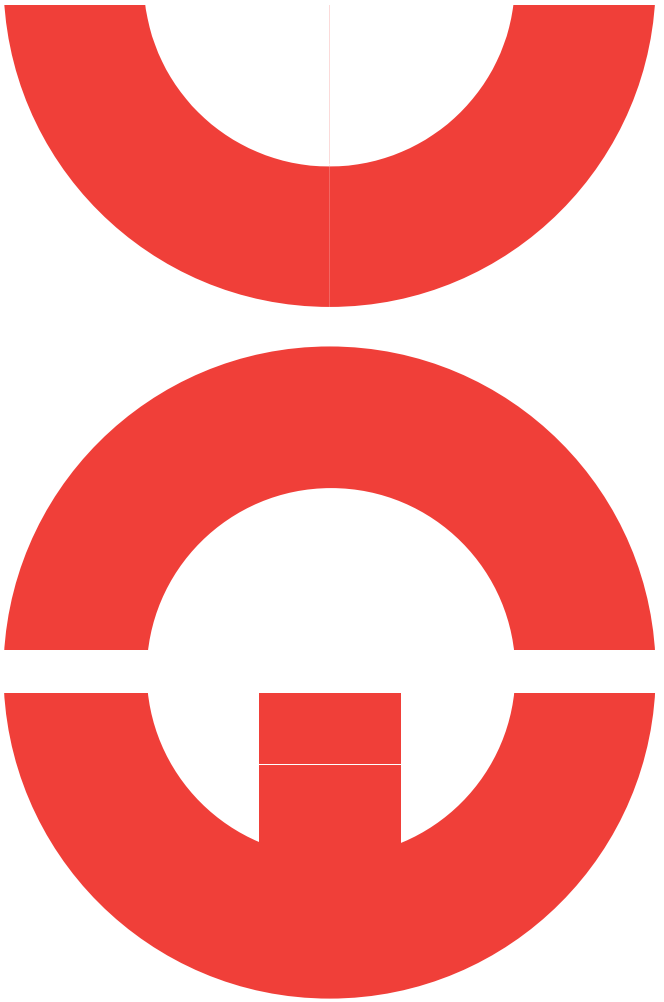

Cambridge Engineering Design Centre

An effective design system lies at the heart of all successful enterprises. Design processes shape not only products and services, but also businesses, educational institutions and entire societies.

Professor P John Clarkson FREng

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Engineering Design Centre, University of Cambridge, UK

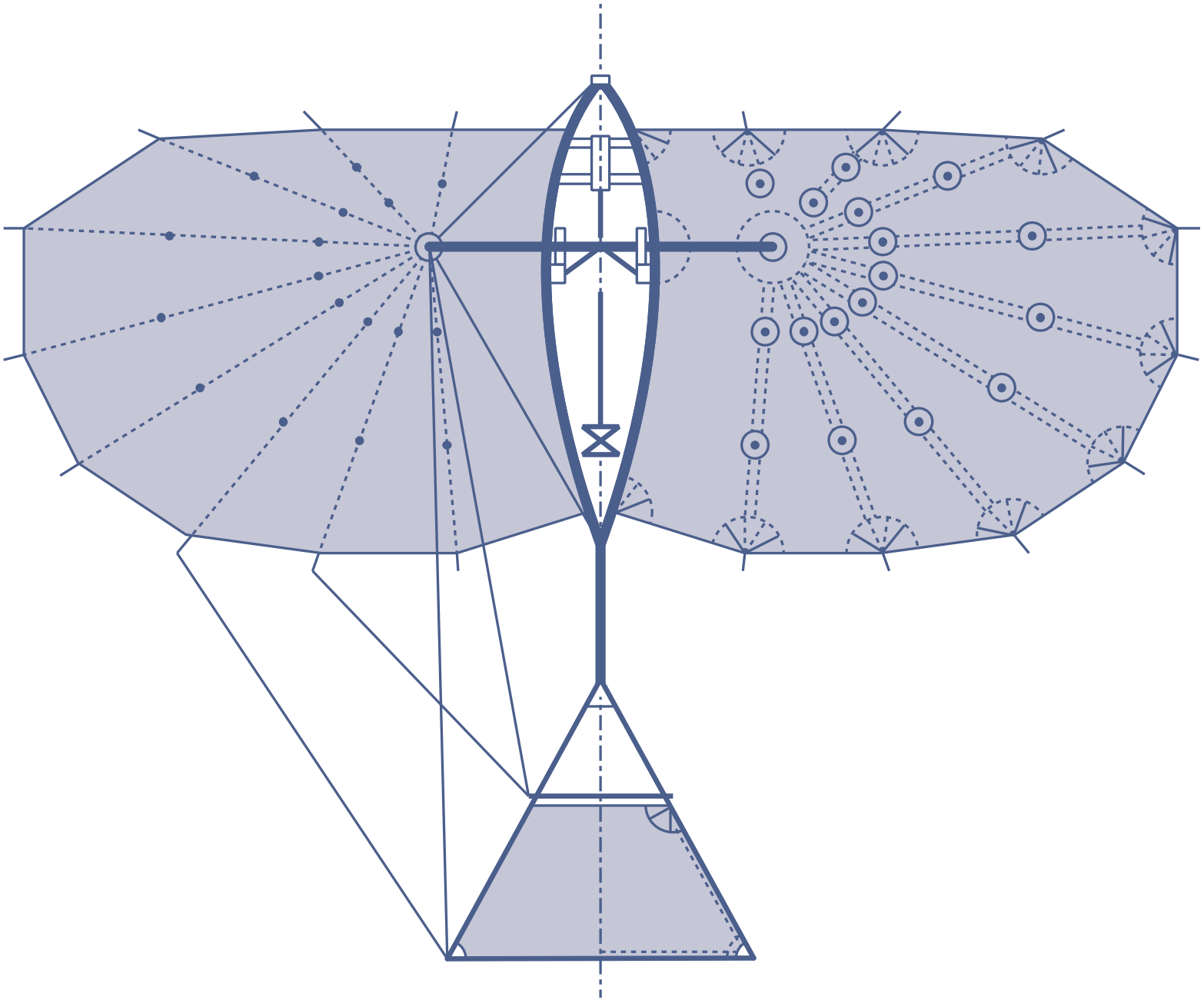
Contents

Foreword

Good design is fundamental to product success and improvements in people and processes are just as vital for the health of a business as developments in technology.

The Cambridge Engineering Design Centre delivers practical tools and methods to industry, based on rigorous research and a deep understanding of engineering design.

Geoff Kirk, former Chief Design Engineer, Rolls-Royce, 2016



Preface

For more than twenty-five years the Cambridge Engineering Design Centre has undertaken fundamental and applied research to generate knowledge that improves the design process.

This book provides an introduction to the diversity of people, activities and collaborators that have contributed so effectively to this endeavour.

John Clarkson, 2016

Cambridge Engineering Design Centre

A simple history

University of Cambridge

The University of Cambridge is one of the world's oldest universities and leading academic centres, founded in 1209 when scholars taking refuge from hostile towns-men in Oxford migrated to Cambridge.

Addressing the world's most pressing problems

1209 University of Cambridge

1440 Gutenberg printing press

1642 Pascal mechanical calculator

1875 Department of Engineering

1937 Frank Whittle jet engine

1991 Engineering Design Centre

2009 University celebrates 800 years

800+

Department of Engineering

The Department of Engineering is the largest department in the University, housing nearly 200 faculty, 300 contract research staff, 900 research students and 1200 undergraduates of all disciplines.

Engineering Design Centre

The Engineering Design Centre (EDC) was founded in 1991 by Professors Wallace, Ashby and Newland to undertake research to create understanding, methods and tools that would improve the design process.

