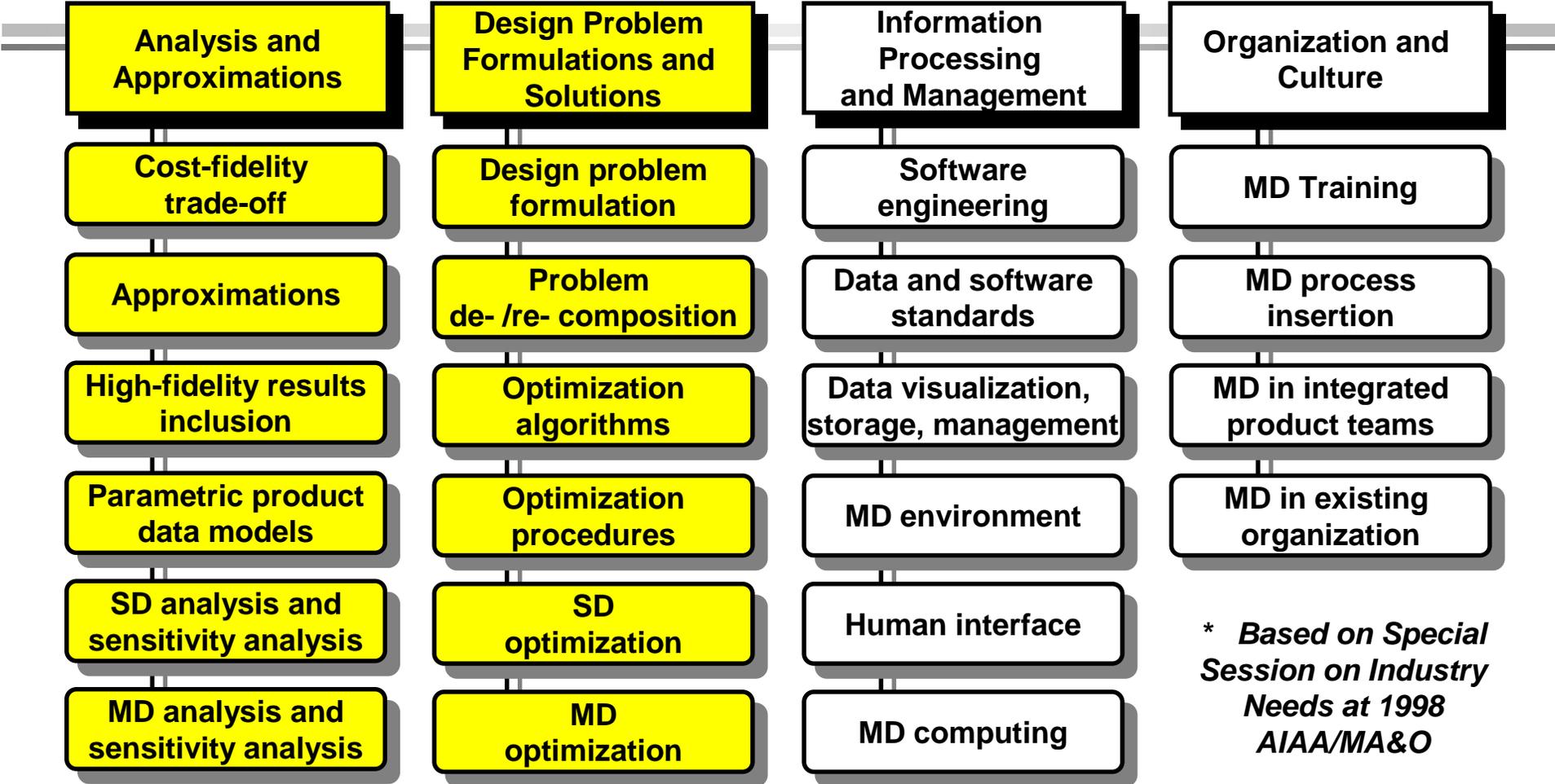

Numerical Methods Overview

Sharon L. Padula
ASCAC Methods Development
Peer Review
November 27-29, 2001

AIAA MDO TC View of MDO



Methods - Overview

- Why Study MDO Methods?
- Analysis and Approximations
 - Parametric Models - Geometry and Cost Modeling
 - Sensitivity Analysis - Automatic Differentiation
 - Cost-fidelity trade-off - Approximation Management
- Design Problem Formulation
 - MD Optimization - Aerodynamics & Structures
 - Optimization Algorithms - Actuator Placement
 - Optimization Procedures - MDO Formulations

Why Study MDO Methods?

