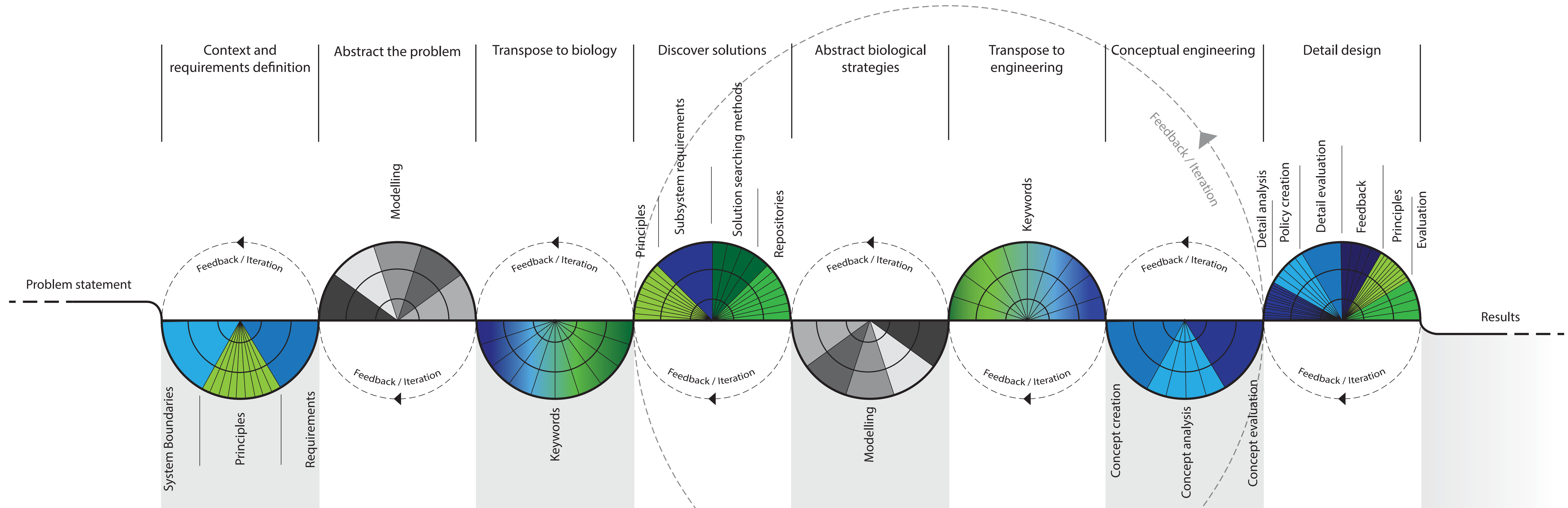
Framework for the Design of Nature-Inspired Maintenance Solutions



Guide: Activities and in- and outputs per phase

Context and requirements definition: Problem and stakeholder statements are the inputs of the project. These are defined in requirements, in addition to requirements set by the experts and designers.

Abstract the problem: The defined problem is abstracted into an analytical model which is focussed on the root cause.

Transpose to biology: The model of the technical system is translated to the field of biology through keywords.

Discover solutions: Biological keywords are used with searching methods and repositories to find organisms that bring ideas to solve the problem.

Abstract biological strategies: The biological systems/solutions are abstracted into an analytical model to make it usable for engineering.

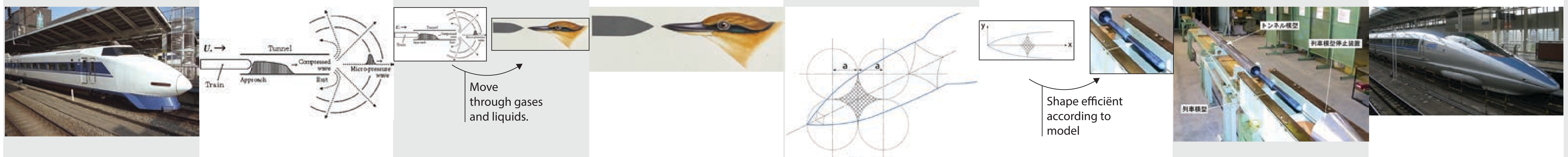
Transpose to engineering: The model of the biological system is translated to the engineering field by the use of keywords.

Conceptual engineering: New concepts are created with the inspiration from the biological solutions. They are also evaluated for iteration.

Detail design: The new technical system is optimised and evaluated. Maintenance policies, tasks and support activities are defined in detail. Feedback for iteration and new projects is documented.

Results: Results of the projects will be implemented in following project phases.

Transportation example: Shinkansen Bullet train



Context and requirements definition: Example of the Shinkansen bullet-train. The train design was aimed at speeds of 300 km/h. This resulted in energy, but especially sound problems. For example, a sonic boom when exiting a tunnel.

Abstract the problem: The sound is created by a pressure wave. This modelled in an analitical representation.

Transpose to biology: Keywords help 'translating' the problem to biology. The train should move more efficiently through air.

Discover solutions: The kingfisher makes almost no splash when diving for fish.