Improving the Design Process

- 1991 Engineering Design Centre
- 1993 Housed in lower drawing office
- 1998 University Technology Partnership
- 2001 Integrated Manufacturing Research Centre
- 2006 Relocation to EDC Loft
- 2011 Opening of Ashby Laboratory
- 2016 EDC celebrates 25 years

25+

Engineering Design Centre

Academic Staff (discipline)

Professor John Clarkson (systems)

Mr Aylmer Johnson (mechanisms)

Dr Geoff Parks (nuclear)

Dr James Moultrie (manufacturing)

Dr Digby Symons (mechanics)

Dr Jerome Jarrett (aerospace)

Dr Nathan Crilly (product)

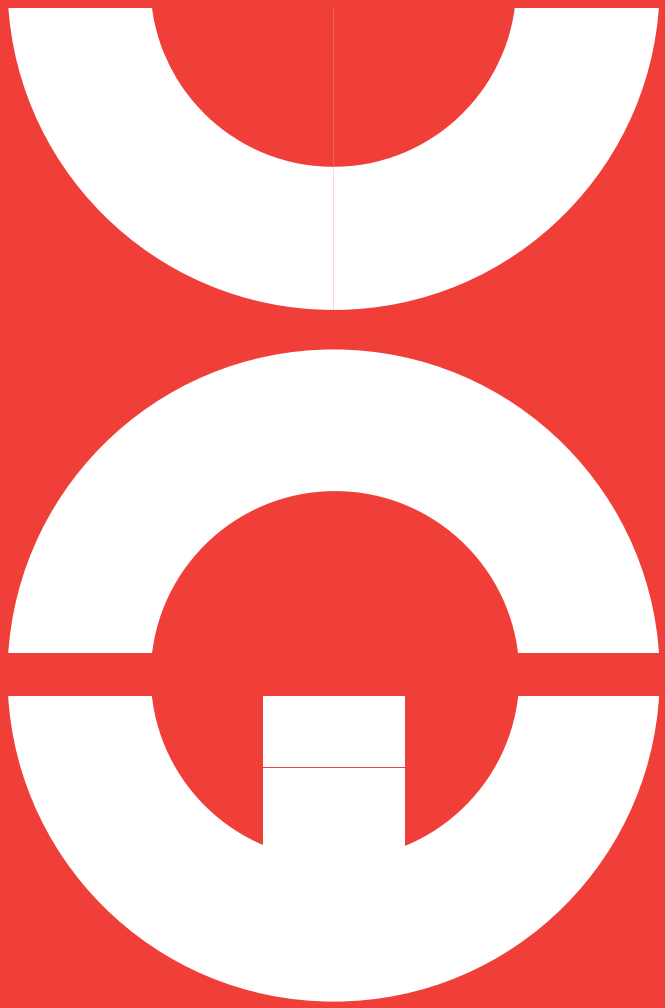
Dr Per Ola Kristensson (interaction)

Professor Steve Evans (sustainability)

Professor Emeritus Ken Wallace (mechanics)

Professor Emeritus Michael Ashby (materials)

Professor Emeritus David Newland (mechanics)



Cambridge Engineering Design Centre

The design process

Dictionary Definitions

design, *n*. The art of drawing or sketching; the process, practice, or art of devising, planning, or constructing something according to aesthetic or functional criteria.

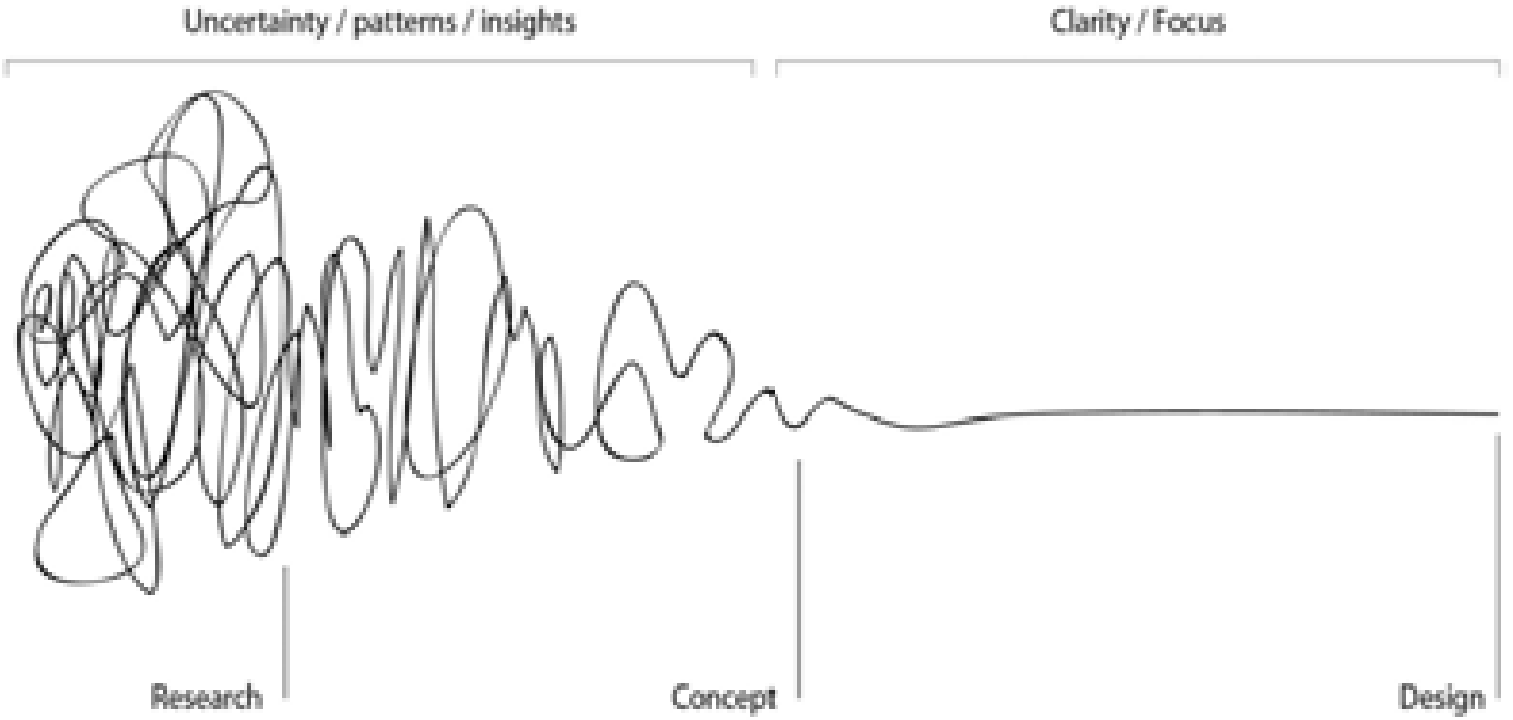
Oxford English Dictionary

Design Process

process, *n*. A continuous and regular action or succession of actions occurring or performed in a definite manner, and having a particular result or outcome, a sustained operation or series of operations.

