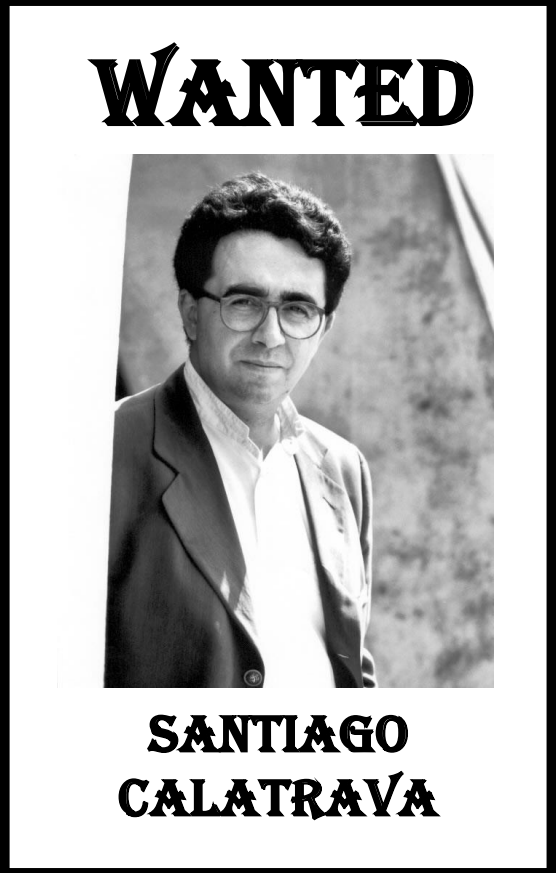
Egress Problem


Combined Construction Methods (Modern-Classic)
Refurbishment of Historical Monument
Interconnected Multiple Uses
Complex use of materials (plastic, steel, stone, etc.)
Copyright © 2007 Eduardo Angel Photography

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018

Therefore



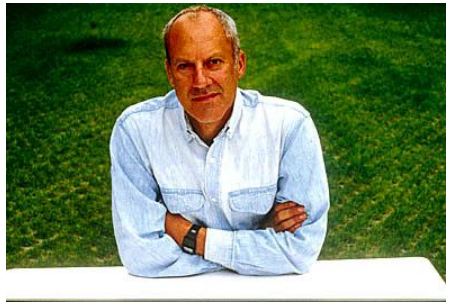
- For involuntary man slaughter?