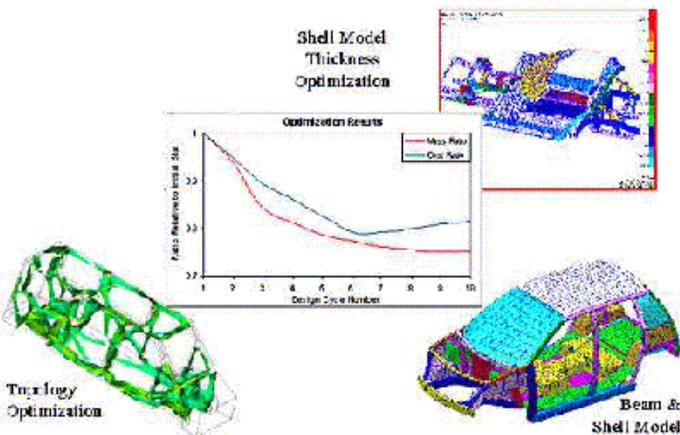
- Majors finding of the Industry Tour in 1994 and the Peer Review in 1996
 - Emphasize MDO methods and tool development
 - Include cost, reliability, manufacturability etc.
 - Use CAD based parametric models
 - Use commercial optimization software where available
- Optimization is gaining popularity with our customers
 - Actuator placement and approximation management research is driven by Langley Research Center needs
 - Geometry modeling and sensitivity research have industry partners
 - MDO formulations research is attracting lots of attention.

Optimization is BIG Business

Engineering companies like Alcoa and Altair use their optimization expertise to design new products.

Alcoa Automotive Engineering

Material and Topology Optimization



The screenshot shows the Altair Engineering website with the following content:

- Altair Engineering** logo and navigation menu: About Altair, Consulting, Software, Support, Partners, Press Office, e-services.
- Software** section listing:
 - Altair® HyperWorks®
 - Altair® HarnesLink™
 - Altair® HyperShape®/Pro
 - Altair® HyperXtreme™
 - Training
- HyperShape®/Pro** description:

Altair® HyperShape®/Pro is a unique design tool for generating optimum structural designs using topology optimization. HyperShape/Pro brings CAE to the beginning of the design process, allowing for optimal design generation from the start.

 - Automatically construct the required finite element mesh
 - Preview design concepts at various mass targets prior to solid generation
 - Automatically generate the optimal topology for the model
 - Provides better product performance, and reduces material costs
 - Allows for easy visualization of conceptual designs
- Footer:** Home | Careers | Contact Us | Site Map. © 2001 Altair Engineering, Inc. All rights reserved.

November 27, 2001

Methods Overview

Sharon Padula 5

Optimization is BIG Business

Vanderplaats R&D News Release

Software companies such as VR&D and Engineous market general purpose optimization codes to industry.