Oxford English Dictionary

The Design Squiggle

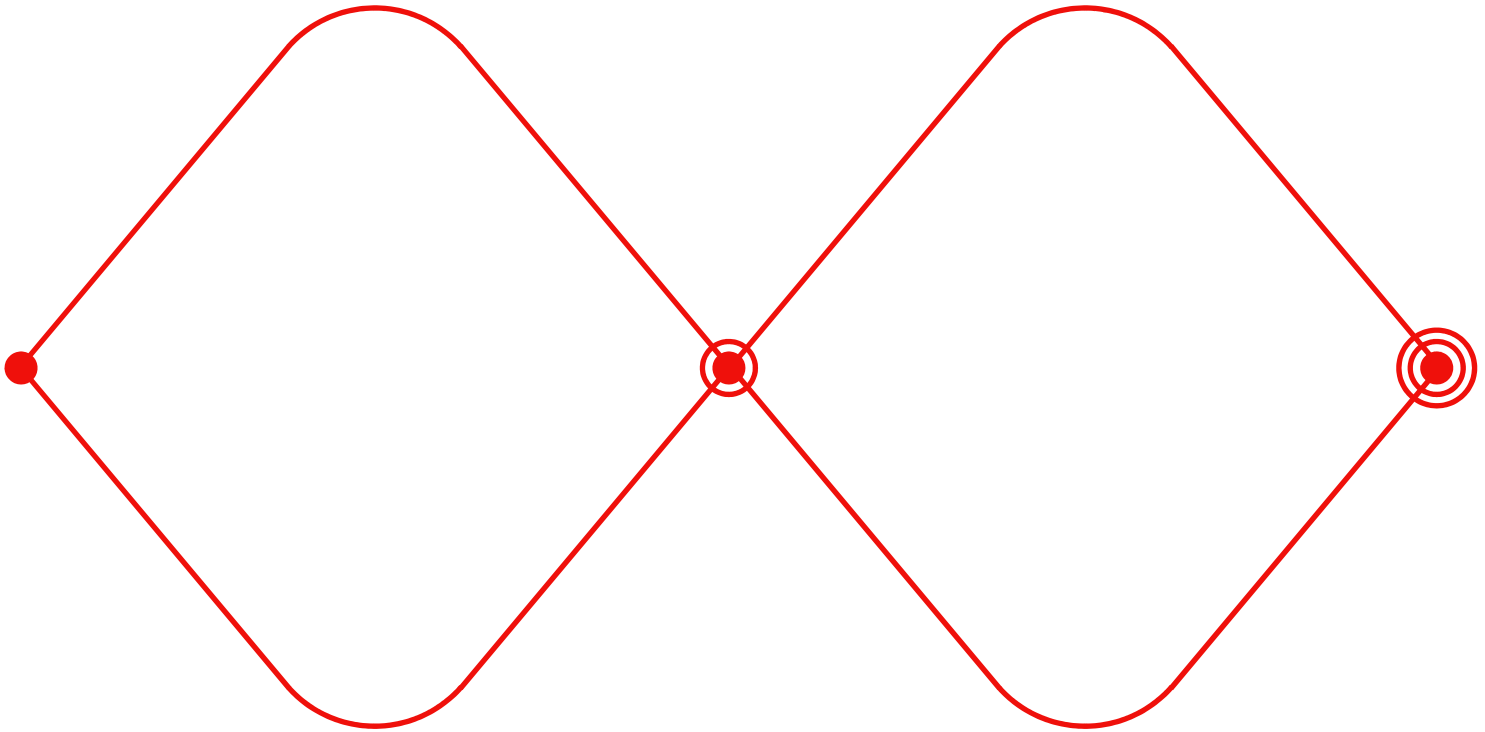


Design Process

The process of design from a great height. My father told me that the design process started with the abstract, moved to the concept and then finally the design.

Damian Newman, Central Office of Design

The Double Diamond



Discover **Define** **Develop** **Deliver**

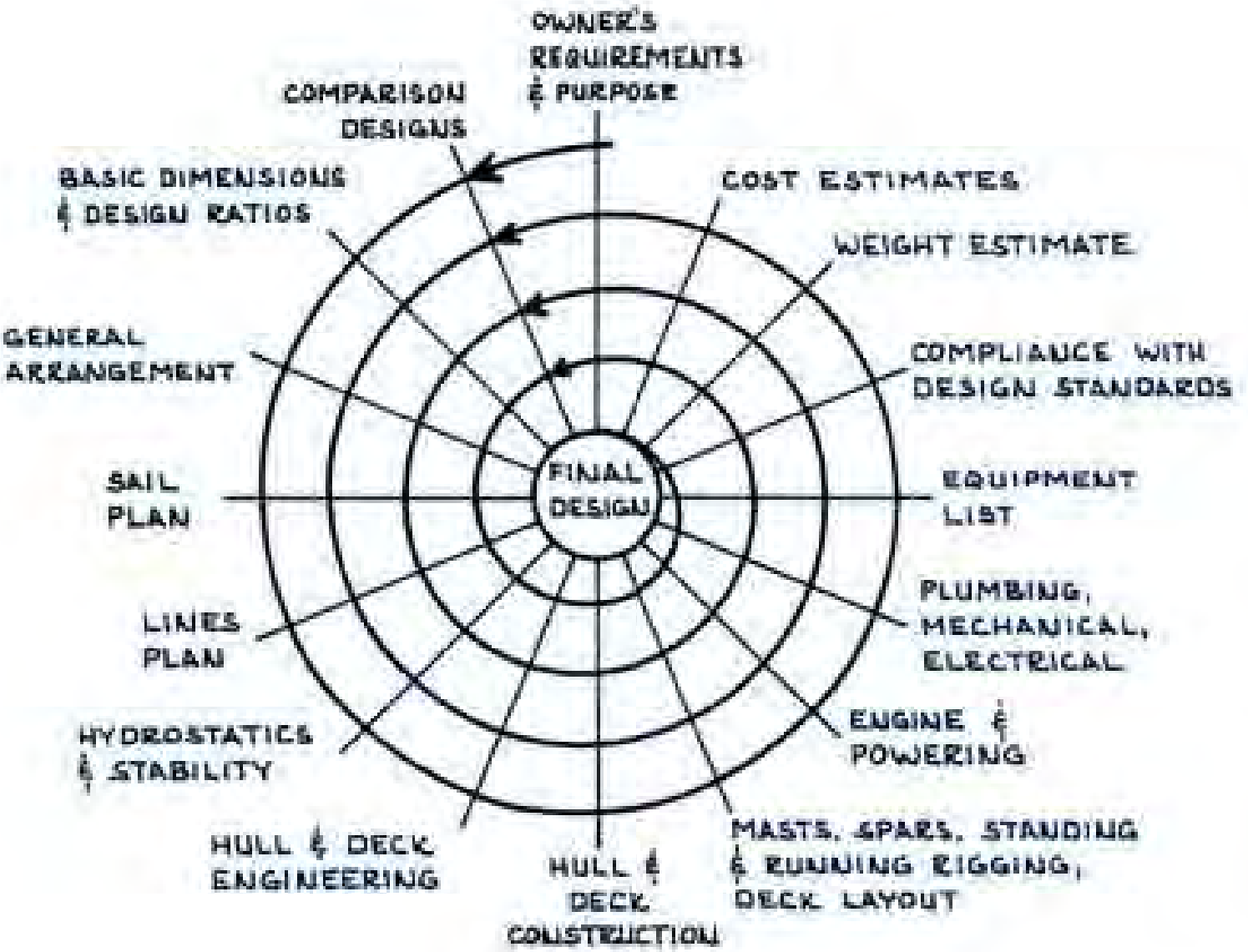
Design Process

Every design specialism has a different approach and ways of working, but there are some commonalities …

… a number of possible ideas are created before narrowing down to the best idea.

