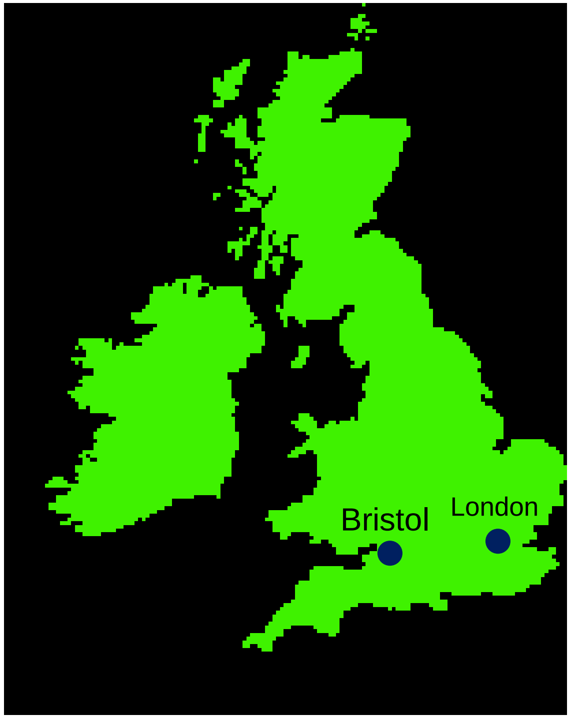
University of BRISTOL

Earthquake engineering and systems thinking at Bristol



Prof Colin Taylor BSc PhD CEng FICE
Professor of Earthquake Engineering

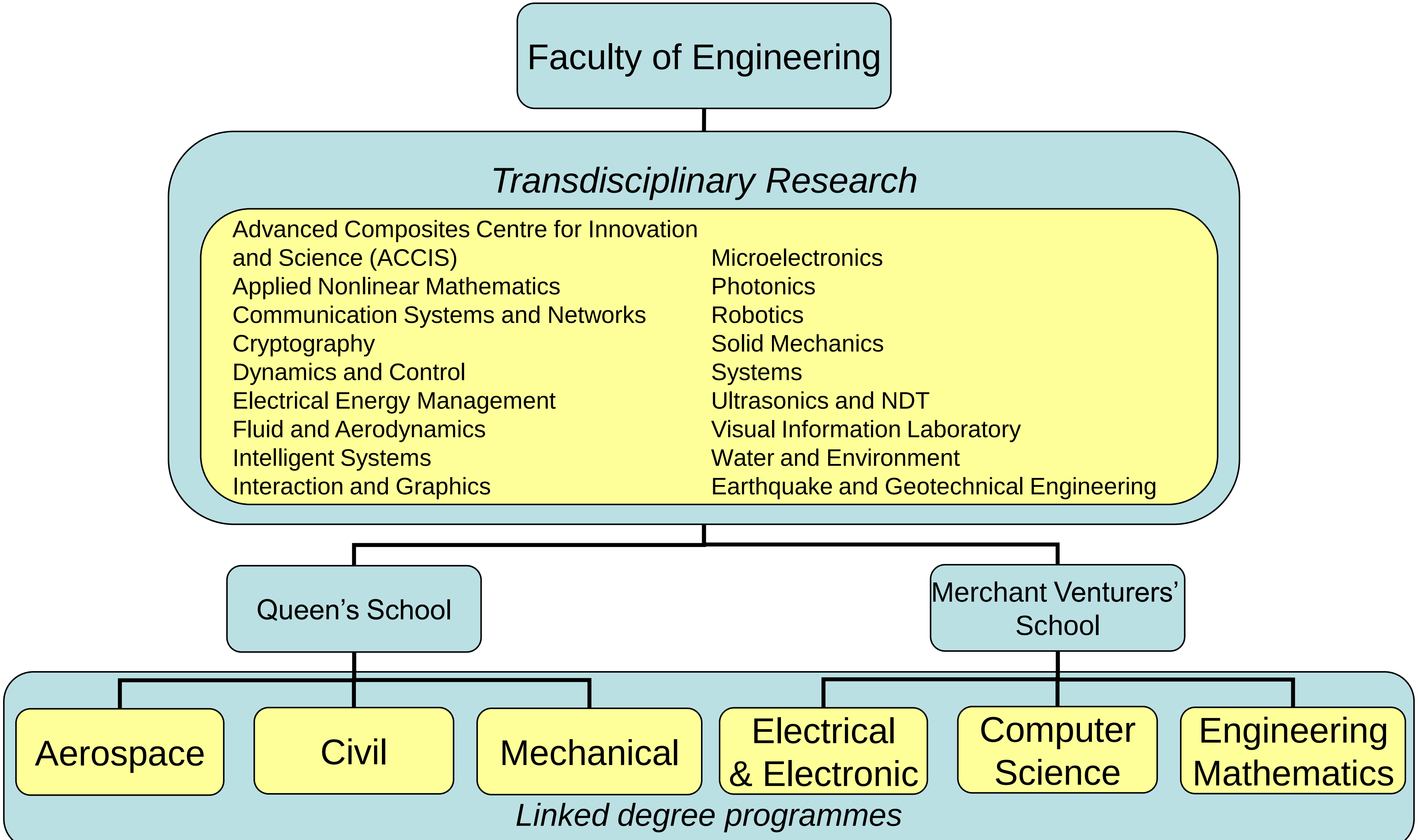
Decision-making and disaster reduction under uncertainty
Cabot-DPRI workshop, Kyoto, 17-19 May 2012

Overview

- About the Faculty of Engineering
- Non-linear dynamics and uncertainty
- Systems-thinking approaches
- Research questions

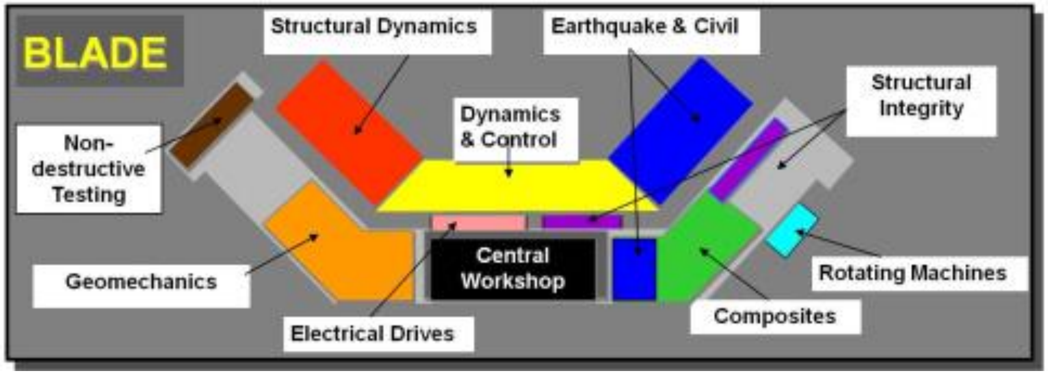
- Facilities and recent projects

Engineering Faculty structure



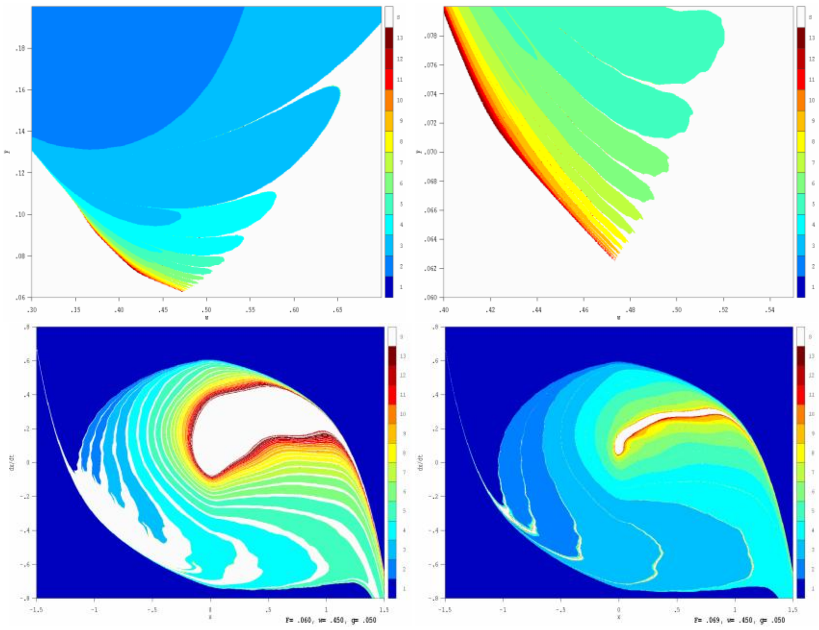
BLADE facilities

- £20m Bristol Laboratory for Advanced Dynamics Engineering
- Integrated dynamics and materials test facilities
- Complemented by new university supercomputer
- Co-locating researchers from different disciplines