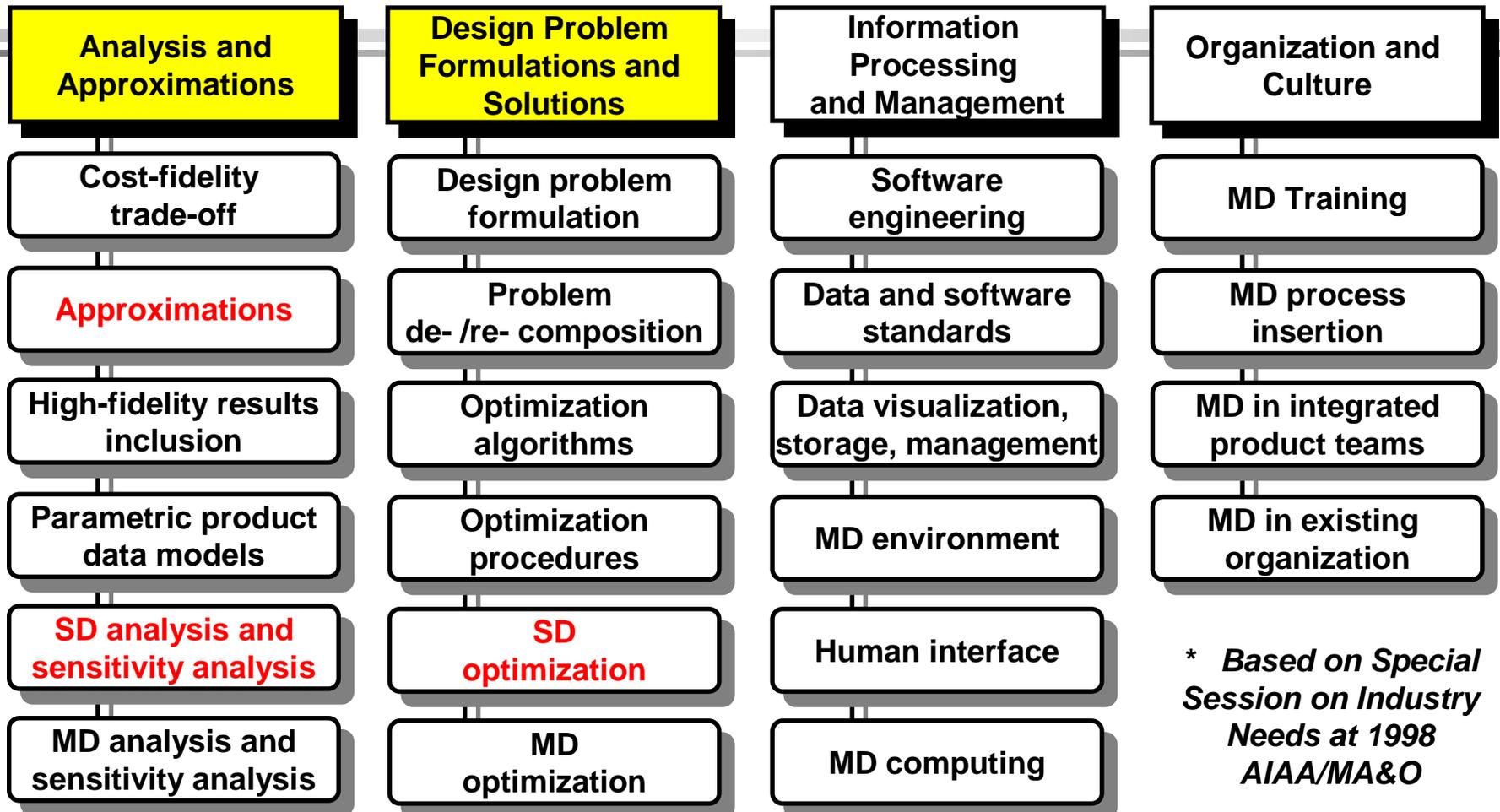
Date	Product	Company(s)
April 03, 2001	Software Sale in Japan.	Taisei Corporation, Sumitomo Precision Products, Hirakata Plant, Showa-Denko, KUBOTA.
March 21, 2001	Piping System Optimization	Applied Flow Technology
August 25, 2000	topology, shape and sizing of automotive components.	GM, Mid-lux Car Group
June 14, 2000	VR&D's optimization software DOT.	TRW Astro Aerospace
April 04, 2000	structural analysis and optimization software GENESIS	SEIKO Instruments, Inc, Japan

Optimization is BIG Business

Engineous Software News Release

Company	Announcement	Date
Daihatsu	Orders iSIGHT	3/15/2000.
Idanta	Invests \$11 Million in Engineous	3/8/2000.
Peugeot Citroen	Uses iSIGHT for Design	2/29/2000.
Prada	Optimizes America's Cup Keel Design	2/22/2000.
Nissan	Engineous Receives Additional Order	2/4/2000.
Toshiba	Uses iSIGHT for Engineering Quality Improvement Program	9/2/99.
Ford Motor Company	Engineous Signs Two-year Contract	8/16/99.
Nissan	Optimize Simulation-based Vehicle Design	8/6/99.
Sony	Home Electronics Products' Production Process Improvements	7/12/99.
Hitachi IJS	Signs Japanese Distribution Agreement	2/1/99.

