Cost (and Other Issues)

W. H. Mason

- The Business Conduct of Engineering
- Basic Considerations for Cost Estimation

Aerospace and
Ocean Engineering

Engineering *Is* In Fact a Business

- Your contribution will be judged in an economic context
  - Somebody pays your salary
    - » It is likely you will fill out a time card
- You have to add value to the product
- There is an economic aspect to all engineering decisions

Business Considerations

- You have to account for every cent
- You have to get approval to spend money
- You must use purchase orders
- Make sure your bosses know what you are doing

A Brief Overview of Aircraft Cost Estimation

- Military and Commercial Aircraft
  - differ in some of the details
- We will follow Roskam, Vol. VIII

Definition of Cost, Price and Profit

follow Roskam, Vol. VIII:

COST: amount of expenditures needed to manufacture the airplane

PRICE: amount paid for the airplane by the customer

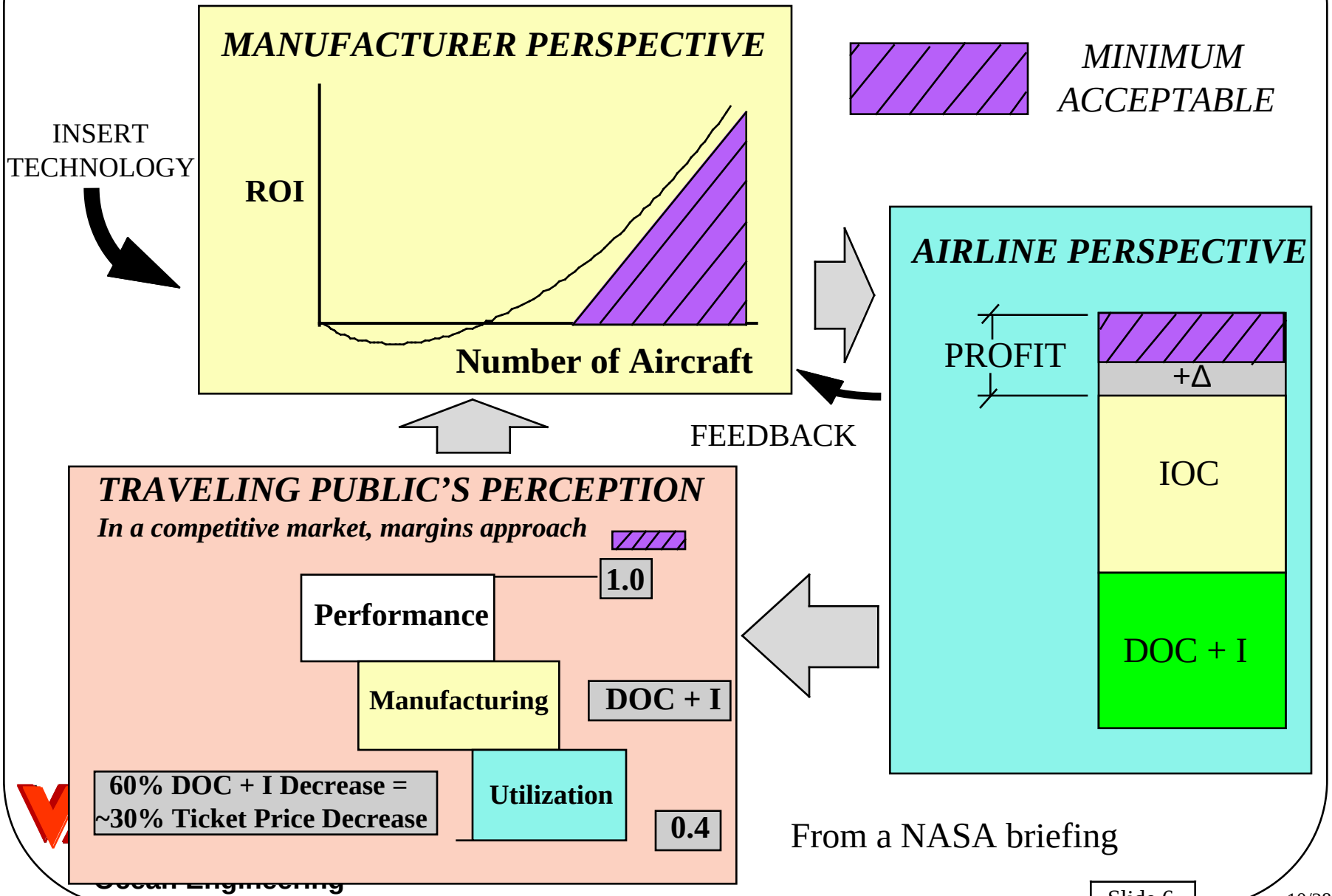
PROFIT: PRICE - COST

Airplane Life Cycle: time for the 6 phases of an airplane program

LIFE CYCLE COST - total cost of an airplane during the airplane life cycle

Note: manufacturer, commercial and personal or corporate owners, and the public all have different viewpoints.