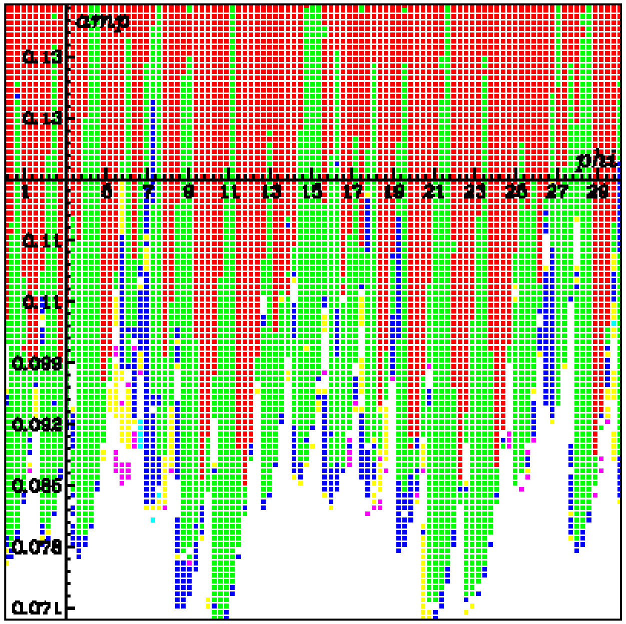


HM The Queen opening BLADE

Fractal performance diagrams

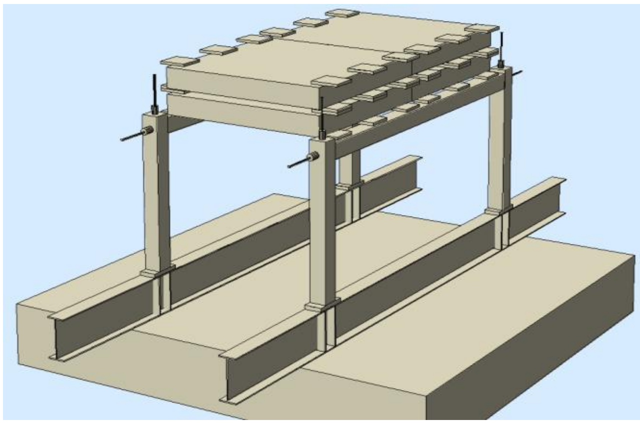


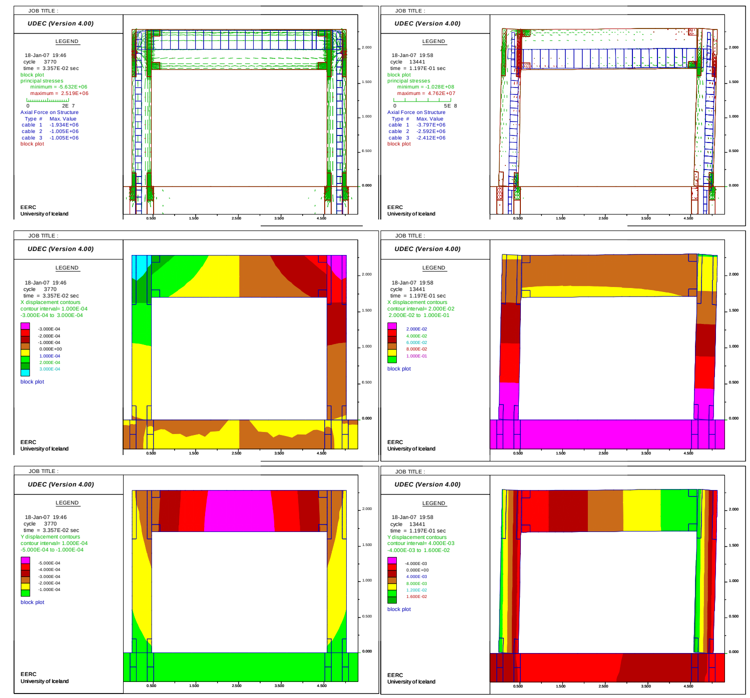
Incremental dynamic analysis

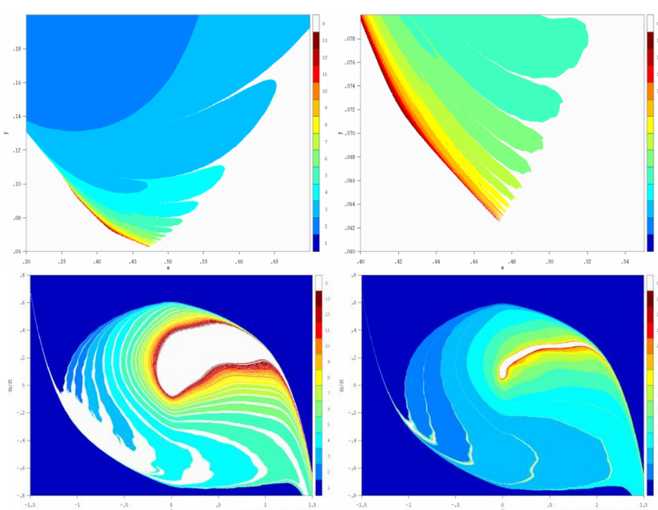


- Non-linear dynamics and uncertainty

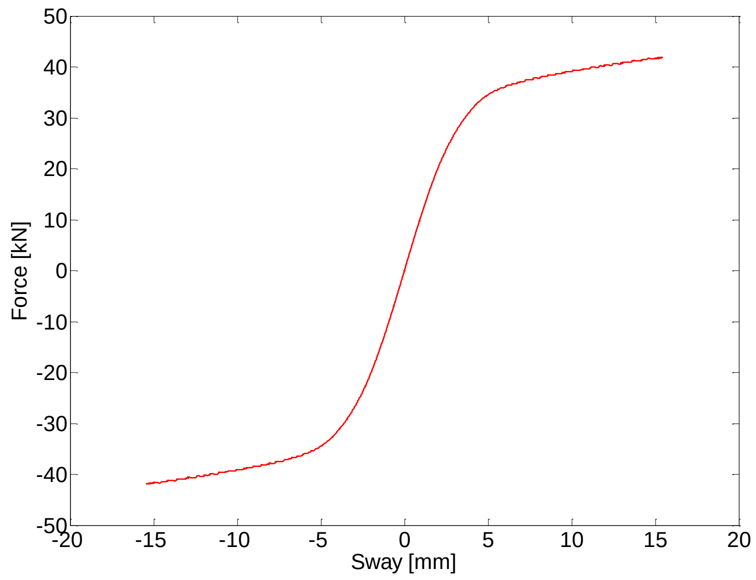
Self-aligning buildings







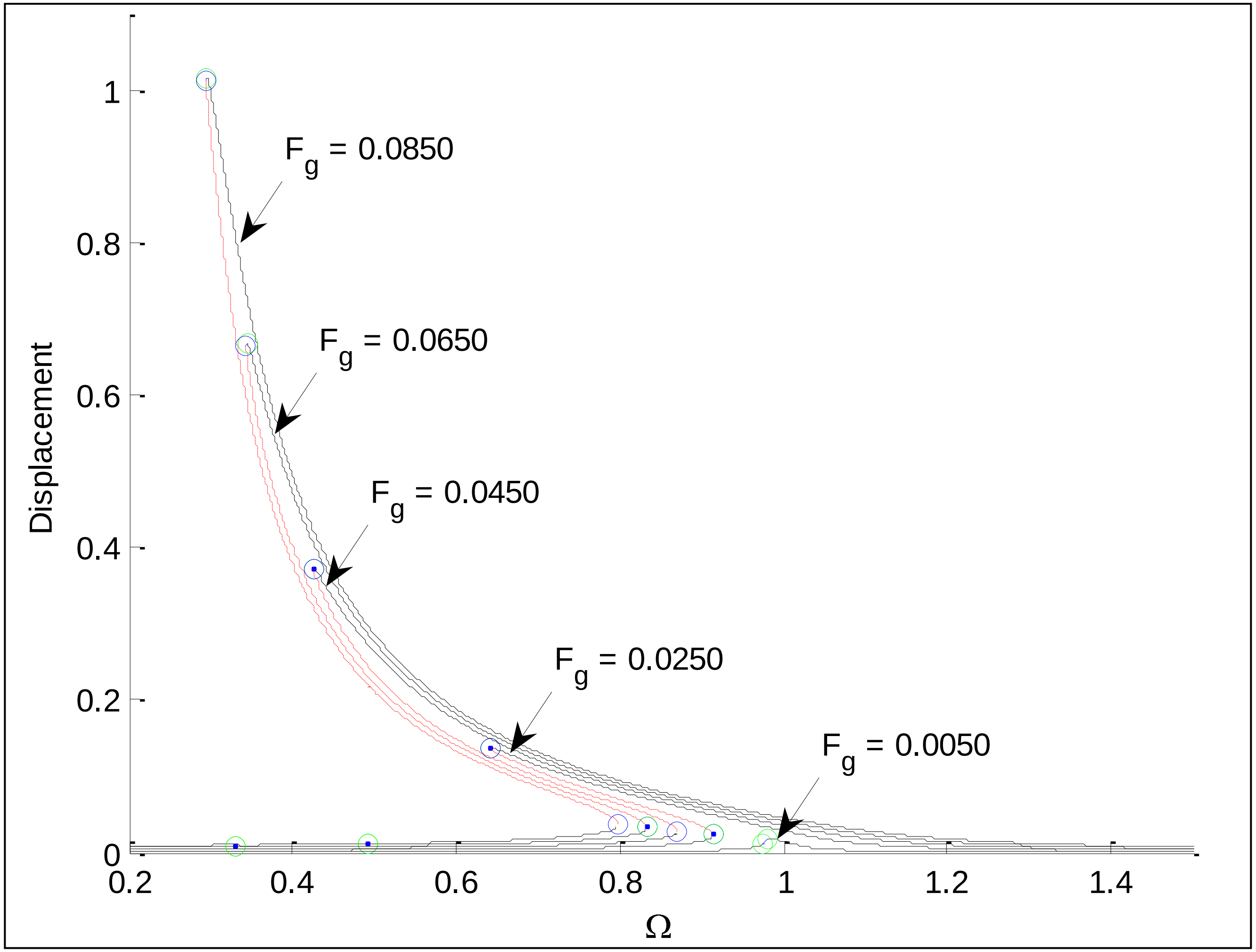
Non-linear elastic MRF



- Non-linear elastic
  - 'Self-centring' capability
- Robustness and durability
  - Large deformation capacity with limited structural damage
  - Repeatable characteristics up to design limit states

