Integral Wind Turbine Design
with
Focus-6

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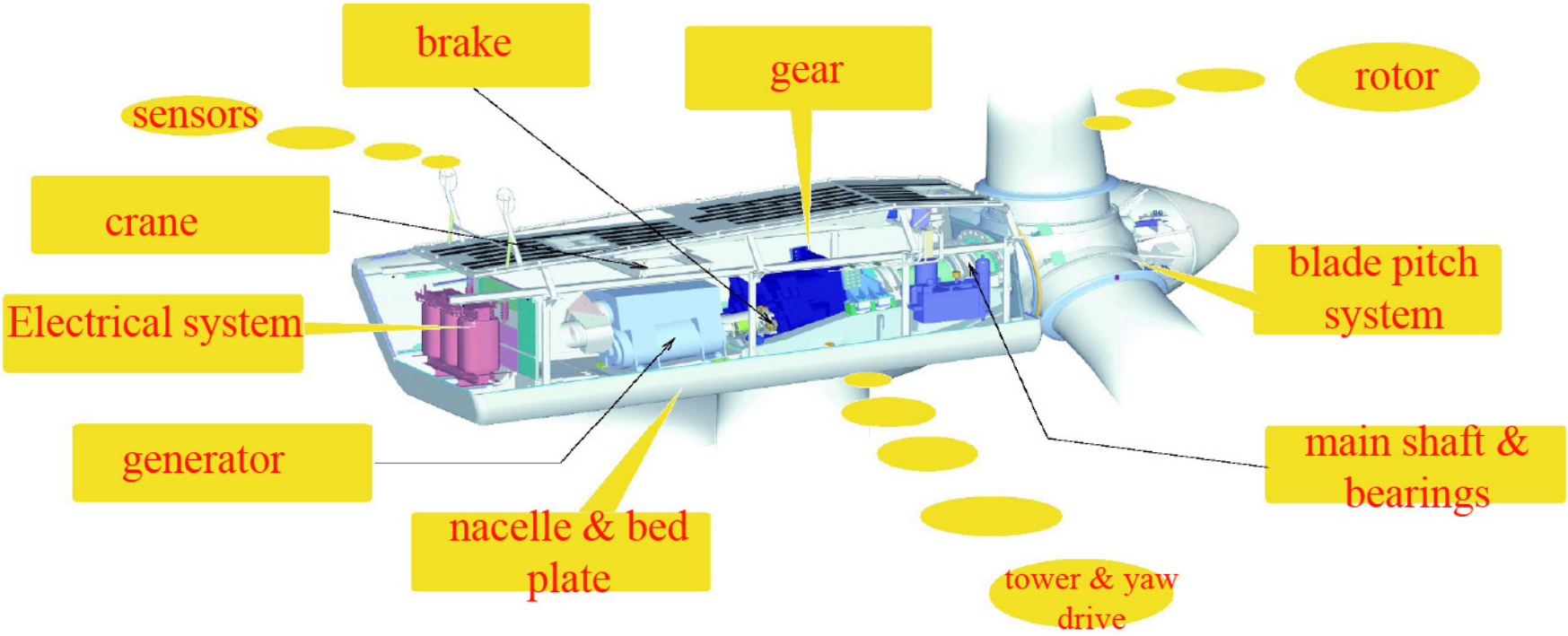
Knowledge Centre WMC

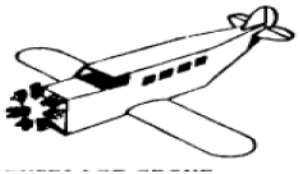
Content

- ✓ Motivation for Integral Design
- ✓ Introduction to multi-disciplinary design optimisation (MDO)
- ✓ Why MDO
- ✓ Implementation of MDO in **FOCUS**
- ✓ Cost Models
- ✓ Search techniques
- ✓ Future of MDO

