Initial Results of an MDO Method Study

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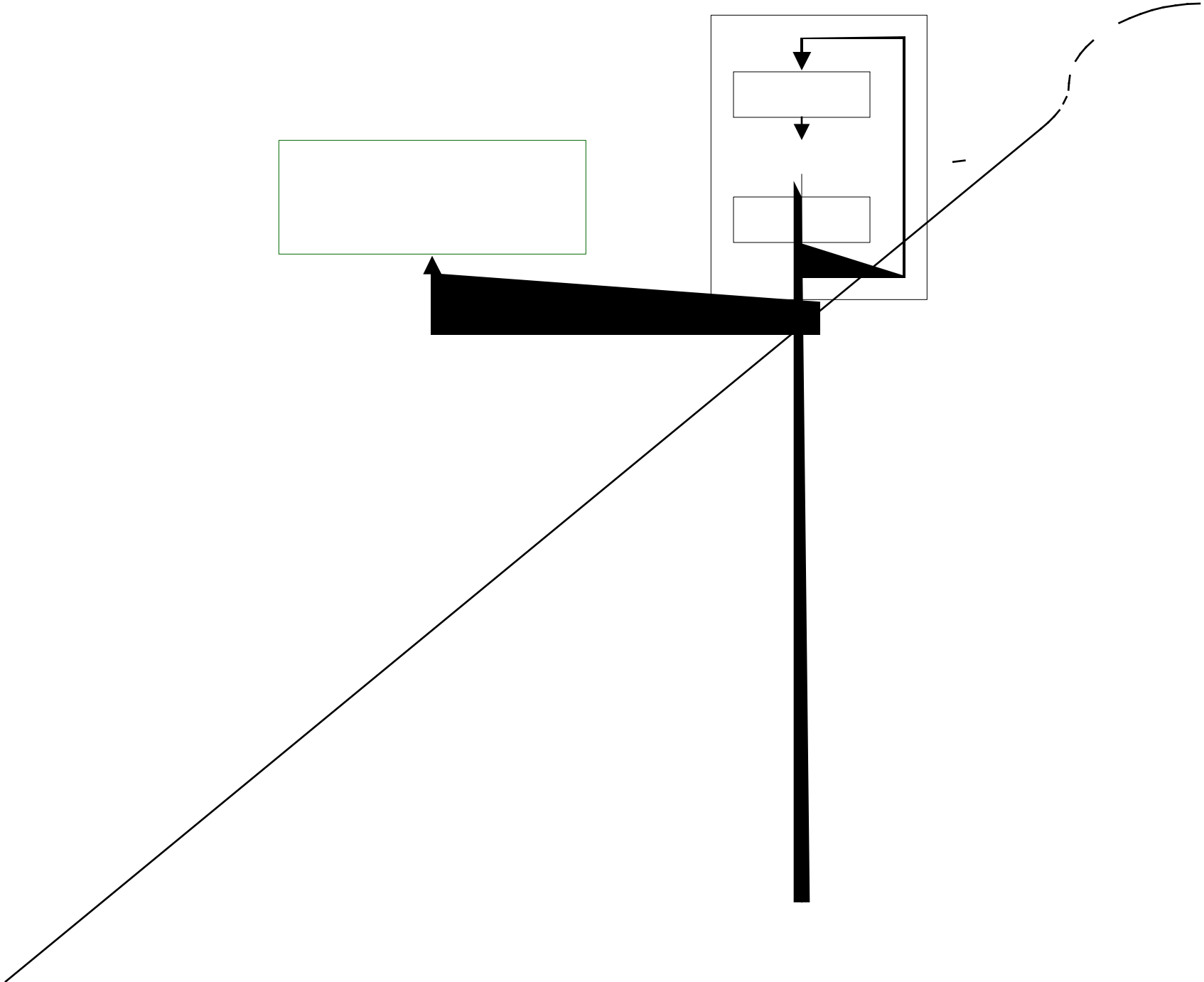
Outline: Objectives—Approach—Methods—Examples—Summary

