Phase 3 Develop

DAEN 460 Capstone Senior Design

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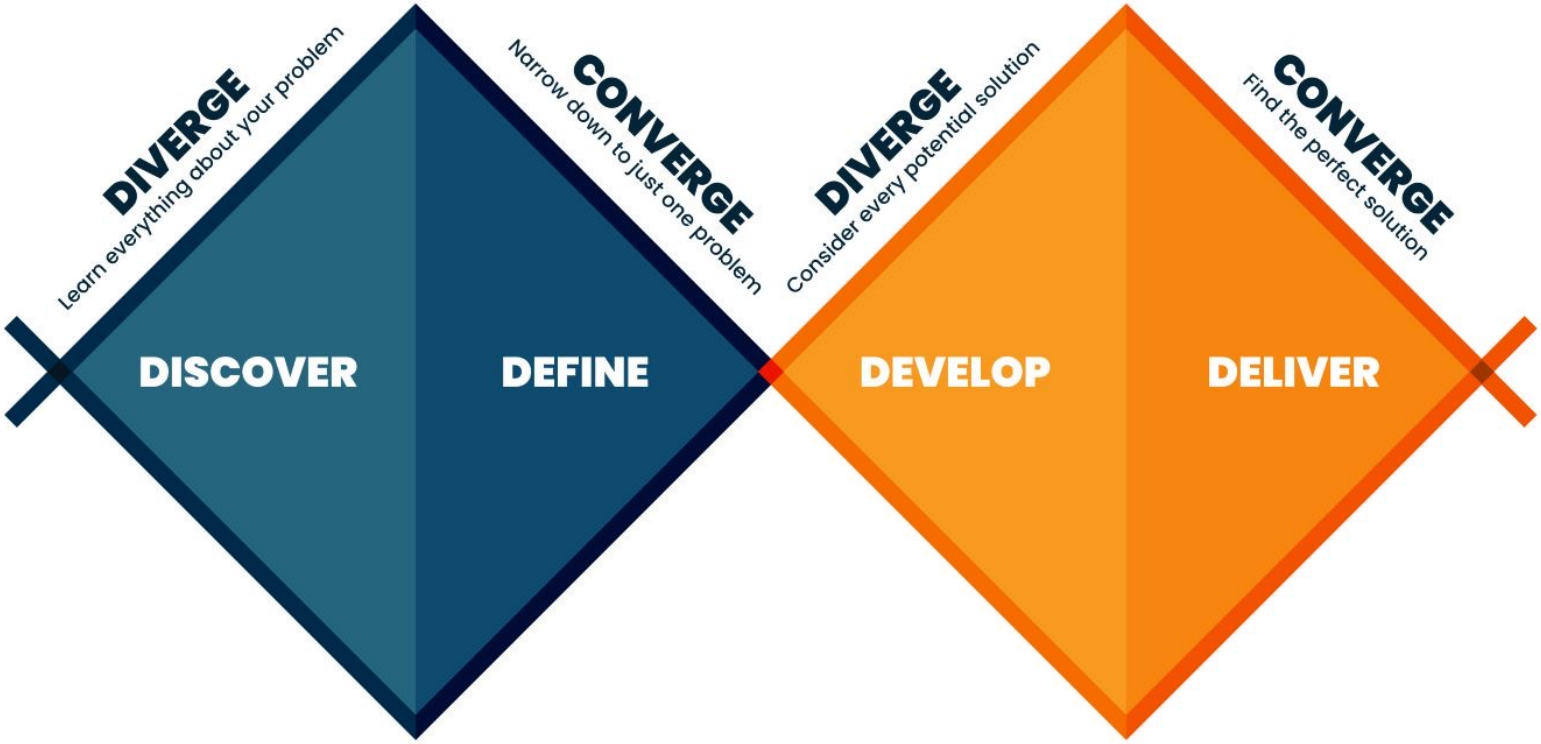
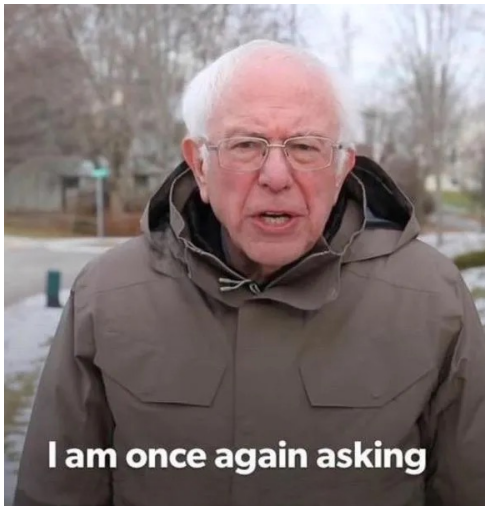
ENGINEERING
TEXAS A&M UNIVERSITY


