Intersections of Philosophy Logic and Biology in Design

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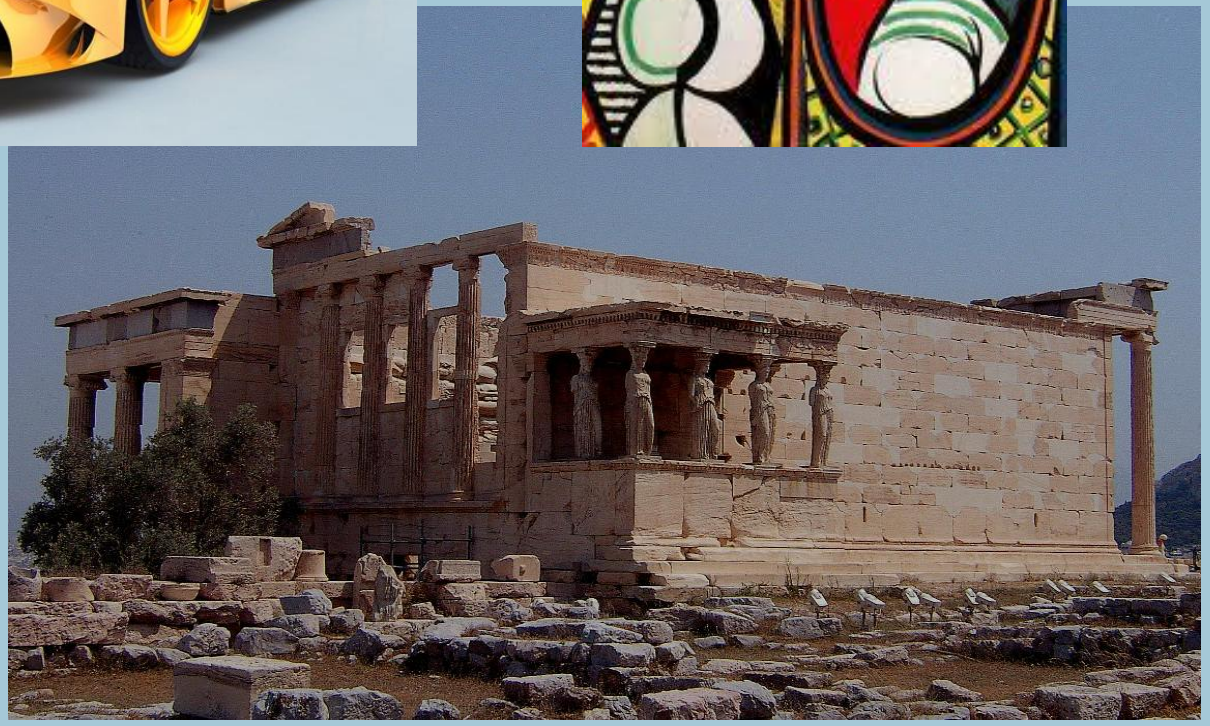
Design



Involves

Creation &

Reflection

Structure of the talk

- How ideas of philosophy, logic and biology have influenced conception of design

  (creation, reflection, design as evolutionary search)

- Intersections in my own scientific work:

  Novel techniques for refinement, analysis and optimisation of dependable systems

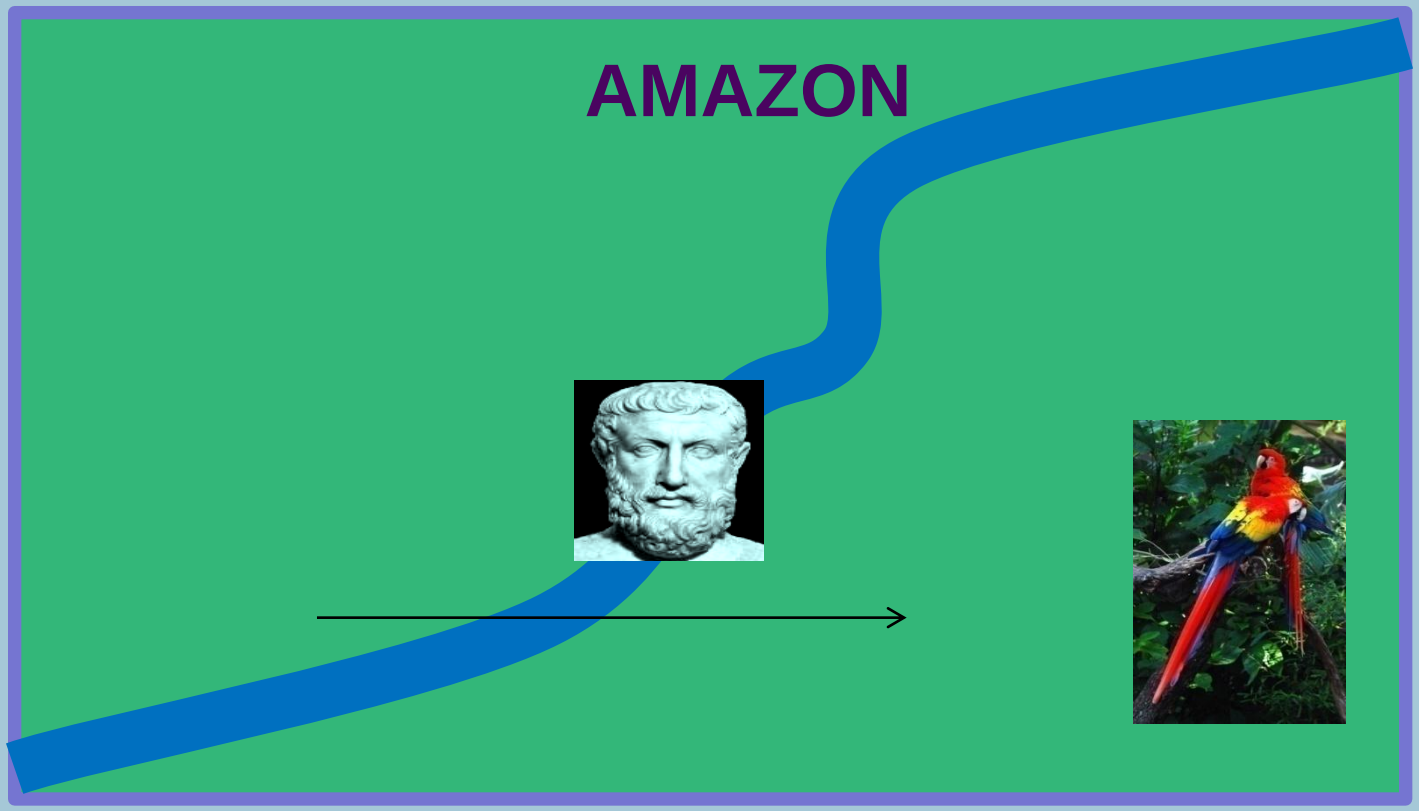
  Art project redefining art work *as* evolutionary journey through a design space