Objectives

- **Conduct a systematic study of promising Multidisciplinary Optimization (MDO) methods with the following aims:**
  - **Accumulate computational data on the performance of a selected set of MDO methods;**
  - **Compare the practical performance of the methods with their proven or conjectured analytical properties;**
  - **Eventually arrive at a classification of the methods and problems amenable to the methods, as well as a set of guidelines for using specific methods;**
  - **N.B. There is no attempt to declare one method generally superior to another.**

Approach: Metrics

- **Generality**
  - **Measures applicability to various classes of problems.**
- **Robustness**
  - **Evaluates capacity to reach a solution or a "satisfactory" point for a variety of perturbed data.**
  - **Measured by attempting solution from several starting points.**
- **Performance**
  - **Measured work as the total number of full equivalent analyses, including function evaluations for finite-difference derivative computations.**



Phase I Problem Set

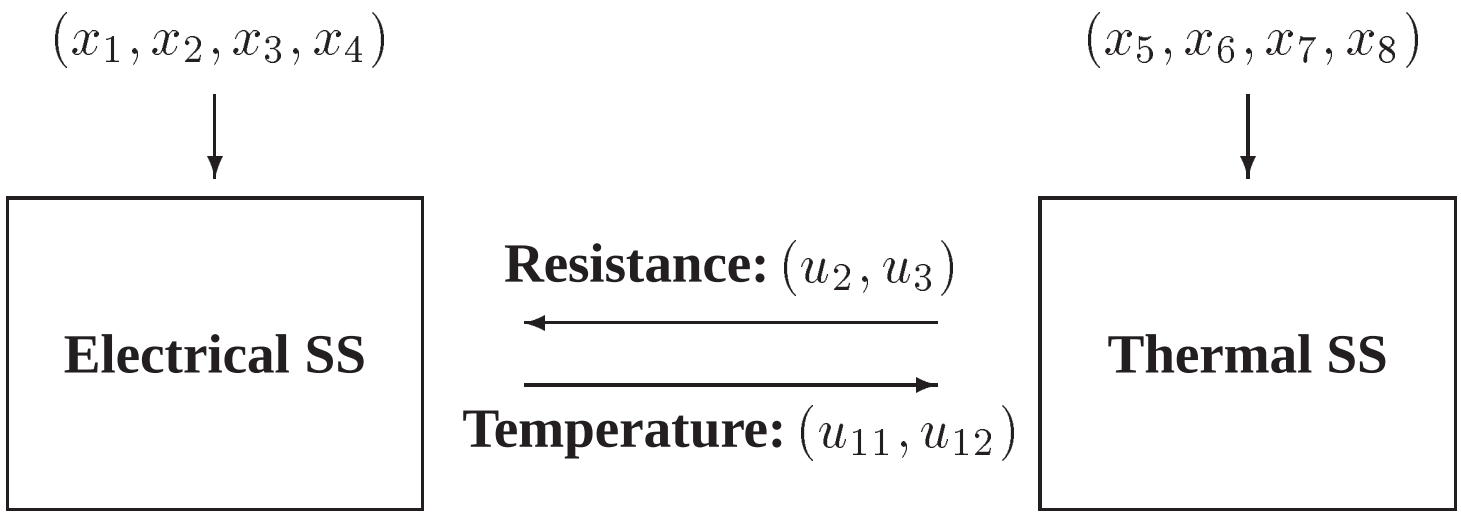
Problem	Title
1	Conceptual Ship Design*
2	Electronic Packaging**
3	Power Converter**
4	Speed Reducer**
5	Combustion of Propane**
6	Heart Dipole**
7	Hub Frame Design**
8	Isomerization of α-Pinene - Collocation Formulation***
9	Propane, Isobutane, N-Butane Nonsharp Separation***
10	Three-Component Separation***