DIVERGE
Learn everything about your problem
CONVERGE
Narrow down to just one problem
DIVERGE
Consider every potential solution
CONVERGE
Find the perfect solution
DISCOVER
DEFINE
DEVELOP
DELIVER

Today's Agenda

- **Introduction**
- **Comms activity**
- **Phase 3 Process and Requirements**
- **Research Project Decision Making Process**
  - **Costs**
  - **Constrains**
  - **Standards**



- **Critique** your own project against **learning outcomes** rather than technical checklists only!
  - You are **not** being graded on **reproducing** a solution but on the **quality of your thinking and decisions**!
- You're not just working alongside your peers, you're learning with them.
  - The goal is to move from individual results to shared success through real collaboration.
  - Peers are teammates, not just people doing the same assignment.
  - The aim is to build a culture of shared responsibility and genuine collaboration.
- Also, paying attention to **how** and **why** you think the way you do when learning!

Learning Outcomes (*syllabus*)

Ability to:

1. **Identify**, **formulate**, and **solve** complex engineering problems by applying principles of engineering, science, and mathematics.
2. **Apply engineering design** to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. **Communicate effectively** with a range of audiences.
4. **Recognize ethical and professional responsibilities** in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. **Function effectively on a team** whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks and meet objectives.
6. **Develop and conduct appropriate experimentation, analyze and interpret data** and use engineering judgment to **draw conclusions**.
7. **Acquire and apply new knowledge as needed**, using appropriate learning strategies.

Upcoming Semester Schedule

- 4/7 Phase 4 Kickoff
- 4/14 Phase 4 Presentations BH/COE
- 4/14 mandatory attendance for all 2:15-3:15 Senior Exit Interviews
- 4/21 Phase 4 Presentations ML
- 4/24 in-person, all day COE Showcase
  check schedule: https://tamueps.secure-platform.com/judges/
- 5/5 5 PM Final Report Due

Final/Phase 4 Presentation

- Welcome to invite sponsors to attend your presentation
- Please coordinate if you need to arrange parking for them

Awards Ceremony

- If your team wins an award in the showcase (either ISEN or overall), you will receive an email inviting you to the awards ceremony!
- There will be a lot of things going on that day (graduation, reception, etc.), but try to make the awards ceremony to have your picture taken with your team and instructors :)