Change – Heraclitus of Ephesus (c. 535-475 BC)

"everything in flux" "A thing rests only by changing"
"One cannot cross the same river twice"

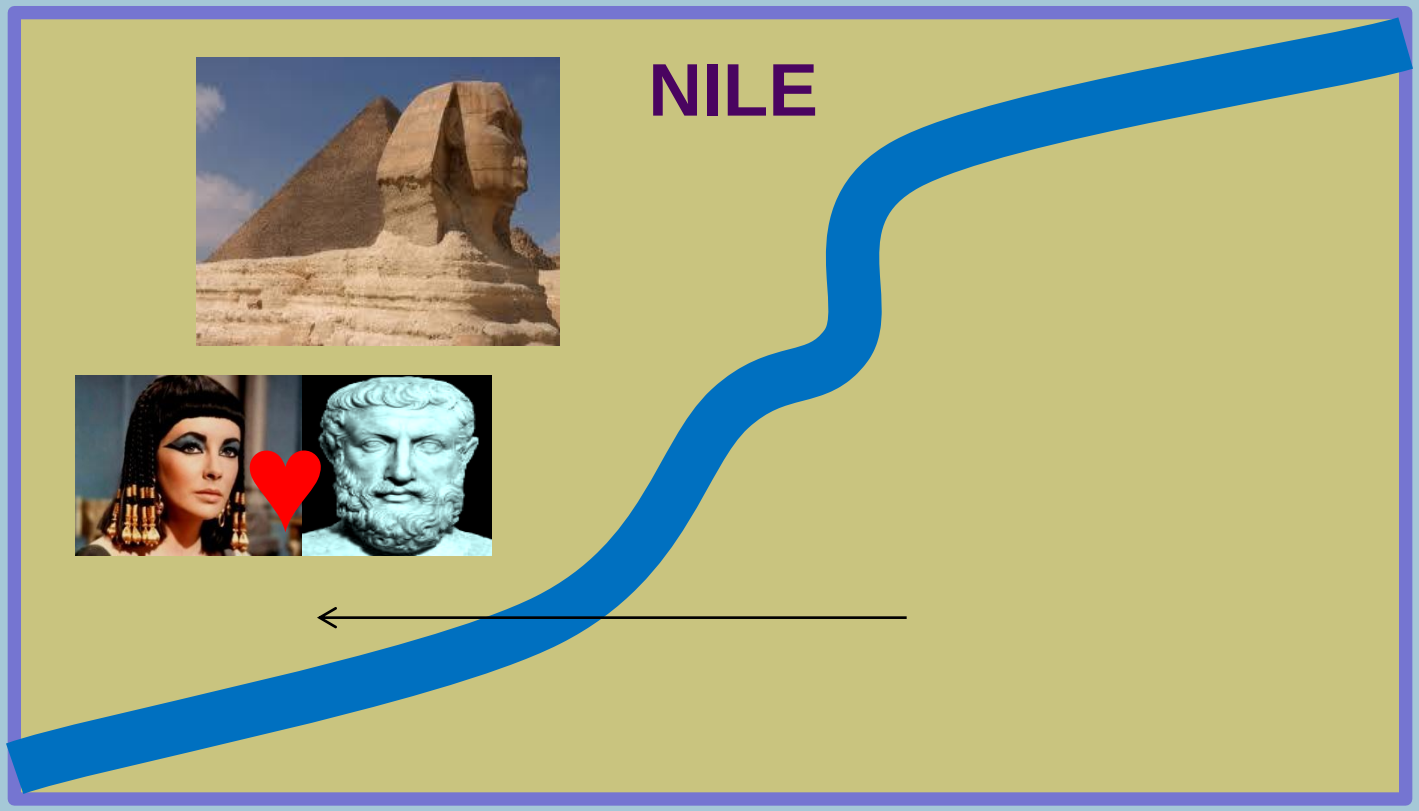
Heraclitus : instability & flux

"One cannot cross the same river twice" (animation)



Heraclitus : instability & flux

"One cannot cross the same river twice" (animation)



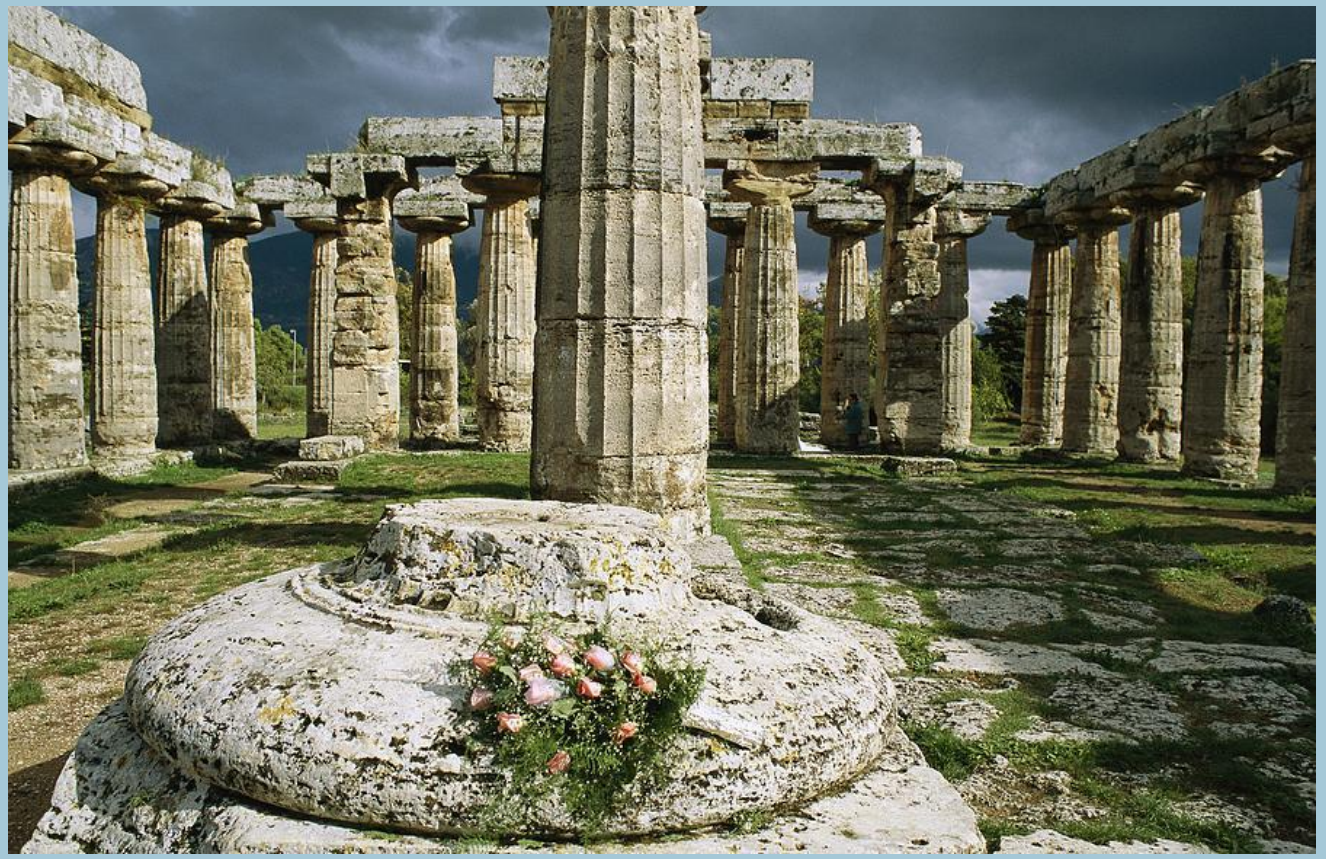
Heraclitus: instability & flux in system design