Motivation for Integral Design



What (could) be the result without integral design

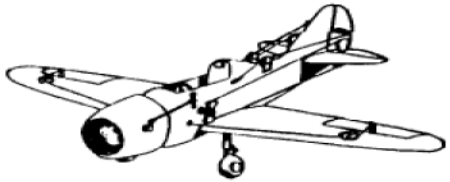


FUSELAGE GROUP

PRODUCTION ENGINEERING GROUP

ARMAMENT GROUP

AERODYNAMICS GROUP

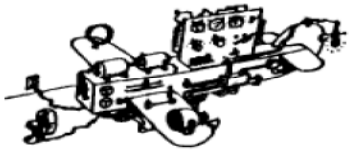


CONTROLS GROUP

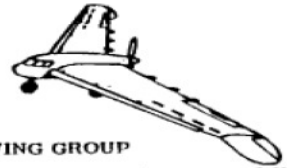
"A completed airplane in many ways is a compromise of the knowledge, experience and desires of the many engineers that make up the various design and production groups of an airplane company".

It is only being human to understand why the engineers of the various groups feel that their part in the design of an airplane is of greater importance and that the headaches in design are due to the requirements of the other less important groups,

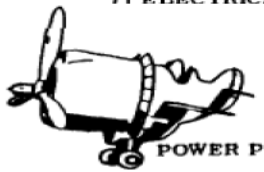
This cartoon"Dream Airplanes by Mr. C. W. Miller, design engineer, indicates what might happen if each design or production group were allowed to take itself too seriously.



ELECTRICAL GROUP

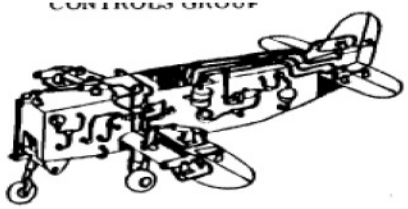


WING GROUP

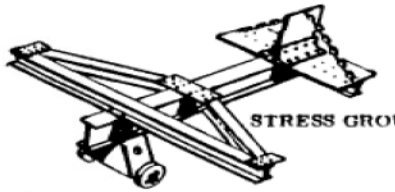


POWER PLANT GROUP

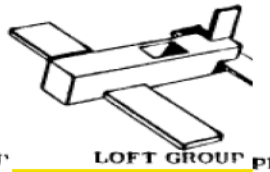
EQUIPMENT GROUP



HYDRAULICS GROUP



STRESS GROUP



LOFT GROUP

PRODUCTION ENGINEERING GROUP

Motivation

- Shorter design loops
- Leads to a higher quality design process
- Increased detail

Pre-requisites

- Tools to determine the objective with an adequate predictive quality
- Sufficient number crunching capacity
- Good parameterisation of the problem

INTRODUCTION TO MDO

- Multi-disciplinary : More than one discipline plays a role.
  Eg. In wind turbine engineering:
  - ✓ aerodynamics
  - ✓ structures
  - ✓ Controls

- Design : Process of translating requirements into detailed product specifications

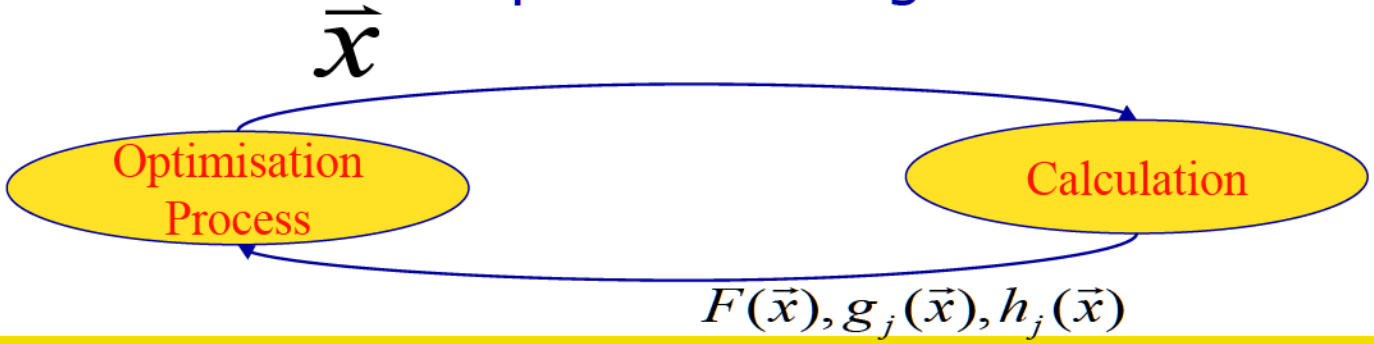
- Optimization : Formal mathematical process of locating the 'best' under 'constraints'

