Bio: Daniel P. Raymer

Aircraft Configuration Layout Designer & Project Engineer ~40 years
AIAA Fellow, 2010 winner of AIAA Aircraft Design Award
President & Founder, Conceptual Research Corporation
Director-Advanced Design at Lockheed, Director-Future Missions at Aerojet,
Project Manager-Engineering at Rockwell North American Aviation, Aerospace
Design Consultant for the RAND Corporation
for Homebuilders” plus numerous technical reports & papers
Developed CRC’s RDS™ and Rockwell’s CDS (aircraft design & CAD codes)

Purdue University: B.S. and M.S. Engineering
(Astronautics & Aeronautics)
University of Southern California: MBA
Hey Dan, how did you come to write your book?

• 1976: Raymer gets his dream job – a drafting table in the Advanced Design Department of North American Aviation (Rockwell then, Boeing now)
  • “but the industry methods I’m learning don’t match those I learned in college!”
• Key difference: in Industry, the whole process revolves around the design concept (actual layout)
• Raymer starts giving “correct way” talks at Northrop University, Naval Postgraduate School, and others
• 1983: Naval Postgraduate School invites Raymer to be a visiting Adjunct Professor for one semester, to teach an Aircraft Design Class
  • Rockwell's Bastian Hello, later AIAA President, authorized it including paying all my expenses (thanks, Buzz!)
  • Every night I made hand-drawn handouts for the next day's class, which the patient secretaries photocopied with minutes to spare
  • Fellow professor Alan Fuhs, later AIAA VP-Publications, saw my notes and say “say Dan, why don’t you turn those into an AIAA textbook?”
  • Sounded easy....

• Weird Fact: Dan Raymer was born in Monterey when his father Gordon Raymer was a student at the Naval Postgraduate School, and his class photo was still on the wall outside Dan’s classroom
BOOK & SHORT COURSE OBJECTIVES

Practical Working Knowledge of Aircraft Design

...As It Is Actually Performed

No Cartoons: designer must include a good initial estimate of all major subsystems, structural layout, engines, landing gear, etc., and do preliminary TOGW sizing to estimate the sizes of wings, tails, engine, wheels, & fuel tanks

Book and short course follow the chronological sequence of industry design practice

Analysis, optimization, and trades studies are treated as mandatory tools to make the design concept better (not ends in themselves)

My target audience: A professor teaching in the middle of nowhere, who never worked in industry

...thank you for your aircraft design book. Being an aerospace engineering student it helps me a lot in my studies. Although our instructor insists on another book, which is really boring, almost 95 percent of our design class use your book.
TOC Scheme

Intro to Book & Design Process

Chapter 1 Design—A Separate Discipline
Chapter 2 Overview of the Design Process

Chapter 3 Sizing from a Conceptual Sketch
Chapter 4 Airfoil and Wing/Tail Geometry Selection
Chapter 5 Thrust-to-Weight Ratio and Wing Loading
Chapter 6 Initial Sizing
Chapter 7 Configuration Layout and Loft
Chapter 8 Special Considerations in Configuration Layout
Chapter 9 Crew Station, Passengers, and Payload
Chapter 10 Propulsion and Fuel System Integration
Chapter 11 Landing Gear and Subsystems

Chapter 12 Aerodynamics
Chapter 13 Propulsion
Chapter 14 Structures and Loads
Chapter 15 Weights
Chapter 16 Stability, Control, and Handling Qualities
Chapter 17 Performance and Flight Mechanics
Chapter 18 Cost Analysis
Chapter 19 Sizing and Trade Studies

Chapter 20 Electric Aircraft
Chapter 21 Vertical Flight—Jet and Prop
Chapter 22 Extremes of Flight
Chapter 23 Design of Unique Aircraft Concepts
Chapter 24 Conceptual Design Examples

Doing that first “Dash-One”