Requirements change so fast that systems are outdated on the date of their release

Verification techniques must become agile and respond to constant flux

Logic vs Experience – Zeno of Elea (c. 490-430 BC)

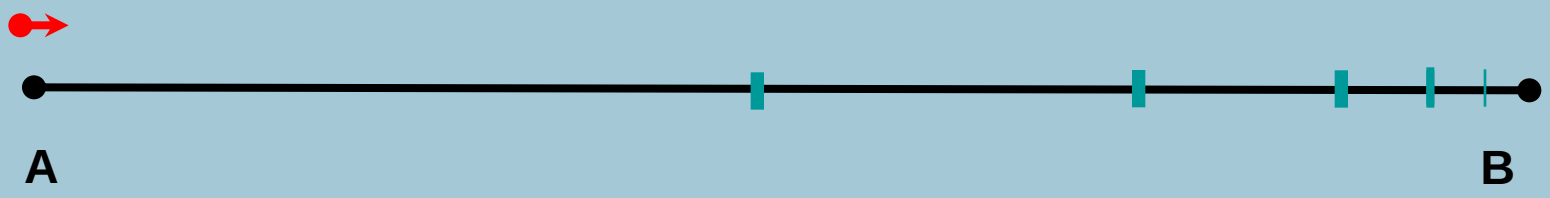
"Nothing changes" we are part of a single "one"



Zeno's paradoxes

Proofs that movement is impossible

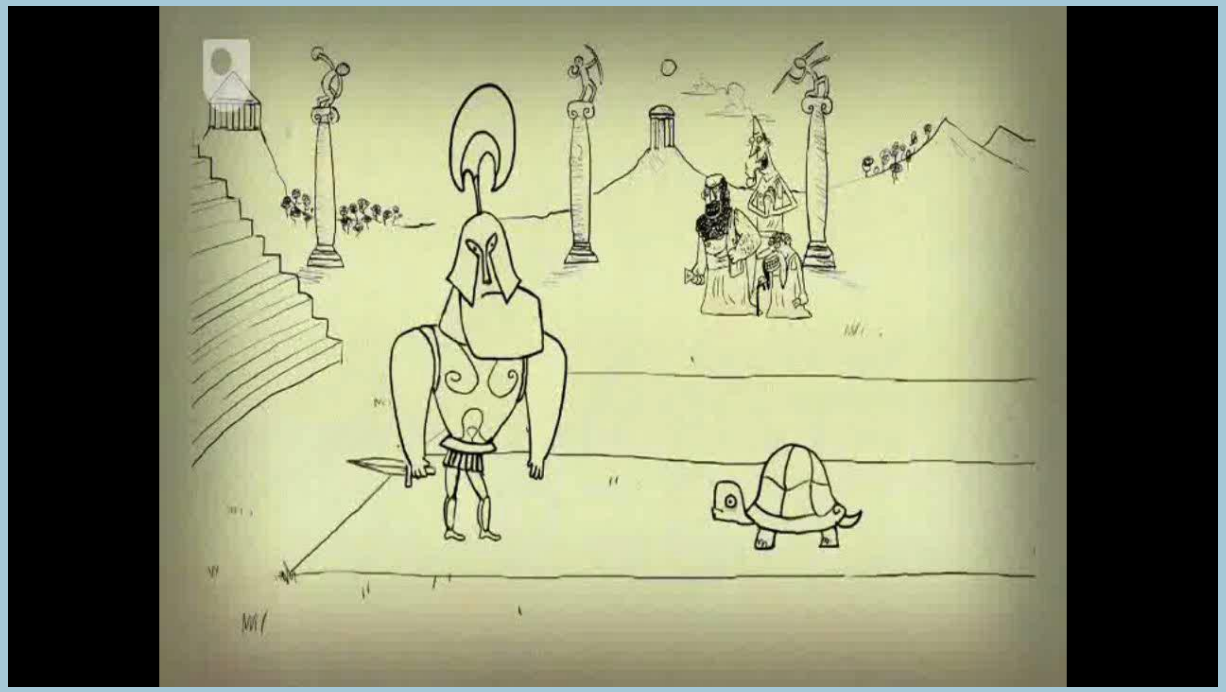
"The arrow will never reach B" (animation)



in aeternum

Zeno's paradoxes
(animation, music by Manos Hatzidakis)

Achilles and Tortoise



Achilles will run after the Tortoise

in aeternum

Zeno's paradoxes: why so important

- Experience is deceptive, reality is different from perception, use logic to investigate the world
- Prove a theory – not just state it