Optimisation

Target function $F(\vec{x})$ and

Boundary conditions $g(\vec{x}) \geq$)
$h(\vec{x}) =$)

combined with an optimisation algorithm



INTRODUCTION TO MDO

Some popular definitions of MDO:

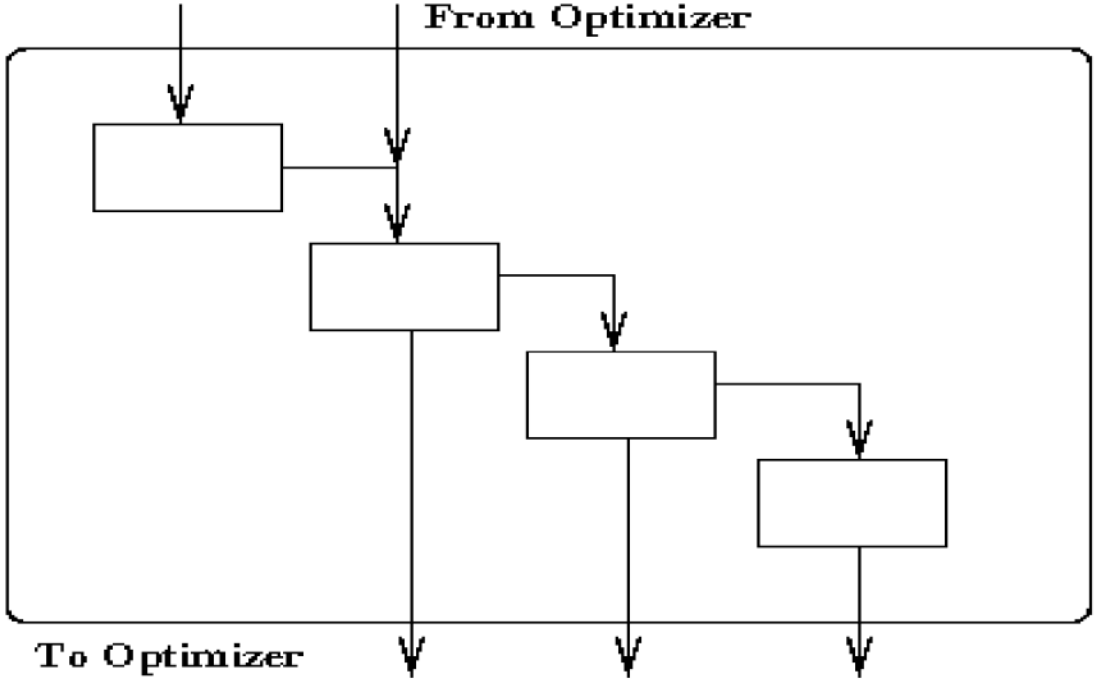
- MDO is methodology for the design of complex coupled systems in which synergetic effects of coupling engineering design codes is exploited in an automated fashion
- MDO is a methodology that combines analysis and in individual disciplines into that for the entire system for optimisation

Why MDO?

- To enable the design of high performance complex products
- Balance product performance considerations with manufacturing, economics, and life cycle issues,
- Achieve design process timetable compression - Economic competitiveness,
- Respect the problem physics of coupled systems - towards a physically meaningful design practice.