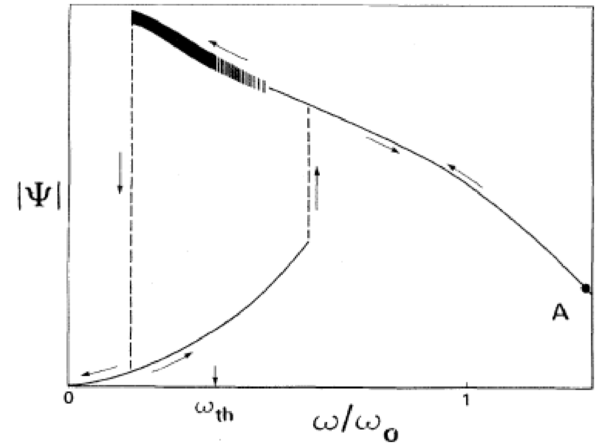
Non-linear softening resonance response

Using numerical continuation

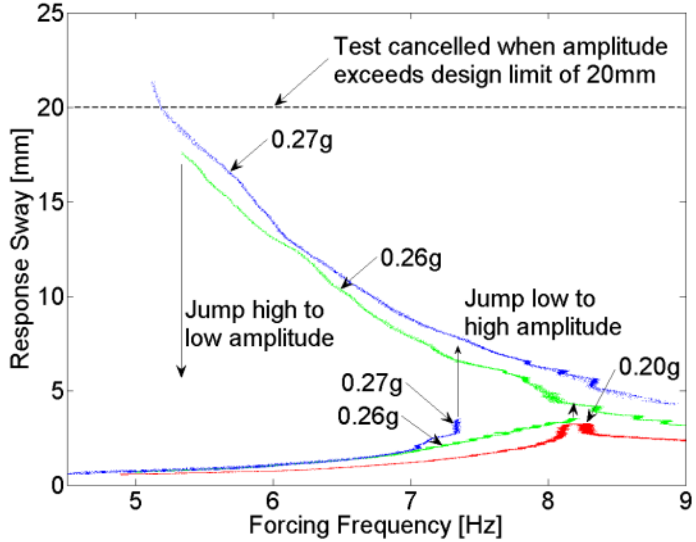


Non-linear dynamic properties

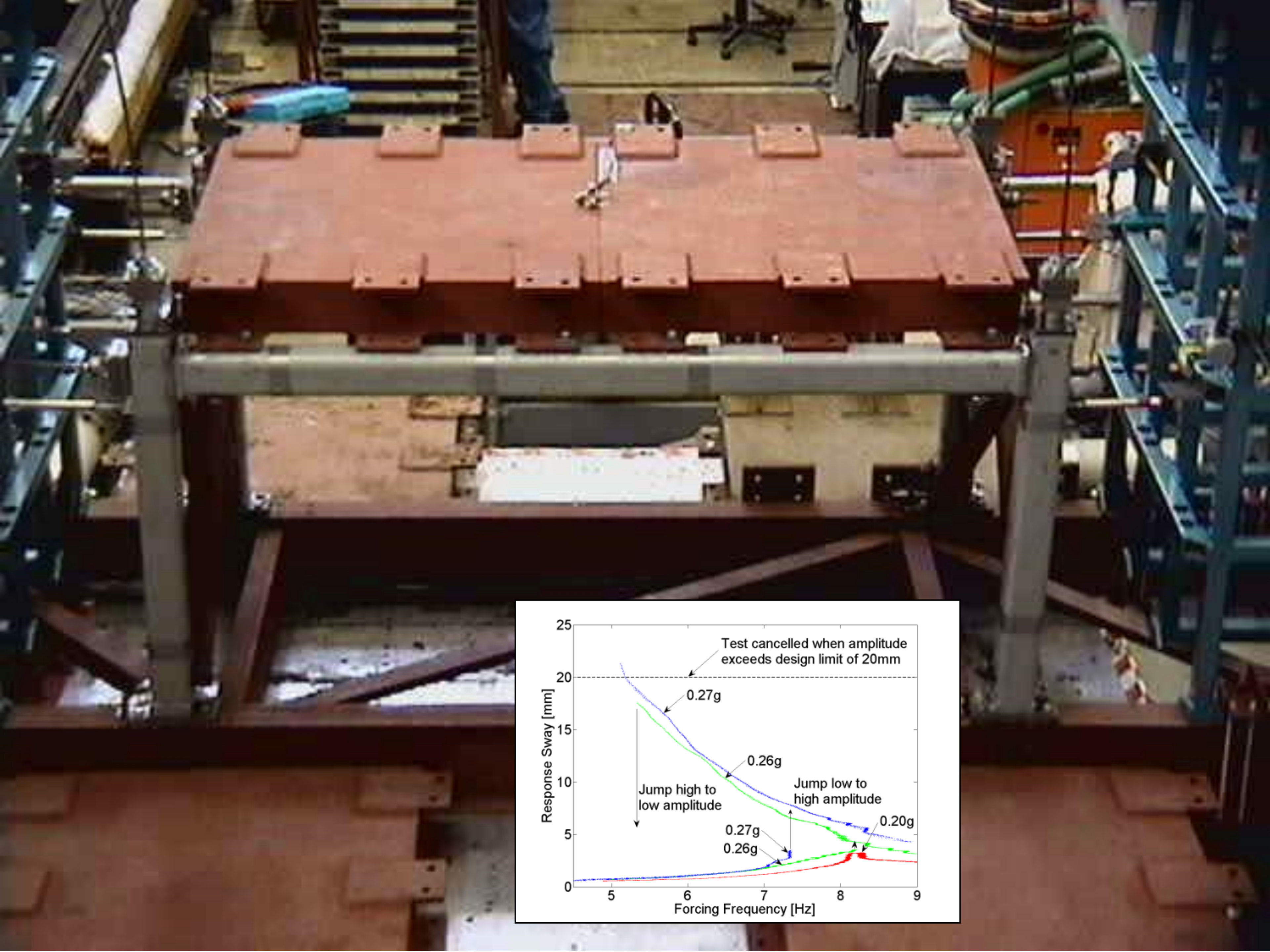
- Amplitude dependant natural frequency
  - Softening
  - Co-existing steady state solutions
  - Jumps due to change in phase between forcing and response velocity (absorbed power P(t) = F(t)*v(t))
  - Chaotic under harmonic forcing
- Sensitivity to initial conditions and forcing
  - Fractal response



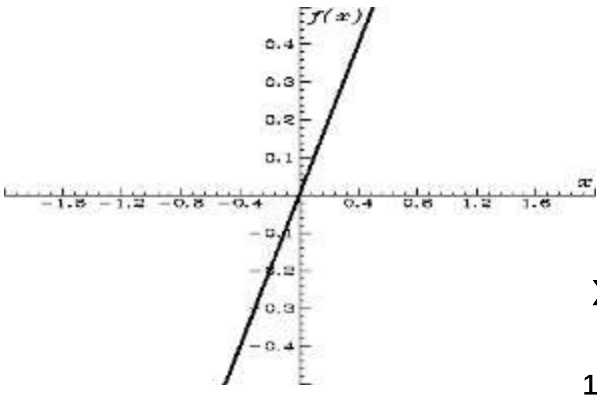
Huberman and Crutchfield, 1979



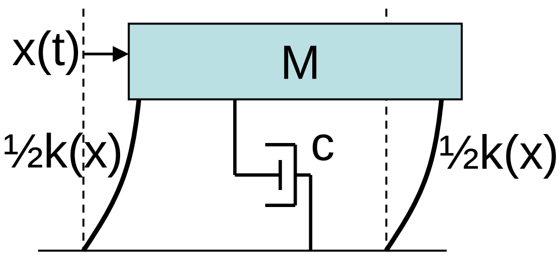
Experimental model

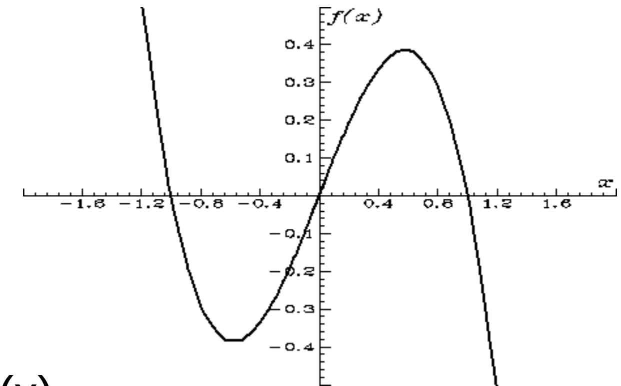

Test cancelled when amplitude
exceeds design limit of 20mm
0.27g
0.26g
Jump high to
low amplitude
Jump low to
high amplitude
0.27g
0.26g
0.20g
Response Sway [mm]
Forcing Frequency [Hz]
0
5
10
15
20
25
5
6
7
8
9

Potential wells for linear and cubical elastic oscillators

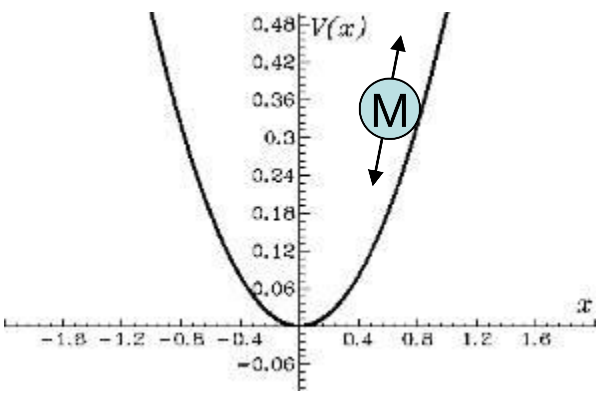


(a) Force-deflection – linear spring



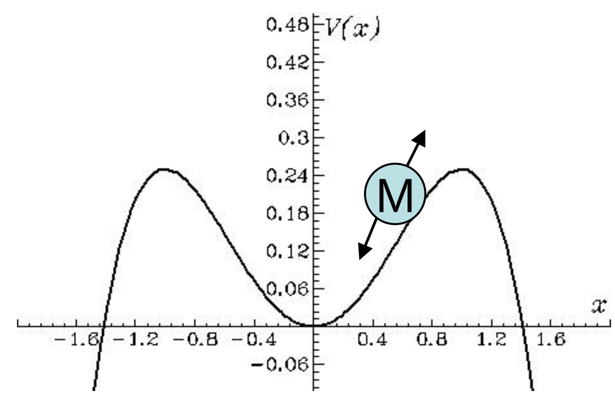


(c) Force-deflection – cubical spring



(b) Potential well – linear spring

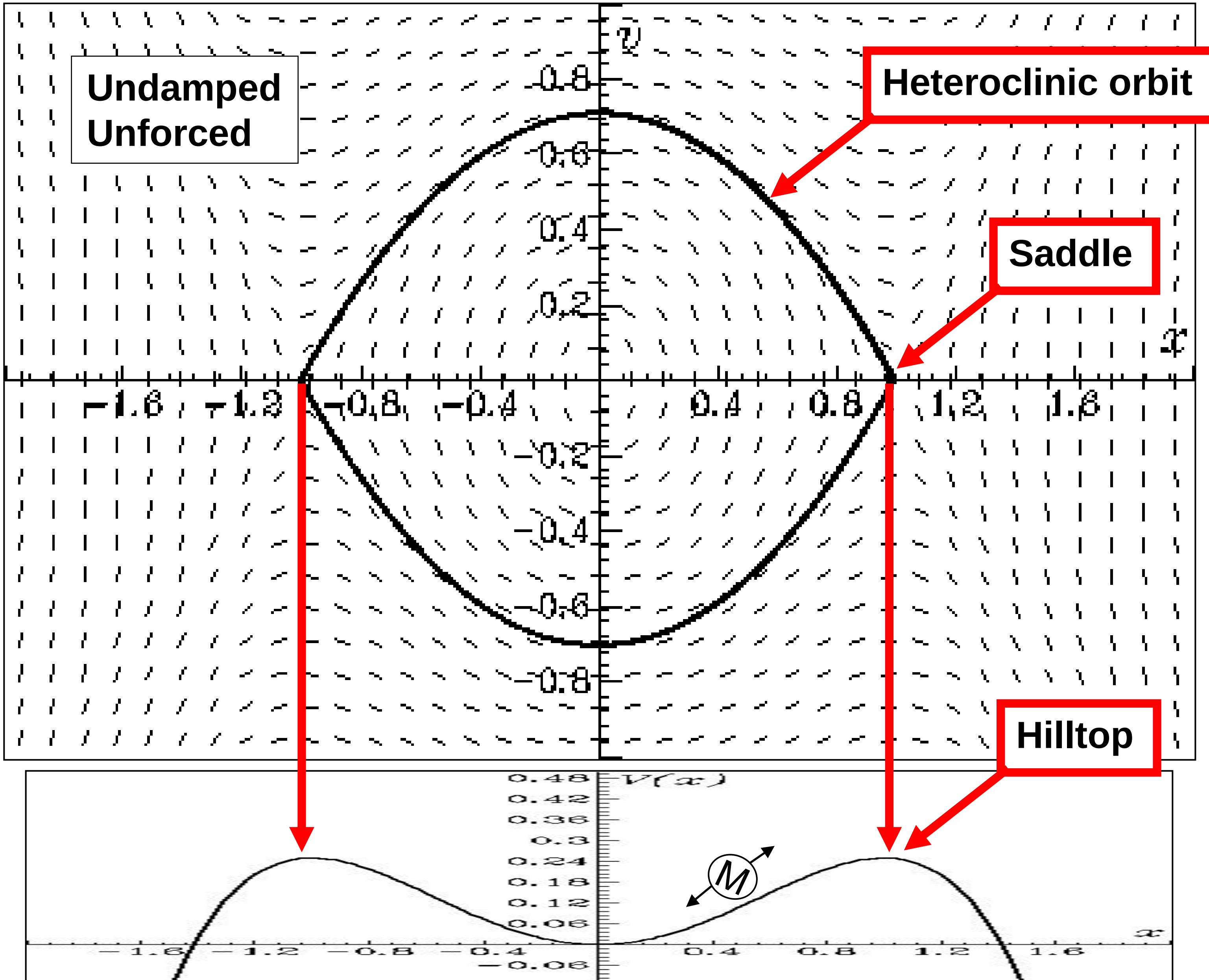
$$V(x) = \int_{-\infty}^{\infty} k(x)dx = k(\frac{x^2}{2})$$



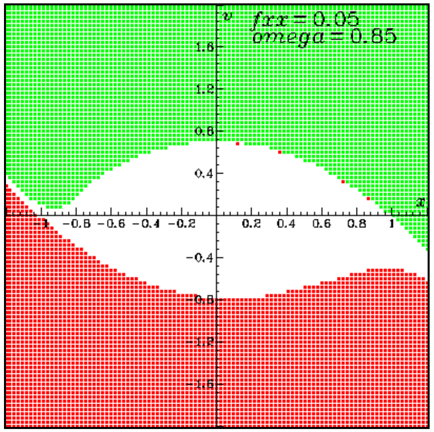
(d) Potential well – cubical spring

$$V(x) = \int_{-\infty}^{\infty} k(x - x^3)dx = k(\frac{x^2}{2} - \frac{x^4}{4})$$