*** ESI / ** MDO Test Suite (refs. in paper) / *** Floudas and Pardalos '91**

Problem Dimensions (some measure of generality)

Problem / Method	1	2	3	4	5	6	7	8	9	10
MDF										
# Variables	6	8	6	7	4	4	120	80	48	52
# Constraints	7	3	4	11	4	4	764	115	38	40
CO										
System:										
# Variables	11	5	6	2	4	8	40	N/A	N/A	N/A
# Constraints	5	2	6	3	2	6	6	N/A	N/A	N/A
# Subsystems	5	2	2	3	2	2	2	N/A	N/A	N/A
Total # subsystem variables	18	12	12	11	7	12	120	N/A	N/A	N/A
IDF										
# Variables	14	12	12	N/A	6	8	N/A	N/A	N/A	N/A
# Constraints	11	5	6	N/A	6	6	N/A	N/A	N/A	N/A

Example: Electronic Packaging

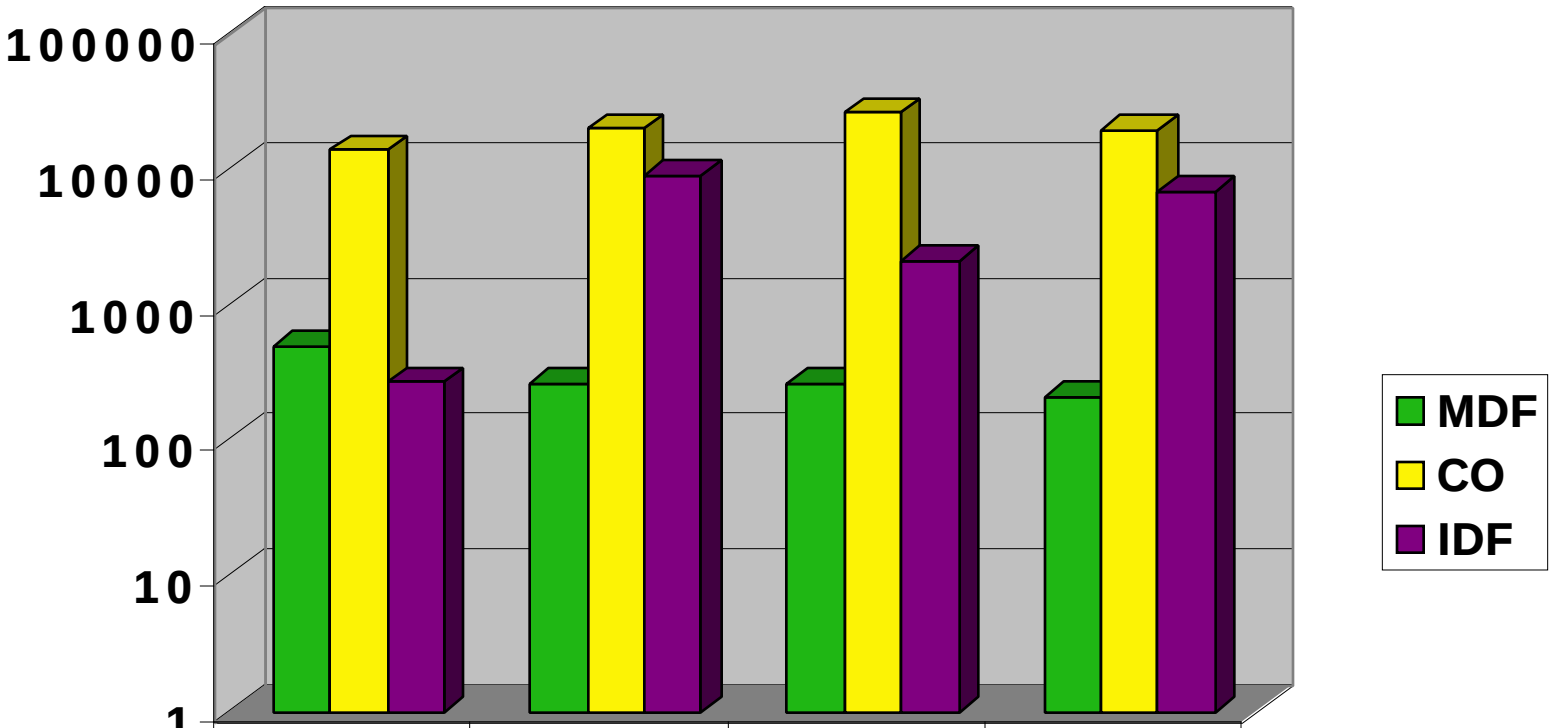


- **A circuit of two resistors mounted on a heat sink, resulting in two coupled subsystems. Operating temperatures affect component resistance; resistance influences the temperature.**
- **Objective: watt density / constraints: threshold temperatures of resistors, current equilibrium / 8 design variables, 13 state variables, 2 parameters.**

