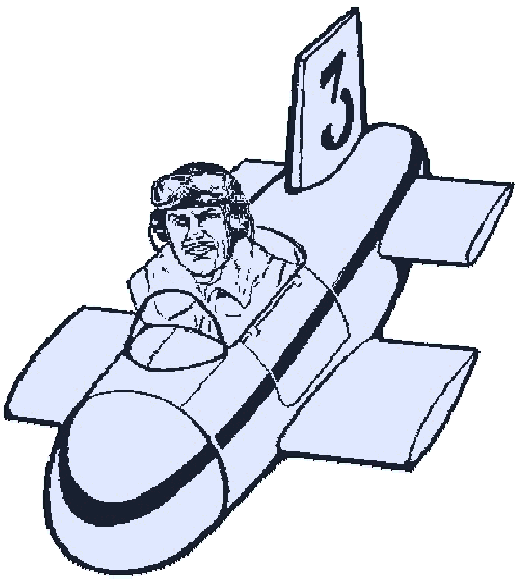
Design-Centric System Synthesis vs. Optimization-Centric System Engineering



or…

Man vs. Machine in the Aerospace Design Office

DANIEL P. RAYMER, Ph.D.
Conceptual Research Corporation

11/9/2007

Who am I ?

A foot in each camp……

- **10 years on the board & CAD scope (and still doing it)**
- **Layout Designer of Rockwell's contenders for F-22, B-2, A-12, T-45, and others, Chief Air Vehicle Design for X-31 (early design)**
- **Developed Rockwell CAD system for aircraft configuration layout**
- **Director, Advanced Design - Lockheed**
- **Ph.D. in Multidisciplinary Optimization**
  - **Genetic Algorithms for Aircraft Conceptual Design**
  - **Methods for modeling effects of parametric design variations**

ARCHITECTING vs. ENGINEERING

Architecting:
- *Unmeasurables*
- *Non-quantitative tools/rules/opinions*
- *Inductive process (general from specific)*
- *Qualitative worth*
- *Client satisfaction*

Engineering:
- *Measurables, hard data*
- *Quantitative tools, equations, science*
- *Deductive process (specific from general)*
- *Quantifiable worth & cost*
- *Fulfillment/optimization of technical objectives*

Architecting pre-dates engineering by 5,000 years !

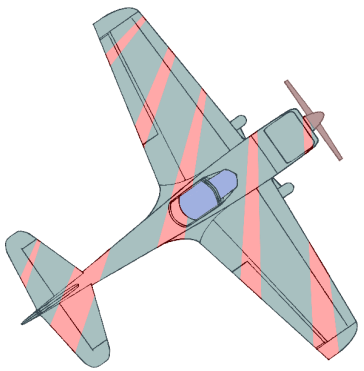
CONCEPTUAL DESIGN BLENDS ARCHITECTING & ENGINEERING

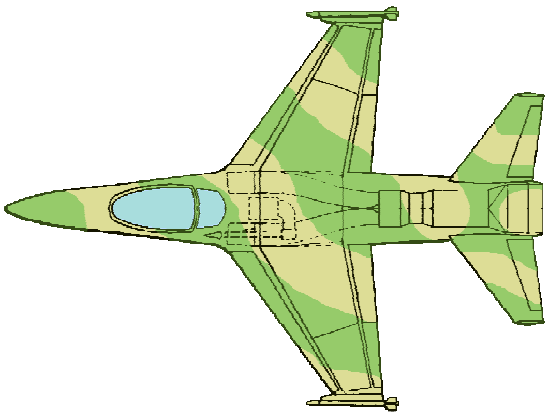
Vision of a new thing
Judgment when numbers are no help
Sense of relative importance
Sense of aesthetics & social worth

Calculations of a new thing
Numbers and data when they can help
Analytical trade-offs and optimizations
Cost-benefit analysis

Raymer on the Record….

"There are two equally important aspects of aircraft design: design layout and design analysis. These very different activities attract different types of people. Some people love playing with numbers and computers, while others can't stop doodling on every piece of paper within reach."