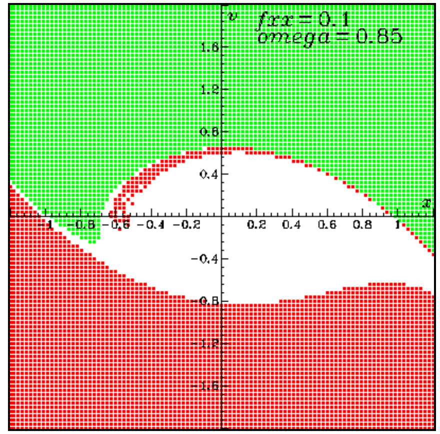
Vector field - cubical elastic well



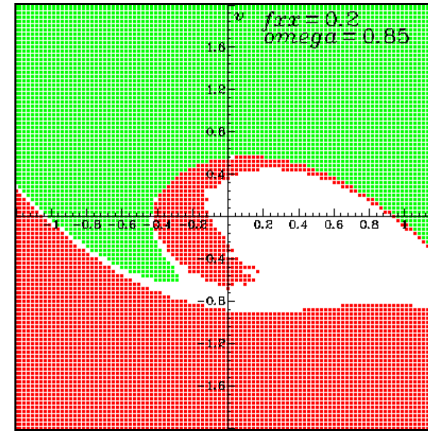
Cubic well basin erosion under increasing sine pulse load



Amp = 0.05



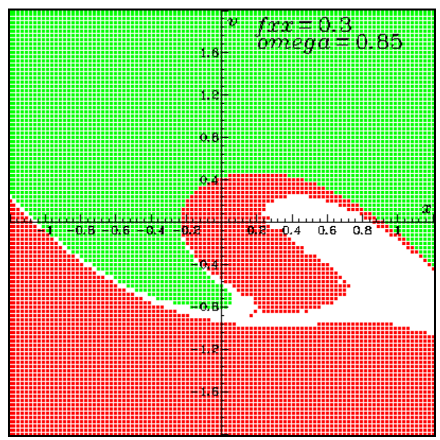
Amp = 0.1



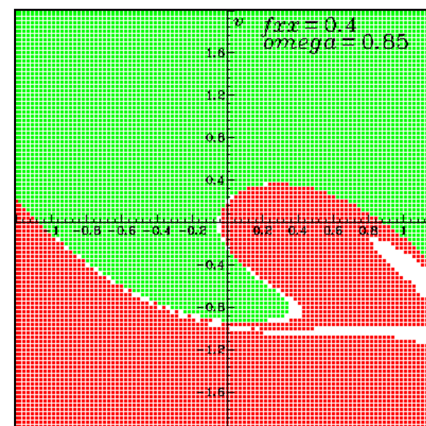
Amp = 0.2

Pixel coords are starting values of system displacement and velocity.

Pixel colour shows outcome
Escape direction
Red = left
Green = right

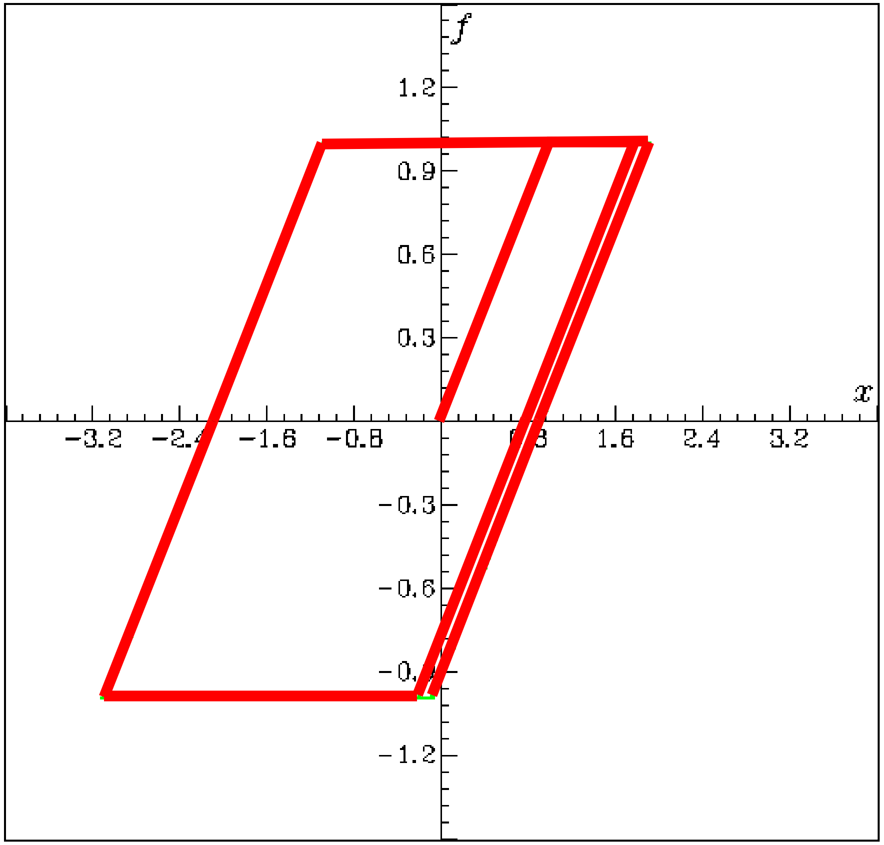


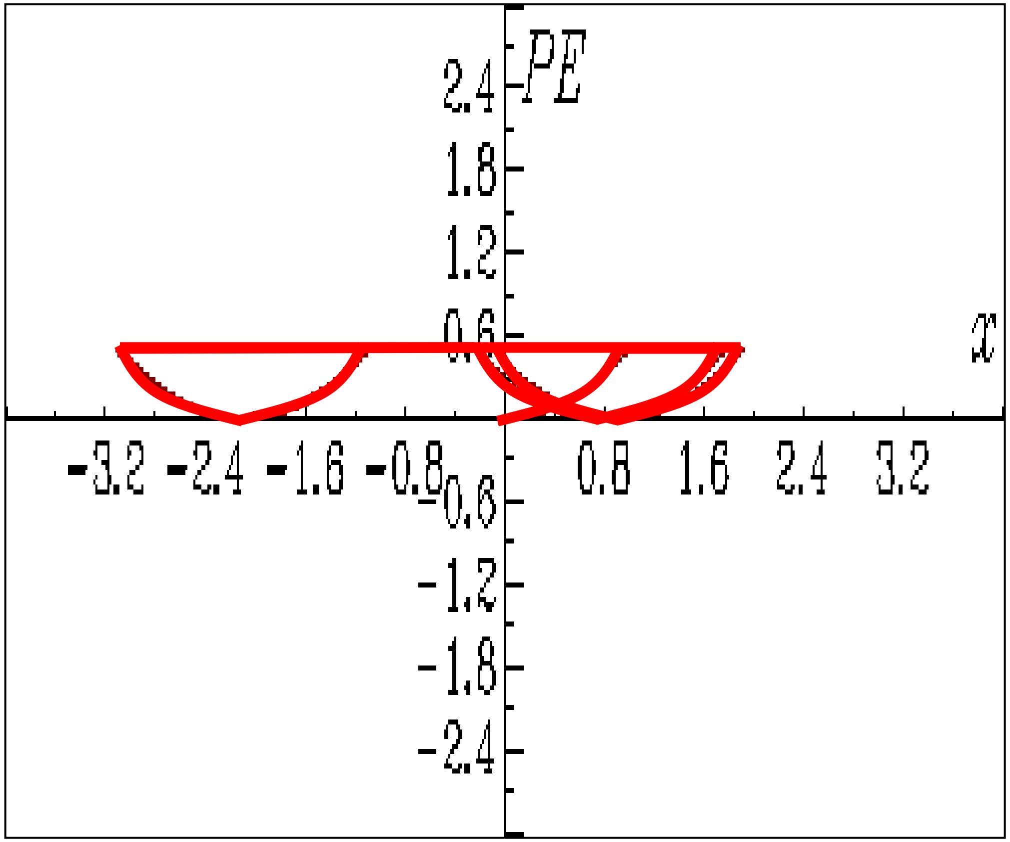
Amp = 0.3



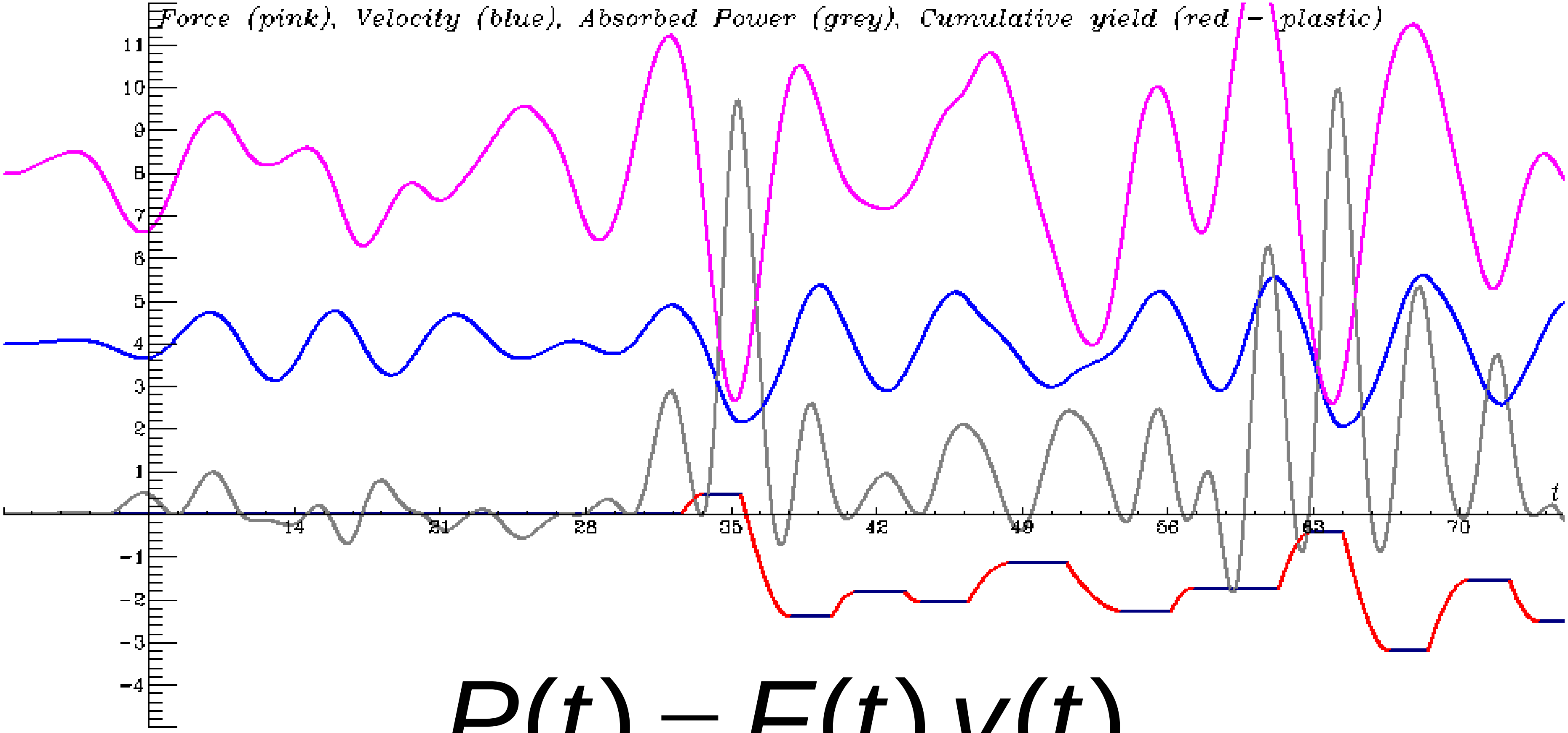
Amp = 0.4

Kinematic elasto-plastic well





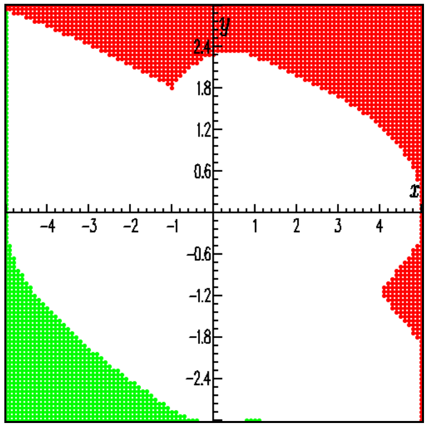
Absorbed power & seismic response



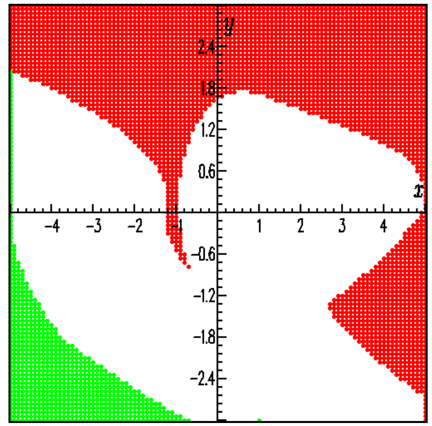
$$P(t) = F(t).v(t)$$

- Maximum power absorbed when forcing and response velocity are in phase

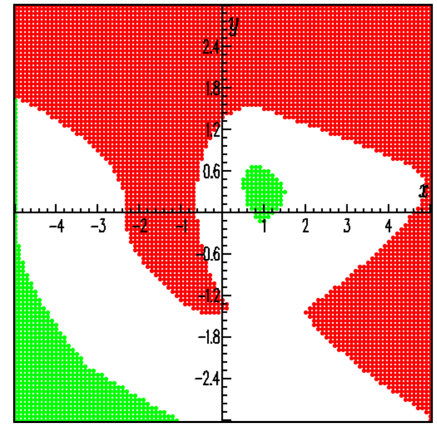
Elasto-plastic basin erosion under increasing impulsive load