The Design Council

The Design Spiral

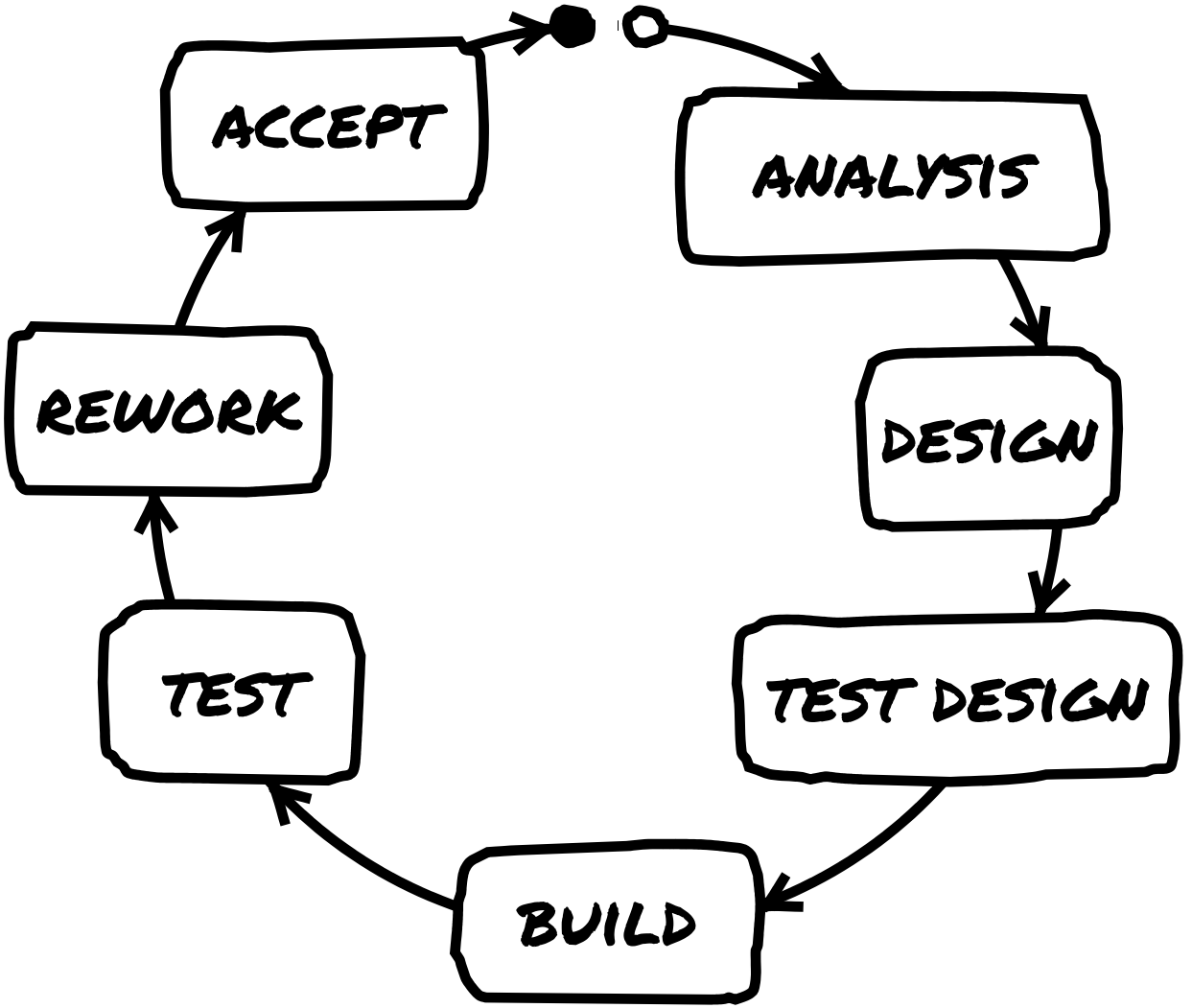


Design Process

At each spoke in the spiral, a little bit of information is created, details drawn, engineering calculations done. Work proceeds around the design spiral until the design is finished.

Eric W. Sponberg, Naval Architect

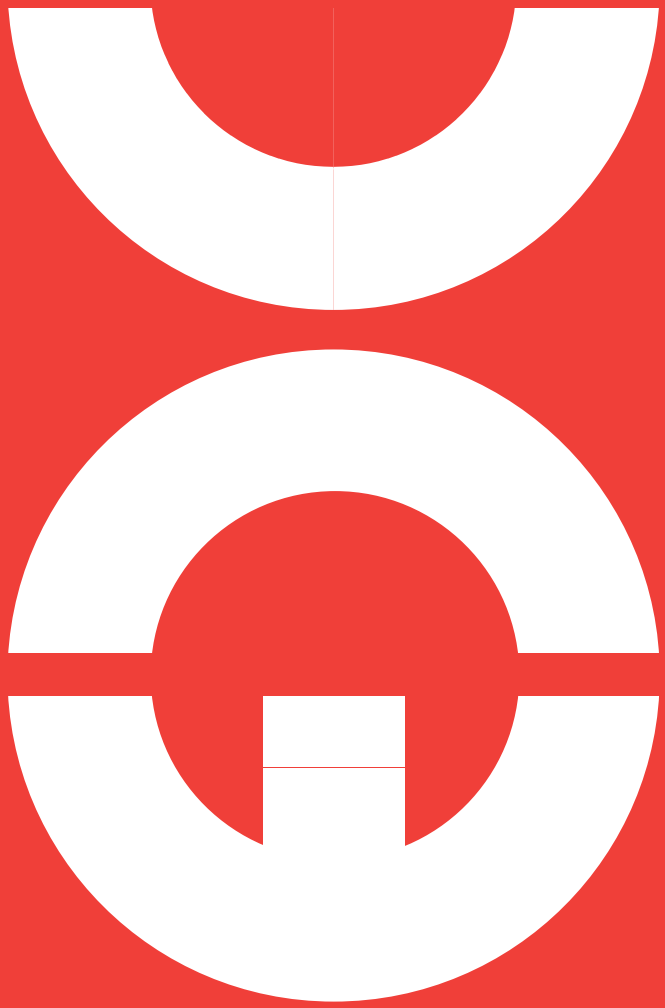
The Design Cycle



Design Process

Engineering design is the systematic, intelligent generation and evaluation of specifications for artefacts whose form and functions achieve stated objectives and satisfy specified constraints.

Clive Dym, Harvey Mudd College



Cambridge Engineering Design Centre

Research groups

Knowledge Management Group

Aylmer Johnson

The Knowledge Management Group researches the role of engineering knowledge, and in particular design rationale, within ever-changing organisations:

- by embedding methods for the capture of design rationale into design practice;
- by developing appropriate techniques for the long-term storage of design rationale;
- by understanding how the timely retrieval of design rationale impacts design practice.

Computational Design Group

Geoff Parks

The Computational Design Group researches the potential of computational synthesis, search, optimisation and analysis tools to support design:

- by applying simulated annealing and genetic algorithms to difficult real-world problems;
- by developing multi-objective optimisation methods to support engineering design;
- by investigating the analysis and design of nuclear reactor systems.

Process Management Group

John Clarkson

The Process Management Group researches the role and nature of process modelling in the successful delivery of new products and services:

- by generating a greater understanding of the nature and demands of complex system design;
- by challenging current planning practice and risk management in complex system design;
- by developing novel and useful design process improvement tools.

Healthcare Design Group

John Clarkson

The Healthcare Design Group researches the role of systems thinking in the UK Health Service as a means to deliver safe, effective and affordable care:

- by developing new models of innovation practice for healthcare practitioners and providers;
- by delivering a framework and tools for safety management into the UK Health Service;
- by establishing a centre for quality and safety research in the UK.

Inclusive Design Group

John Clarkson

The Inclusive Design Group researches the interplay between the demands products make of their users and the diverse range of capabilities of those users:

- by understanding the impact of user diversity in product and service interaction;
- by developing models of good design practice for design and retail professionals;
- by embedding good design practice in the design and retail community.

Change Management Group

John Clarkson

The Change Management Group researches the impact of change propagation in complex systems made up of components, activities or people:

- by generating a better understanding of the nature of change in complex systems;
- by challenging current management of change practice in product and service design;
- by developing novel and useful design change management tools.

Design Practice Group

Nathan Crilly

The Design Practice Group researches the relationships between designers, artefacts and users by studying practices that impact on

- the specification of artefacts by designers and how designers consider users in that process,
- the interaction between users and artefacts, and how users consider designers during those interactions, and
- the communication between designers and users, and how artefacts mediate those communications.

Design Management Group

James Moultrie

The Design Management Group researches the role of understanding and improving the ways in which design and new product development are managed:

- in creating sustainable, desirable, usable and producible new products and services;
- in acting as an integrator between technology and users;
- in promoting the importance of design at firm and national levels.

Intelligent Interactive Systems Group

Per Ola Kristensson

The Intelligent Interactive Systems Group researches the role of design in the delivery of interactive systems that amplify people's ability:

- by extending our current understanding of human-computer interaction;
- by understanding the importance of accessibility, inclusive design and augmentation;
- by utilising machine learning, signal processing and human-computation to infer people's actions.