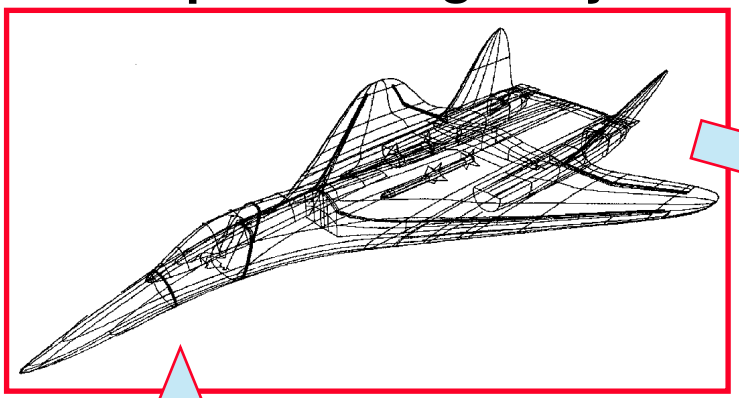




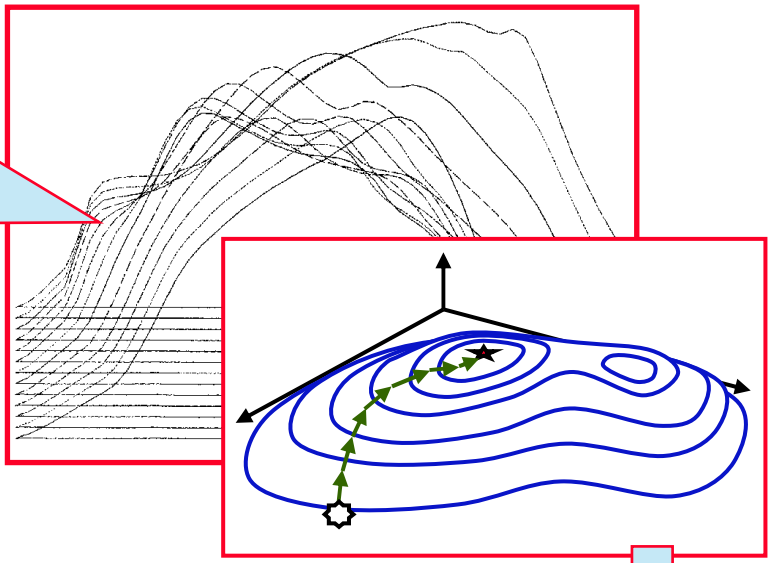
From the introduction to *AIRCRAFT DESIGN: A Conceptual Approach*, D. Raymer, AIAA, 1989

Design-Centric System Synthesis

Conceptual Design Layout



Analysis & Optimization



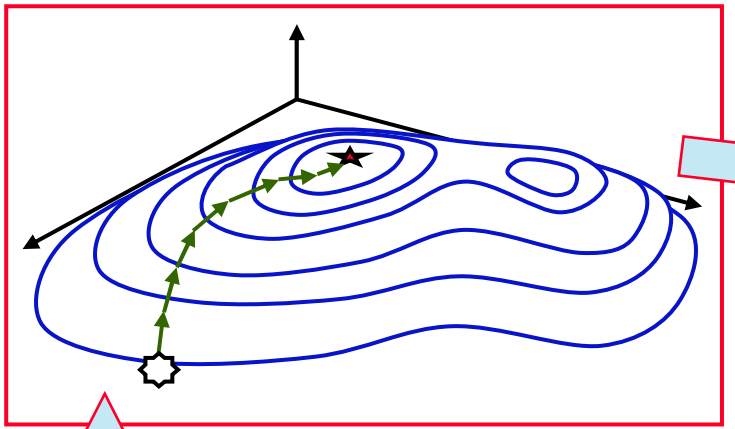
Designer conceives balanced improvements incorporating real-world considerations

