Air Vehicle Design

AOE 4065 – 4066

I. Foundational Elements

Course Module F4

Decision Making with Ethics & Integrity

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AOE 4065-4066:
Capstone Air Vehicle Design (AVD) Course Modules (CMs)

Overview of AVD Courses

I. Foundational Elements

- **F1. Design:** ***An Engineering Discipline***
- **F2. Systems and Systems Thinking**
- **F3. Basics of Systems Engineering**
- **F4. Decision Making with Ethics and Integrity**

II. Air Vehicle Design Fundamentals

- **A1. Purpose & Process**

Conceptual Design

- **A2. Understand the Problem**
- **A3. Solve the Problem**
- **A4. Initial Sizing:** ***Takeoff Weight Estimation***
- **A5. Initial Sizing:** ***Wing Loading and Thrust Loading Estimation***
- **A6. Cost Considerations**
- **A7. Concept to Configuration:** ***Key Considerations***
- **A7A. Configuration Layout:** ***Drawings & Loft***

Conceptual & Preliminary Design

- **A8. Trade Studies**
- **A9. Use of Software Tools**
- **A10. Preliminary Design:** ***Baseline Design Refinement & Validation***

III. Project Management Topics

- **P1. Basics of Project Management and Project Planning**
- **P2. Project Organization**
- **P3. Roles & Responsibilities of Team Members**
- **P4. Project Execution:** ***Teamwork for Success***
- **P5. Project Risk Management**
- **P6. Delivering Effective Oral Presentations**
- **P7. Writing Effective Design Reports**

Disclaimer

Prof. Pradeep Raj, Aerospace and Ocean Engineering, Virginia Tech, collected and compiled material contained herein from publicly available sources solely for educational purposes.

Although a good-faith attempt is made to cite all sources of material, we regret any inadvertent omissions.

CRUCIALLY IMPORTANT

CMs only introduce key topics and highlight some important concepts and ideas…but without sufficient detail.

We must use lots of Reference Material* to add the necessary details!

(*see Appendix in the Overview CM)

Outline

F4. Decision Making with Ethics & Integrity

F4.1 Decision-Making Process

F4.2 Decision-Making Methods

F4.2.1 Qualitative Methods

F4.2.2 Quantitative Methods

F4.3 Ethics, Integrity and Professionalism

Decision-making: *A Key Component of Design*

Design is an iterative decision-making activity performed by team of engineers to produce plans by which resources are converted, preferably optimally, into systems or devices to meet human need.

T.T. Woodson

Introduction to Engineering Design, 1966

de·ci·sion

A report of a conclusion.

A determination arrived at after consideration.

Decision making is a process consisting of three basic steps: (i) identifying decision to be made; (ii) gathering information; and (iii) assessing alternative solutions.

An *Effective* Decision-making Process

Pretty Straightforward!

Source: Internet

Decision Criteria Play Key Role in Decision Making

- **Alternative solutions are essential to choosing the *best***
  - Allows for original and creative solutions to be considered
  - Difficult to claim a solution is 'best' without comparison with some other solutions
- **Decision criteria help in developing alternative solutions**
  - Using decision criteria is key to making good decisions
    - For example, if you are deciding which refrigerator to purchase, your decision criteria might be energy saving, cost, functionality, reliability, size, color
  - Measurable decision criteria are preferable
  - Typical examples of decision criteria include:
    - Ability to satisfy requirements/ needs
    - Costs
    - Quantity
    - Quality
    - Physical resources needed
    - Human resources needed
    - Risk
    - Schedule
    - Compatibility with other systems
    - Reliability
    - Acceptability to users/ customers
- **Assigning weights to decision criteria helps assess their relative importance**
  - For example cost might be weighted higher than color or aesthetics

Source: Internet

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Qualitative Decision-making Methods

- **Pro/Con Charts**
- **Decision Matrix**
- **Pugh Matrix**
- **Quality Function Deployment (QFD)**

Pro/Con Charts

"…divide half a sheet of paper by a line into two columns, writing over the one Pro, and over the other Con." – Benjamin Franklin, 1772

Example: High-wing Configuration vs. low- or mid-wing



Pros

- Facilitates loading/unloading of cargo
- More useful space inside the fuselage
- Facilitates engine installation on the wing
- Facilitates struts installation for lighter structure
- Makes the aircraft laterally more stable
- High-wing likely to produce more lift than mid- or low-wing
- Lower stall speeds
- Pilots have full view under the aircraft
- Less susceptible to runway FOD (Foreign Object Debris)

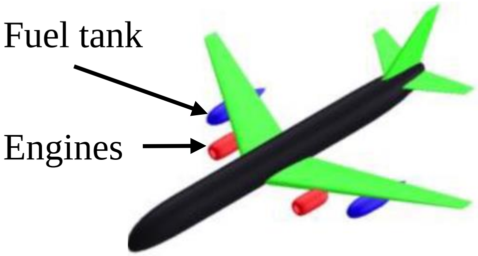
Cons

- Slightly higher take-off run due to less benefit of ground effect
- Longer landing gear if connected to the wing
- Potentially higher horizontal tail area
- Typically about 20% higher wing weight than low wings
- Somewhat weaker lateral control

Source: Section 5.3.1, Ref. AVD 5 (Sadraey); images from Internet

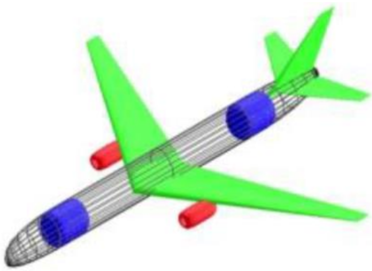
Pro/Con Charts

Example: Bio-LNG aircraft concepts for higher fuel volume



Pros
- Reduces bending moment on wing
- Ease of maintenance
- Short fuel piping

Cons
- Wing flow interference
- Reduced cruise lift-to-drag ratio



Pros
- Large volume-to-area ratio
- Reduced boil-off
- No possibility of bird strike damage