Amp = 0.6

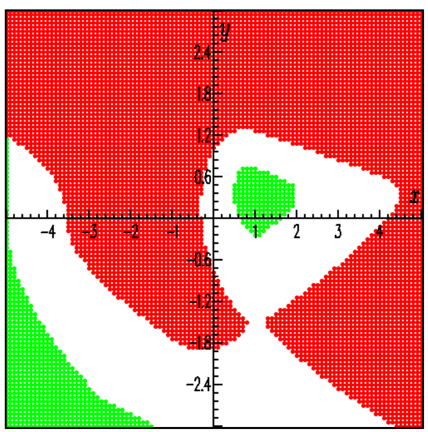


Amp = 1.0

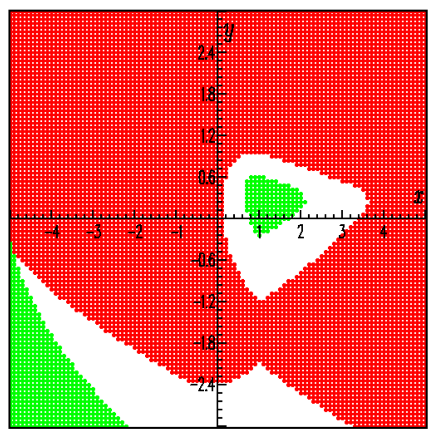


Amp = 1.15

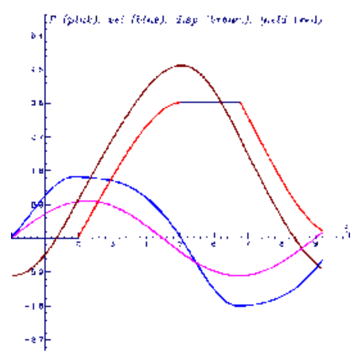
Escape direction
Red = right
Green = left