Potential Improvements

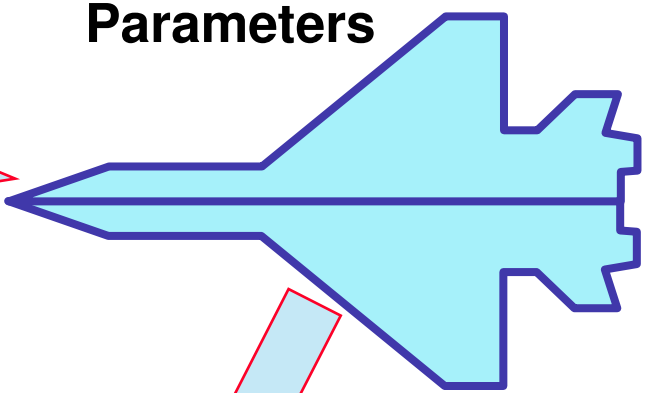
Goal: Facilitate iteration to allow real-world design problems to be solved early & cheaply

Optimization-Centric System Engineering

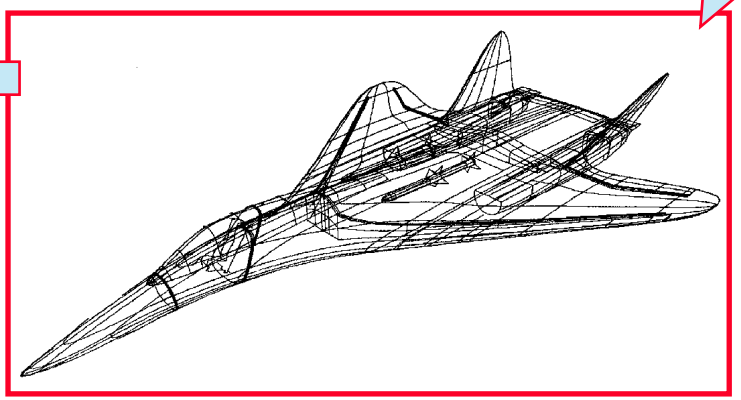
Pre-Layout Optimization



Optimal Design Parameters



Designer creates CAD model from optimized design, adding real-world considerations as needed



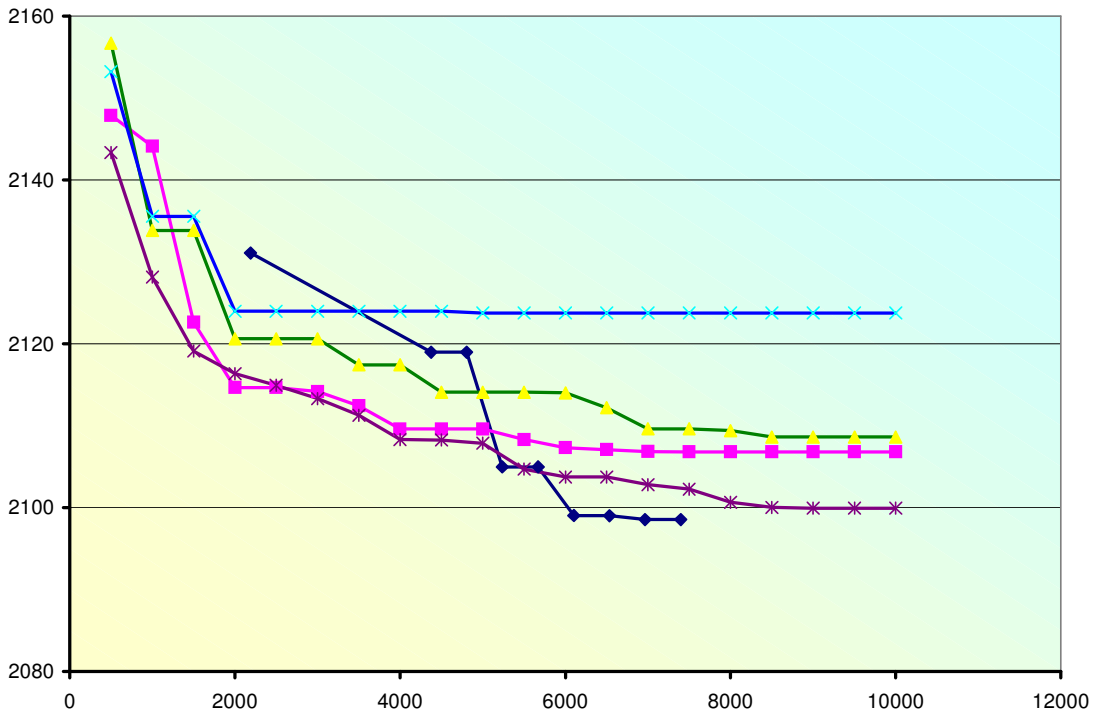
Iterate as required

Goal: Eliminate iteration by the perfection of analytical optimization (DPR biased opinion)

Raymer on the Record: Ph.D. Thesis

"Aircraft Conceptual Design can be improved by application of Multidisciplinary Optimization methods, with no additional downstream costs."