Cons
- Tank mounting must meet higher FAA g-load limits
- Possibility of vapor leakage into fuselage
- Lost cargo volume

Pros
- Reduced ground noise
- Improved cruise lift-to-drag ratio
- Reduced bending moment on wing

Cons
- Long fuel pipes through fuselage
- Shorter tail moment
- Must increase wing box volume

Pros
- Improved cruise lift-to-drag ratio
- Reduced bending moment on wing
- No cryogenic fuel lines in fuselage

Cons
- Long fuel pipes through fuselage
- Shorter tail moment
- Must increase wing box volume

Source: Burston et al," Conceptual Design of Sustainable Liquid Methane Fueled Passenger Aircraft,' 20th ISPE, 2013, pp 391-400

Using Pro/Con Charts for Assessing Design Alternatives

Design objectives	Weight (%)	High wing	Low wing	Mid-wing	Parasol wing
Stability requirements	20				
Control requirements	15				
Cost	10				
Producibility requirements	10				
Operational requirements	40				
Other requirements	5				
Summation	100	93	76	64	68

Focus on choosing the best concept/configuration to achieve <u>your</u> <u>specific design objectives</u>— key to meaningful outcomes

Source: Table 5.1, Ref. AVD 5 (Sadraey)

Pros & Cons of 'Pro/Con Charts'

Pros

- ***Rigor***
  - ✓ Making the effort to think through all possible pros and cons, and capturing them in writing, increases likelihood of considering all critical factors
  - ✓ Assigning weights promotes better-quality decision making
- ***Objectivity***
  - ✓ Decision viewed as an external problem to minimize the impact of emotions
- ***Familiarity and Simplicity***
  - ✓ Generally well understood requiring no special computational or analytical expertise
  - ✓ Elegantly simple to administer

Cons

- ***Vulnerable to cognitive biases***
  - ✓ *Framing Effect*—overly constraining the set of possible outcomes by using a "thumbs up or thumbs down" scenario
  - ✓ *Overconfidence Effect*—individuals may assume a level of accuracy in their assessments of pros and cons that simply isn't there
  - ✓ *Illusion of Control*—individuals may believe that they can control outcomes that in reality are not controllable

Use it only as a very high-level preliminary thinking aid

Source: https://hbr.org/2017/01/the-pros-and-cons-of-pros-and-cons-lists

Qualitative Decision-making Methods

- **Pro/Con Charts**
- **Decision Matrix**
- **Pugh Matrix**
- **Quality Function Deployment (QFD)**

Decision Matrix

General Format

		Concept Variants					
		Concept 1		Concept 2		Concept 3	
Criteria	Weights	Value	WV	Value	WV	Value	WV
Criterion 1							
Criterion 2							
Criterion 3							
Criterion 4							
...							
Sum:							
Weighted Sum:							

Criteria/subcriteria Weights (W)

Criteria	Sub-Criteria		Percentages		Ratios	
Performance	-----	-----	50.0%	-----	3.3	-----
- - -	speed		- - -	15.0%	- - -	3.0
- - -	acceleration		- - -	15.0%	- - -	3.0
- - -	payload		- - -	10.0%	- - -	2.0
- - -	fuel consumption		- - -	5.0%	- - -	1.0
- - -	ceiling		- - -	5.0%	- - -	1.0
Reliability	-----	-----	15.0%	-----	1.0	-----
- - -	MTBF		- - -	15.0%	- - -	1.0
Safety	-----	-----	15.0%	-----	1.0	-----
- - -	Safety		- - -	15.0%	- - -	1.0
Logistics	-----	-----	20.0%	-----	1.3	-----
- - -	Supply Lines		- - -	5.0%	- - -	1.0
- - -	Spare Parts		- - -	5.0%	- - -	1.0
- - -	Crew Training		- - -	10.0%	- - -	2.0
			100.0%	100.0%		

Value Scheme (V)

Far Below Average	0
Below Average	1
Average	2
Above Average	3
Far Above Average	4

Source: https://www.nap.edu/read/10566/chapter/6#24

Decision Matrix:
A Student Design Project Example



	Scaling Factor	Aeolus	Gobble Hawk	Oya
Overall Cost	10	3	3	2
Structural Efficiency	9	3	5	2
Powerplant Configurations	8	4	5	3
Payload Management	7	4	5	2
Aerodynamic Efficiency	7	4	3	3
Ease of Operation/Maintainability	5	3	3	2
Manufacturability	5	5	3	4
Fuel System Flexibility	4	3	5	2
Empennage Sensitivity	4	3	4	1
Landing Gear Configuration	3	3	5	3
Marketability	2	2	4	3
	Total	222	260	154

Note:
- **‘Scaling Factor’ is analogous to ‘Weights’**
- **Numerical entries for each concept are ‘Values’**

Source: VT 2013-14 NASA HALE UAV Team (Lead: Schmit)

Pros & Cons of Decision Matrix

Pros

- Encourages team interaction (causes the design team to consider attributes of a variety of potential solutions and their relative importance and thus a good way to help calibrate the team).
- Analysis can be performed relatively quickly
- The method can identify non-viable design variant options and remove them from further consideration.