Amp = 1.3

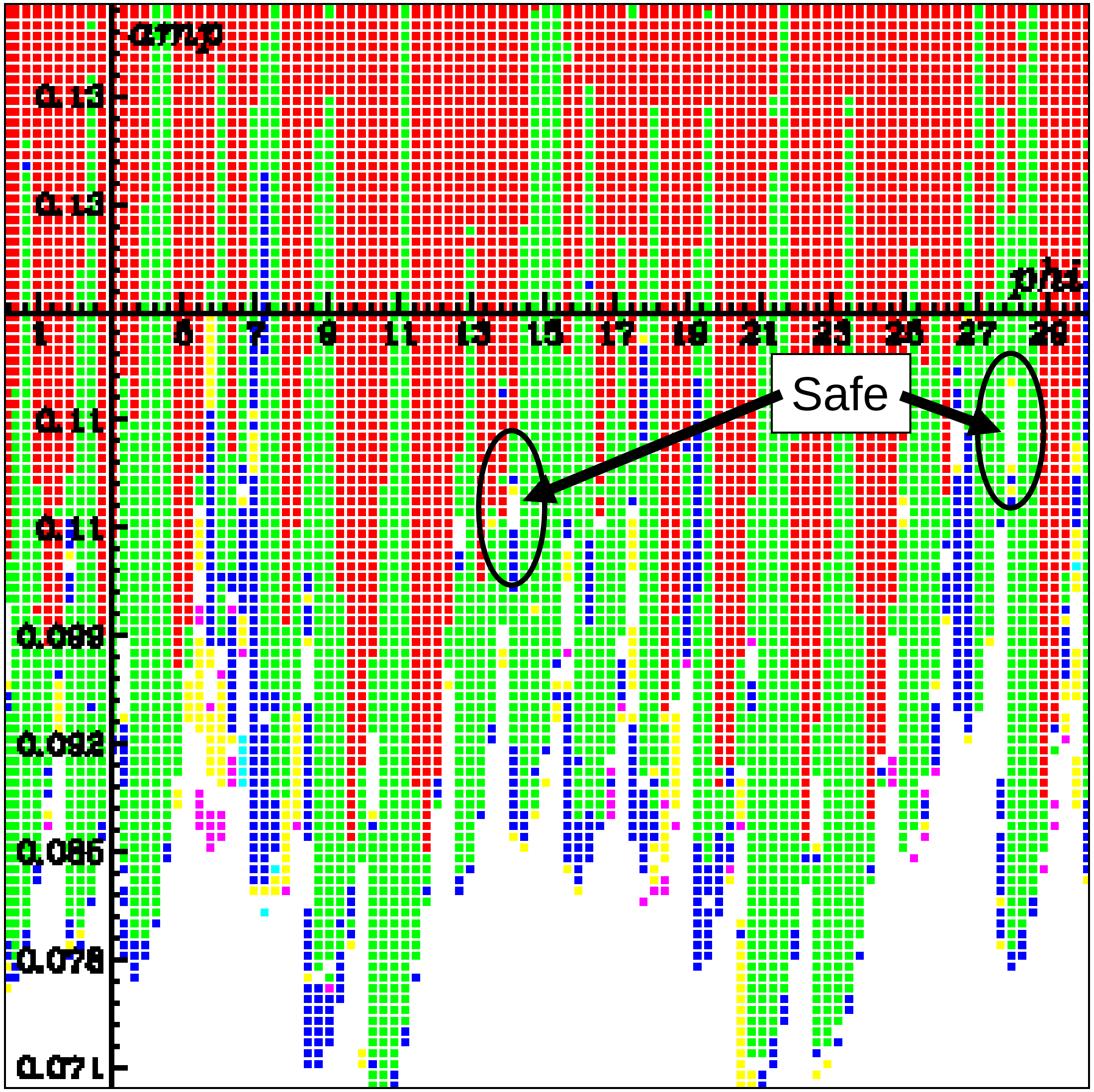


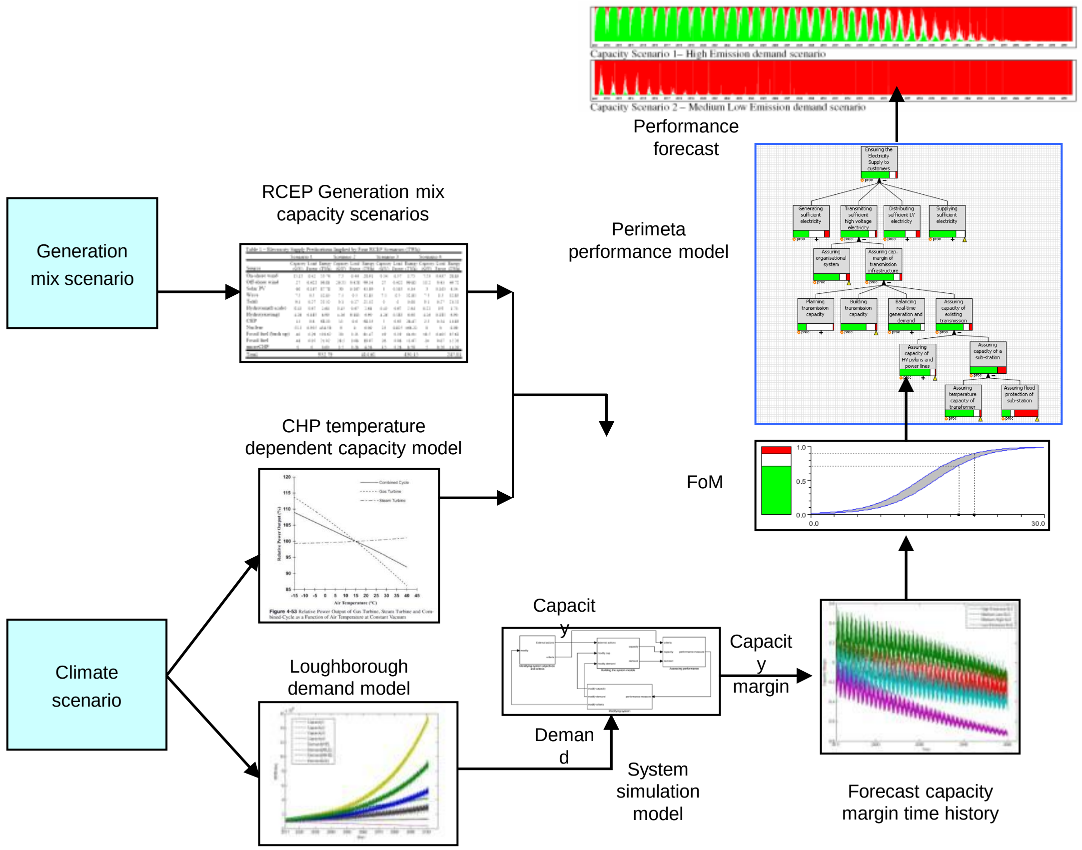
Amp = 1.55



Seismic fractal escape

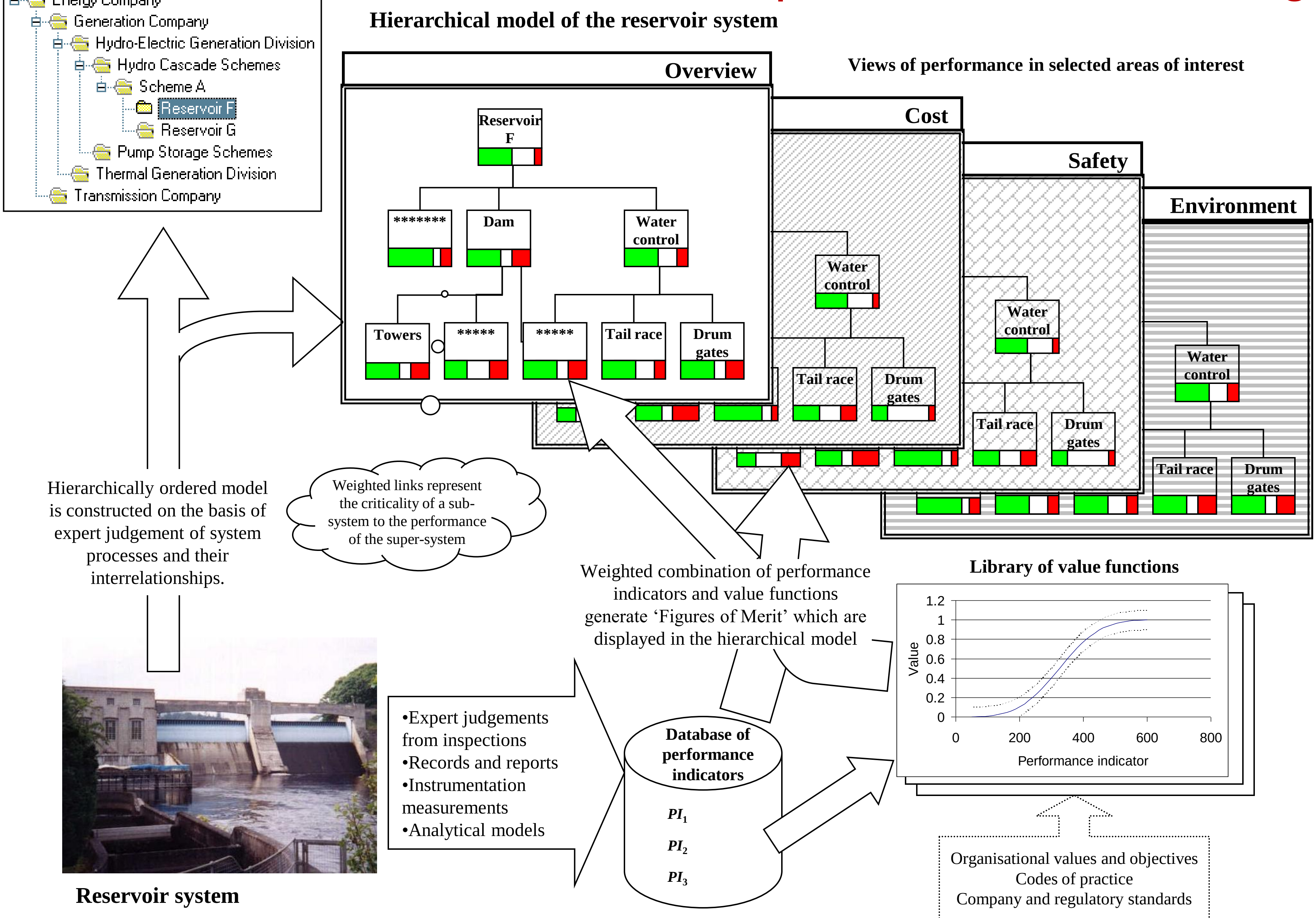
- Constant Kanai-Tajimi input power spectrum
- Vary
  - Slope of linear phase distribution
  - Amplitude
  - Compute response
- White – safe
- Red – fail in 2nd 16th time segment of input
- Green – fail in 3rd 16th time segment
- Blue – 4th 16th segment
- etc



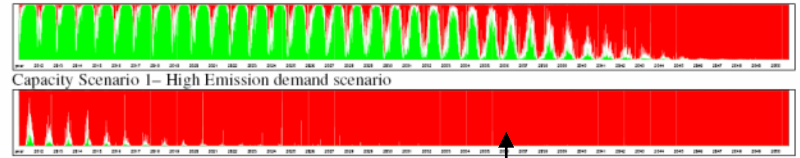


- Systems thinking, system performance, decision-making and uncertainty

Hierarchical performance modelling



ESI example



Performance forecast

Generation mix scenario

RCEP Generation mix capacity scenarios

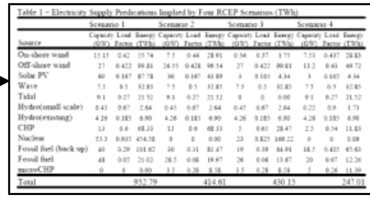
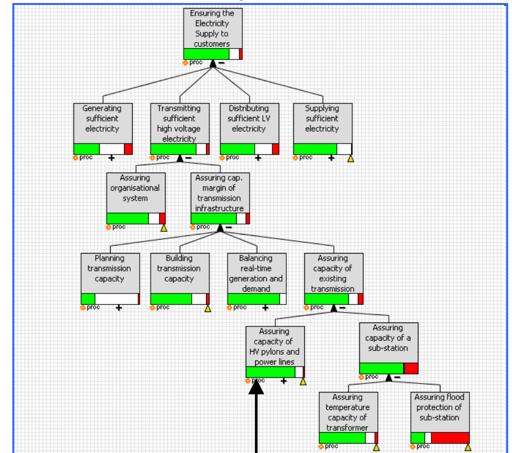


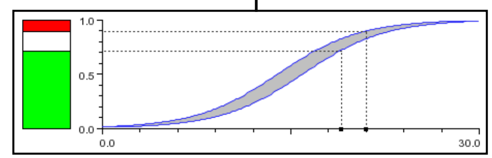
Table 1 – Electricity Supply Predications Implied by Four RCEP Scenarios (TWh)

	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
Source	Capacity (GW)	Load Factor	Energy (TWh)	Capacity (GW)	Load Factor	Energy (TWh)	Capacity (GW)	Load Factor	Energy (TWh)	Capacity (GW)	Load Factor	Energy (TWh)
On-shore wind	15.15	0.42	55.74	7.5	0.44	28.91	0.54	0.37	1.75	7.53	0.437	28.83
Off-shore wind	27	0.422	99.81	26.55	0.428	99.54	27	0.422	99.81	13.2	0.43	49.72
Solar PV	60	0.167	87.78	30	0.167	43.89	3	0.165	4.34	3	0.165	4.34
Wave	7.5	0.5	32.85	7.5	0.5	32.85	7.5	0.5	32.85	7.5	0.5	32.85
Tidal	9.1	0.27	21.52	9.1	0.27	21.52	0	0	0.00	9.1	0.27	21.52
Hydro(small scale)	0.45	0.67	2.64	0.45	0.67	2.64	0.45	0.67	2.64	0.22	0.9	1.73
Hydro(existing)	4.26	0.185	6.90	4.26	0.185	6.90	4.26	0.185	6.90	4.26	0.185	6.90
CHP	13	0.6	68.33	13	0.6	68.33	5	0.65	28.47	2.5	0.54	11.83
Nuclear	55.5	0.935	454.58	0	0	0.00	23	0.825	166.22	0	0	0.00
Fossil fuel (back up)	40	0.29	101.62	30	0.31	81.47	19	0.39	64.91	18.5	0.405	65.63
Fossil fuel	48	0.05	21.02	28.5	0.08	19.97	26	0.06	13.67	20	0.07	12.26
microCHP	0	0	0.00	3.5	0.28	8.58	3.5	0.28	8.58	5	0.26	11.39
Total			952.79			414.61			430.15			247.01

Perimeta performance model



FoM



CHP temperature dependent capacity model

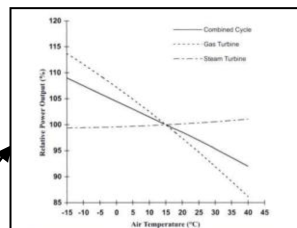
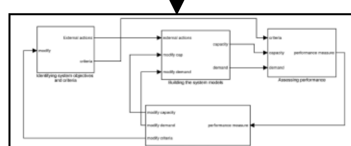
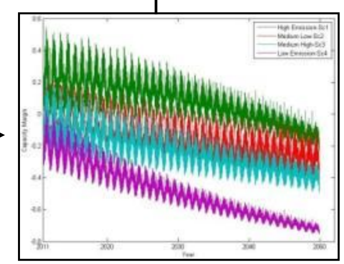


Figure 4-53 Relative Power Output of Gas Turbine, Steam Turbine and Combined-Cycle as a Function of Air Temperature at Constant Vacuum