Cost Perspectives: Commercial Aircraft



From a NASA briefing

Phases of an Airplane Program

1. Planning and Conceptual Design
2. Preliminary Design and System Integration
3. Detail Design and Development
4. Manufacturing and Acquisition
5. Operation and Support
6. Disposal

Preliminary Cost Definitions

Costs:

CRDTE: Research, development, test and evaluation

CACQ: Acquisition cost (CMAN + CPRO)

- CMAN: manufacturing cost
- CPRO: manufacturer's profit

COPS: Operating cost

CDISP: Disposal Cost

Life Cycle Cost:

LCC = CRDTE + CACQ + COPS + CDISP

COPS >> CACQ >> CRDTE

But: Phase 1 and 2 lock in LCC!!

Viewpoints on Important Cost

Military:

claims to use Life Cycle Cost

- but Congress often minimizes initial cost, at expense of LCC

Commercial:

often uses operating cost,

- made up of direct (DOC) and indirect (IOC) pieces

Commercial Airplanes

Boeing Cost Method

Total Operating Cost (TOC) =

Indirect Operating Costs (IOC)

+

Direct Operating Costs (DOC)

Example: 1000 nm domestic trip 60% load factor (1985)

	737-200ADV	747-100B
IOC		
Airplane Related	16%	14%
Passenger Related	26%	29%
Cargo Related	2%	6%
Total	44%	49%
DOC		
Maintenance	8%	7%
Fuel	17%	16%
Crew	12%	5%
Interest	8%	10%
Insurance	1%	1%
Depreciation	10%	12%
Total	56%	51%

Indirect Operating Costs

As defined by Boeing:

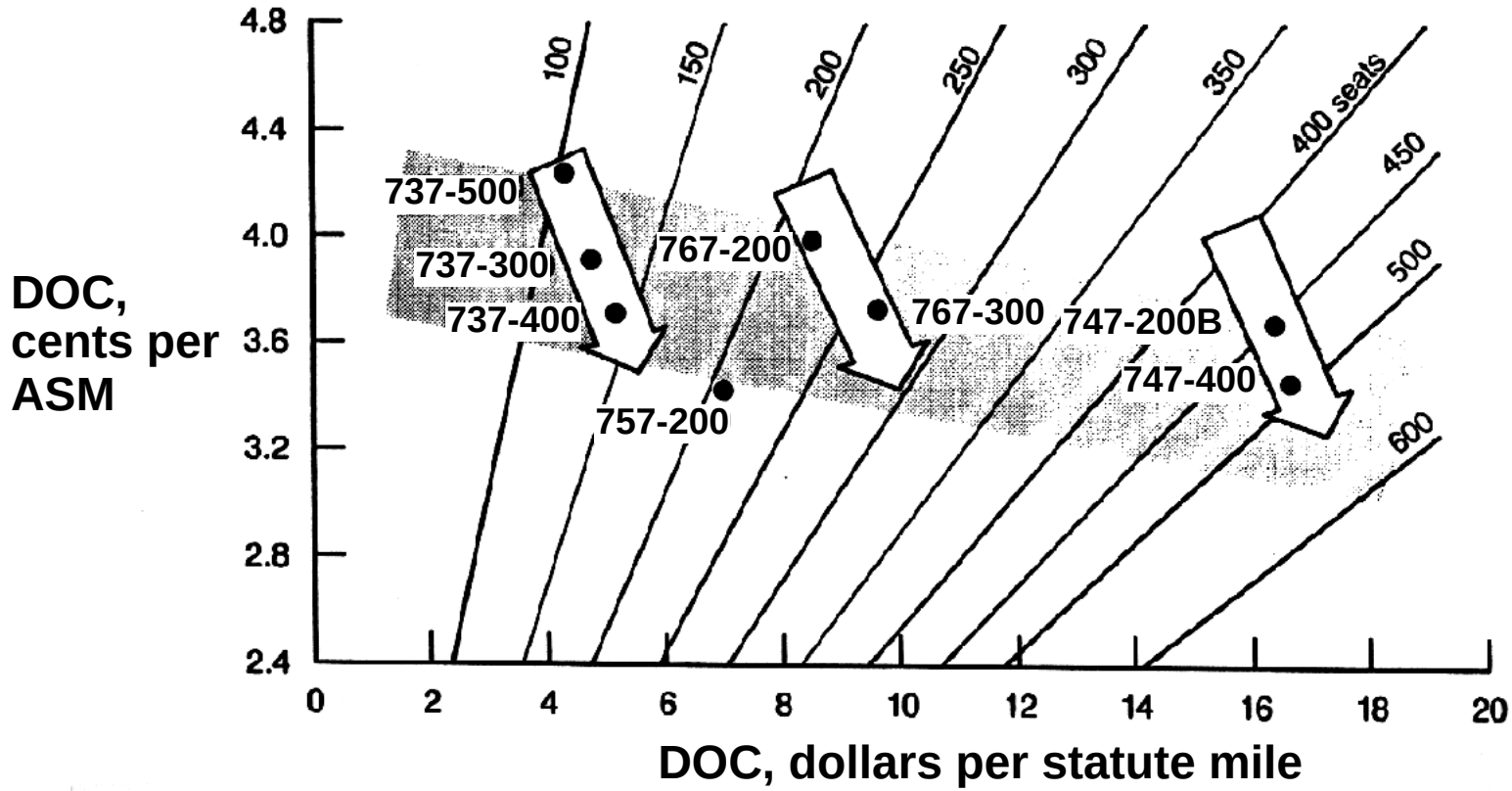
Airplane Related	**Passenger Related**	**Cargo Related**
Ground Property & Equipment	*Passenger Food*	Cargo Handling & Ins.
Maintenance & Burden	Passenger Liability Insurance	Cargo Res. & Sales
Ground Property & Equipment	Passenger Handling	Cargo Commissions
Depreciation & Amortization	Passenger Baggage Handling	Cargo Advert. & Pub.
Cabin Crew	Passenger Reservations & Sales	General & Admin.
Control & Communications	Passenger Commissions	
Aircraft Handling	Passenger Advertising & Publicity	
APU Fuel (Ground Power)	General & Administrative	
Landing Fees		
General & Administrative		