Cons

- Criteria may have interdependencies
- Risk must be overtly addressed as an additional criterion
- Weighting has built-in uncertainty--often reflects the design team's subjective opinion
- Not a stand-alone decision tool
- Teams may be tempted to use it merely to rationalize decisions

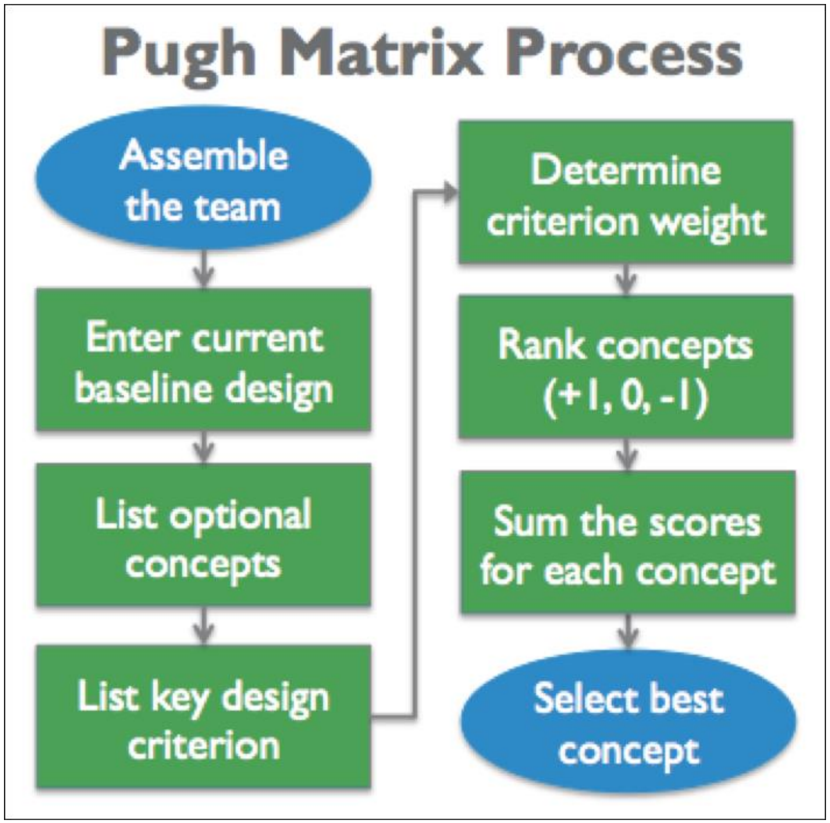
Source: https://www.nap.edu/read/10566/chapter/6#24

Qualitative Decision-making Methods

- Pro/Con Charts
- Decision Matrix
- Pugh Matrix
- Quality Function Deployment (QFD)

Pugh Matrix

Specifically developed by Stuart Pugh (1990) as an aid to compare a number of design alternatives and choose the one that best meets the criteria.



VALUE GENERATION PARTNERS — Pugh Matrix

Project Name:

Project Manager:

Date:

	Concepts					
Key Criteria	Baseline	Concept 1	Concept 2	Concept 3	Concept 4	Weight
Criterion 1	0					
Criterion 2	0					
Criterion 3	0					
Criterion 4	0					
Criterion 5	0					
Criterion 6	0					
Sum of Positives (+)	0					
Sum of Negatives (-)	0					
Overall Total	0	0	0	0	0	
Weighted Total	0	0	0	0	0	

Source: https://vgpblog.files.wordpress.com/2015/04/pugh-matrix-template-value-generation-partners.png

Pros & Cons of Pugh Matrix

Pros

- Encourages team interaction (causes the design team to consider attributes of a variety of potential solutions).
- Serves as a common visual
- Helps retain a set of strong concepts, and identify opportunities for combining features.

Cons

- Quality of outcome is strongly dependent upon the experience of team members.
- Scoring often reflects the design team's subjective opinion
- Risk must be overtly addressed as an additional criterion
- Not a stand-alone decision tool
- Teams may be tempted to use it merely to rationalize decisions

Source: https://vgpblog.files.wordpress.com/2015/04/pugh-matrix-process-value-generation-partners.png

Qualitative Decision-making Methods

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Quality Function Deployment (QFD)

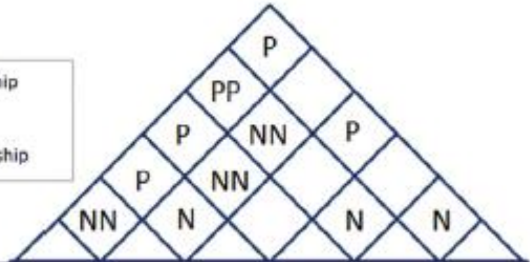
A method to generate a specific link between customer attributes and design parameters by answering three primary questions:

- *What attributes are critical to our customers?*
- *What design parameters are important in meeting customer attributes?*
- *What should the design parameter targets be for the new design?*

Source: https://www.nap.edu/read/10566/chapter/6#24

QFD Approach

PP = Strong positive relationship
P = Postive relationship
N = Negative relationship
NN = Strong negative relationship



Interrelationships, e.g. SIZE has a strong negative effect on DRAG and strong positive effect on lift

Example: More power is favorable, so the arrow points up

Engineering Challenges

From customer surveys

Customer Requirements	Importance 1 (not) – 5 (very)		SIZE OF AIRCRAFT	DRAG	LIFT CAPABILITY	WEIGHT	PRODUCTION COST	POWER (BHP)	Our Design	Competitor AC 1	Competitor AC 2
FAVORABILITY				▽	△	▽	▽	△			
FAST	3.0	16.2%	9	9	3	9	9	9	2.5	2.0	1.5
EFFICIENT	5.0	27.0%	1	9	9		9	3	4.0	3.5	3.5
RELIABLE	4.5	24.3%	1				1	3	4.0	4.0	4.0
SPACIOUS	4.0	21.6%	9	3			3	1	4.0	3.5	3.5
INEXPENSIVE	2.0	10.8%	3	3	3	9	9	9	2.5	2.0	2.0
SUM =	18.5	100%	4.24	4.86	3.24	2.43	5.76	4.19	24.73		
			17.2	19.7	13.1	9.8	23.3	16.9			