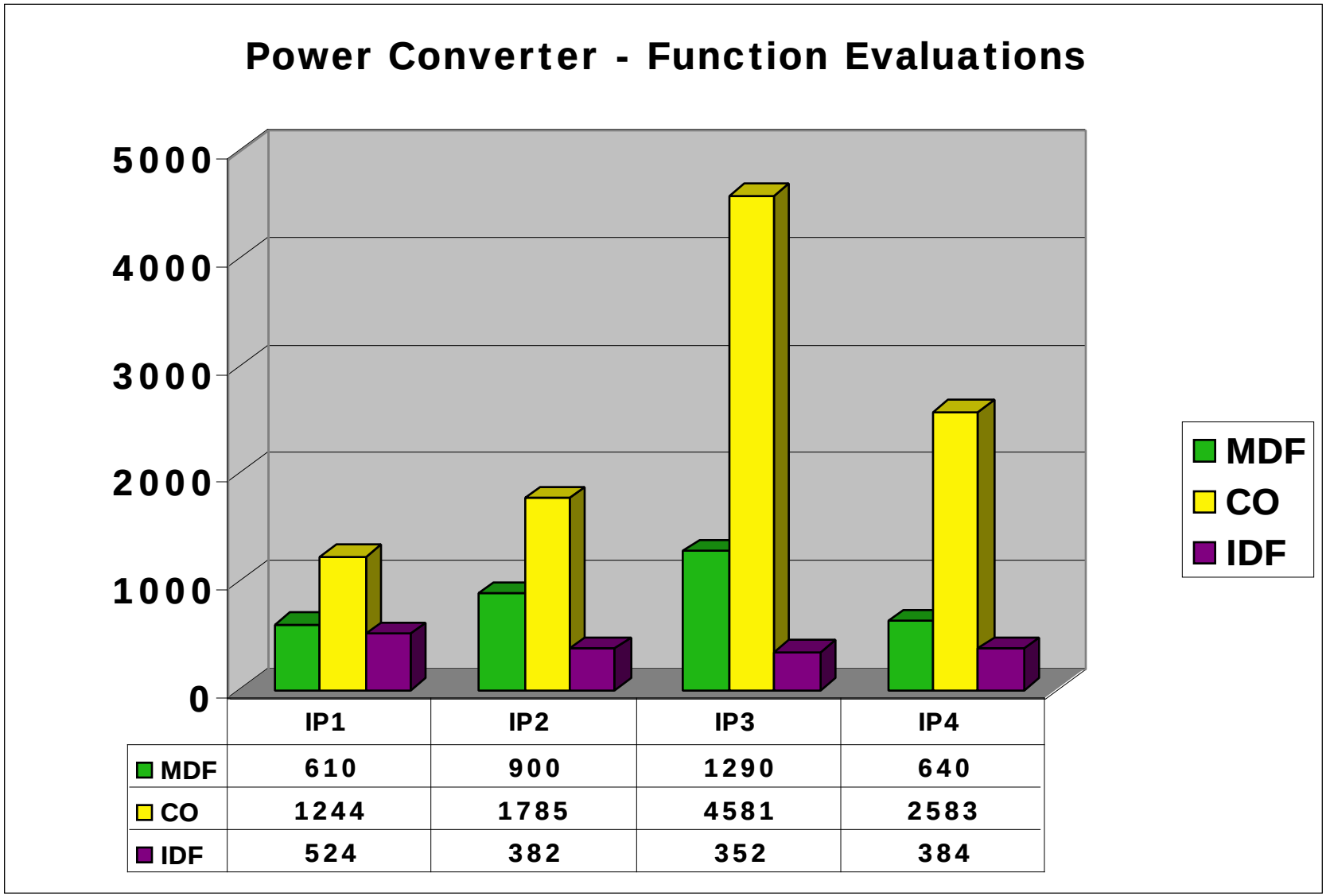
Example—Electronic Packaging—CO results

Initial Point	Initial Obj. (System)	Final Obj. System)	Work
1	7.7944D+01	3.51968D+05	110 s.i. / (4886 + 8899) = 13785
2	6.8300D+03	6.57163D+05	123 s.i./ (6315 + 13577) = 19872
3	1.5111D+03	6.5D+04^F	138 s.i./ (13414 + 12650) = 26064
4	1.4607D+03	6.5D+04^F	94 s.i./ (10205 + 9396) = 19701