Some Details

1. *Ways to quote DOC*
   - DOC: US dollars per block hour
   - DOC: dollars per statute mile
   - DOC: cents per ASM (Available Seat Mile)
2. *Leasing*: Leasing is now a popular approach, and alters the "typical" cost breakdown distribution
3. *Inflation*: Comparing data from different years, you must include inflation factor adjustment to get an "apples-to-apples" comparison, and consider fuel cost variations also.
4. *Military Aircraft Pricing*: Military procurement cost studies have been done by the Rand Corporation, and they have produced the methods used for military aircraft estimates

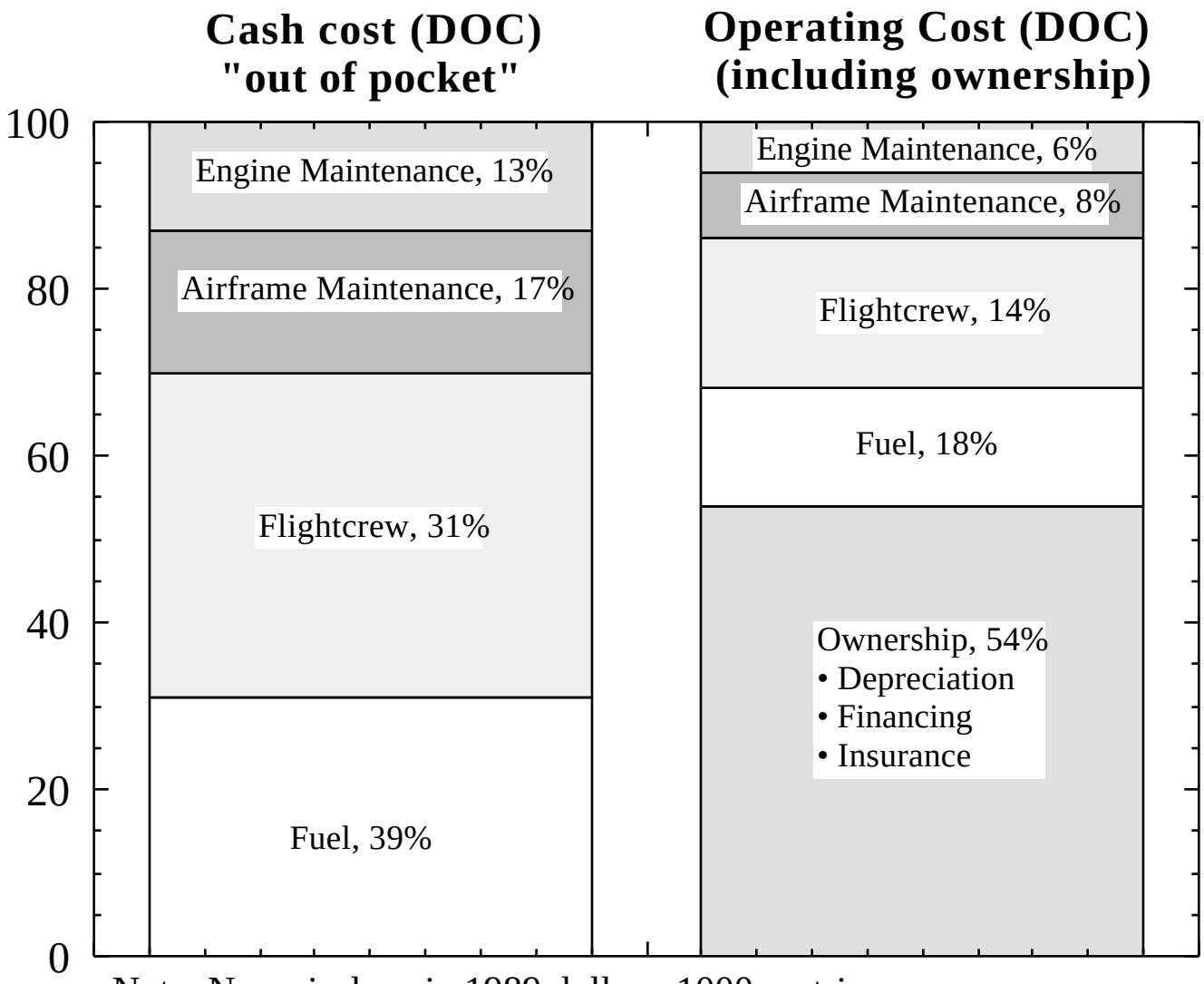
Connecting DOCs

- 2 class seating
- 1,000 nmi
- 1989 U.S. domestic majors



from John Steiner, "Jet Aviation Development: One Company's Perspective" A Boeing Report

Another Boeing Cost Breakdown

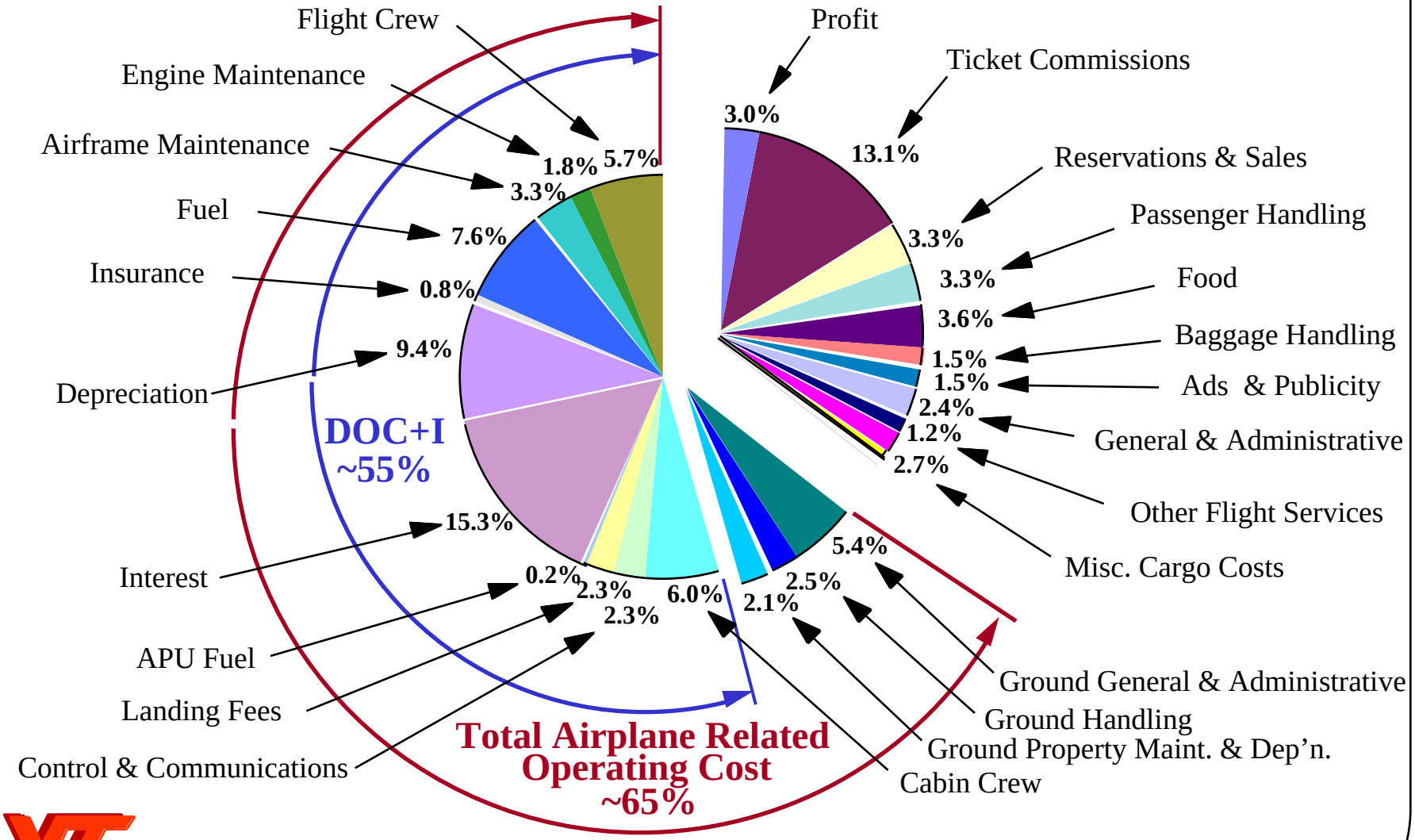


Note: New airplane in 1989 dollars, 1000nm trip

from John Steiner, “Jet Aviation Development: One Company’s Perspective” A Boeing Report