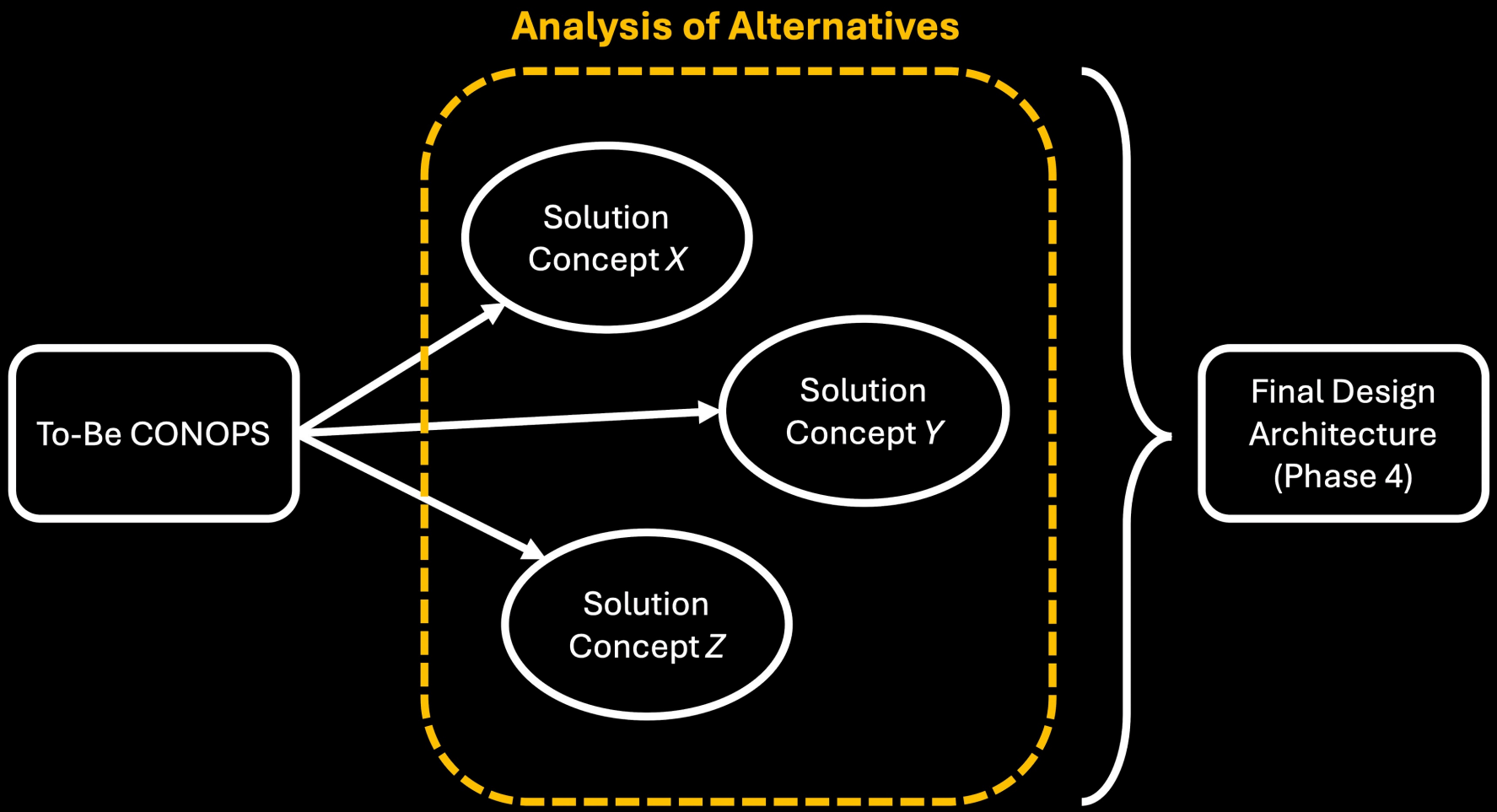
Peer Evaluation

- Peer Evaluation will be due after the final report
- You will be asked to rate your performance on the project as well as your teammates
- A grade (representing 12% of your overall grade) will be determined using:
  - Peer Evaluation ratings and comments
  - Class attendance/tardiness/participation
  - Instructors' observation of team participation/contribution

Comms Activity

Phase 3

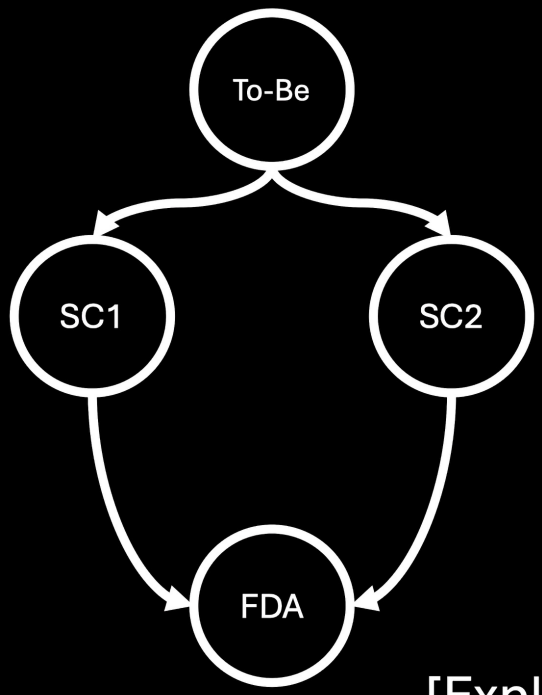
- Phase 3 is about moving into solutions
- You should be able to convert your "as-is" model into a "to-be" model
  - Addresses needs/requirements/actions previously defined
  - Model can be revision of as-is, or a new model (i.e. simulation)
- To-be model should be solution independent, it should be achievable in various ways
  - Solution Concepts