Aeronautical Design Group

Jerome Jarrett

The Aeronautical Design Group researches the role of computational models in the delivery of highly interactive technical systems:

- by developing high performance design optimisation approaches;
- by studying the use of robust computational design in aerospace systems;
- by investigating the aerodynamic design of shock control bumps for swept transonic flows.

Industrial Sustainability Group

Steve Evans

The Industrial Sustainability Group researches how industry develops solutions that move us towards a sustainable future:

- by understanding methods to rapidly scale resource efficiency;
- by developing effective business model design tools;
- by challenging current trajectories and preparing for a restorative industrial future.


474 FBS

Automotive Design Group

John Clarkson

The Automotive Design Group researches the role of interaction design in the delivery of increasingly sophisticated vehicles:

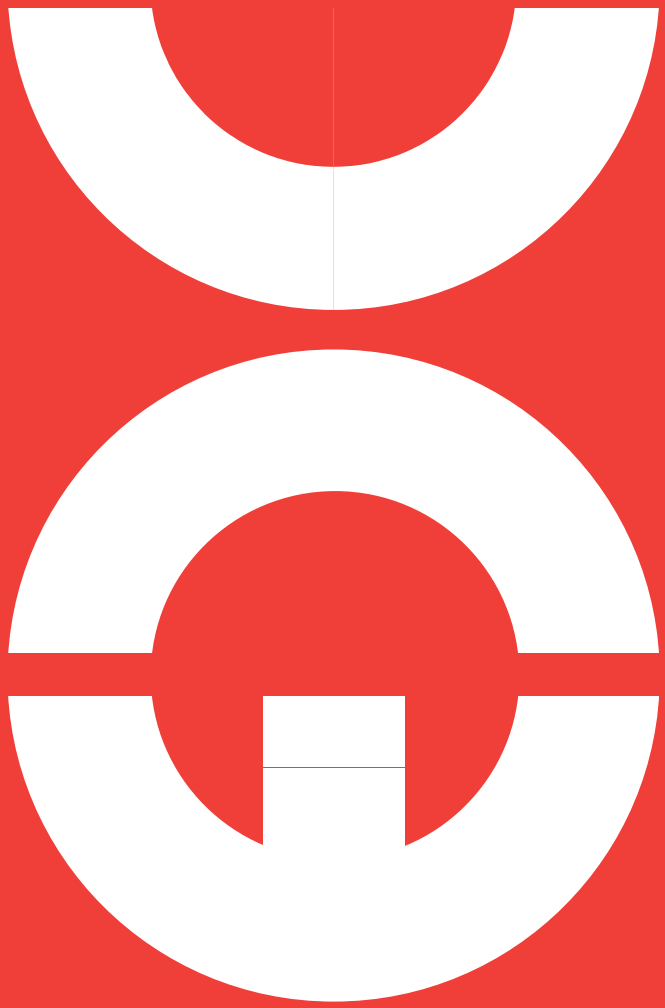
- by modelling driver behaviour to assist the design of inclusive, user-centred interfaces;
- by reducing the impact of vibration on the use of interactive display devices;
- by investigating the challenge of changing demands on driver attention.

Product Design Group

Digby Symons

The Product Design Group researches the application of engineering science to challenging mechanical design problems:

- by developing relevant analytical numerical models to provide fundamental insights;
- by translating engineering insights into practical design guidelines;
- by developing optimal designs for the health, process and sports industries.



Cambridge Engineering Design Centre

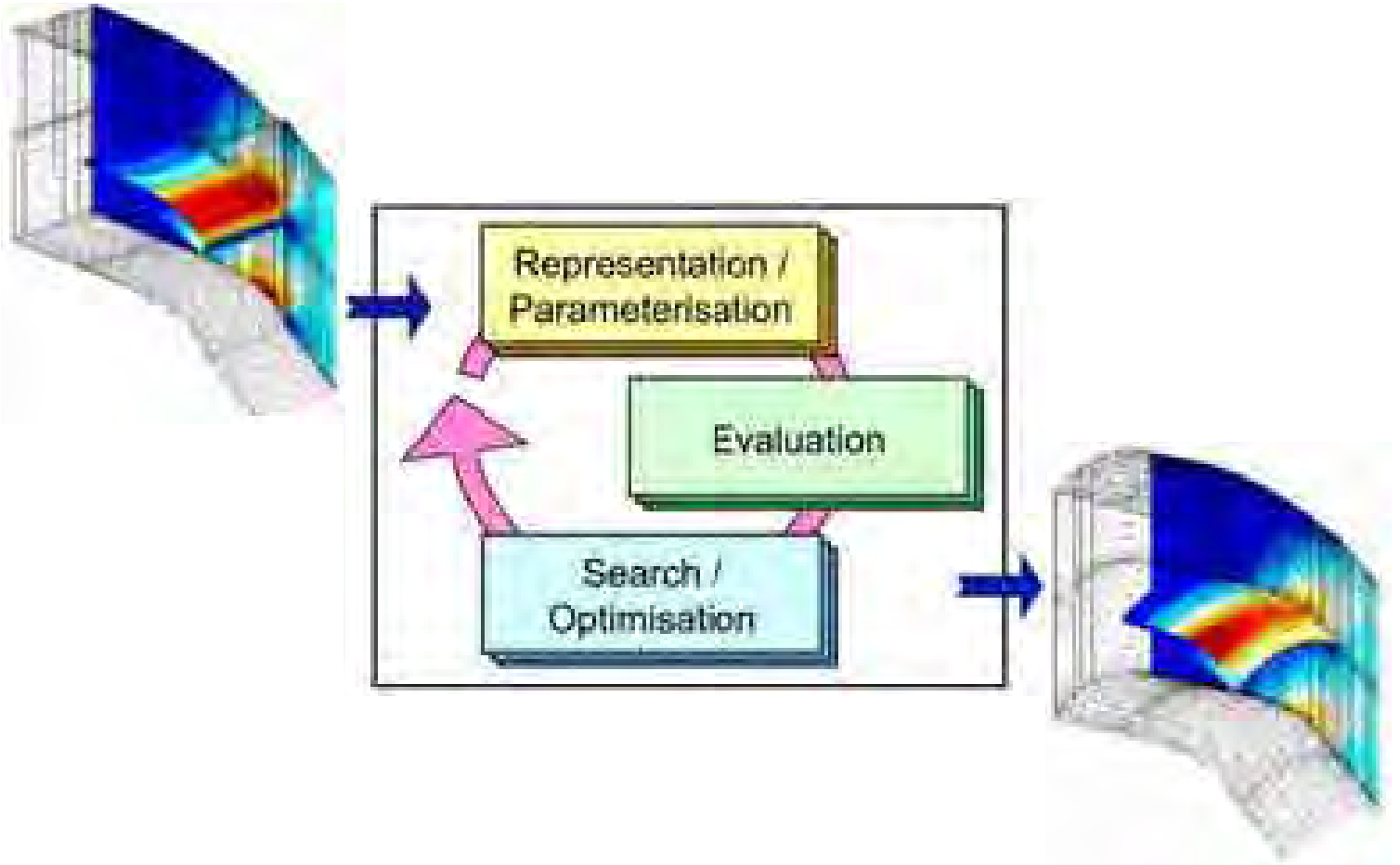
Practical impact

Capture, storage and retrieval of Engineering knowledge

We used DRed in the first weeks of the Qantas Flight 32 investigation to explore possible failure scenarios and to formally capture evidence from hardware and data analysis.