TICKET PRICE BREAKDOWN

Typical Long-Range 4-Engine Passenger Mission



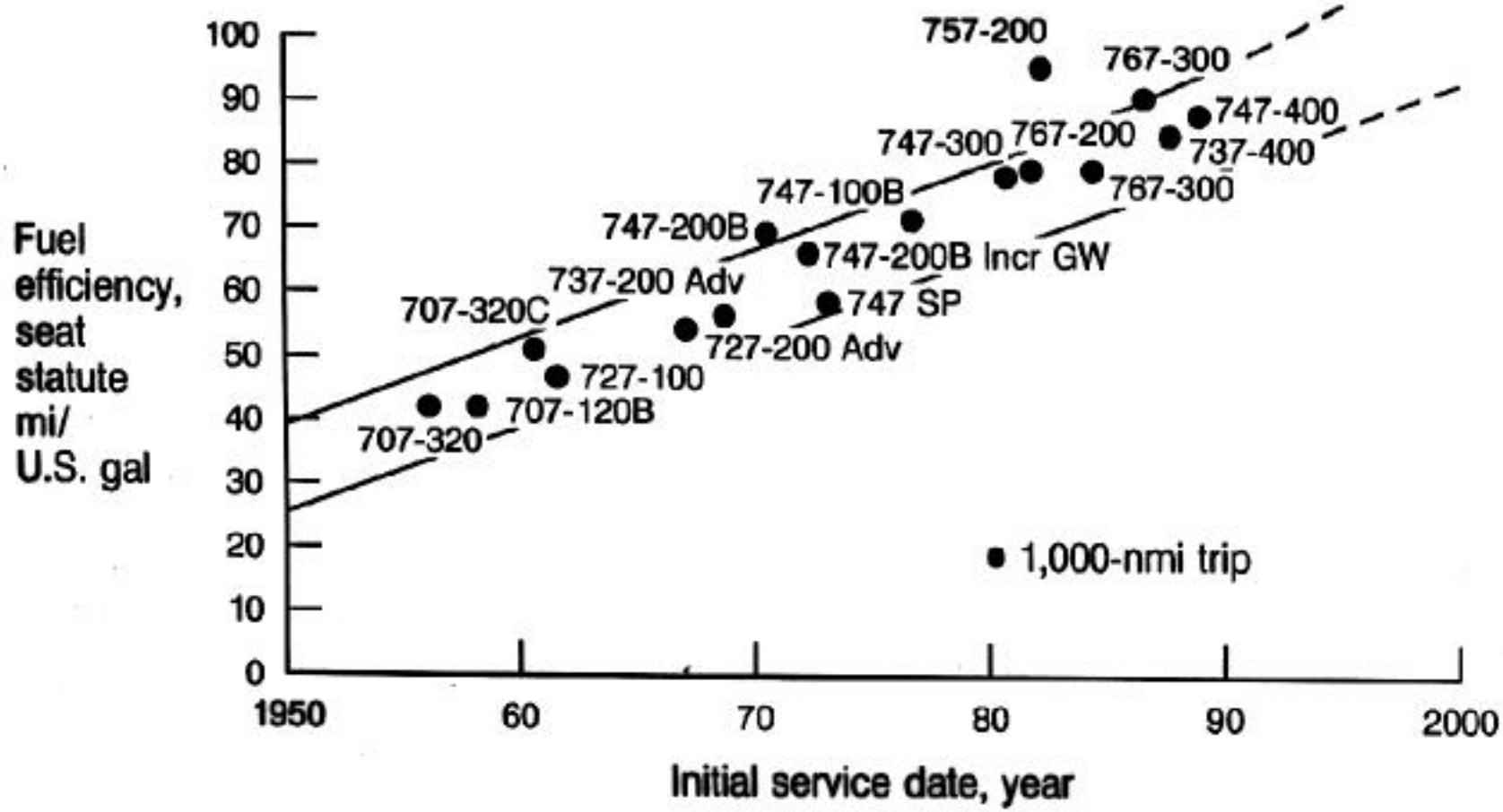
Aerospace and
Ocean Engineering

from the NASA Scenario Based Strategic Planning Study

What can the designer do to reduce DOC?

- Reduce fuel use
  - Examine the Brequet Range Eqn.
    - > *L/D*
    - > *sfc*
    - > *TOGW*
- Reduce purchase price of the plane
  - Reduce *TOGW*
  - Reduce manufacturing cost (complexity)

Some Fuel Efficiency Trends of Boeing Aircraft



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Examples of Airline Economics