Same scale as customer requirements

Percentages of the above numbers

Association between customer requirements and engineering challenges

9 means a strong influence
3 means a medium influence
1 means a weak influence
0 or ' ' means no influence

Source: Figure 1-21, Ref. AVD 4 (Gudmundsson)

Pros & Cons of QFD

Pros

- Encourages team interaction
- Converts customer needs into numeric scores to help define areas to focus on
- Provides a thorough appraisal of the project scope
- Can be used as a standalone tool

Cons

- Can take considerable effort to develop
- Highly dependent on the perspectives of the design team members

Source: https://www.nap.edu/read/10566/chapter/6#24

Qualitative Decision Making: A WORD OF CAUTION

Prudent to evaluate alternatives by using at least two different independent methods.

Strong willed individuals whose ideas are not selected may resort to critiquing the final selection based on emotion, experience, and bluster.

Nothing takes the place of disciplinary knowledge, common sense and good judgment!

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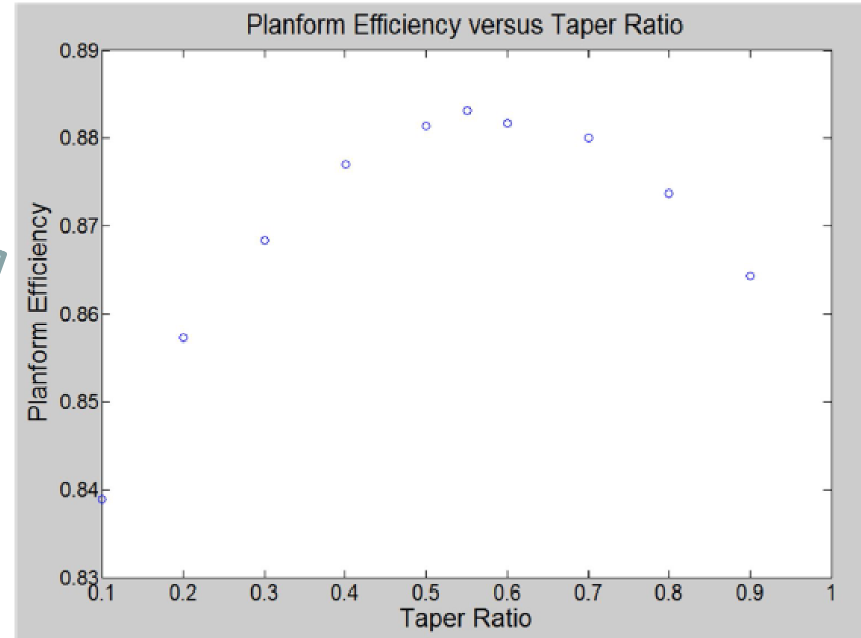
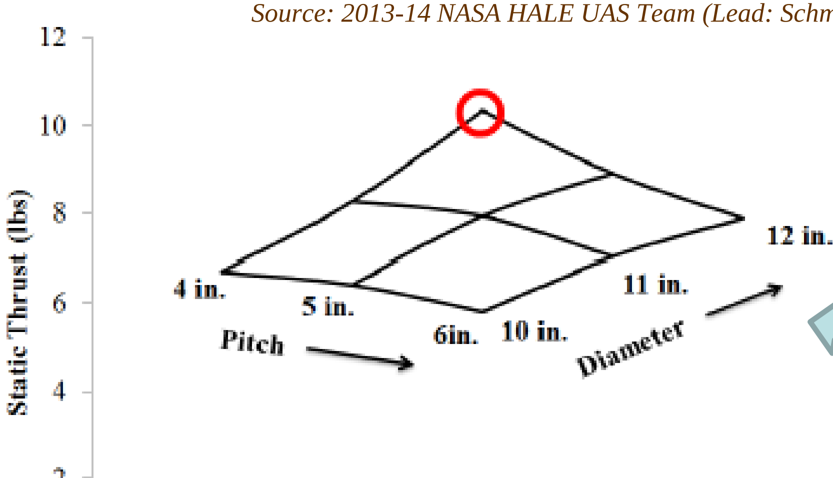
Quantitative Decision Making

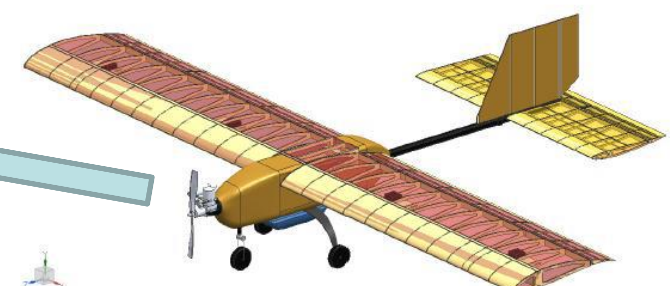
Based on Trade-off Studies or Parametric Sensitivity Studies using data from engineering analyses or other sources

Sensitivity of wing planform efficiency to taper ratio

Source: 2013-14 NASA HALE UAS Team (Lead: Schmit)