Industry Uses Optimization Today



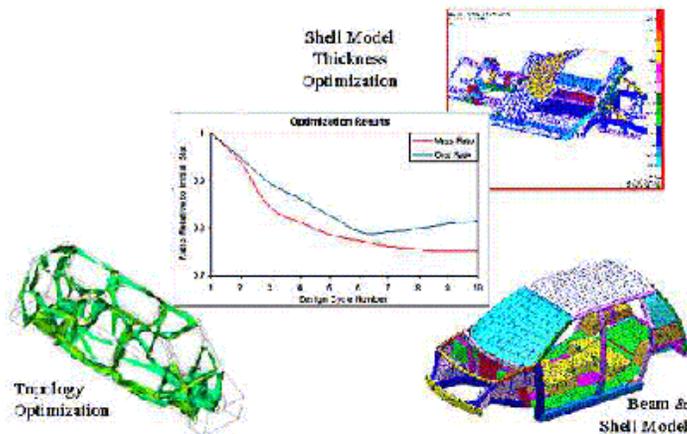
Methods - Overview

- Why Study MDO Methods?
 - Industry sees value in optimization research
 - NASA is encouraged to push the state-of-the art
- Analysis and Approximations
 - Parametric Models - Geometry and Cost Modeling
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Geometry and Cost Modeling

Alcoa Automotive Engineering

Material and Topology Optimization

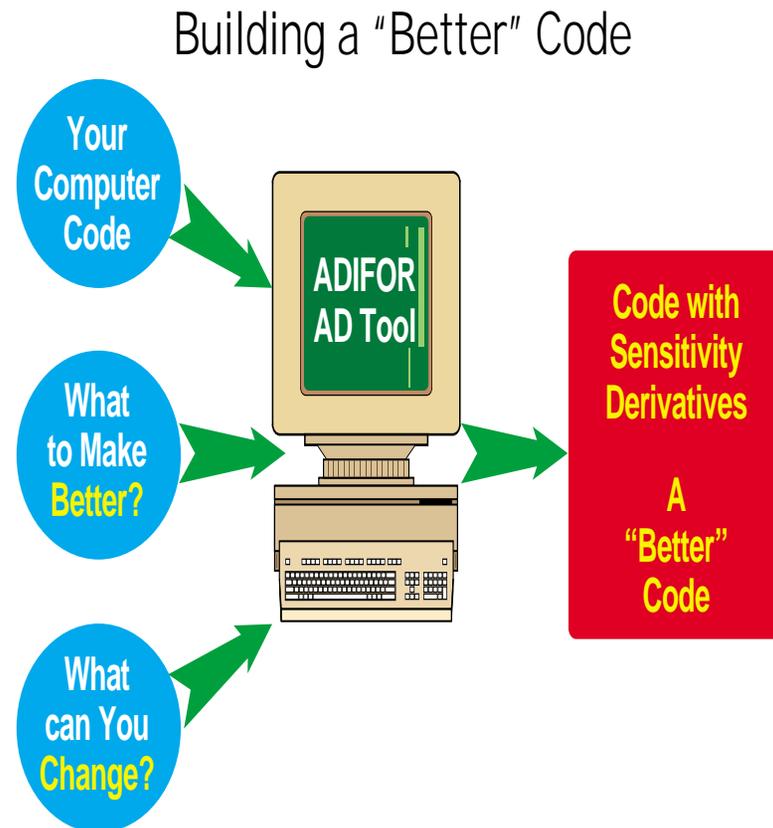


- Today we minimize the weight of each component
- Tomorrow we will minimize the cost
- Today we model structures & aerodynamics separately
- Tomorrow we will produce consistent parametric models from CAD packages

Sensitivity Analysis- Options

- Finite Difference
 - Perturb design and approximate derivatives
- Analytical
 - Derive and code equations for derivatives
- Quasi-analytic
 - Combination of first two methods
- Global Sensitivity Equations
 - Use chain rule to assemble derivatives
- Automatic Differentiation
 - Use compiler to augment the code