Rest & Review

Intermission Step-by-Step Development of a New Design

Analyze & Optimize the Dash-One, get ready to do the Dash-Two

Weirder Airplanes and finally, some examples

PHASES OF AIRCRAFT DESIGN

CONCEPTUAL DESIGN
What requirements drive the design?
Explore widest possible design space
Design alternative aircraft concepts
Extensive design trade studies

PRELIMINARY DESIGN
Starts when single concept selected
Study it to find improvements, fix problems
Phase in sophisticated analysis & test
Key milestone: Configuration Freeze
Develop Lofting

DETAIL DESIGN
Design Actual Pieces to Be Built
Test Major Items – Structure, Landing Gear, ...
Finalize Weight & Performance Estimates

FABRICATION
DESIGN PROCESS FLOW
Conceptual, Preliminary, & Detail

NEW CONCEPT IDEAS

DESIGN REQUIREMENTS

TECHNOLOGY AVAILABILITY

CONCEPT SKETCH

INITIAL LAYOUT

INITIAL ANALYSIS
- Aerodynamics
- Weights
- Propulsion

PRE-LAYOUT SIZING

SIZING & PERFORMANCE OPTIMIZATION

REVIEWED LAYOUT

ANALYSIS
- Aerodynamics
- Weights
- Propulsion
- Stab & Control
- Structures
- Cost
- Subsystems
- etc...

REFINED SIZING & PERFORMANCE OPTIMIZATION

CONCEPTUAL DESIGN

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TYPICAL INITIAL CONCEPTUAL DESIGN

3-D CAD Layout
Rockwell ATF

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**INITIAL SIZING EQUATION**

Fuel is estimated from $W_0$ based on empty weight estimates, not from how big a fuel tank you can find!

\[
W_0 = W_{\text{crew}} + W_{\text{payload}} + W_{\text{fuel}} + W_{\text{empty}}
\]

This can be solved for $W_0$ as follows:

\[
W_0 - \left( \frac{W_f}{W_0} \right) W_0 - \left( \frac{W_e}{W_0} \right) W_0 = W_{\text{crew}} + W_{\text{payload}}
\]

\[
W_0 = \frac{W_{\text{crew}} + W_{\text{payload}}}{1 - \left( \frac{W_f}{W_0} \right) - \left( \frac{W_e}{W_0} \right)}
\]

*Beware of the “leverage effect!”*

No weight drops permitted, and assumes “rubber engine”

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**Chromosome Gene String Definition**
(as used in this research)

<table>
<thead>
<tr>
<th>T/W</th>
<th>W/S</th>
<th>A taper</th>
<th>sweep</th>
<th>t/c</th>
<th>fuselage l/d</th>
<th>C_c-design</th>
</tr>
</thead>
<tbody>
<tr>
<td>000000</td>
<td>000000</td>
<td>000000</td>
<td>000000</td>
<td>000000</td>
<td>000000</td>
<td>000000</td>
</tr>
</tbody>
</table>

• Spectrum from lowest to highest permitted value

• Example: wing loading ranges from 40 to 100 (user input)

000000 → 40

111111 → 100

001010 → 40 + (100-40)(10/63) = 49.52

\[
\text{resolution} = \frac{x_{\text{max}} - x_{\text{min}}}{2^l - 1}
\]

Where $l$ is the number of bits per variable

Resolution of W/S = 0.95 = (100-40)/63
Raymer Thoughts on Teaching Design

1. For 1st semester exposure, every student does everything themselves - sketch, initial sizing, layout, analysis, trade studies, & optimization - NO TEAMS!

2. Use a designer-oriented textbook (need a hint?)

3. Teach/provide/allow rapid analysis methods so that students don’t spend most of their time in calculations

4. Result of 1st project is NOT a final, good design, and student reports should reflect that. “My design DOESN’T work yet, here is what is wrong, and here is how the next iteration will get closer to convergence!” Trade study results are critical.

5. In follow-on class, work in teams to further develop a selected design from the initial class

6. DBF is excellent but beware of too much student time doing fabrication grunt work. Use ARF & existing components, allow Q&D fab methods (balsa, blue foam sheet), and select simple project