We get a better airplane for free.



Raymer, D., ***Enhancing Aircraft Conceptual Design using Multidisciplinary Optimization***, Ph.D. Thesis, Swedish Royal Institute of Technology, Stockholm, Sweden, 2002

Thoughts on the Limits of MDO

- MDO (GA) is more like dog breeding than Darwinian evolution - the overall form stays the same
- To truly create brand new design concepts in a computer, we would need a way to evolve the optimizer's defining bit string
- How would you model and analyze the unexpected forms?

T/W	W/S	A	taper	sweep	t/c	fuselage l/d	C_L-design
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Some Thoughts on Design (1)

A concept originates in the mind of one person…a configuration designer. Every pertinent discipline in the company shares development of the concept. Likewise do associate contractors, suppliers, and the customer. But the prime contractor's configuration designer becomes the focal point of all these efforts.

Harry Scott, Aerospace America, 1979

Some Thoughts on Design (2)

There is a tendency today, which I hate to see, toward design by committee - reviews and recommendations, conferences and consultations, by those not directly doing the job. Nothing very stupid will result, but nothing brilliant either. And it's in the brilliant concept that a major advance is achieved."

Kelly Johnson, *"Kelly"*, 1985

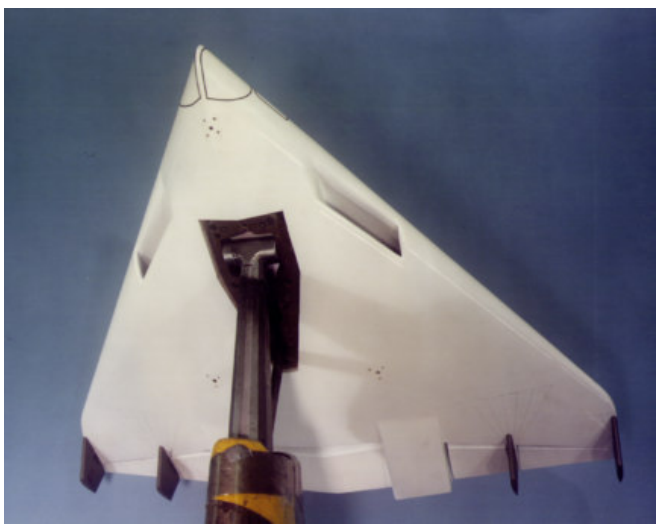
Some Thoughts on Design (3)

"The designer must protest irresponsible demands... The designer has to be tough and he has to protect his machine from irresponsible advisors...The designer must avoid the 'epidemic of improvements'... It's hard to make a good machine and very easy to spoil it - and it's the designer who is responsible."

J. Stalin, 1940's

Some Thoughts on Design (4)

No one person designs an aircraft. However, the configuration designer creates the initial concept and nurses it to configuration freeze. He should be forgiven if he occasionally refers to it as "his airplane."



Dan Raymer,
Aerospace America, 1979

Summary of Raymer's Opinions:

1. Designs are created by designers, who conceive the overall shape and features in response to requirements, customer desires, aesthetics, and preliminary analysis. Conceptual design is a difficult and critical skill, and takes years to learn.

2. Optimization is a key tool to take the designer's concept and make it as good as possible. Designers who fail to incorporate state-of-the-art optimization in their design process will be left in the dust. Ditto emerging CAD tools which improve design by facilitating iteration and providing early analysis.

3. "Automagic" optimization can never replace the designer's creativity and ability to invent something never before seen.

4. Optimization programs promoted as "not needing an initial baseline" actually have one, but nobody knows what it is.