Chief Engineer, Rolls-Royce Civil Aerospace, 2013

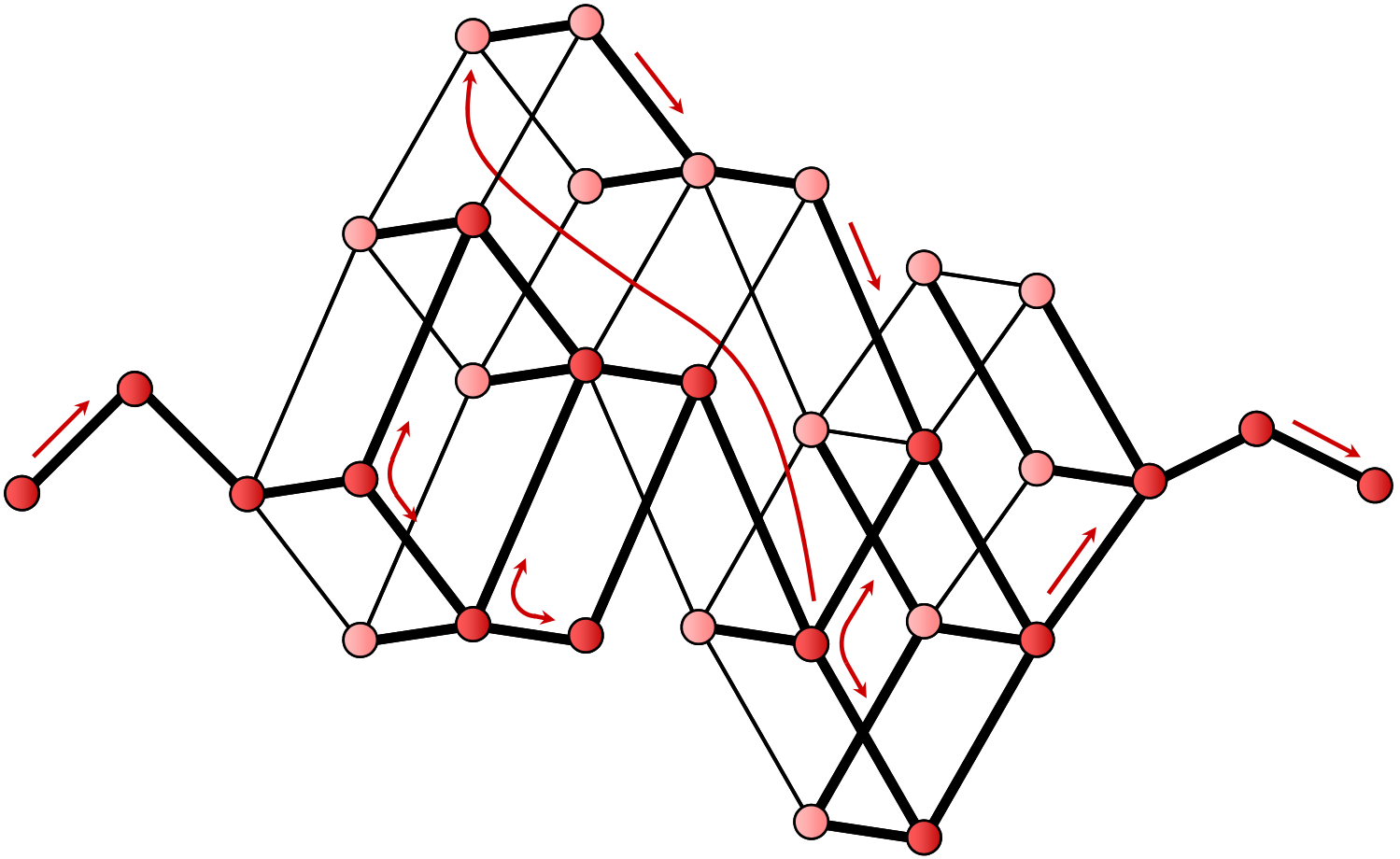
Integrated optimisation methods and tools



Most large, real-world design problems are inherently multidisciplinary and multi-objective. Therefore, it is valuable to address multi-objective problems from a multidisciplinary perspective.

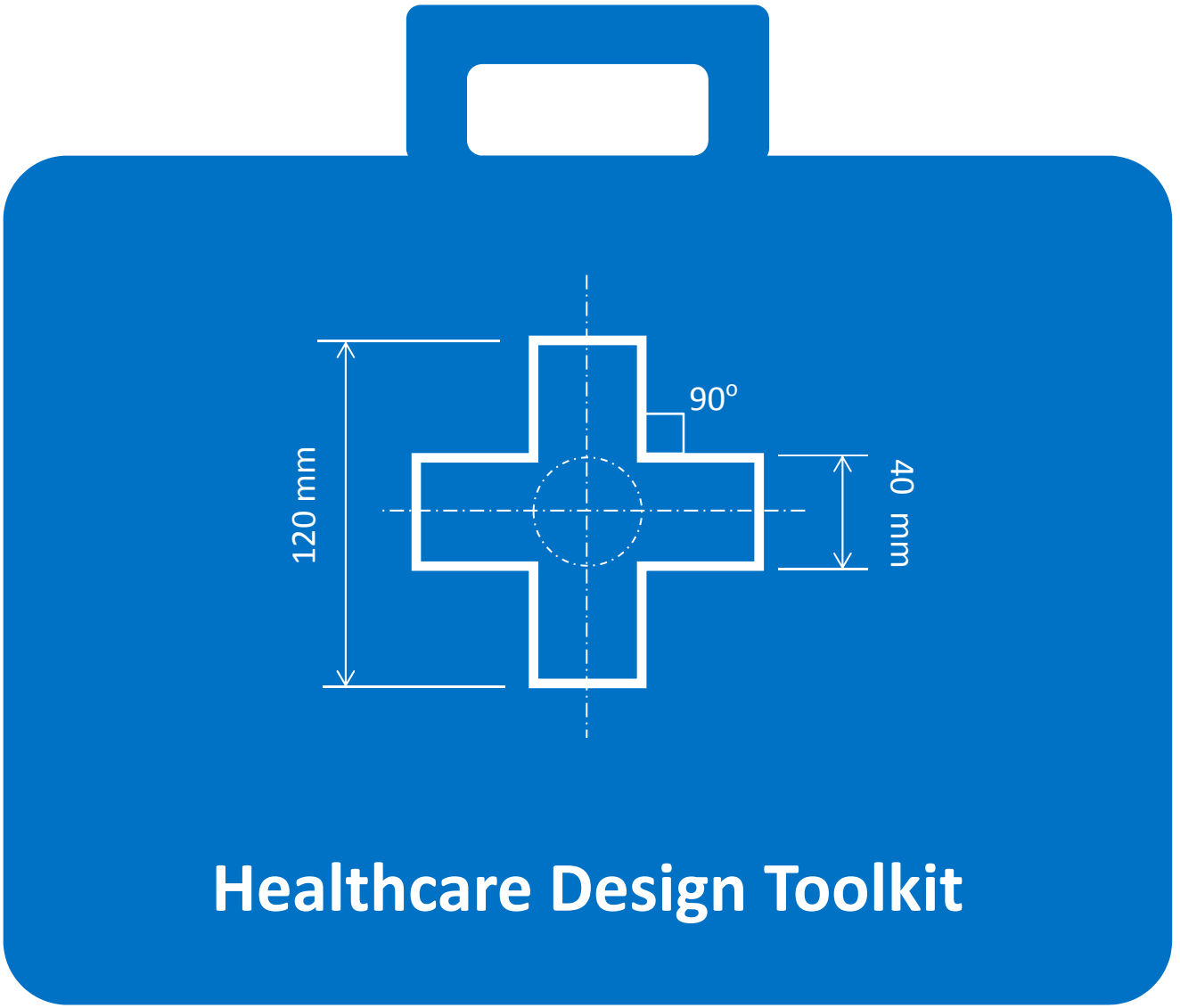
Geoff Parks, 2015

Improving design process performance



As a research student I met some inspirational people that combined a questioning mind with a healthy sense of pragmatism that I believe marks the EDC out from other design schools.

Jamie Hamilton, Monitor Group, 2012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Healthcare Design Toolkit

The EDC's innovative and proactive approach provided a clear framework to look at the complexity of managing medical records and has been widely welcomed at the hospital.