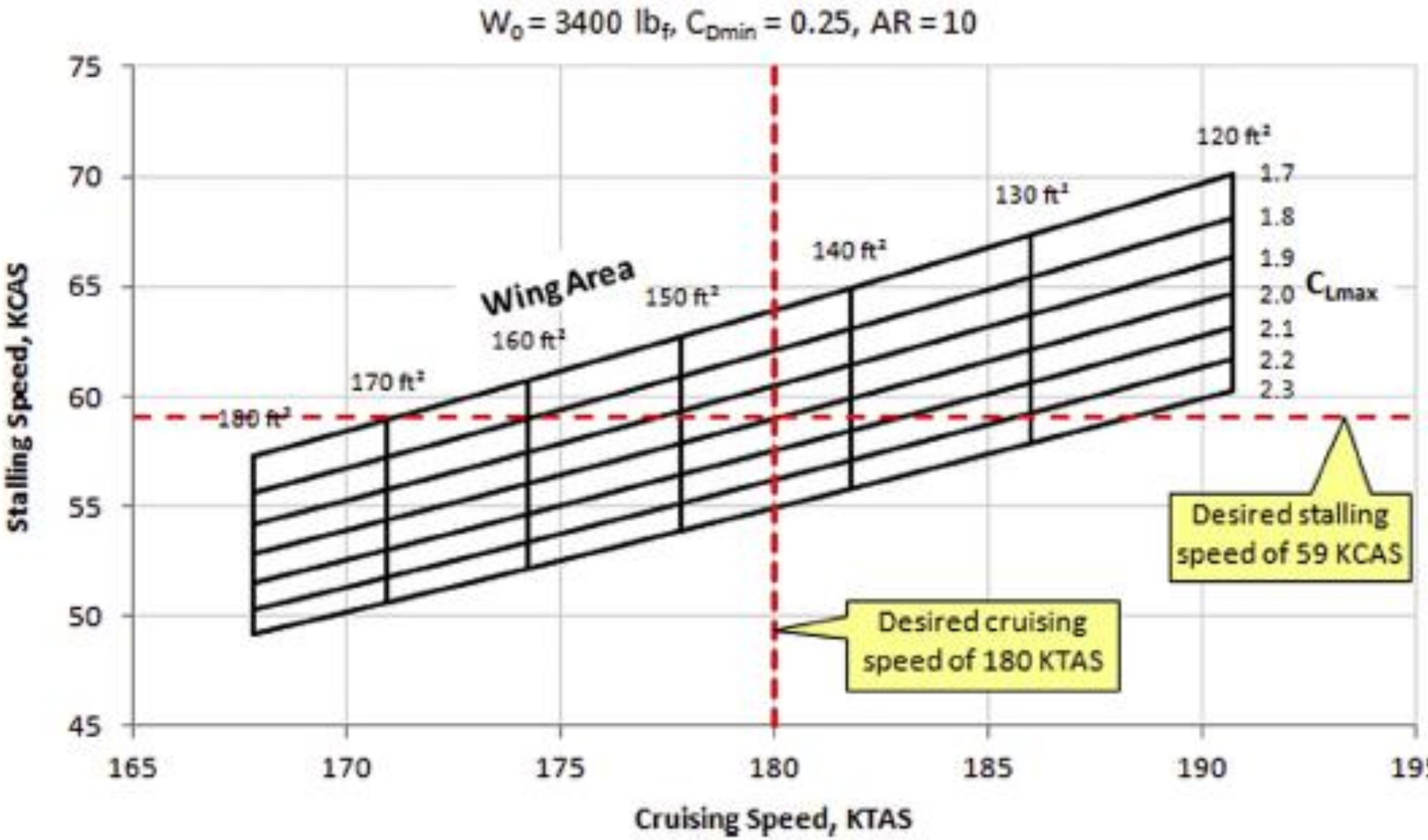
Carpet Plot for Propeller pitch and diameter selection for highest static thrust

Source: 2012-13 SAE Aero Design Team (Lead: Keys)

Quantitative Decision Making

Most balanced wing area selection to meet cruise and stall speed targets for a General Aviation (GA) aircraft

Stall Speed vs Cruise Speed Carpet Plot



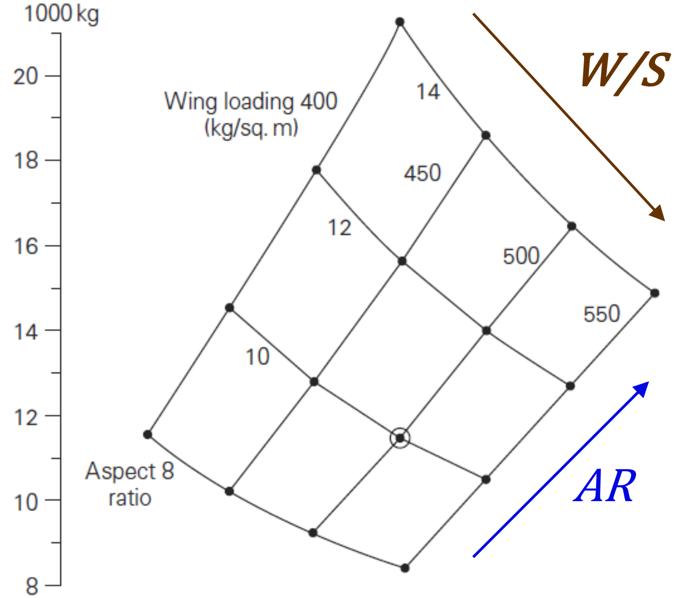
- **Large wing area gives lower stall speed but higher drag and weight**
- **More effort required to find a suitable compromise among lift, drag and weight**

Source: Fig. 3-6, Ref. AVD 4 (Gudmundsson)