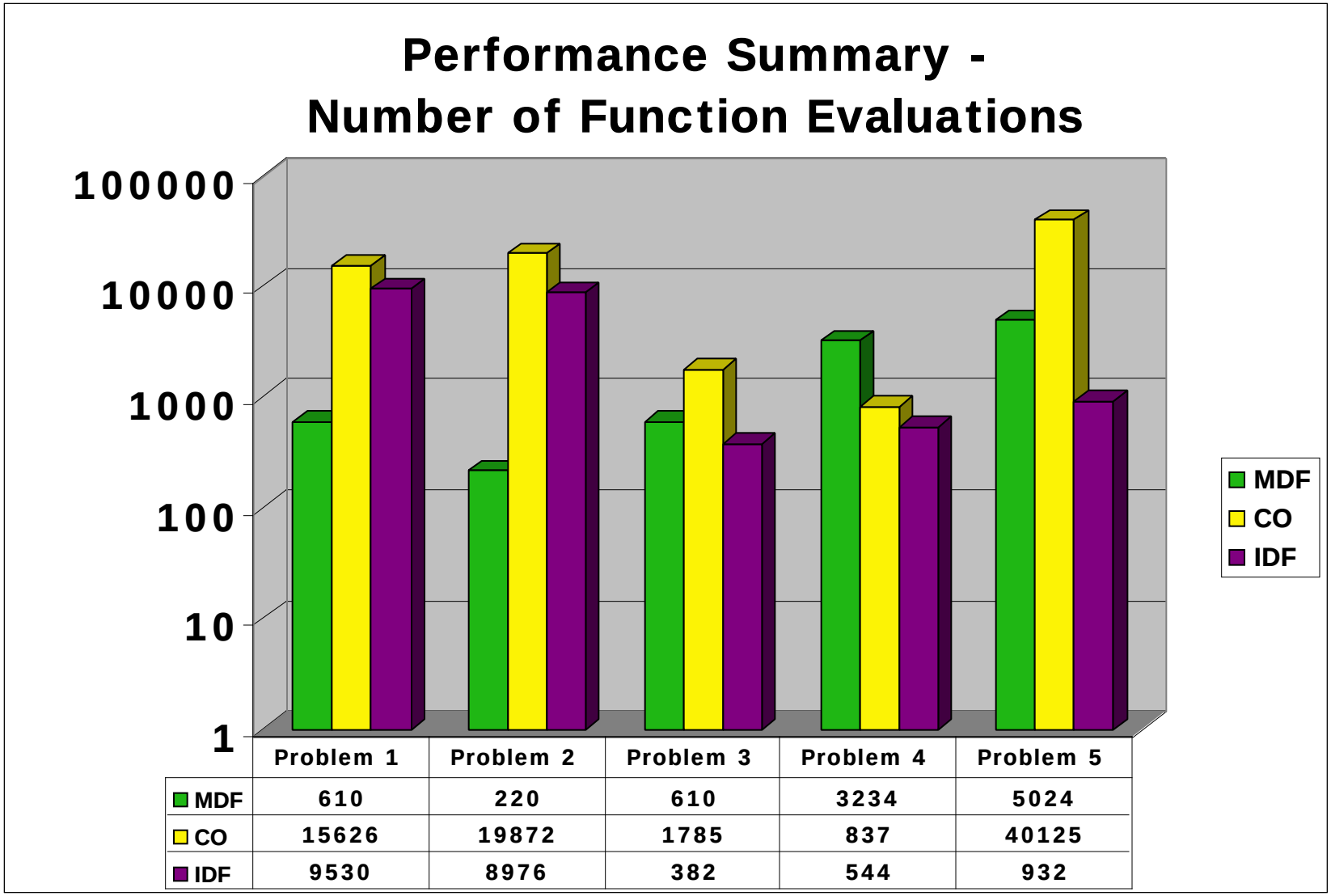
- System: 5 variables, 2 constraints (≤ 0.0001). Solved by combination of exterior penalty function method and method of feasible directions in iSIGHT (http://www.engineous.com).
- Subsystems: 6 variables each. Solved by DONLP (SQP) in iSIGHT.
- Exhaustive iteration history recorded.