1994 Data

Airline	Fleet Size	Pass. Rev. Miles (mil)	Yield c per RPM	Operating Cost c per ASM
United	554	108,016	11.23	8.48
American	566	98,736	12.98	9.16
Delta	543	86,298	13.00	9.53
Northwest	382	57,851	13.36	9.41
British Airways	230	53,583	16.08	12.17
Japan Airlines	119	39,108	19.93	16.23
US Air	441	37,940	15.61	11.32
Continental	311	37,510	11.26	7.91
TWA	194	24,901	11.32	8.62
Southwest	199	19,789	11.65	7.14
Air Canada	107	14,152	14.33	9.19
America West	86	12,199	10.76	7.03

source: Aviation Week, Jan. 8, 1996

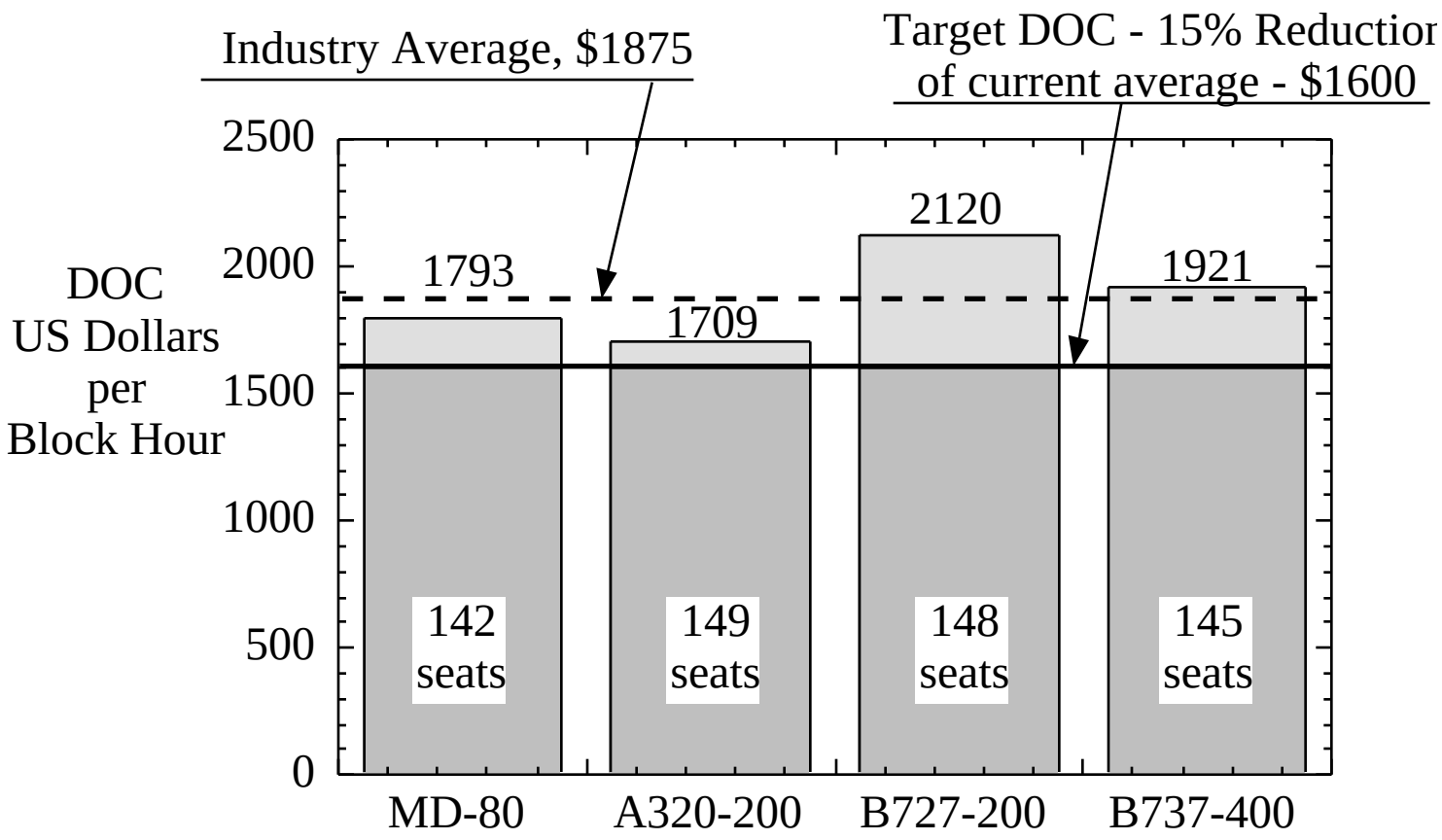
A Comment on Hub & Spoke

- Invented by Federal Express for Freight
  - excellent for overnight delivery

- Widely applied to passenger operations
  - does not "scale up," airlines don't get economy of scale
  - personnel & equipment to handle peak demand leads to very inefficient use of equipment and people on an average basis