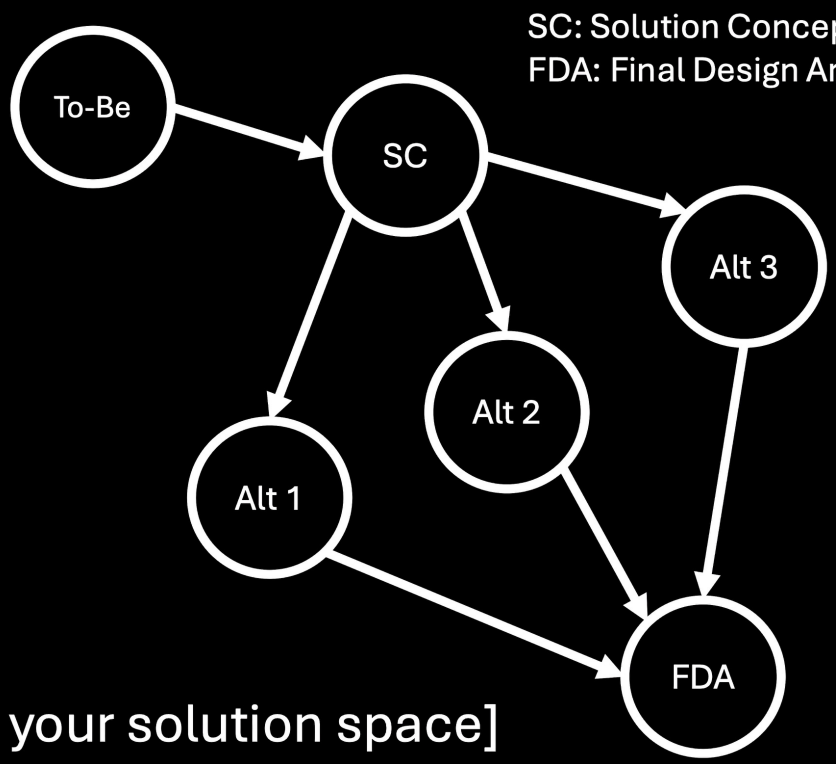

Analysis of Alternatives
To-Be CONOPS
Solution Concept X
Solution Concept Y
Solution Concept Z
Final Design Architecture (Phase 4)

Solution Concepts

- Develop various concepts that provide a solution to your problem
  - Even if you've decided on a path already, you should be able to present alternative solutions that you considered
- Screen out any concepts that are not feasible or practical
- Ensure that remaining concepts meet requirements (leading to "To-be")
  - Present concepts independent of evaluation criteria first

What if we know what we're going to do?





[Explore your solution space]

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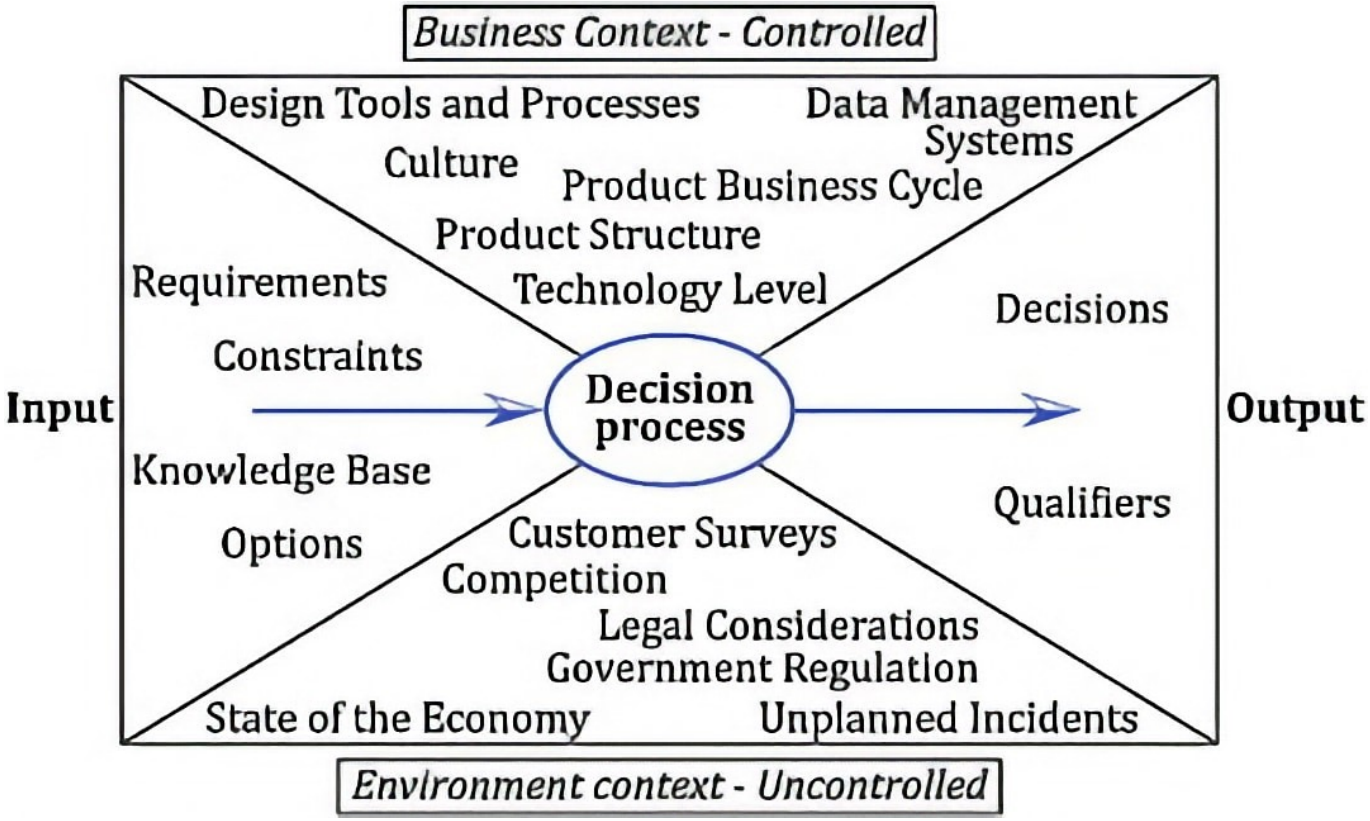
Keep in mind …