Automatic Differentiation

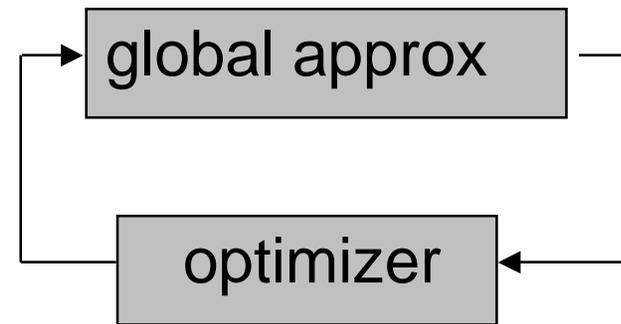
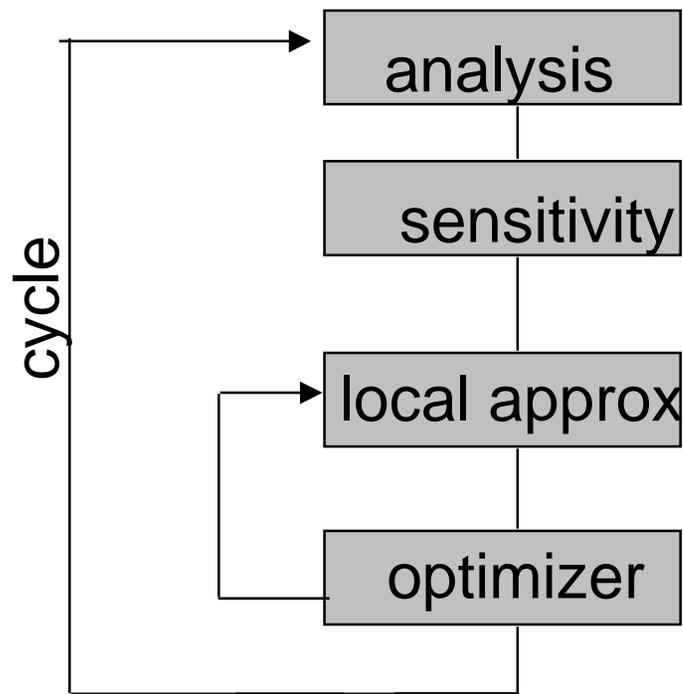


- Starting with any standard Fortran code
- Identify independent and dependent variables
- Process with ADIFOR tool
- Produce new code which calculates sensitivity derivatives in addition to its normal output