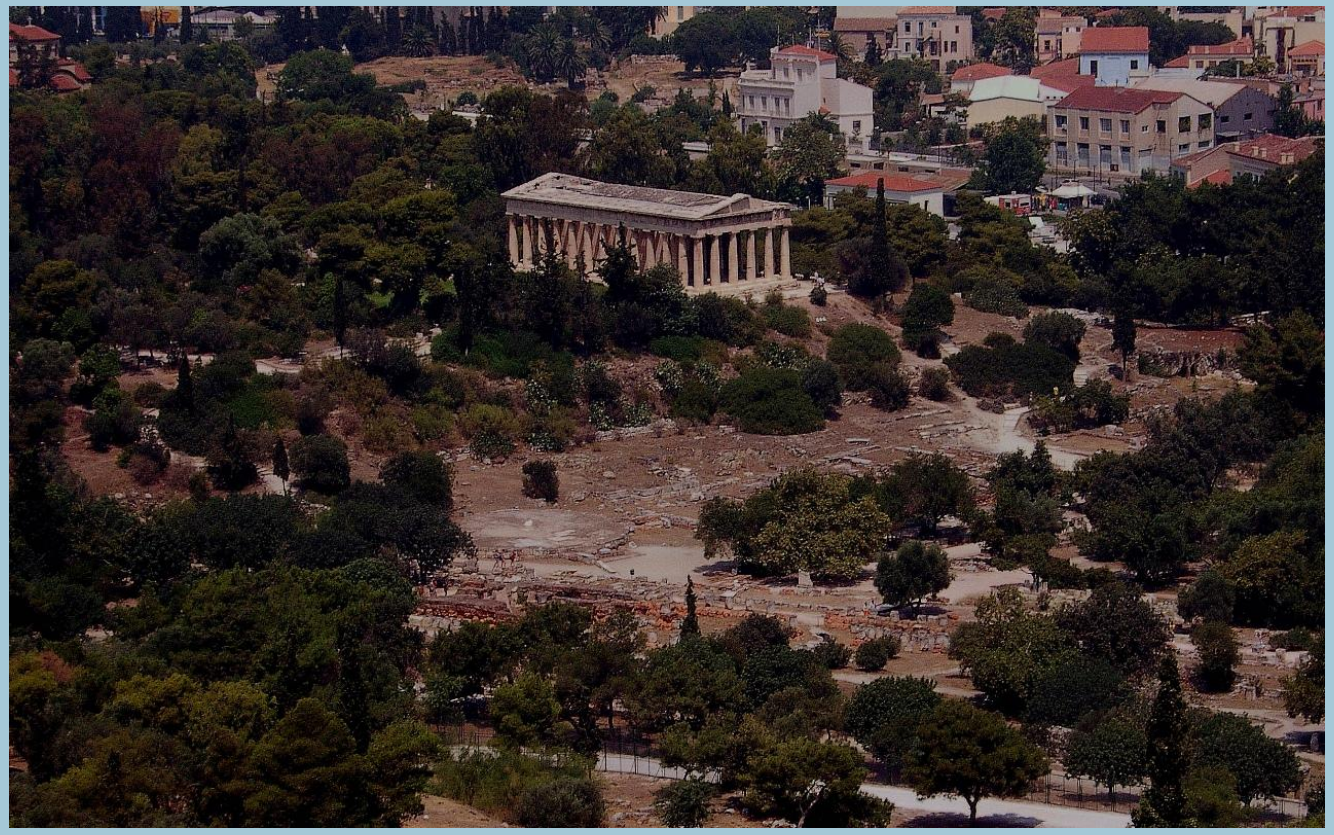
  Use of thought experiment

  Proof by contradiction (*reductio ad absurbdum*)
- Foundation of logic as discipline, established by Aristotle developed by Chrissippus, Frege, Russell, Tarski

  Logic is the main tool for reflection in many types of design, e.g. to prove the correctness of software

Models and abstractions – Plato (c. 424 - 348 B.C.)

Behind flux and instability, Plato saw a parallel world of perfectly stable abstract forms (ideas)

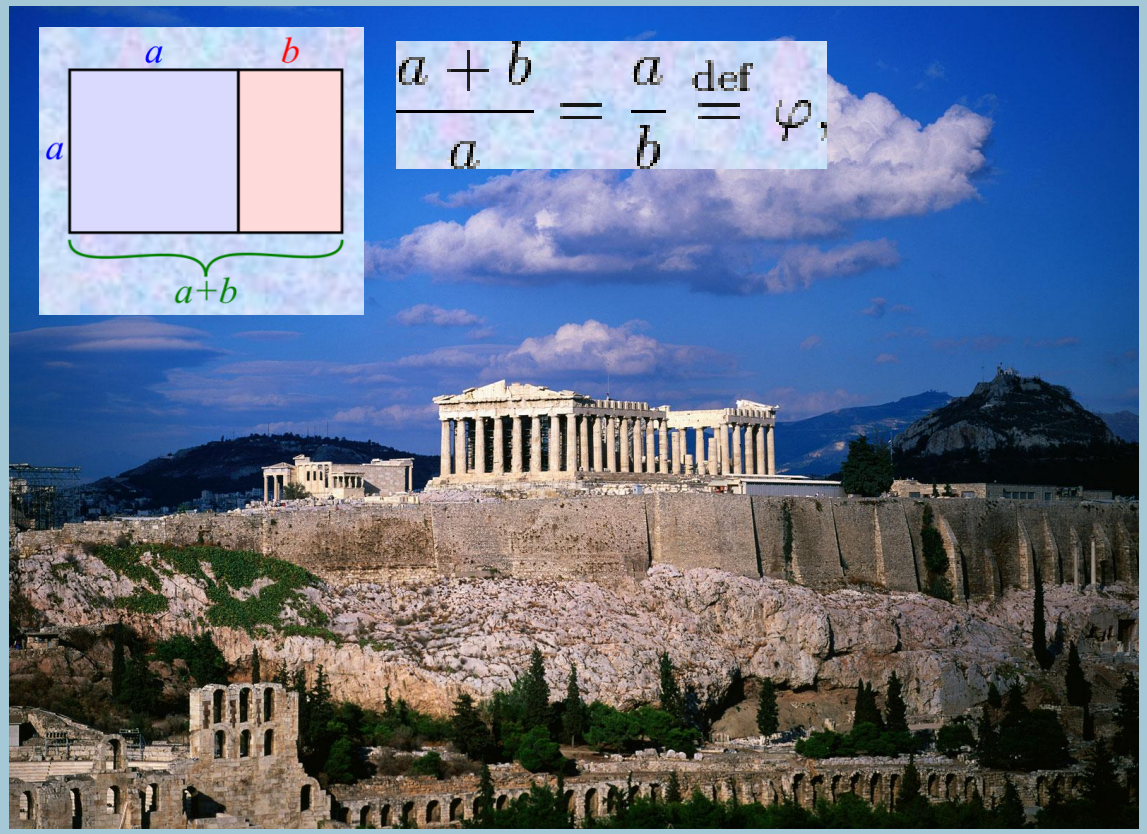


His Academy was set in a Athenian garden

(no fees)