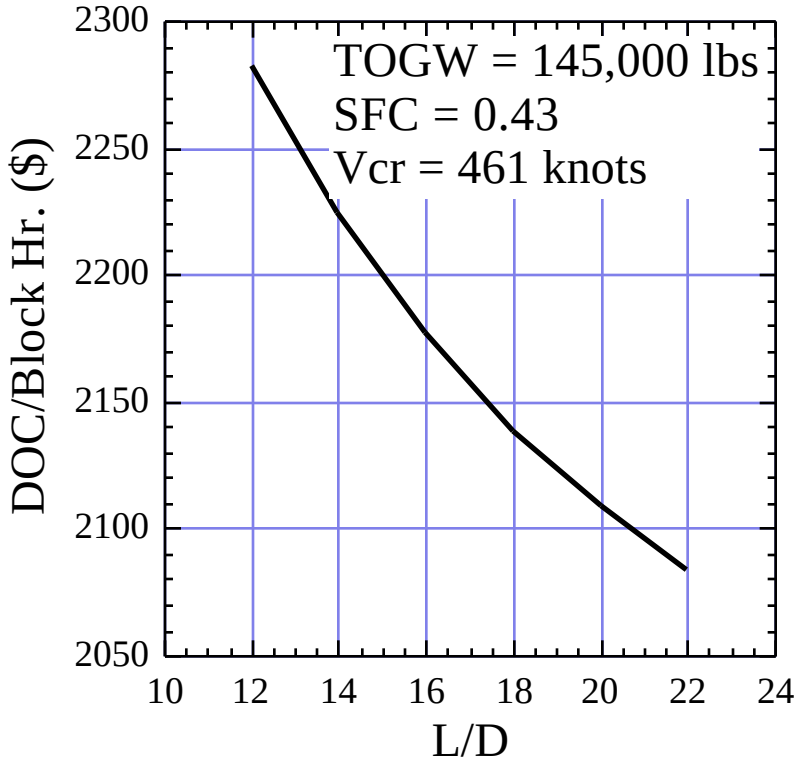
see Stephen D. Solomon, "American Airlines: Going, Going...?", NY Times Magazine, Sept. 5, 1993

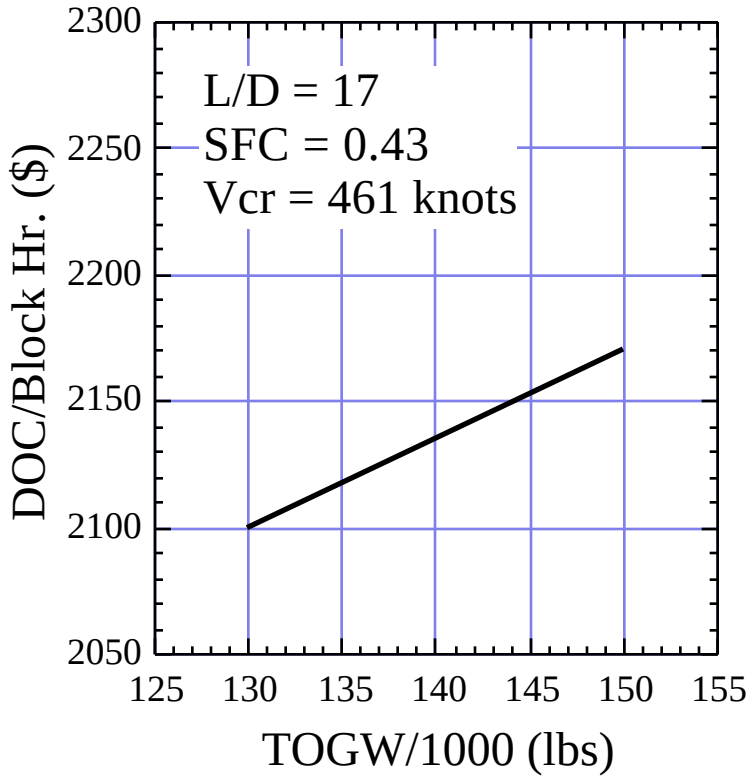
From a previous VPI design study: 1993 data



the Miser design team, John Pierson leader
1993-1994 (3rd place in AIAA Competition
see also: Vincent Press, cost analyst,
AVIATS Aviation, Inc. Reston, VA