	IP1	IP2	IP3	IP4
MDF	498	264	264	210
CO	13785	19872	26064	19701
IDF	270	8976	2106	6874



	IP1	IP2	IP3	IP4
MDF	610	900	1290	640
CO	1244	1785	4581	2583
IDF	524	382	352	384



	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
MDF	610	220	610	3234	5024
CO	15626	19872	1785	837	40125
IDF	9530	8976	382	544	932

Number of successful runs / number of attempted runs

(Generality / Robustness)

Problem Method	1	2	3	4	5	6	7	8	9	10
MDF	12/12	12/12	12/12	12/12	3/3	5/12	10/10	1/6	5/10	5/6
CO	4/4	2/5	3/5	4/5	5/5	4/5	0/5	N/A	N/A	N/A
IDF	4/4	5/5	4/5	N/A	4/5	3/5	N/A	N/A	N/A	N/A

Summary

- **It is premature to classify methods/problems. However, we found this systematic study informative. very informative.**
- **General principle: tradeoff between**
  - **autonomy of subsystem processing and efficiency;**
  - **ease of subsystem integration and efficiency.**
- **Method studies are proceeding on several fronts:**
  - **testing procedures are being fine-tuned for the Phase I methods;**
  - **Phase II with two additional methods has been initiated;**
  - **more realistic problems are being added to the problem test set.**
- **We invite other researchers to contribute to accumulating systematic data.**

Sources of Further Information

- **http://techreports.larc.nasa.gov/ltrs/**
  - **Electronically downloadable paper (these proceedings);**
  - **Forthcoming NASA Contractor Report (Kodiyalam ’98) with complete listing of data;**
  - **Forthcoming paper on analytical and computational aspects of CO (Alexandrov and Lewis, ’98)**
- **http://fmad-www.larc.nasa.gov/mdob/MDOB/**
  - **Method Evaluation Homepage (all available data; implementation description files; latest developments; related information and links; instructions on how to contribute, etc.);**
  - **MDO Test Suite Homepage.**