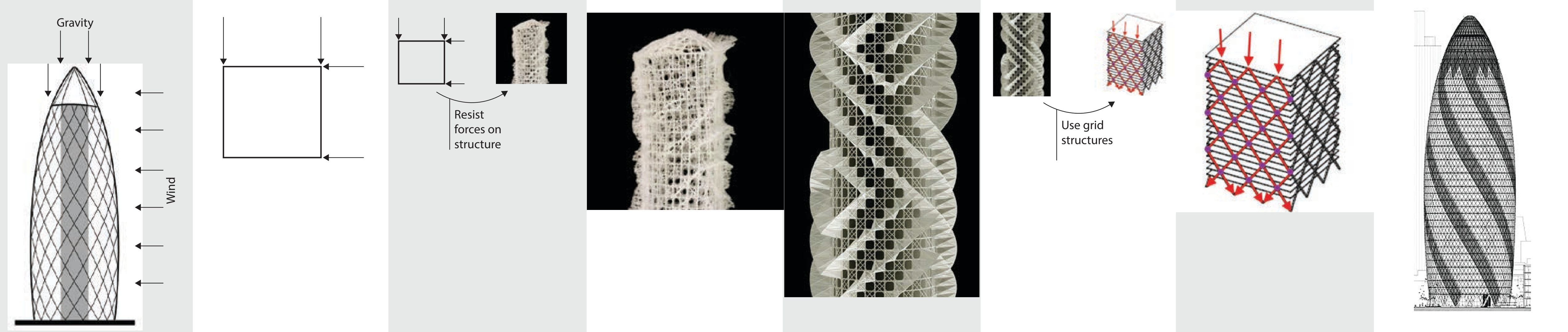
Abstract biological strategies: The beaks shape, which is very aerodynamic, is defined in a model.

Transpose to engineering: The model is transferred back to the engineering field. Keywords can be of use, besides the model itself.

Conceptual engineering: The new ideas are tested and developed for implementation.

Detail design: The new shape for the nose of the train is applied and results in quieter and more efficient runs.

Civil engineering example: 30 st Mary Axe London



Context and requirements definition: Example of 30 St Mary Axe 'The Gherkin'. This 40 floor, 180 m., tall building in London, has to resist the wind and gravity forces acting on the structure.

Abstract the problem: The forces can be modelled to be acting on a frame.

Transpose to biology: Transferring the problem to biology. How to maintain physical integrity? Manage structural compression, tension, shear forces. Prevent structural deformation failure.

Discover solutions: The Euplectella Aspergillum or Venus Flower Basket (seasponge) resists the strong currents of the ocean with a cylindrical lattice-like structure. This efficiently disperses the stresses acting on it.

Abstract biological strategies: Researchers have modelled the lattice-structure to find efficient structures for buildings.

Transpose to engineering: Transferring the idea to the engineering field; the lattices can be mimicked by grid structures. Such as a diagrid.

Conceptual engineering: The diagrid structure is conceptually designed for the building and tested in computer simulations.

Detail design: The diagrid structure is implemented in The Gherkin. It resists the wind pressure and its own weight. Leaving the core protected from other forces than gravity, resulting in less diagonal reinforcement.

Biomimicry & Maintenance tools per category and project phase

Context and requirements definition

System Boundaries
-System boundary definition

Principles
-16 patterns of nature
-Catalogue of biological principles
-The ten fundamental principles of biological systems
-Bioniquity
-Transfer checklist of biological association
-Nature-inspired design principles
-Life's Principles
-Nature-inspired solutions
-Ontology of biomimetics

Requirements
-Requirements definition

Abstract the problem

Modelling
-Functional Modelling
-Systematic reverse engineering of biological system
-SAPPhIRE
-Functional modelling
-DANE

Transpose to biology

Keywords
-Natural language analysis
-Biologically meaningful keywords
-Biomimicry Taxonomy
-Categorisation of natural language keywords
-Engineering-to-biology thesaurus
-BiOPS
-Automatically populating the Biomimicry Taxonomy for scalable systematic biologically inspired design
-Automatic extraction of causally related functions from natural-language text for biomimetic design
-Bioscrabble
-Structure-Function Patterns

Discover solutions

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Subsystem requirements
-Subsystem requirements definition

Solution searching methods
-BidLab search tool
-Idea-Inspire
-BioTRIZ
-A computational approach to biologically inspired design

Repositories
-A systematic catalogue for biomimetic design
-Ontology for bioinspired design
-AskNature
-Biologue
-Bionicinspiration.org
-Ontology explorer
-Design Study Library

Abstract biological strategies

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Transpose to engineering

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Conceptual engineering

Concept creation
-CPS framework for maintenance problem solving

Concept analysis
-Functional block diagram
-Failure mode and maintenance analysis (light) (FMMA)
-Failure mode and effect analysis (light) (FMEA)
-Hazard and operability analysis (light) (HAZOP)

Concept evaluation
-Concept evaluation matrix

Detail design

Evaluation
-T-chart
-BioP-C
-Biotransferability framework
-Four-Box method

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Feedback
-Systematic quantative equip. evaluation
-Design Review
-Data feedback system

Detail evaluation

Policy creation
-Select support structures
-Logic tree analysis (LTA)
-Maintenance task selection
-Select solutions
-Create detailed protocols

Detail analysis
-Parameter profile matrix
-Failure mode and effect analysis (full) (FMEA)
-Failure mode and maintenance analysis (full) (FMMA)
-Hazard and operability analysis (full) (HAZOP)
-Parameter profile analysis
-Resource allocation table
-Root cause failure analysis
-Criticality analysis
-Comparative reliability analysis
-Design constraints and most reliable solutions
-Equal strength (weakest link) principle
-Check list
-Fault tree analysis (FTA)

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