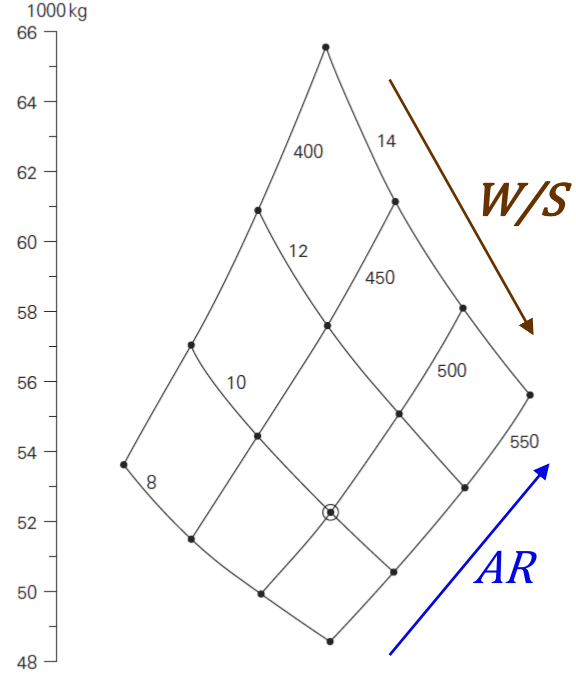
Quantitative Decision Making

Wing Geometry Parameters: *Aspect Ratio, AR*, and Wing Area, *S* (or *W/S*)

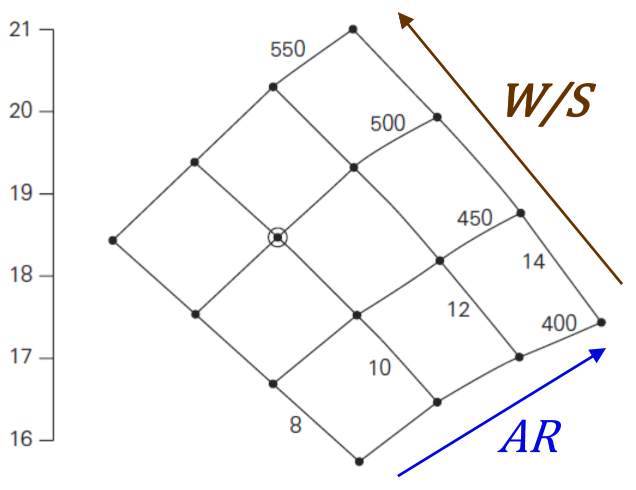
Wing Mass



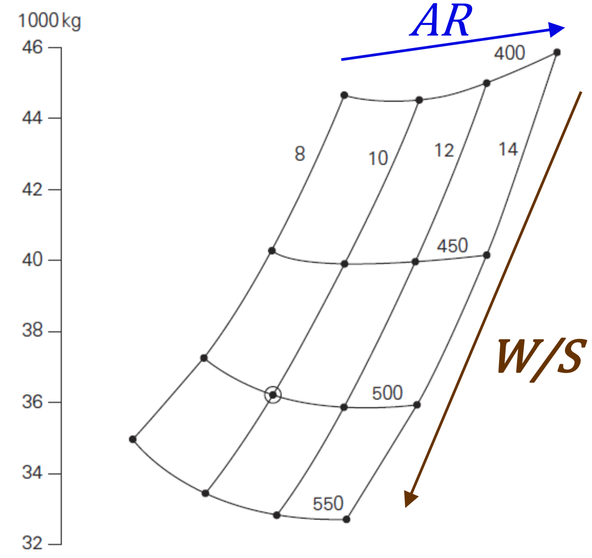
Empty Mass



$(L/D)_{cruise}$



Fuel Mass



Source: Chapter 4, Ref. AVD 21 (Jenkinson)

Best Quality Decisions Require *Critical Thinking*

- **Critical Thinking is a *process* that involves a search for *evidence before making decisions*.**
  - *In Engineering, quantitative data is the evidence.*
- **Critical Thinking requires *analysis* of the validity of what is said or claimed.**

"Without data you're just another person with an opinion."

- W. Edwards Deming
American Engineer
1900-1993

Source: Internet

Outline

F4. Decision Making with Ethics & Integrity

Why Ethics & Integrity?

- **Engineering Design is an *iterative decision making activity performed by teams of engineers***
- **Making decision on a course of action to pursue requires choosing from a set of different options**
- **Technical decision criteria and technical data are absolutely necessary to make engineering design decisions…but they are *not sufficient for making the RIGHT decision***
- **Engineers must consider public health and safety, as well as global, cultural, social, environmental, economic, and other factors**

Engineers Must Understand the Critical Role of Ethics & Integrity to be an <u>Engineering Professional</u>!

Source: Internet

Engineering Professional

pro·fes·sion·al: a person who earns a living from performing engineering activities using the knowledge, skills, good judgment, and behaviors necessary to perform their specific role--subject to strict code of conduct enshrining rigorous ethical and moral obligations--as expected from a person who is trained to a job well.

Learn and/or strengthen the relevant skills and behaviors while practicing teamwork for capstone design project!

Ethics

eth·ics: values relating to human conduct, with respect to the ***rightness*** and ***wrongness of*** certain ***actions*** and to the ***goodness*** and ***badness*** of the ***motives and ends of such actions***.

Ethical Conduct:

Doing the RIGHT thing--always.

You Must Learn and Practice the Highest Standards of Ethical Conduct. Period.