Plato and his “ideas”

Platonic abstractions (maths, geometry, models) help us reason about an unstable world and enable design



Golden ratio:

Le Corbusier & Botta,
Béla Bartók,
Geometry of crystals,
Structure of leaves
Atomic scale
Human DNA

Biology – Design as automated search

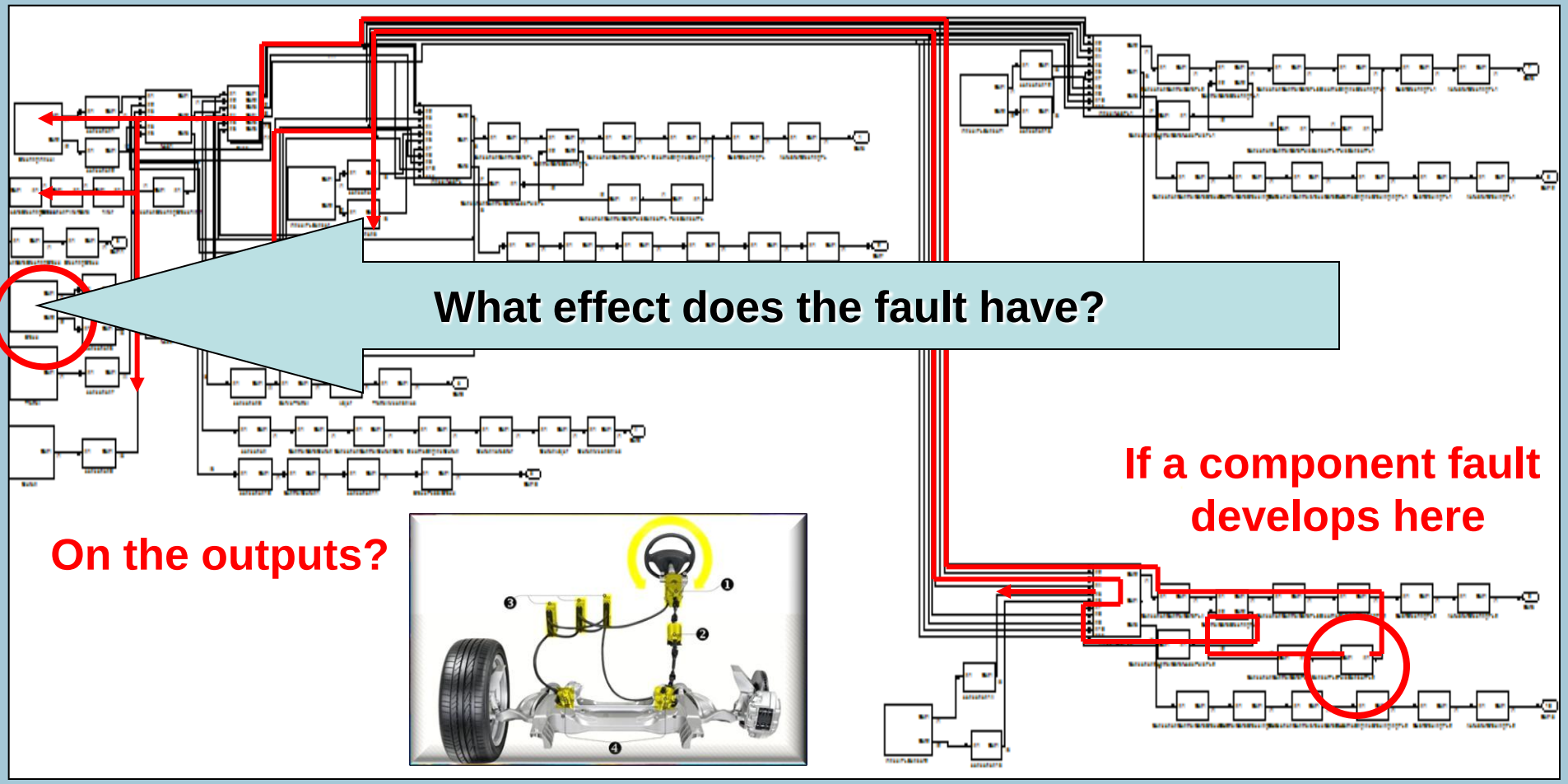
- Aristotle: biological determinism “acorn is destined to become an oak tree”
- Darwin: theory of evolution of species, refined by subsequent geneticists
- Genetic theories influenced the way we view design in engineering.
- The elements of a car make innumerable combinations that define a design space. One is a BMW.
- Design can be seen as the task of searching potential design spaces for useful solutions

Intersections in my scientific contribution

- Dependable systems
- Increasing concerns about new systems

  Computer controlled dependable systems emerge in new areas.
- Increasing complexity of systems, rapid technological change, reduced product development times & budgets cause difficulties in classical dependability analyses

Problem & Motivation (animation)



My work in the field of dependability

- Methods and tools that partly automate & simplify dependability analysis and design optimisation
- Known as Hierachically Performed - Hazard Origin and Propagation Studies (HiP-HOPS)
- Effectively a synthesis of models, logic and biology
- Contributing to the state-of-the-art