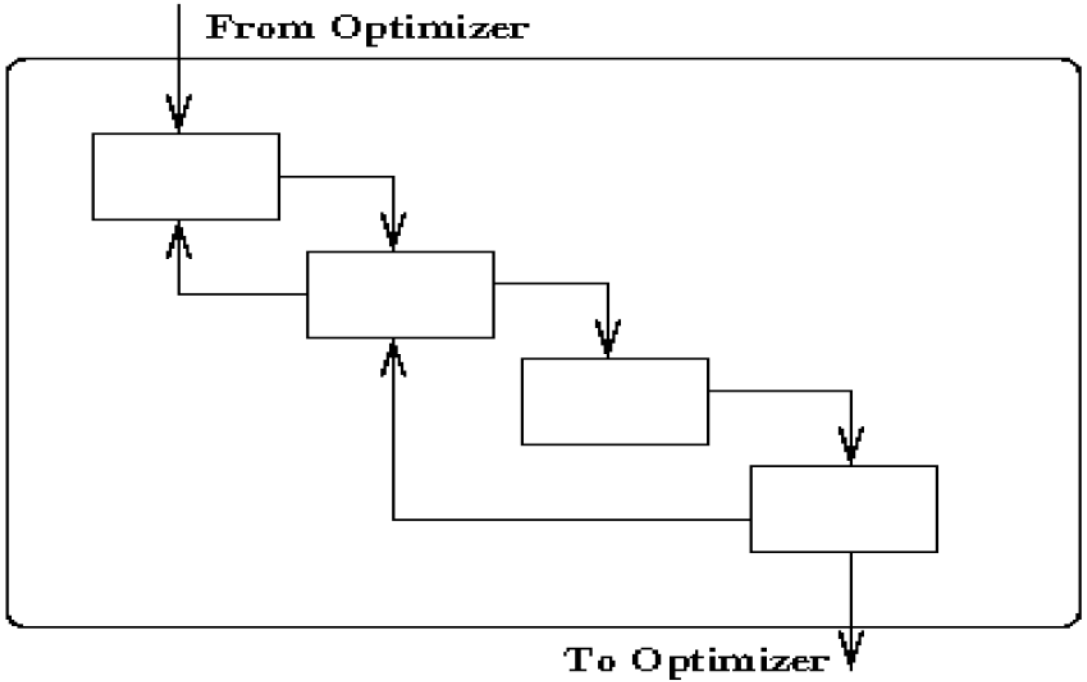
IMPLEMENTATION of MDO in FOCUS

Multiple options

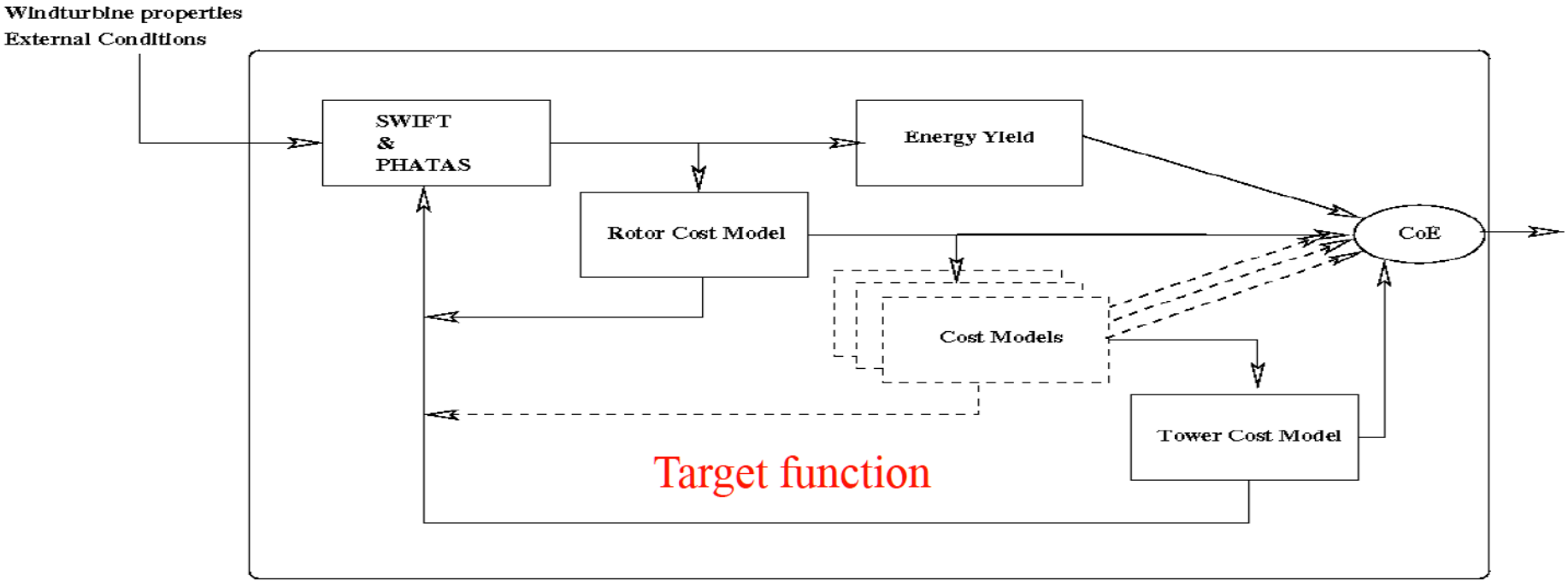


IMPLEMENTATION of MDO in FOCUS

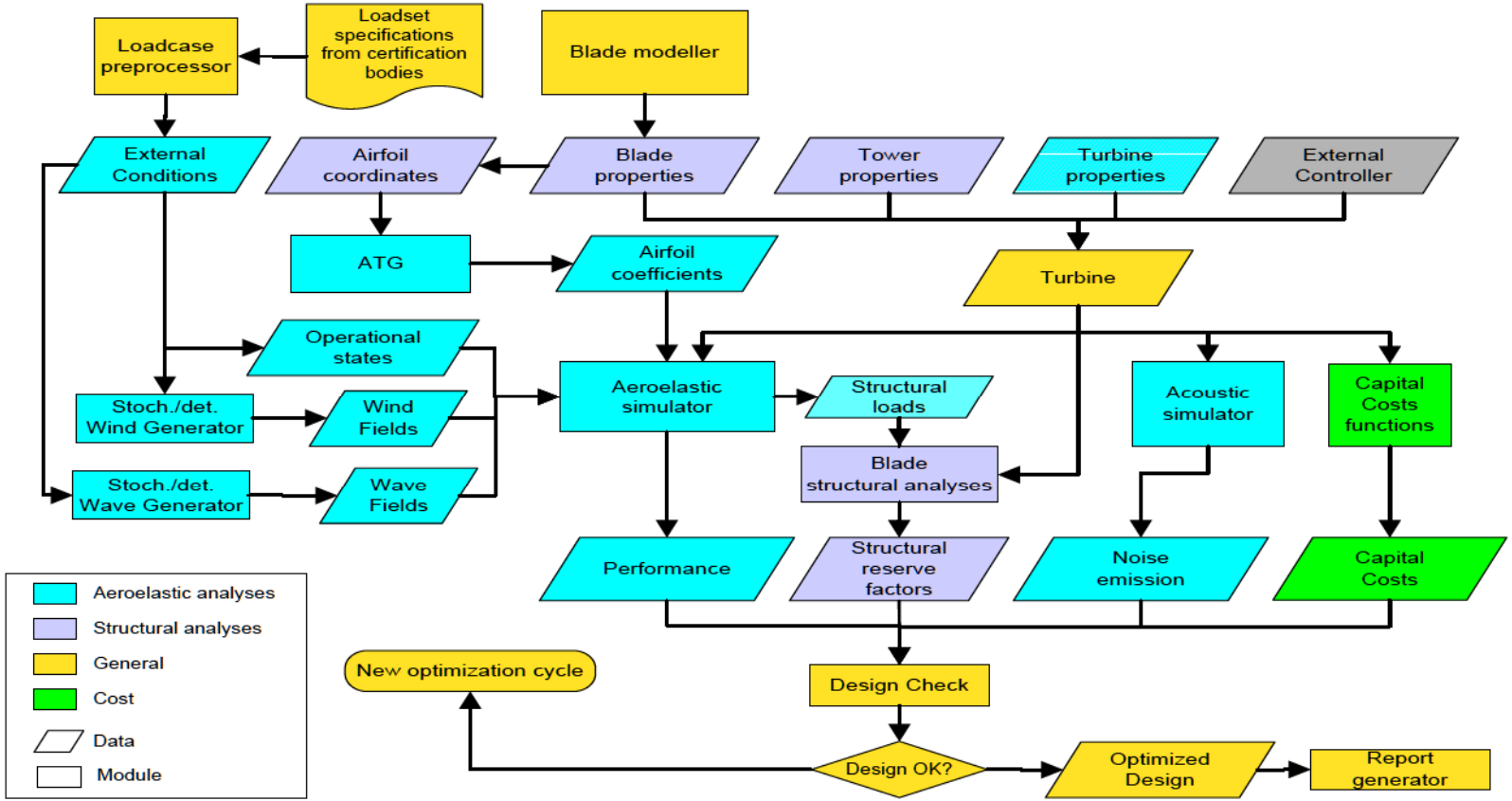
Multiple options



IMPLEMENTATION of MDO in FOCUS



FOCUS-6


Loadcase preprocessor
Loadset specifications from certification bodies
Blade modeller
External Conditions
Airfoil coordinates
Blade properties
Tower properties
Turbine properties
External Controller
ATG
Airfoil coefficients
Turbine
Operational states
Stoch./det. Wind Generator
Wind Fields
Stoch./det. Wave Generator
Wave Fields
Aeroelastic simulator
Structural loads
Blade structural analyses
Acoustic simulator
Capital Costs functions
Performance
Structural reserve factors
Noise emission
Capital Costs