Source: Internet; Dilbert.com

AIAA Code of Ethics

Members of the AIAA uphold the highest standards of ethical conduct and hereby agree to:

1. Hold paramount the safety, health, and welfare of the public in the performance of their duties;
2. Promote the lawful and ethical interests of AIAA and the aerospace profession;
3. Reject bribery, fraud, and corruption in all their forms;
4. Properly credit the contributions of others, accept and offer honest and constructive criticism of technical work; and acknowledge and correct errors;
5. Avoid harming others, their property, their reputations or their employment through false or malicious statements or through unlawful or otherwise wrongful acts;
6. Issue statements or present information in an objective and truthful manner, based on available data;
7. Avoid real and perceived conflicts of interest, and act as honest and fair agents in all professional interactions;
8. Undertake only those tasks for which we are qualified by training or experience, or for which we can reasonably become qualified with proper preparation, education, and training;
9. Maintain and improve our technical and professional competencies throughout our careers and provide opportunities for the professional development of those engineers under our supervision;
10. Treat fairly and respectfully all colleagues and co-workers, recognizing their unique contributions and capabilities.

Adopted 9 May 2013.

Applies to all aerospace professionals!

Ethical Conduct Isn't the Same as Legal Conduct

Ethical conduct has more to do with Morals & Values

Legal

- Based on laws created and enforced by government
- Observance of laws is mandatory
- Non-adherence is punishable

Ethical

- Based on codes of conduct or morals observed by a certain population
- Observance of ethical standards is voluntary
- Non-adherence may not be punishable

"Doing the Right Thing" Forces You to Face Ethical Dilemmas

Source https://difference.guru/difference-between-legal-and-ethical/

What is an Ethical Dilemma?

- **Competing values, rights, and goals are part of different options from which to choose a course of action**
- **Decision maker might potentially suffer personal harm**
- **Decision might cause harm to others**
- **There might be "Ripple Effects" of the decision: long term, far-reaching implications**

Source: www.csun.edu › Lecture Slides_Chapter Ethics

Resolving Ethical Dilemmas: *Some Recommendations*

- Identify **relevant facts**
- Identify **relevant issue(s)**
- Identify primary stakeholders
- Identify possible solutions
- Evaluate each possible solution
- Compare and **assess consequences**
- Decide on solution
- Take action

Source: www.csun.edu › Lecture Slides_Chapter Ethics

How to Evaluate Solutions: *Some Theories*

- **Stakeholder/utilitarian theory**: greatest good to the greatest number
- **Rights Theory**: Respecting and protecting individual rights to fair and equal treatment, privacy, freedom to advance, etc.
- **Justice Theory**: fair distribution of benefits and burdens: can harm to individual be justifiable?
- **Categorical Imperative**: “what if everyone took such action?”
- “**Front Page Test**:” What if my decision was reported on the front page of the *Los Angeles Times*?

Source: www.csun.edu › Lecture Slides_Chapter Ethics

When Making Decisions… Ask Yourself

Is it Safe?

Is it Legal?

Is it the Right thing to do?

Is it Just, Balanced, and Fair?

How will it make me feel about myself?

If something terrible happened, could I defend my actions?

Does this choice lead to the greatest good for the greatest number?

Source: www.csun.edu › Lecture Slides_Chapter Ethics

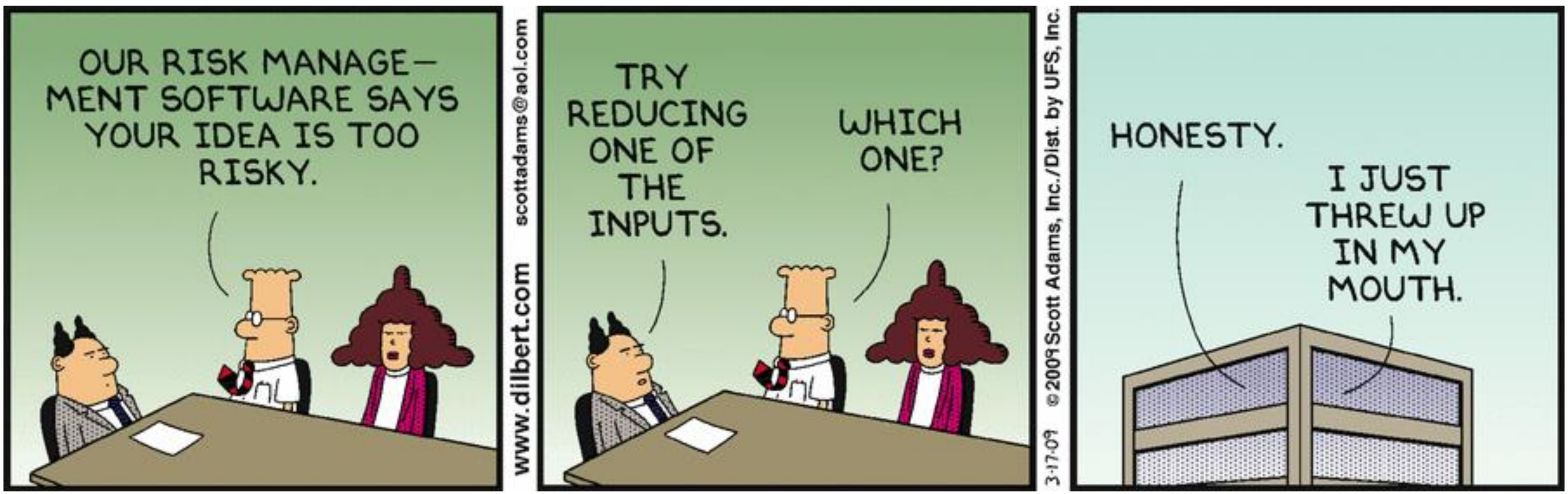
Ethical Compromise in Engineering is *Never* a Good Option

- **As an engineer, you won't routinely encounter serious ethical dilemmas. When you do, think it through and seek advice as appropriate**
  - Nine of the most dangerous words in the English language are: ***"If I ignore it, maybe it will go away"***
- **Most large companies and organizations have an Ethics office that allows employees to report or discuss ethics concerns confidentially**

Source: www.csun.edu › Lecture Slides_Chapter Ethics

Integrity

in·teg·ri·ty: individuals should be truthful, honest with themselves, complete tasks, honor debts, exceed expectations, keep promises, and have strong moral principles.