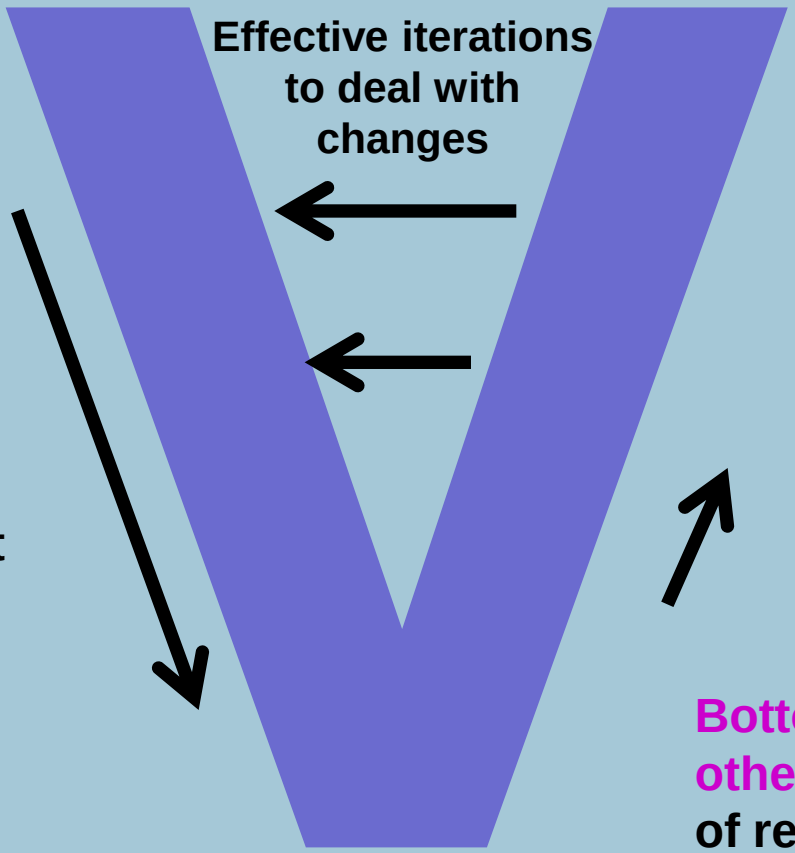
Aspirations (& achievements) of HiP-HOPS

all processes model-based and largely automated

Dependability-driven design

dependability requirements allocated to sub-systems and components during refinement

With the aid of automation and metaheuristics

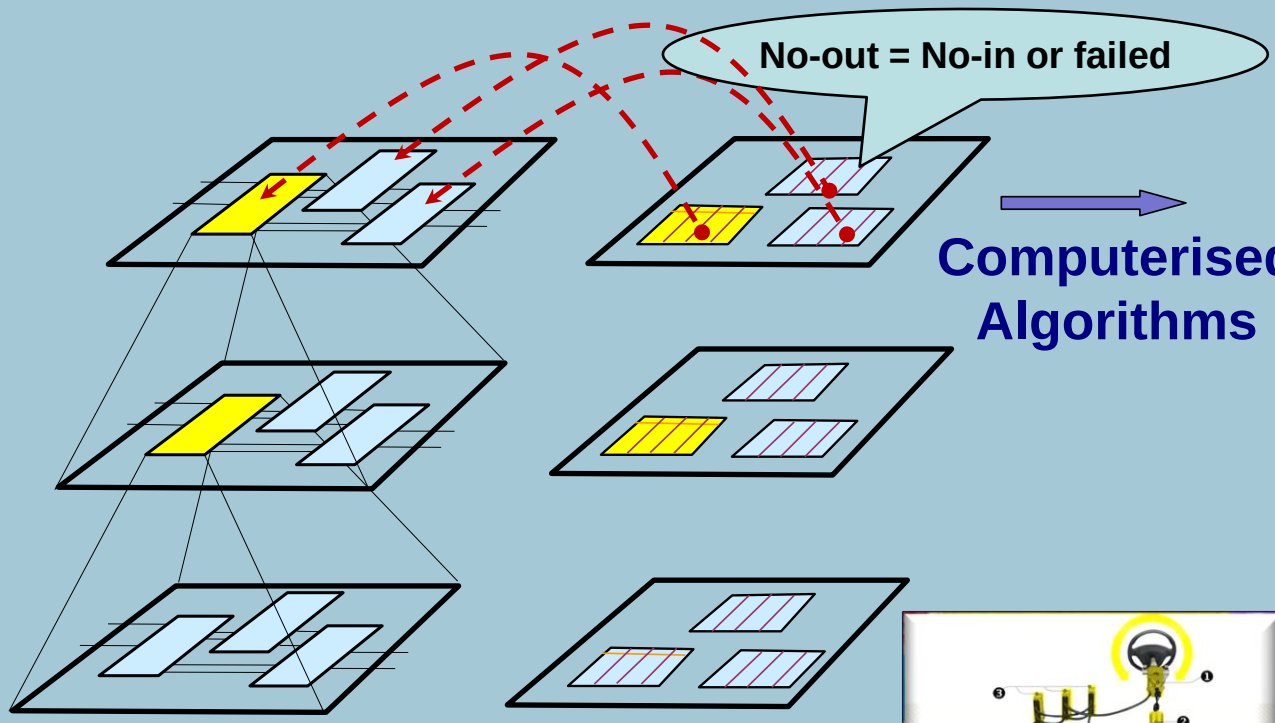


Metaheuristic Optimi-sation of system architecture and maintenance with respect to dependability, cost, ...

Bottom up dependability and other analyses and verification of requirements

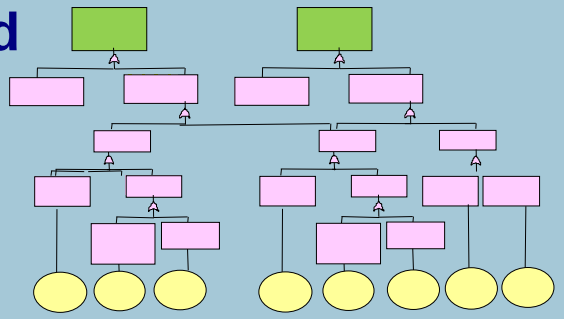
HiP-HOPS : A Platonic view

System Model + Error logic of components = Global view of failure:

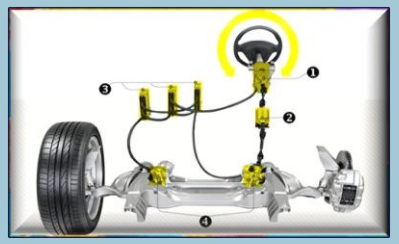


Computerised Algorithms

System failures



Component failures



Novel language for modelling error logic
(recall Zeno)

- A contribution in itself
- Includes PANDORA (with Martin Walker) a new temporal logic (extension of Boolean logic)
- It enables new forms of design reflection in which the effect of sequences of fault can be analysed in fault trees

Moving beyond dependability analysis to automatic improvement of dependability

- What happens when design is not dependable enough?

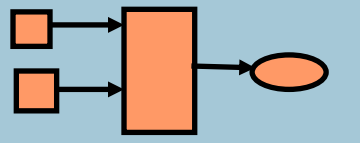
  How can system dependability be improved?

  Substitute components & sub-systems, replicate increase frequency of maintenance

- Which solution achieves minimal cost?