Capacity



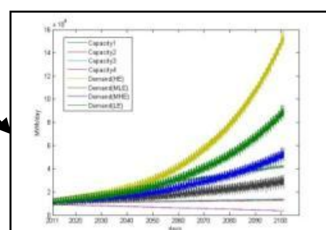
Capacity margin



Demand

Climate scenario

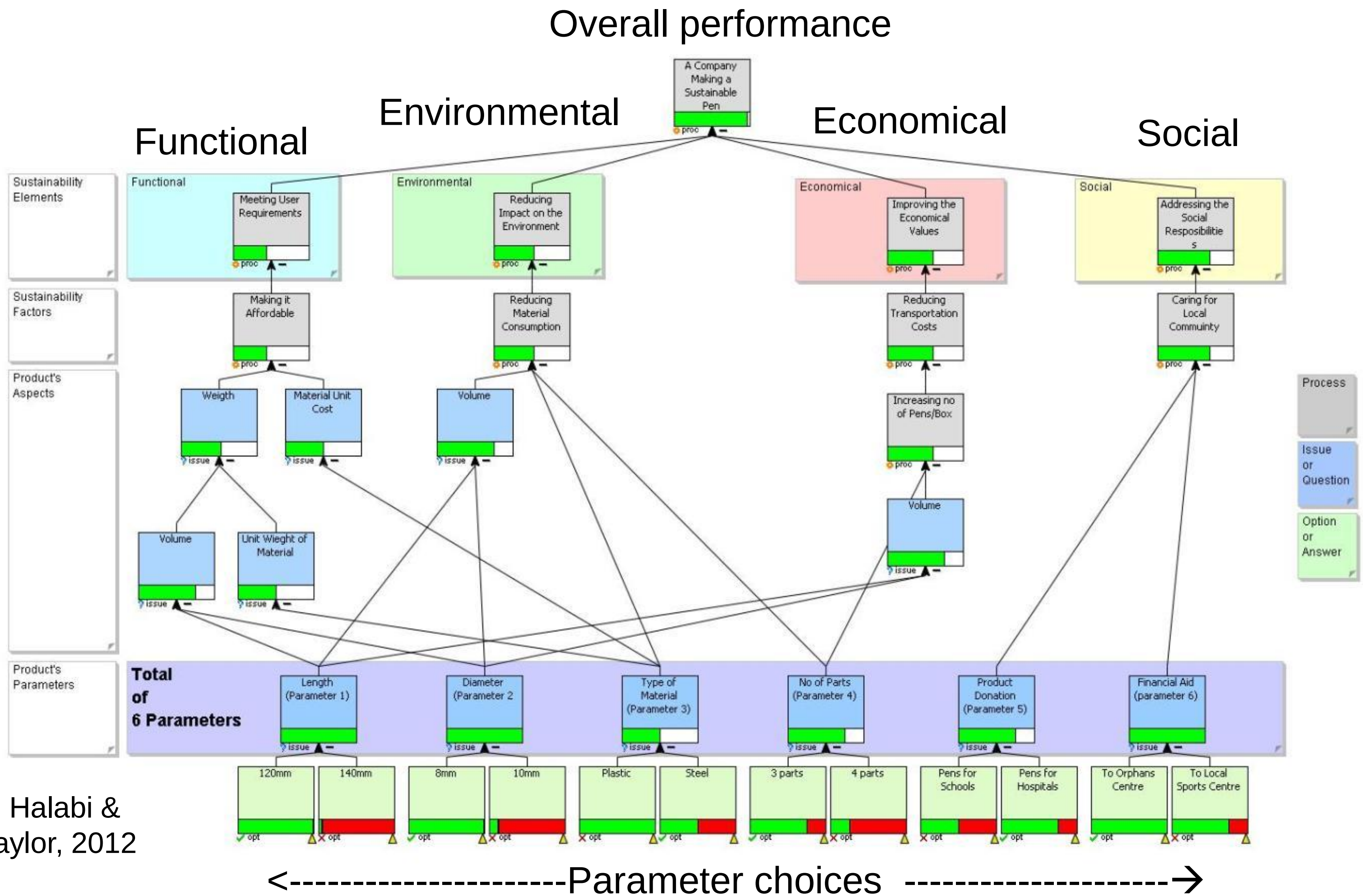
Loughborough demand model



System simulation model

Forecast capacity margin time history

Mapping sustainable performance to available asset choices and decisions



el Halabi & Taylor, 2012

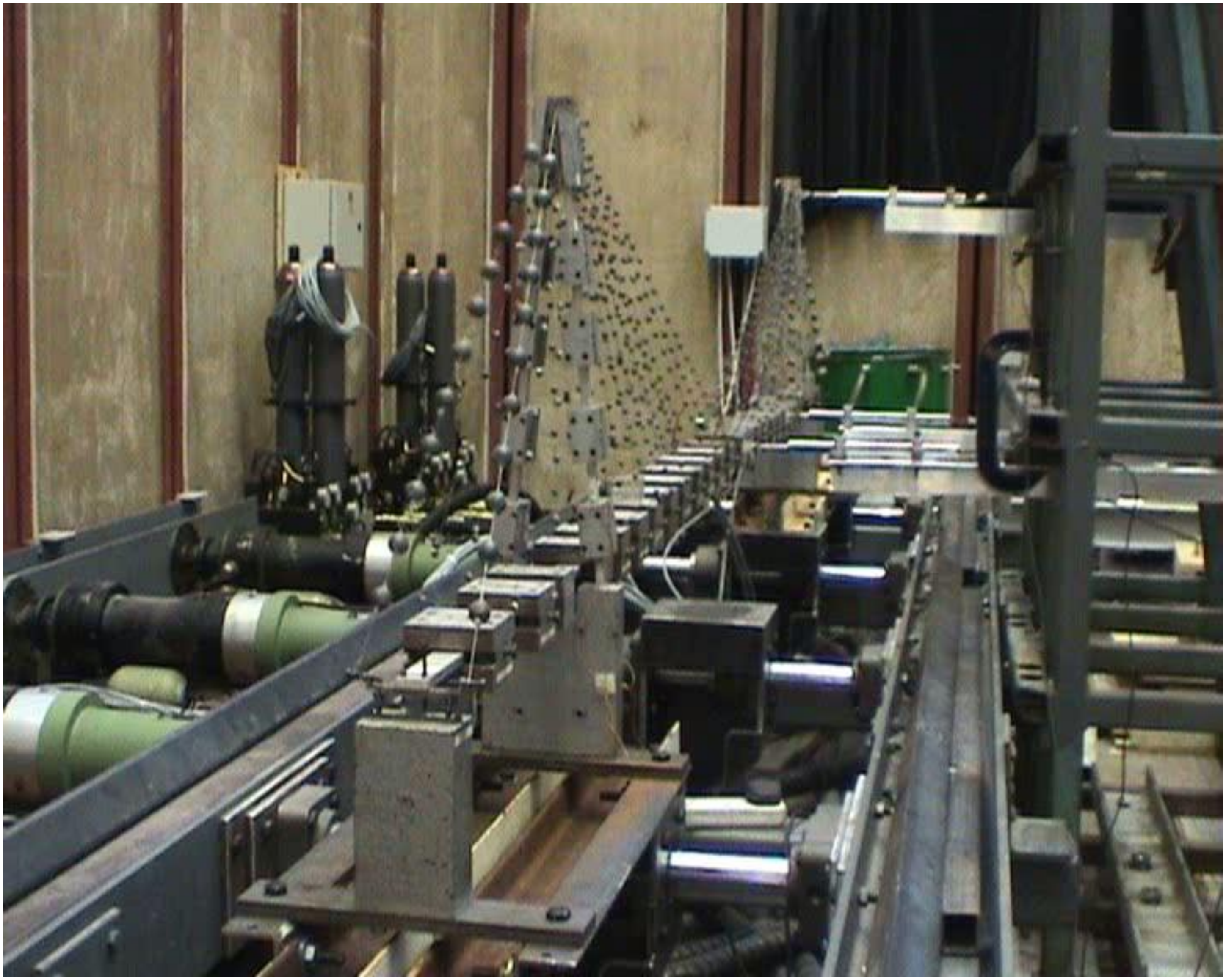
- Long term infrastructure performance: Clifton Suspension Bridge

Risk awareness training

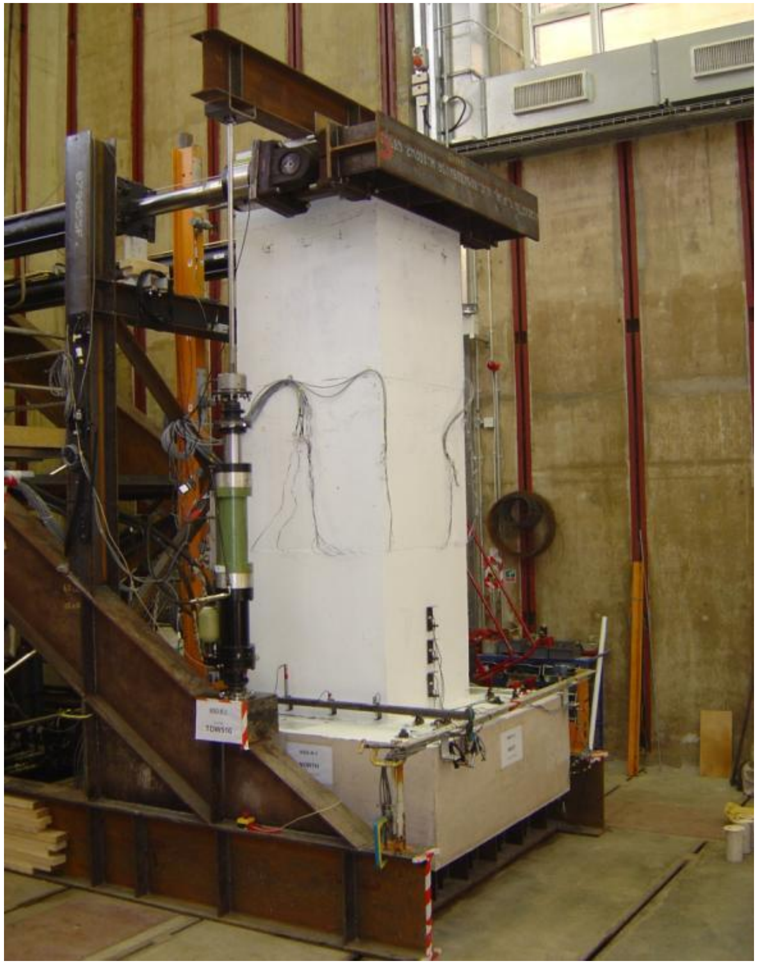
UK research questions

- Infrastructure
  - Renewal, life extension
    - “Getting more from less”?
    - Primary focus on service delivery, not asset?
  - Interdependencies, vulnerabilities and resilience
    - Social learning leading to definition/calibration of resilience?
    - Improve reliability, reduce cost?
  - New ownership, governance, investment and business models
    - Secure, long term, investment proposition?
    - Making infrastructure an ‘entrepreneurial’ space?
  - Needs-driven performance
    - Focus on service provided by asset, not asset itself
  - Decision-appropriate risk assessment methods/tools

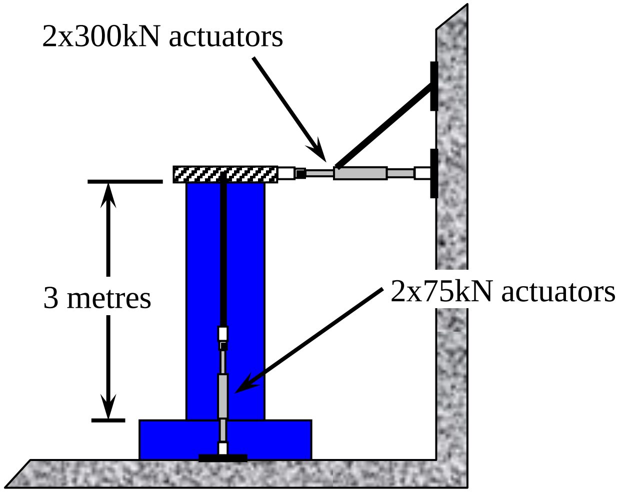
Advanced composite bridge decks



Nonlinear Seismic Assessment of Reinforced Concrete Reservoir Towers



Intake and outlet towers regulate reservoir water release, sometimes in emergencies

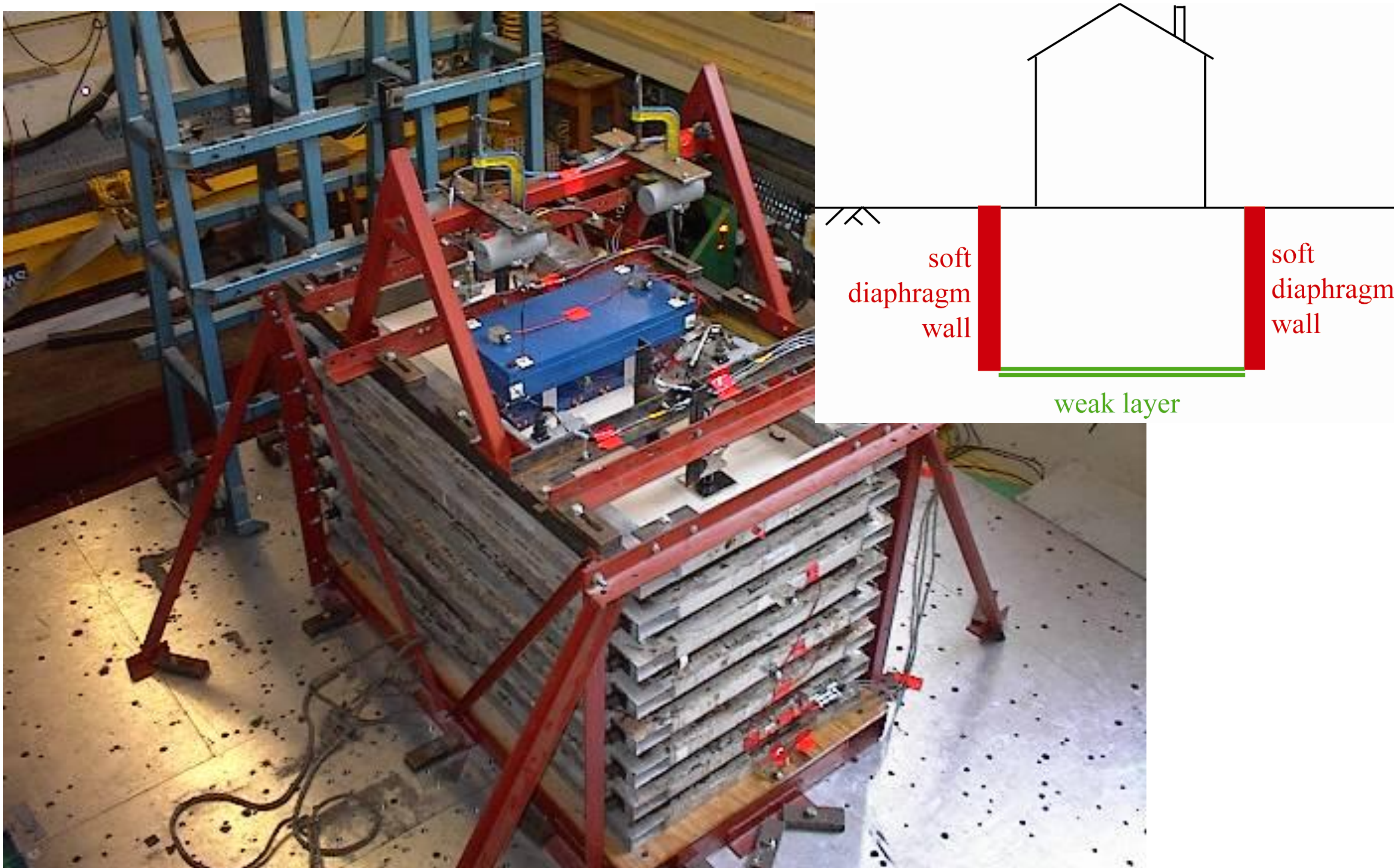


Reaction wall set-up for tower specimens

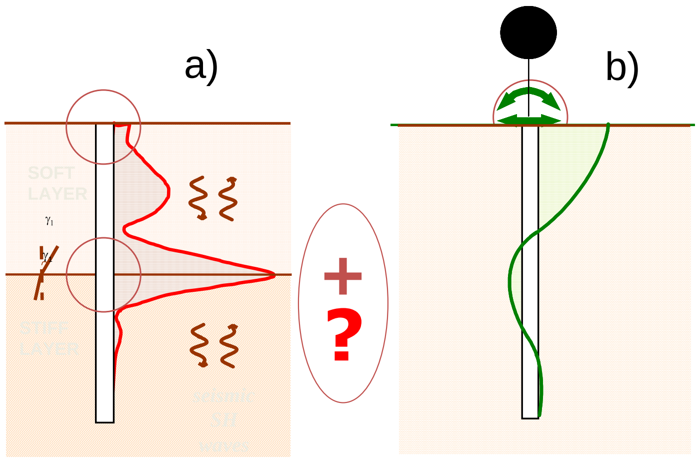
GRP ‘wallpaper’ strengthening of masonry walls