New optimization cycle
Design Check
Design OK?
Optimized Design
Report generator
Aeroelastic analyses
Structural analyses
General
Cost
Data
Module

Cost Models

- Engineering cost models
  - ✓ Simple existing design procedures (automated) resulting in design parameters like mass etc and Cost

- Parametric cost models
  - ✓ Curve fitting of previous designs as a function of chosen parameters, e.g. rated power or rotor diameter

Cost Models in to be implemented in Focus

- Basic cost functions
  - ✓ Rotor blade
  - ✓ Tower
  - ✓ Generator
  - ✓ Gear box
  - ✓ Etc.
- User written cost functions
  - ✓ Your knowledge

Search Techniques or Optimisation algorithm

- Gradient based methods .e.g SQP
  - ✓ Many variables possible
  - ✓ Constraints on target function, variables and response variables
  - ✓ Can easily be parallelised

- Stochastic search techniques
  - ✓ Many variables possible
  - ✓ No direct processing of constraints
  - ✓ High number of target functions calls

Search Techniques or Optimisation algorithm

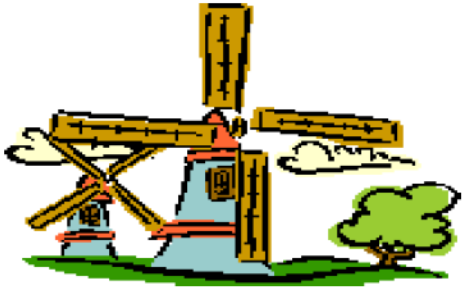
- Direct search technique
  - ✓ Limited number of variables
  - ✓ Constraints on variables as well as response variables
  - ✓ Low number of target functions calls

Future of MDO

- Distributed (parallel) processing
- A link to knowledge based engineering
- Expand MDO from preliminary/conceptual design to integrated detail design tool

Thank you!

More information on Focus can be found @
www.wmc.eu
&
www.ecn.nl/ewis



Acknowledgement: The FOCUS-6 project is sponsored by AgentschapNL (Min. of Economical affairs)