- Hard design problems that can only be addressed effectively with automation

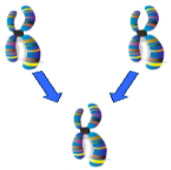
Evolutionary Design Optimisation Algorithms

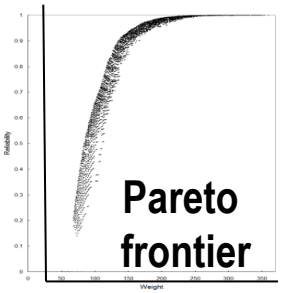


Model, Variants Cost, Weight Failure data

HiP-HOPS

Genetic Algorithm

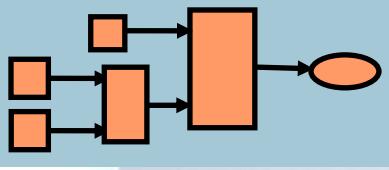




Cost analysis

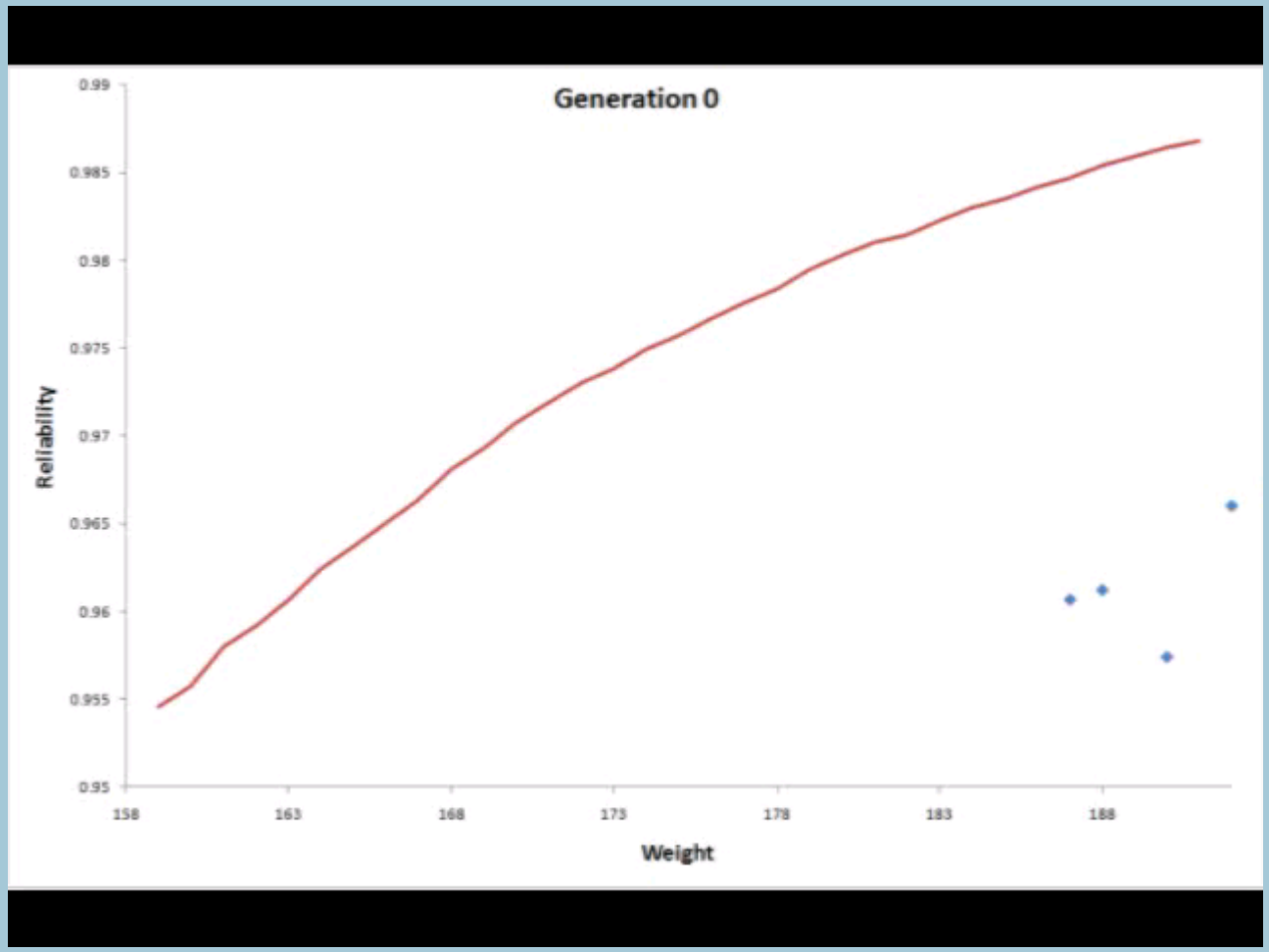
Dependability analysis

Weight analysis



Set of Optimised models

Evolution in action: improving a technological design (animation of evolutionary search)

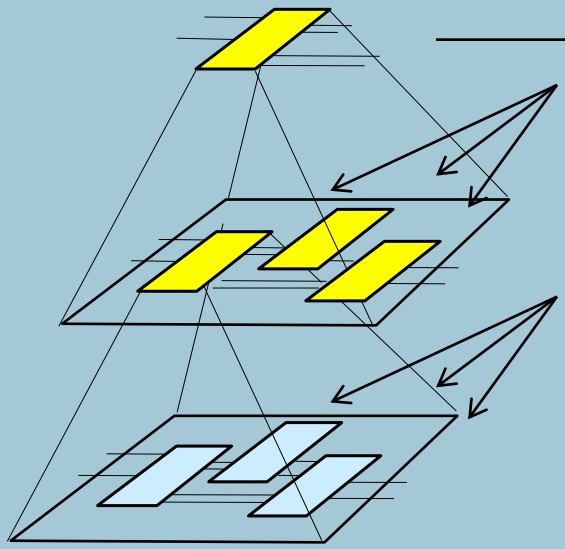


Allocation of Dependability Requirements

- **Why wait to design system first in detail to then assess whether dependability requirements have been met?**
- **Why risk failing to meet requirements and need to redesign?**
- **Why not have a top-down dependability-driven design process in which dependability requirements can be optimally allocated to sub-systems during refinement?**
- **Many standards like IEC61508, APR4754, ISO26262 aspire to this**

HiP-HOPS enables Dependability-Driven Refinement of Design

Cost-optimal allocation of System Dependability Requirements is done using model-based analyses and metaheuristic search