Seismic safety of graphite nuclear reactor cores

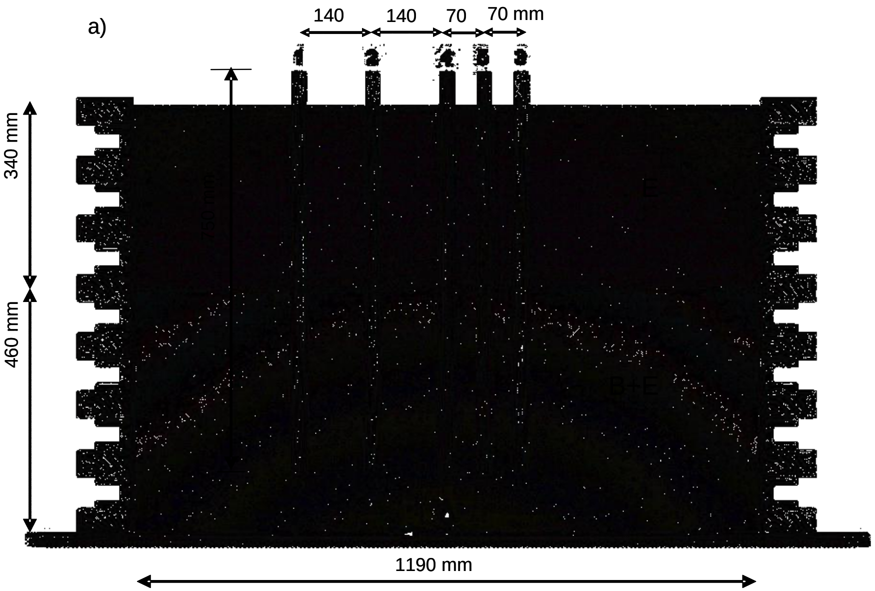
Motion isolation using soft caisson



Kinematic and inertial moments in piled foundations



Kinematic Inertial

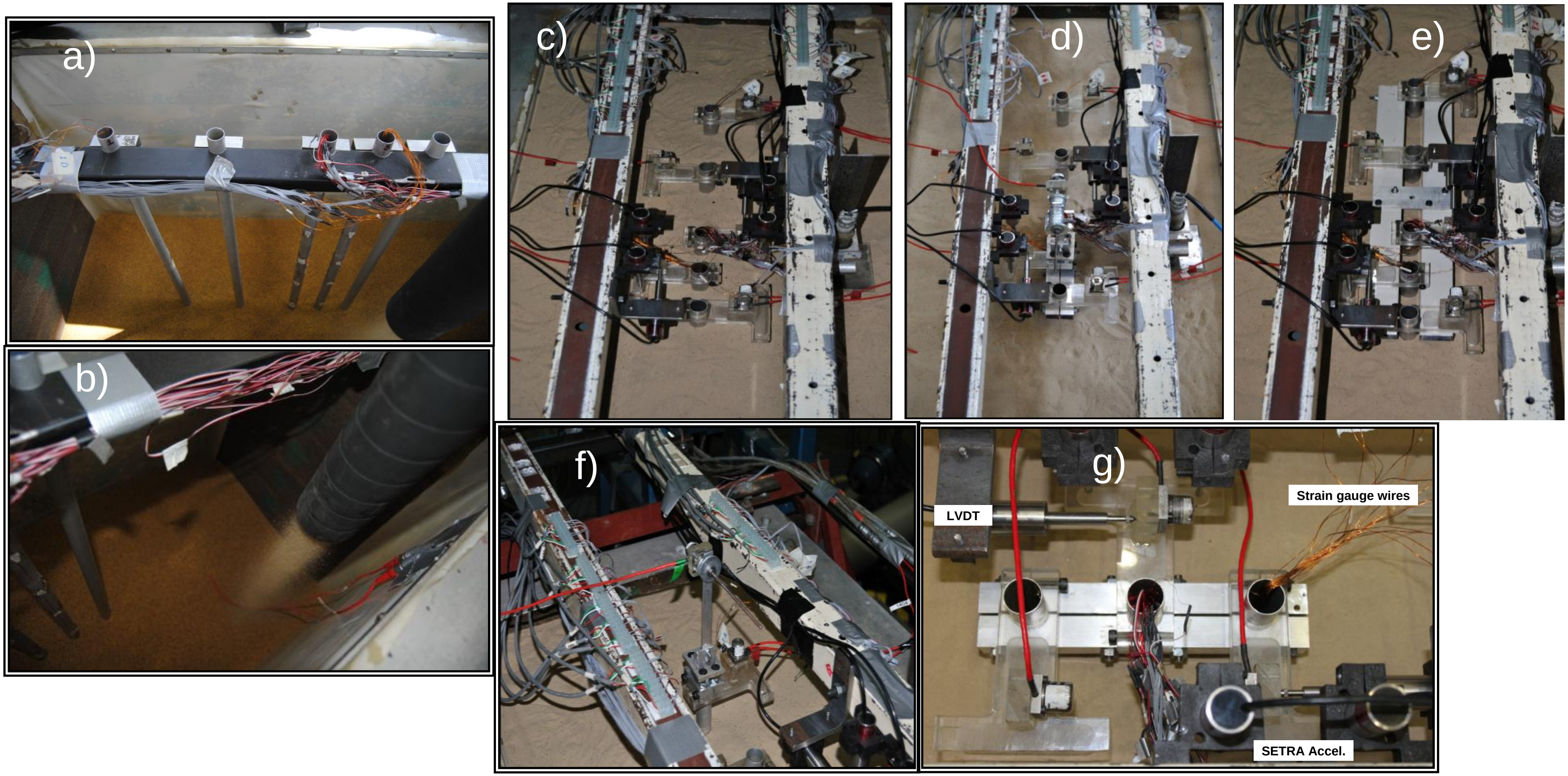


Pile group in layered sand in shear stack

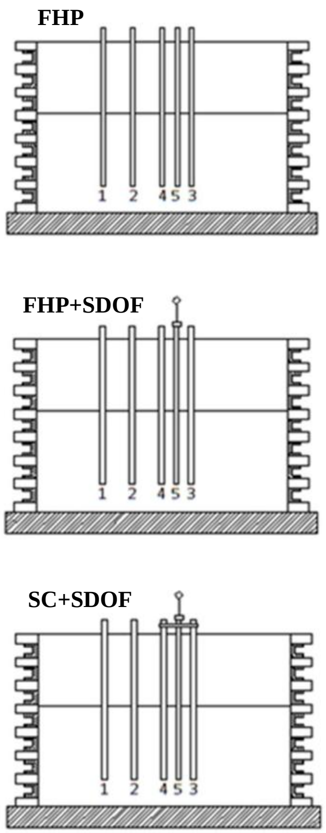
University of Sannio, Italy
University of Calabria, Italy
University of Patras, Greece
Ecole Centrale Paris, France
NGI, Norway

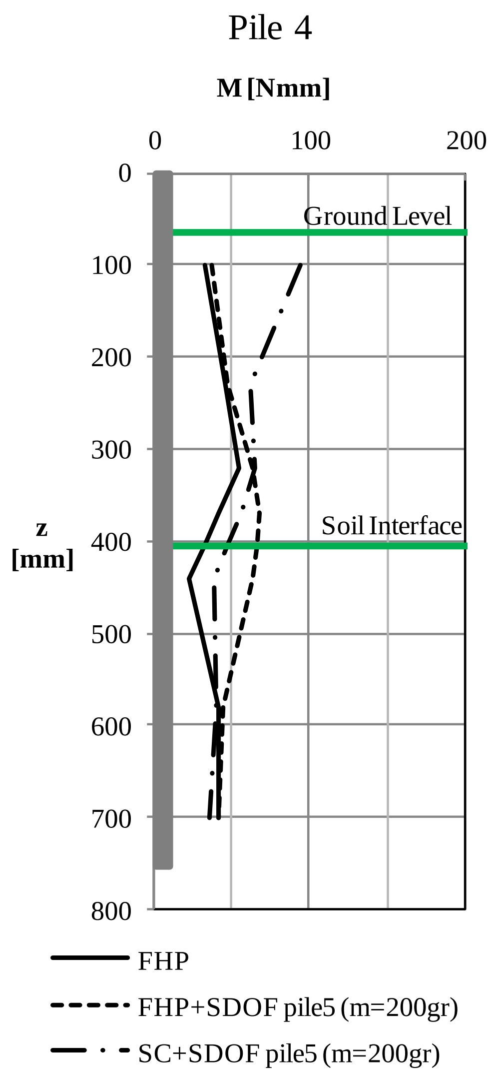
EU FP7 SERIES Project:

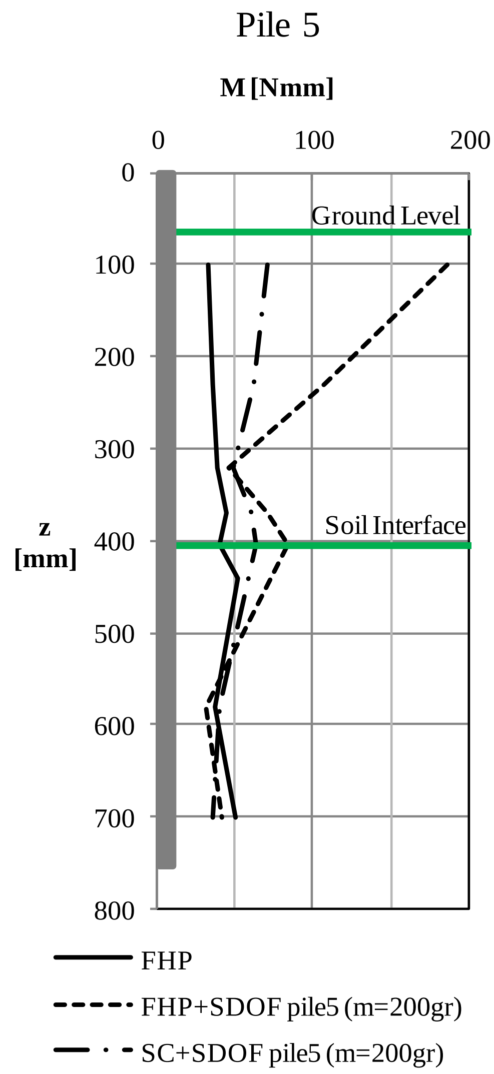
Experimental piles setup



Measured moments in piled foundations







Other EU SERIES funded projects