From a previous VPI design study: DOC Sensitivity to Design Parameters





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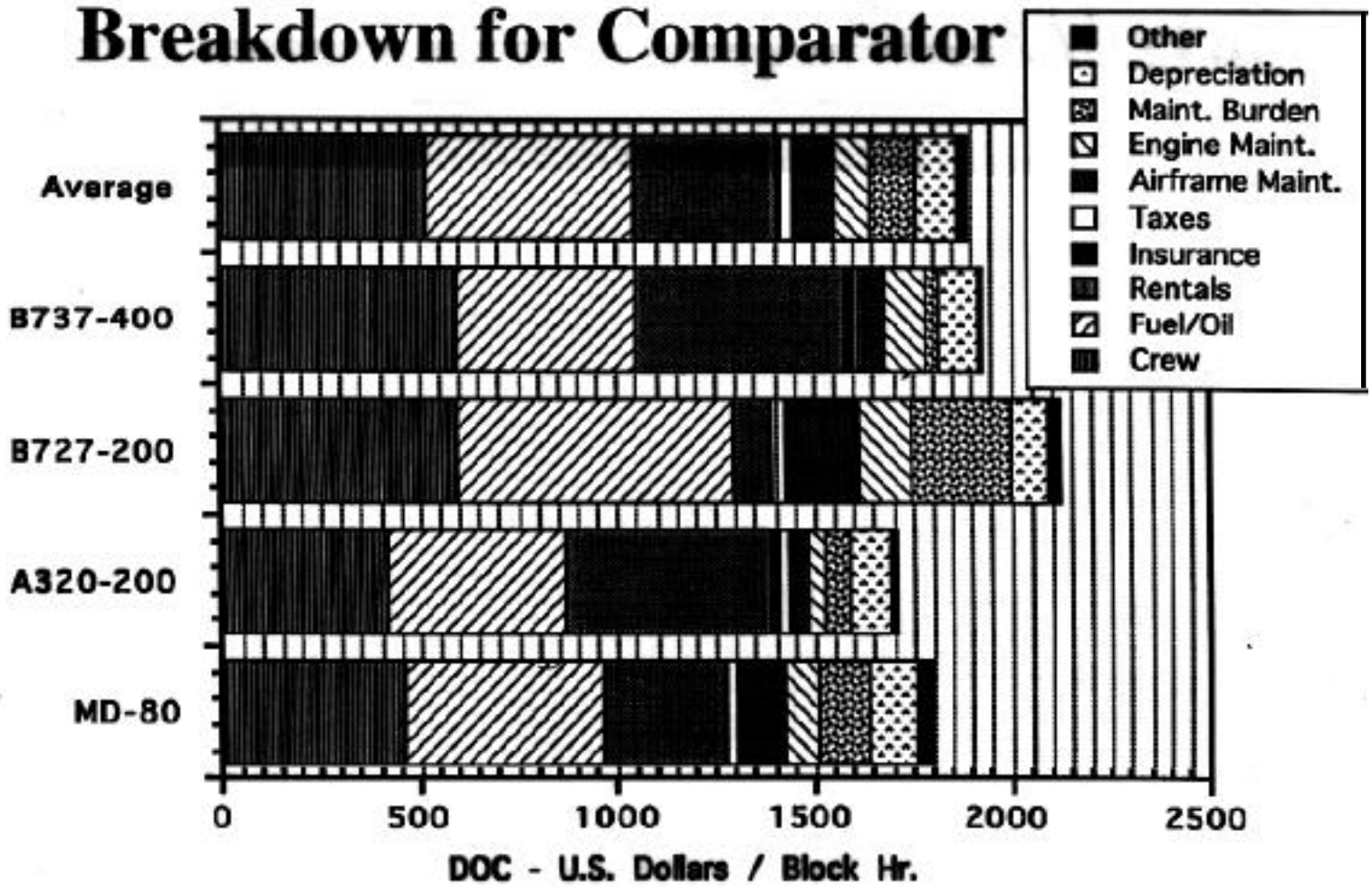

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source: *Aviation Daily* (Mar 30, 1994 & Nov. 8, 1993

Cost Estimating

Roskam's Volume VIII presents a method to estimate each cost

- Use as a guide
- Adjust Roskam's method to reflect what you know about your design

Finally, Roskam gives:

- 88 Design Guidelines for Low Cost (page 246-254)
- 17 Lessons Learned from past airplane programs (page 280-284)

Some Other References

Commercial

Dal V. Maddalon, “Estimating Airline Operating Costs” NASA TM 78694, 1978 (N78-23046)

American Airlines, “A New Method for Estimating Current and Future Transport Aircraft Operating Economics” NASA CR-145190, March 1978 (N78-20094)

Military

J. Wayne Burns, “Aircraft Cost Estimation Methodology and Value of a Pound Derivation for Preliminary Design Development Applications,” SAWE Journal, Fall 1994

Help Making the Calculation?

Roskam's Company, DARcorporation
http://www.darcorp.com

COST for Windows, Version 1.0
($49.96 or $25 with purchase of text)

Raymer: http://www.aircraftdesign.com
his software contains some type of cost module

In the past,
students have coded the algorithms themselves
I have one code (by Scott Dyer - military cost)

Is All This Important?

Check the RFP, ask your customer.

Phil Condit,
1996 Wright Brothers Lectureship

"Today, technology is only one component in the design of an airplane. More and more, our airline customers describe their needs in terms of economics. Their number one priority is for airplanes that are less expensive to own and operate. As a result, our industry is now applying the same kind of creativity and ingenuity to reducing the cost of designing and building airplanes as we do to developing the technology that goes into them."

Important - And Not Addressed Here Yet: *Risk*

Companies commit to the product before building it!

You bet your company

Key Decisions:

- Level of Technology Used
  - Use of Technology without validation:
    - > cost overrun
    - > even a “show stopper”
    - > has happened over and over again
- Plan for future versions/product derivatives

Finally:

In defense programs, congress often feels that there are two phases to a program:

1. It's too early to tell

2. It's too late to do anything about it