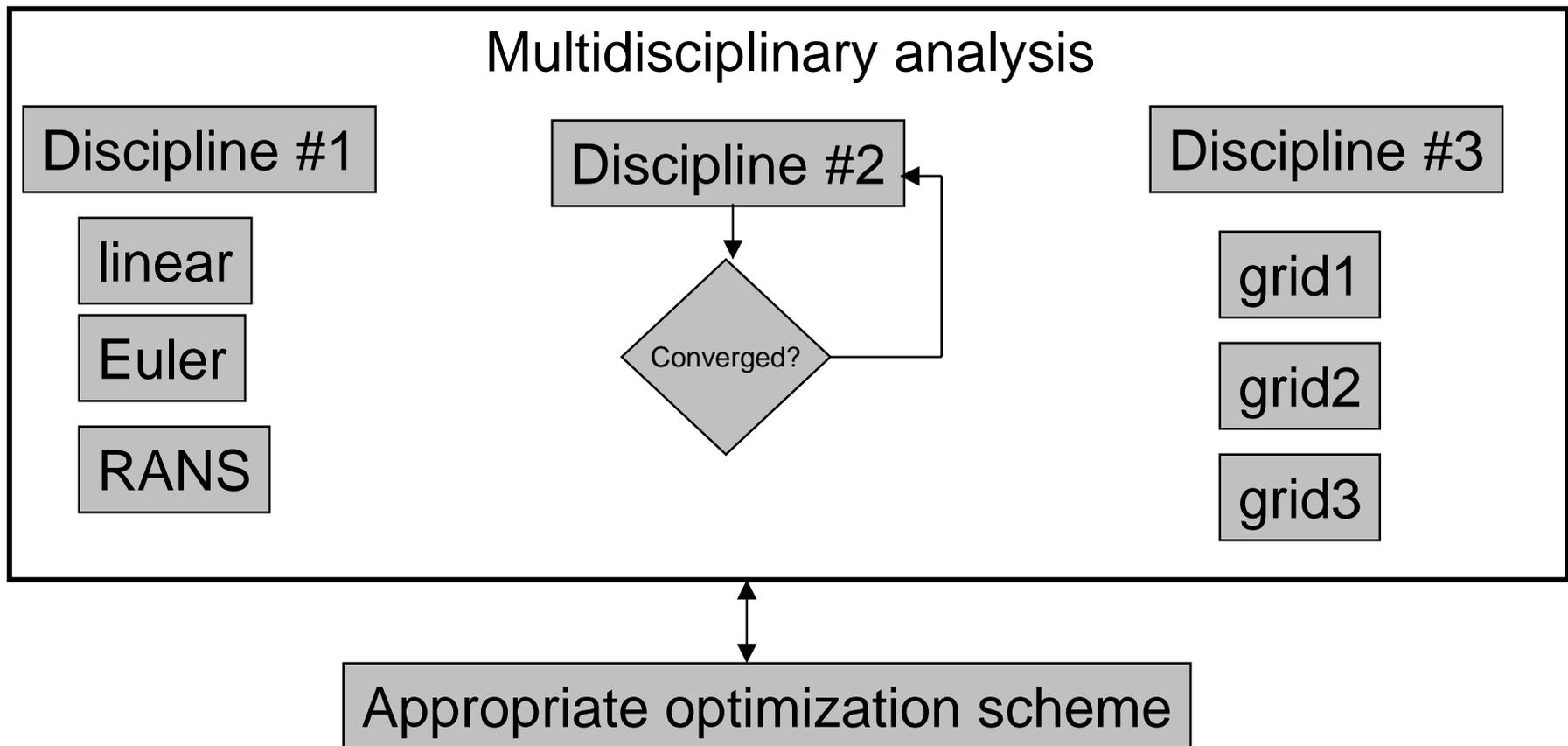
Cost-Fidelity Tradeoff

- Computational cost of optimization increases with:
 - Number of design variables
 - Number and degree of coupling of disciplinary analyses
 - Cost of a single analysis
 - Inclusion of discrete design variables or uncertain parameters
- Careful use of approximation can reduce cost by:
 - Substituting low-fidelity for some high fidelity analysis
 - Using crude approximations in early stage of optimization process
- MDOB research supplies theoretical foundation and aerospace demonstrations of cost-fidelity tradeoff.

Approximation + Optimization - Traditional View



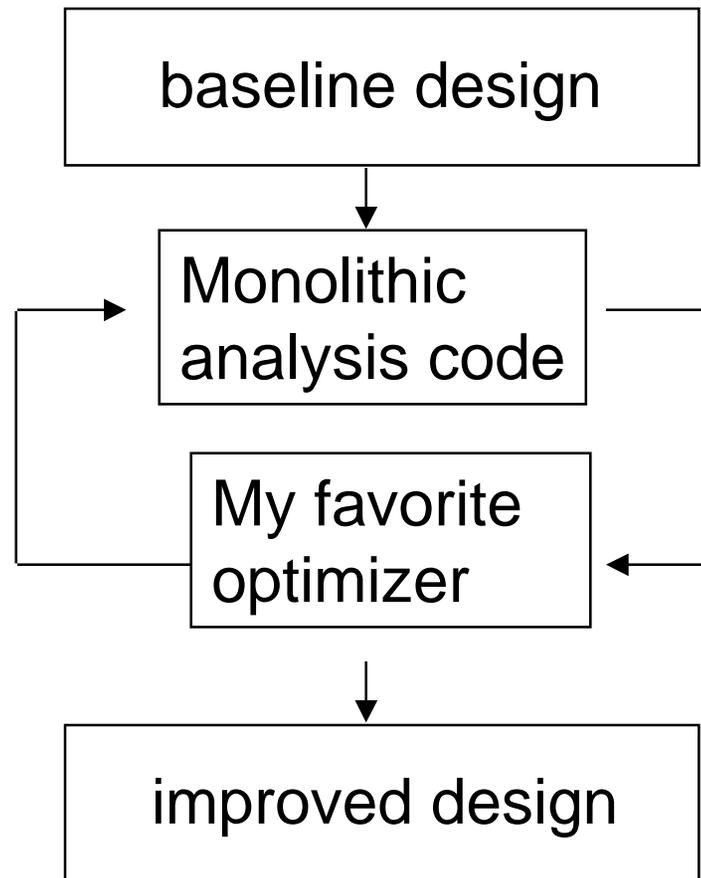
Approximation + Optimization - MDOB View