Glenn Pascoe, Cambridge University Hospitals, 2010

Countering design exclusion

Oval commissioned the EDC to undertake a User Study to validate its autoinjector designs, enabling them Oval to better understand the requirements and limitations of future products.

Mathew Young, Oval Medical Technologies Ltd., 2010

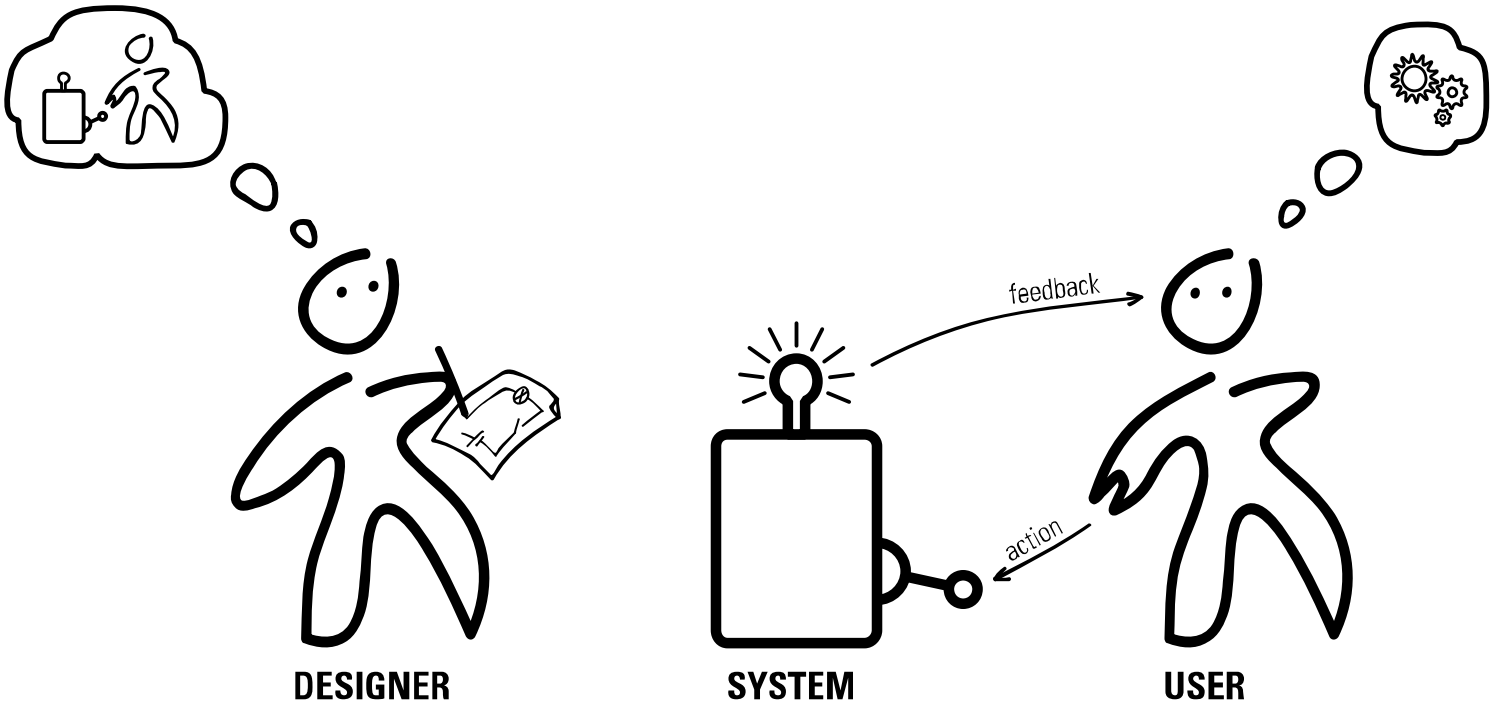
Modelling change in products

Change Management Group

Laing O'Rourke are investing in new technologies and design methods. This creates a strong need for better ways of managing the dependencies between products and delivery processes.

Adam Locke, Laing O'Rourke, 2014

Relating designers, artefacts and users



Research conducted on the way in which people respond to product design featured throughout an *amici curiae* brief for the United States Court of Appeals case of Apple versus Samsung Electronics.

United States District Court, Case No. 11-CV-1846, 2014

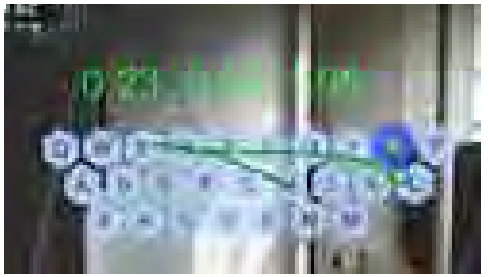
Managing design to create better products

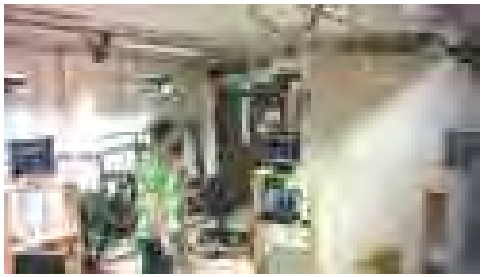
Design Management Group

A design audit tool that assesses the maturity of 25 key design activities, covering design execution and design management, has been created based on insights from literature and real cases.

James Moultrie, 2004

Designing, building and studying interactive systems





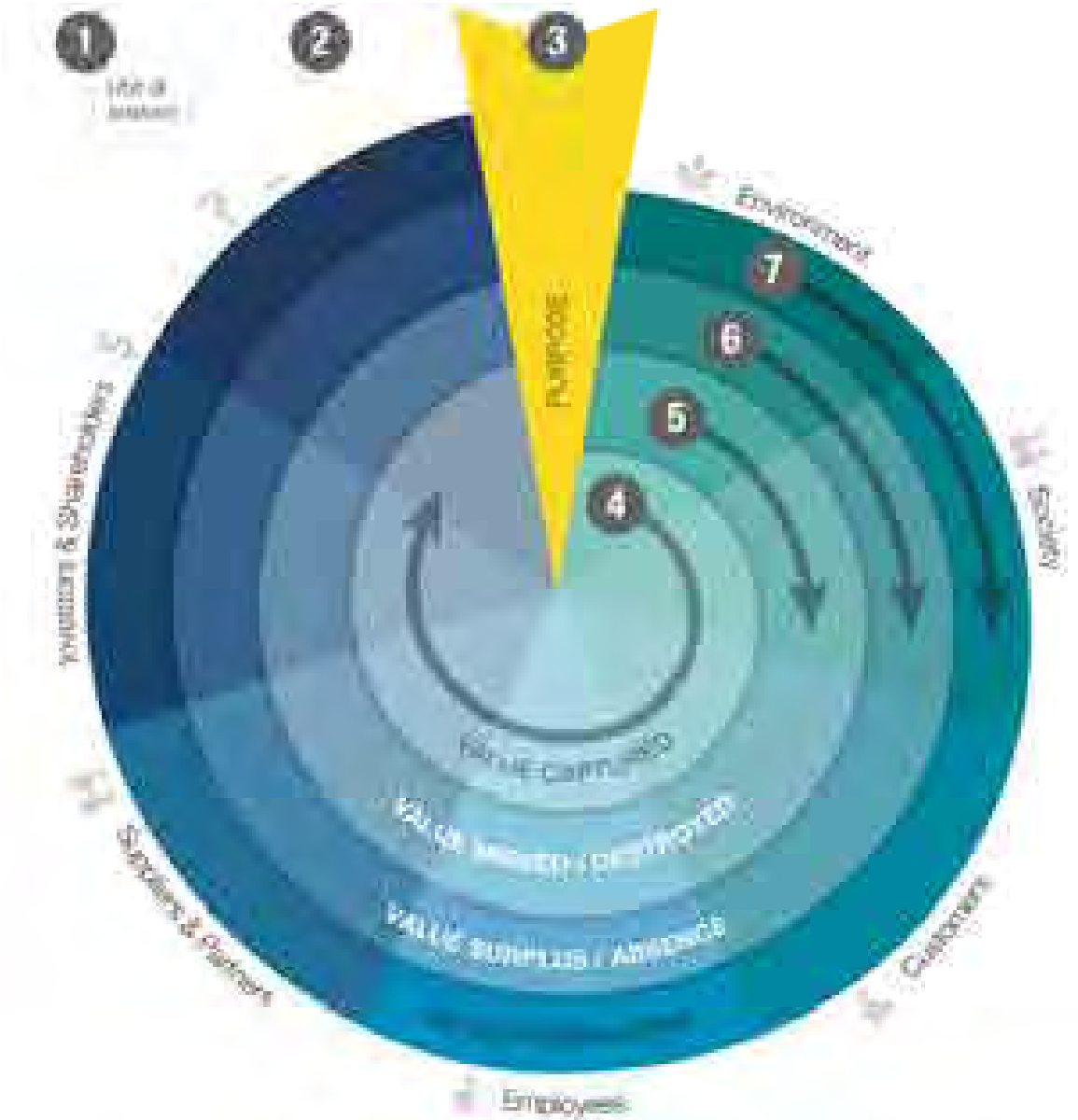
This is one of the best examples I have seen that demonstrates how design, science, engineering, and empirical studies can work together on both the machine and human sides of the equation.