System Requirements
(derived via risk analysis)

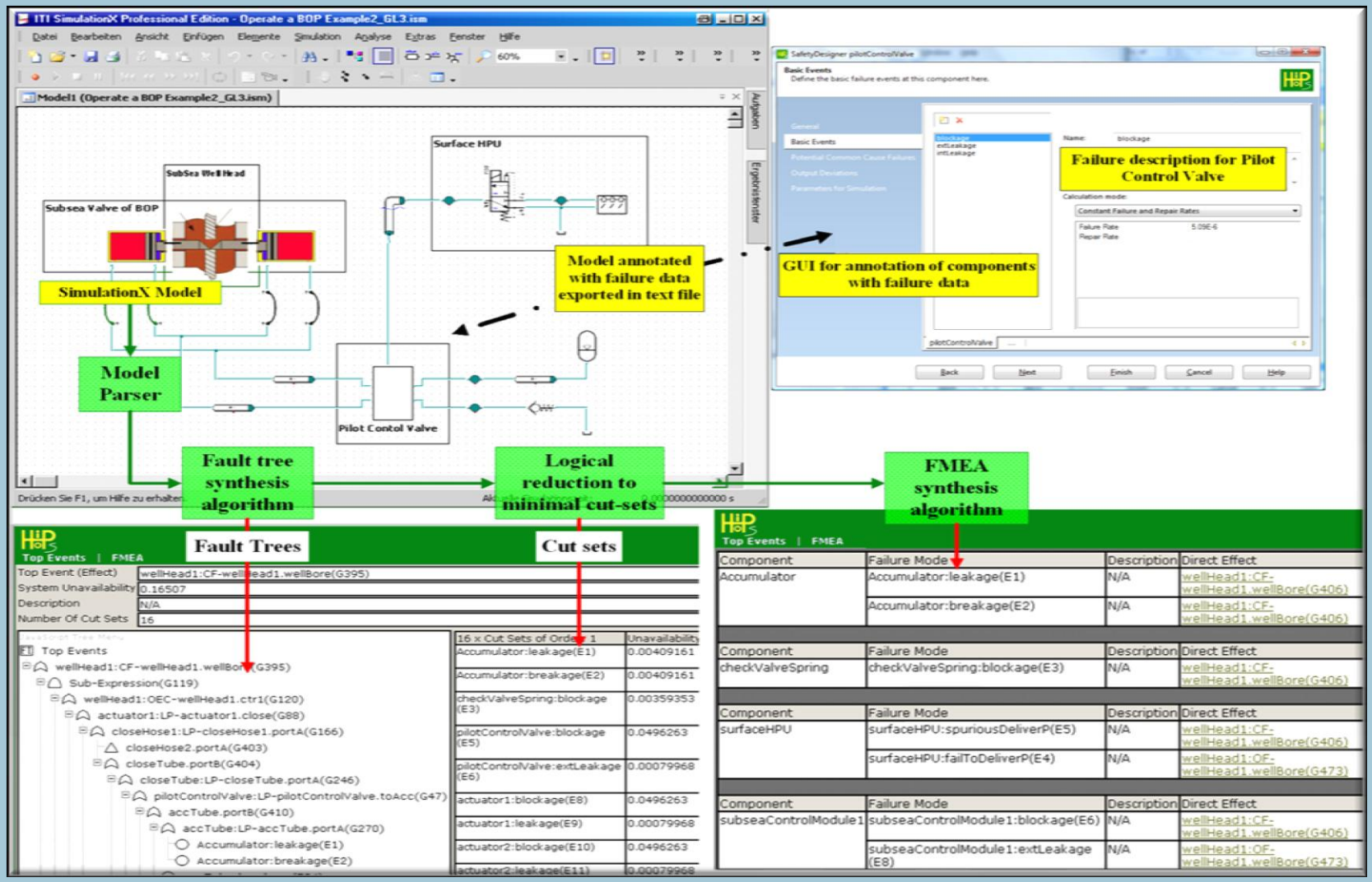
allocated/decomposed

Subsystem Requirements

allocated/decomposed

Component Requirements

Commercialisation of technologies



Technology transfer with global reach

Taken up by Honda, Toyota, Continental, Fiat, Volvo
Embraer, Honeywell, DNV-GL

Art project: from fixed artefact to design space

- Roberto Bono (Sicilian Abstract Painter)
  Andrea Alberti (Euphrates Artists - musician - Rome)
  Bob Salmieri (Milagro Acustico - musician - Rome]
  David Parker (Computer science colleague)

- Roberto's abstract painting in twelve double sided panels

  Idea to enable people to make their own configuration

  Possible configurations (paintings) in order of quintillions. To view design space requires the age of Universe

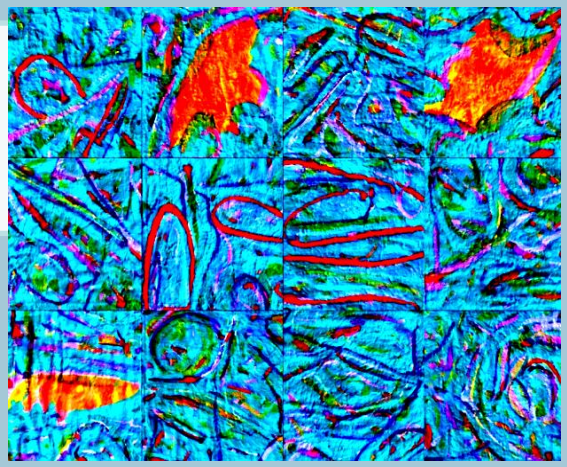
  Created a computer system that takes random and evolutionary journeys through this design space

Art Work as exploration of a design space

(click on West-East links to see artshows – requires installing MS-Silverlight)

West

- **Roberto Bono & Andrea Alberti**



East

- **Roberto Bono & Bob Salmieri**

Summary

- **Philosophy (& logic and biology) have historically enhanced positively our conception design**
- **I have illustrated some influences in my work from engineering to an artistic project**
- **Plenary paper describes**

A) Challenges in Model-Based Safety Assessment

B) View on how they can be tackled with a synthesis of logic and biology – i.e. a synthesis of verification techniques that rely on logic and biologically inspired search and optimisation techniques.

C) Summary of my work in this direction within HiP-HOPS

Five year plan:

- Intergalactic domination of HiP-HOPS
- Define the future of audio-visual art
- Retire in a Greek island

Thank you!