WANTED

WANTED

WANTED

WANTED



NORMAN
FOSTER

WANTED

ZAHA
HADID

WANTED

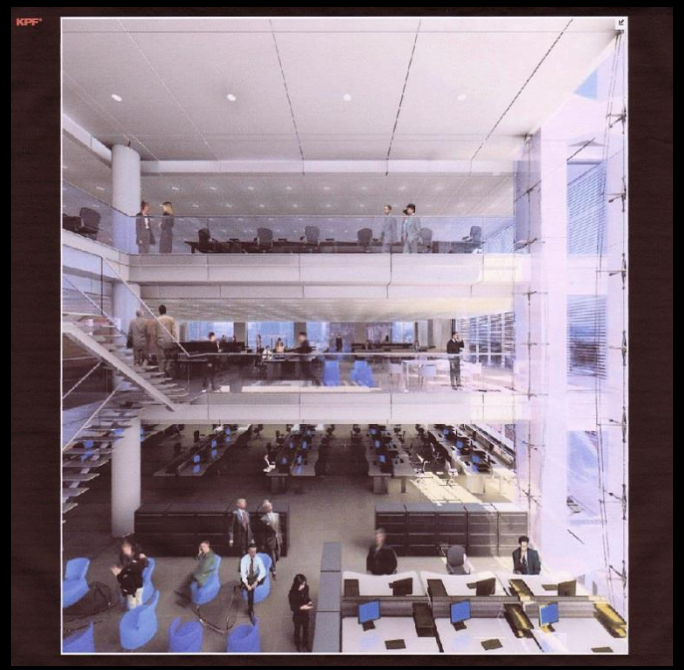
RICHARD
ROGERS

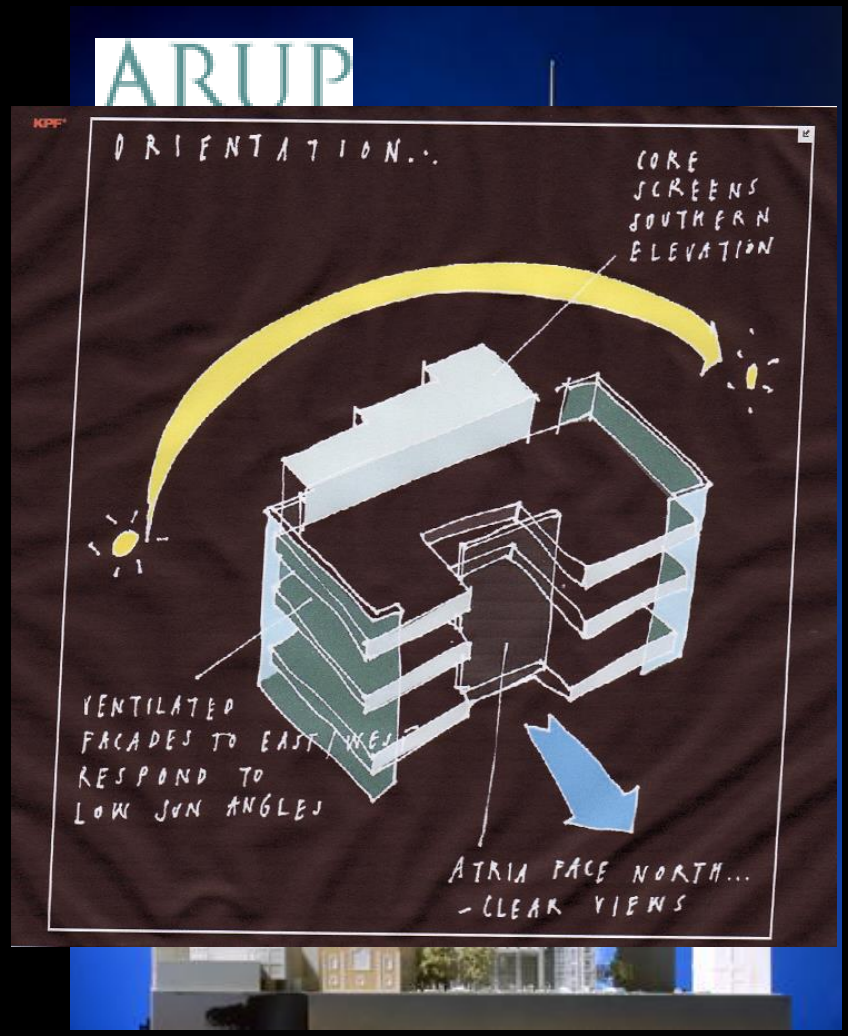
- **No!**
- **The solution is:**
  - **proper engineering!**

When it is done right

Heron Tower

- Kohn Pedersen Fox
- 80 Storey Building in London
- Formed of many 4 storey "villages"
- Arup: Fire Engineering