Bill Buxton, Microsoft Research, 2014

The design of complex systems demands a balance between the selection of an optimal configuration and the refinement of the detail. Careful management of this process can greatly reduce design time.

Jerome Jarrett, 2012

Creating a sustainable future



The Cambridge Value Mapping Tool adopts a multi-stakeholder perspective to systematically analyse various forms of value in a business and its network to stimulate innovation for value creation.

Steve Evans, 2016

Driving new vehicle designs

Cars that can drive themselves will soon be on public roads. It is imperative to understand how drivers will react to this new technology and how best to design the driver-automation interaction.

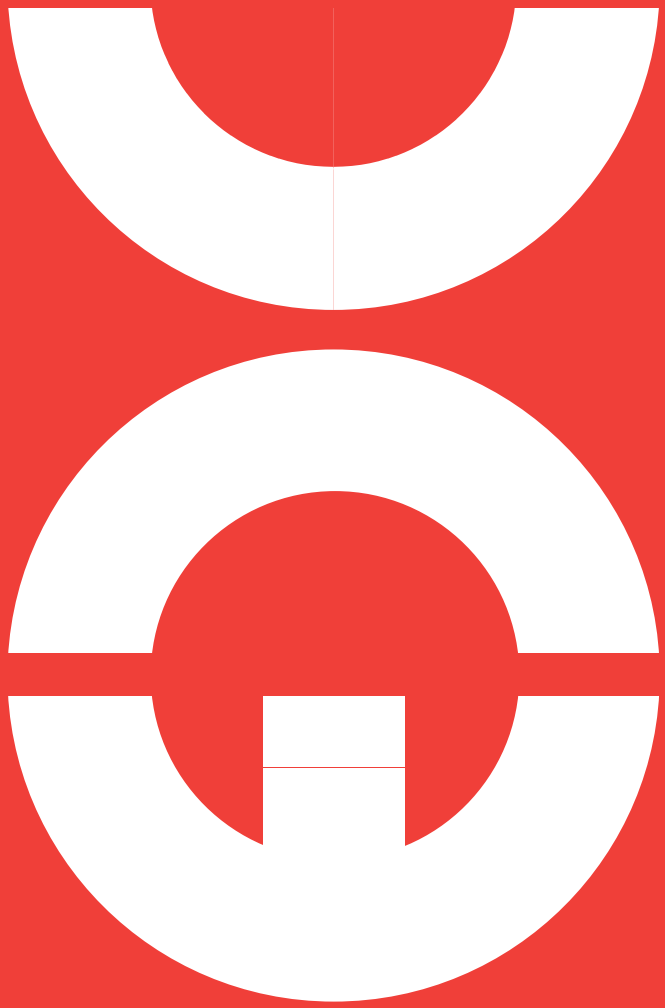
Patrick Langdon and Mike Bradley, 2016

Innovative mechanical design

Product Design Group

Questioning tradition in design of systems, both at a hardware and at a process level, has lead to significant performance gain for our track team. I bless the day I walked into the Engineering Department.

Tony Purnell, British Cycling, 2016



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vi Design Process Improvement, reproduced with permission of Springer
14 Damian Newland, Central Office of Design
15 https://revisionlab.wordpress.com/that-squiggle-of-the-design-process/
16 The Design Council
17 http://abeldb.com/en/reports/design-process-the-double-diamond/
18 Eric W. Sponberg, Naval Architect, USA
19 http://www.ericwsponberg.com/articles/
21 Engineering Design: Representation and Reasoning, Cambridge University Press, 2014
46 Jaguar Land Rover
52 Rolls Royce Civil Aerospace
53 http://impact.ref.ac.uk/casestudies2/refservice.svc/GetCaseStudyPDF/14057
57 Conversation with Jamie Hamilton, Monitor Group, 2012
59 Conversation with Glenn Pascoe, Cambridge University Hospitals, 2010
61 Conversation with Mathew Young, Oval Medical Technologies Ltd, 2010
63 Conversation with Adam Locke, Laing O'Rourke, 2014
64 http://www.slideshare.net/ajovalasit/nathan-crilly-hcdi-talk-when-users-thing-about-design
66 http://www-edc.eng.cam.ac.uk/research/designmanagement/
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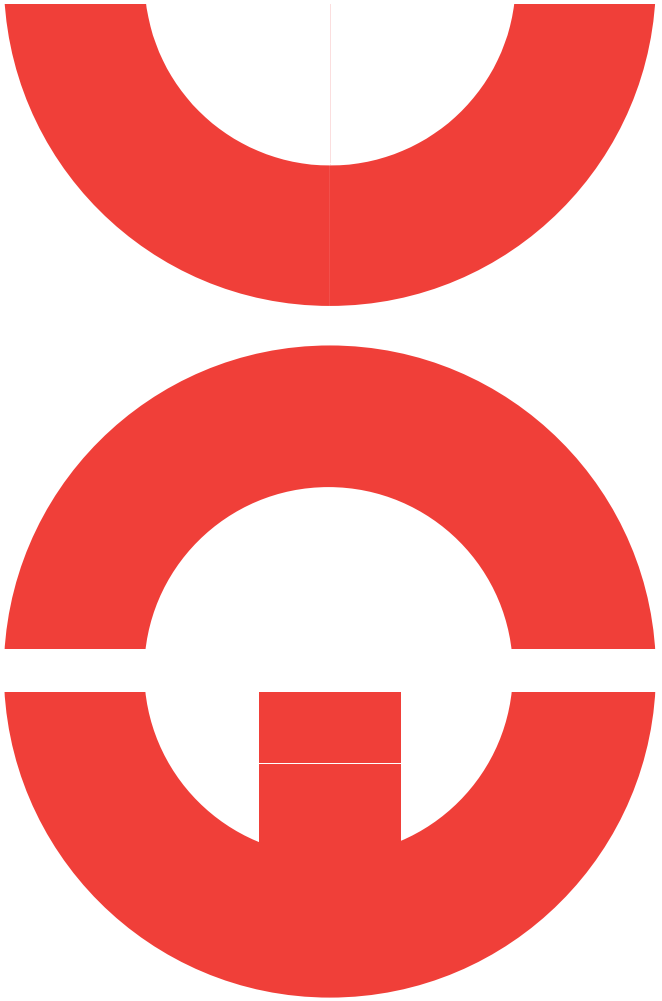
70 http://www-edc.eng.cam.ac.uk/research/industrialsustainability/
76 British Cycling



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