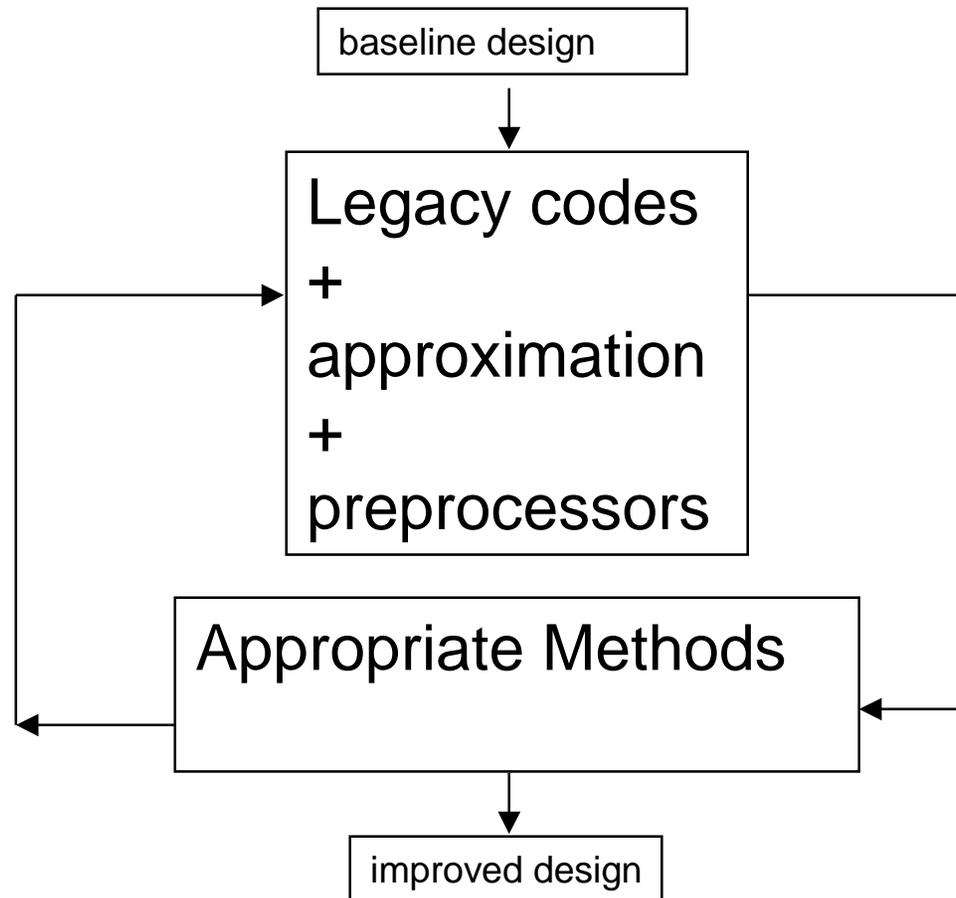
Design Problem Formulation

- Optimization methods developed for:
 - Linear objective and constraints
 - Nonlinear objective and constraints
 - Continuous design variables
 - Discrete or integer-valued design variables
- MDO methods for:
 - Multiple objectives
 - Multiple design points
 - Uncertain Input Parameters
 - Multiple disciplinary codes