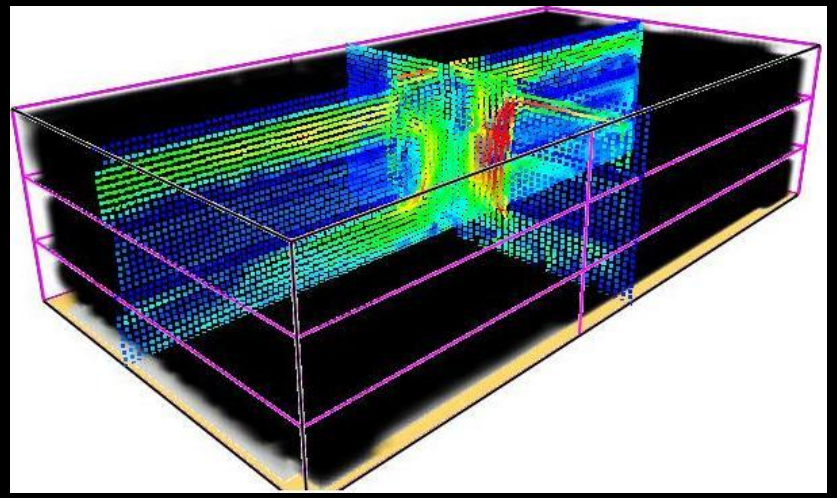


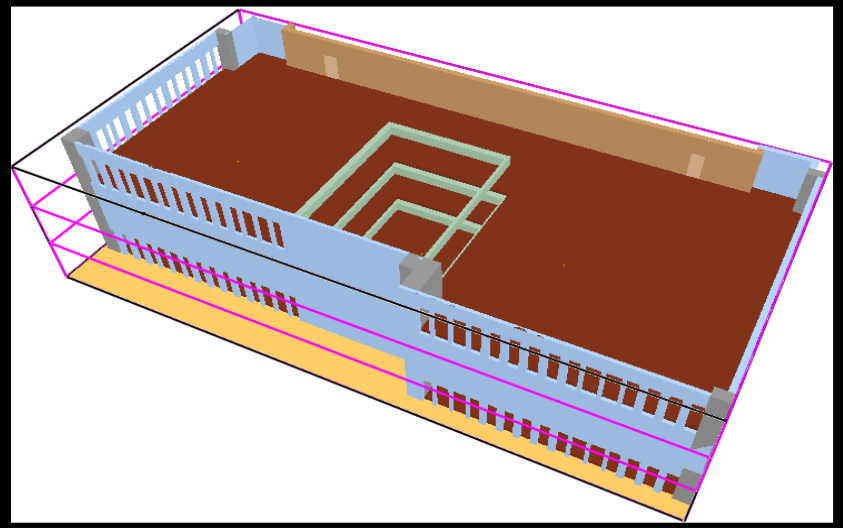


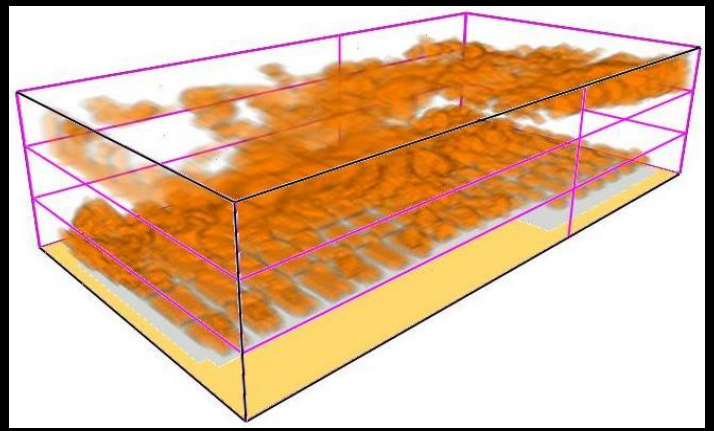
Key Issues

- How Would a 4 Storey Fire affect:
  - The structural performance of the building?
  - Egress?
  - Fire Detection & Suppression?