Source: Internet; Dilbert.com

Critical Importance of Integrity

"Integrity is doing the right thing even when no one is watching."

-- C.S. Lewis

"It takes twenty years to build a reputation and five minutes to ruin it."

-- Warren Buffet

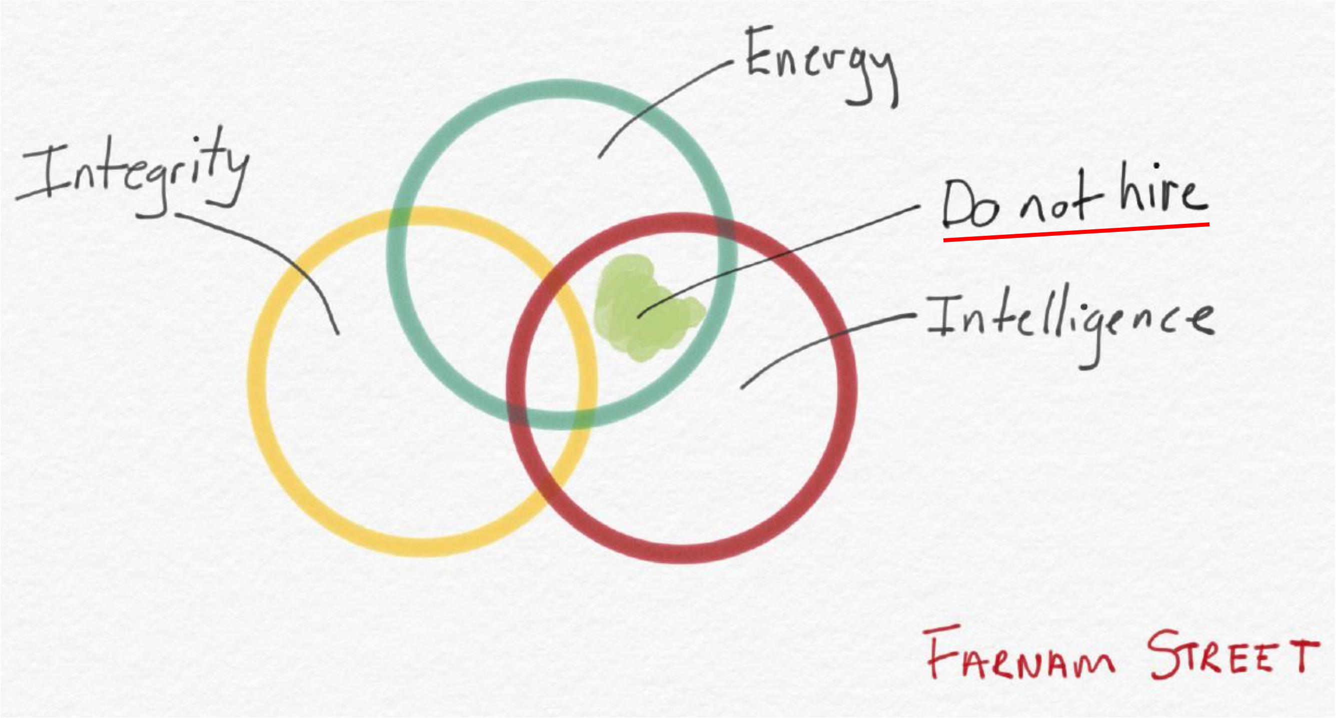
Nothing—Absolutely Nothing—is Worth Compromising Your Integrity

Source: Adapted from Wikipedia

"Integrity is up to You!"

Three Things Buffet is Looking For in a Person

"You're looking for three things, generally, in a person: intelligence, energy, and integrity. And if they don't have the last one, don't even bother with the first two."



"Everyone has the intelligence and energy. But integrity is up to you. You weren't born with it." *-- Warren Buffet*

Source: farnamstreetblog.com/2013/05/warren-buffet-the-three-things-i-look-for-in-a-person

Ethics and Integrity:
Real-life Challenges

Ford Pinto Gas Tank Controversy (1970s)

Four poorly arranged bolts protruded from the rear differential directly adjacent to the tank. In rear-end collisions over 25 mph, the protruding bolts punctured the exceptionally thin walls of the fuel tank, resulting in fuel leakage…a high chance of ignition, culminating in fatal consequences.

A cost-benefit analysis--weighing the cost of a $11 per car fix against the cost of settling cases including death or injury—guided management decision to make no changes.

https://en.wikibooks.org/wiki/Professionalism/The_Ford_Pinto_Gas_Tank_Controversy

VW Emissions Scandal (2010s)

Approximately 480,000 VW and Audi automobiles equipped with 2-litre TDI engines, and sold in the US between 2009 and 2015, had an emissions-compliance "defeat device" installed. Volkswagen had insisted for a year before the outbreak of the scandal that discrepancies were mere technical glitches.

Per 2016 final settlement…Volkswagen paid $2.7 billion for environmental mitigation and another $2 billion for clean-emissions infrastructure.

https://en.wikipedia.org/wiki/Volkswagen_emissions_scandal

Absolutely nothing is worth compromising your integrity!

Ethics and Integrity:
Real-life Challenges

https://www.youtube.com/watch?v=apZynV7lfic

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