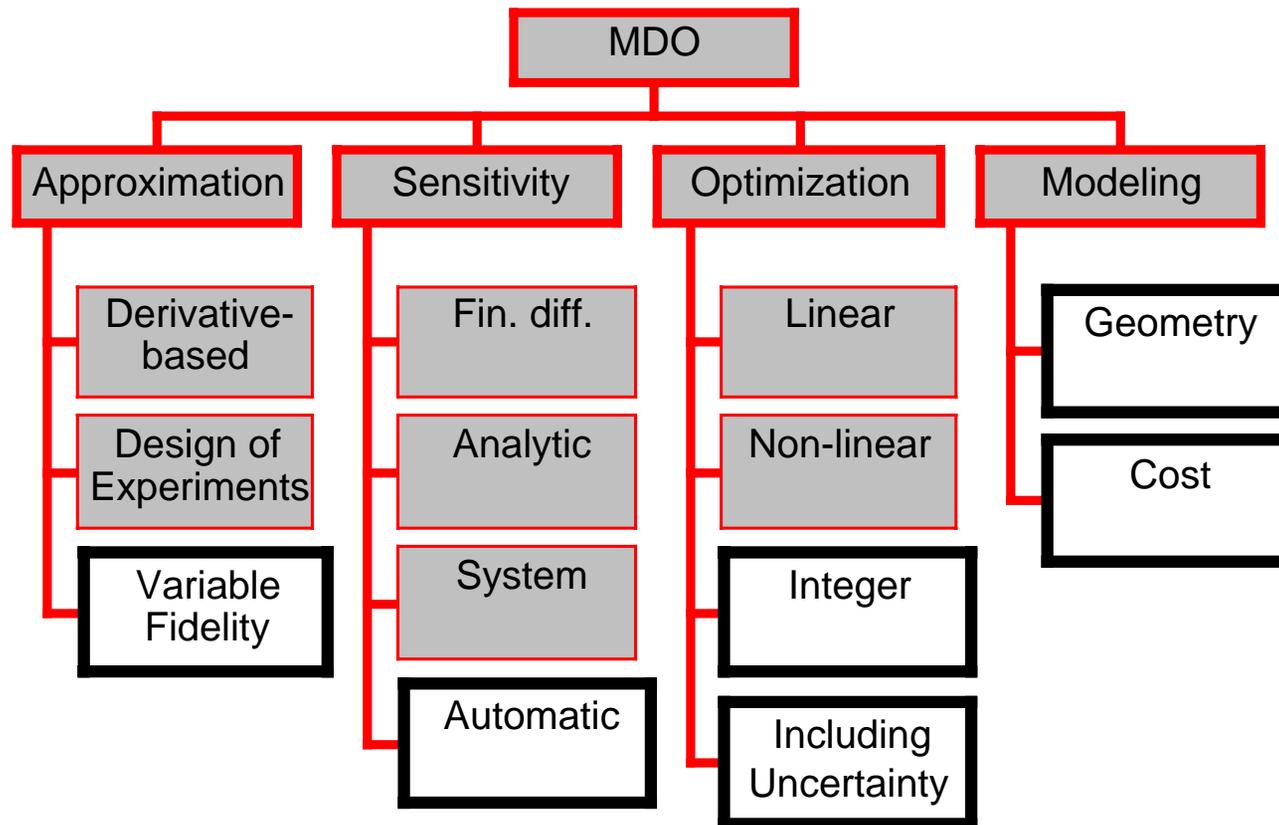
Optimization - Traditional View



Optimization - MDOB View



MDO Methods - Presentation Topics



Methods - Presentations

- Analysis and Approximations
 - Jamshid Samareh - Parametric Models - Geometry and Cost
 - Larry Green - Sensitivity Analysis - Automatic Differentiation
 - Natalia Alexandrov - Cost-Fidelity trade-off - AMMO
- Design Problem Formulations
 - Clyde Gumbert - MD Optimization - Aerodynamic-Structures
 - Sharon Padula - Optimization Algorithms - Actuator Placement
 - Natalia Alexandrov - Optimization Procedures - MDO formulations

Numerical Methods - External Product Users

- I Automatic Differentiation
 - Boeing Helicopter sends codes and attends ADIFOR workshop
 - Cooperative agreement with Boeing Long Beach
- I Actuator Placement
 - Beech flight test of active structural acoustic control
- I MDO Formulations
 - Assessment with Engineous using iSIGHT framework