Modelling of the Fire







Today: Design for Implicit Performance

One Size Fits All

Standardization of Space

- Means of Escape
- Compartmentation
- Geometry

Standardization of Response

- Active
- Passive
- Fire Service

Unsustainable

Consequence: Enormous Safety Factors

- Loss of Function
- Compromised Aesthetics
- Waste
- Unidentified Mistakes

ety Factors: Sustainable

on

Architecture

People

Physiology
Psychology
Sociology

Reactive Flow

Burning

Material Science

Materials

Smoke/Heat

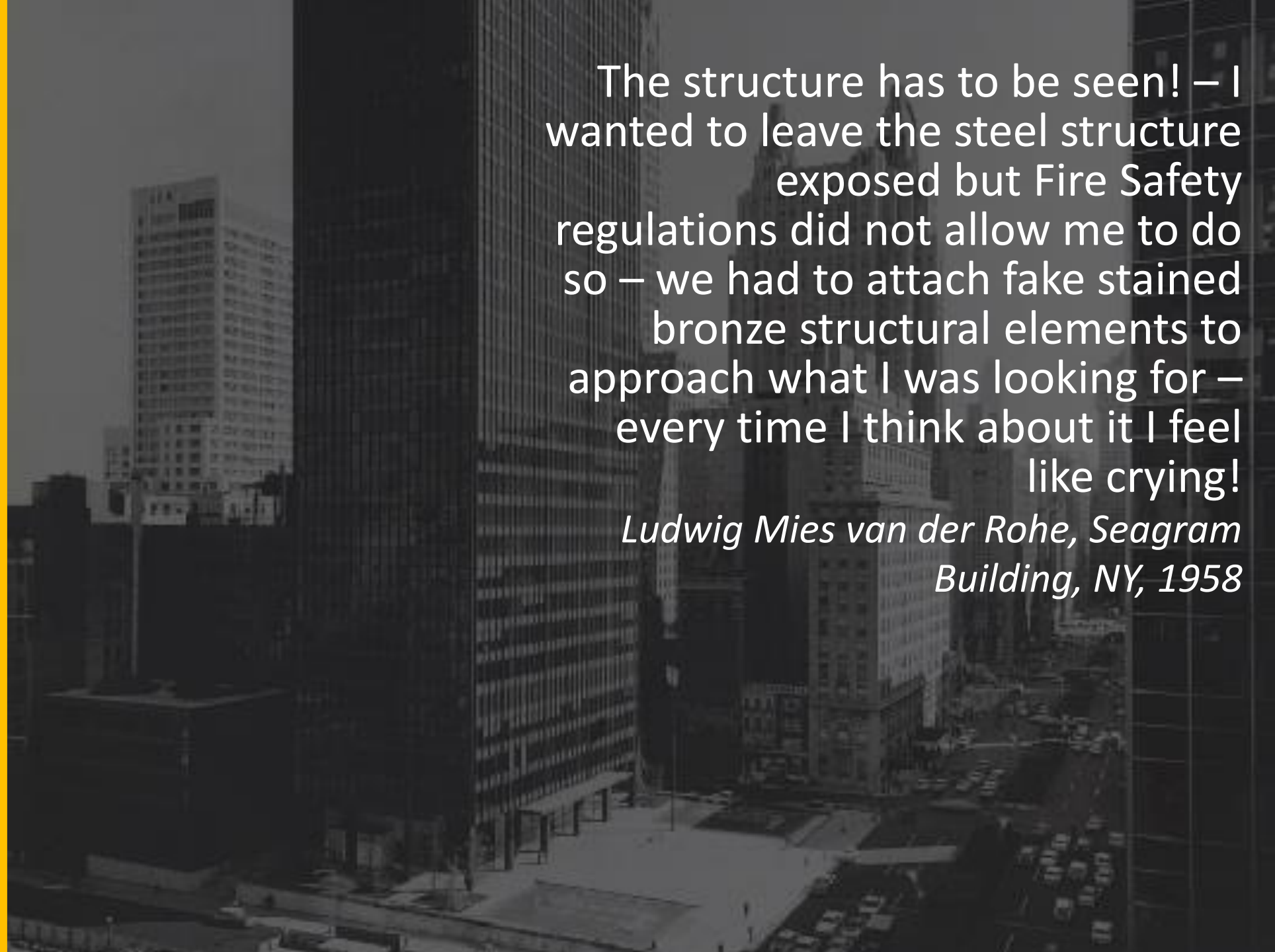
Solid Mechanics

Structure

Fluid Mechanics
Heat Transfer

Tomorrow: Design for Explicit Performance

ESIA – Ecole des Sciences de l'Incendie et Applications – Obernai, 27 mai au 1er juin 2018



The structure has to be seen! – I wanted to leave the steel structure exposed but Fire Safety regulations did not allow me to do so – we had to attach fake stained bronze structural elements to approach what I was looking for – every time I think about it I feel like crying!

Ludwig Mies van der Rohe, Seagram Building, NY, 1958