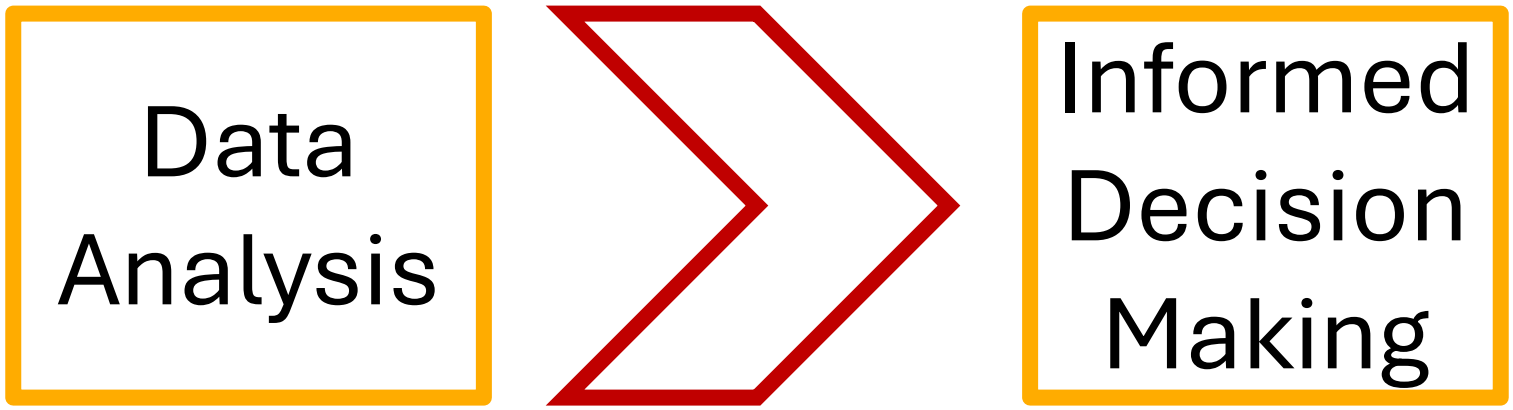
- Where has your sponsor given you the freedom to make an engineering decision?



- Hopefully, you have already made some progress regarding the solution you will be delivering your sponsor.
- It doesn't make sense to ***backtrack*** with your Analysis of Alternatives (AoA).
- By that, I mean:
  - If you are developing a data analytics tool, it is far less fruitful to compare platforms (VBA vs. PowerBI vs. Python vs. R vs. C/C++ vs. Java, etc.) than compare algorithmic approaches.
- **Refining Rather than Restarting**: You've already done significant work in defining needs, requirements, and engineering actions.
- AoA helps **refine** and **validate** your direction **rather** than sending you back to *square one*.

- **Data-Driven Justification**

  AoA quantifies trade-offs so that you can justify your final solution selection with **economic**, **risk**, and **performance-based** reasoning.



Evaluation Criteria

- Develop the criteria to be used to evaluate concepts
  - Engineering standards
  - Constraints
  - Economic
- All the above must be considered in your evaluation (ABET requirement)
  - Economic analysis can be estimation of costs and/or benefits but must be appropriate and as thorough as possible.

Costs

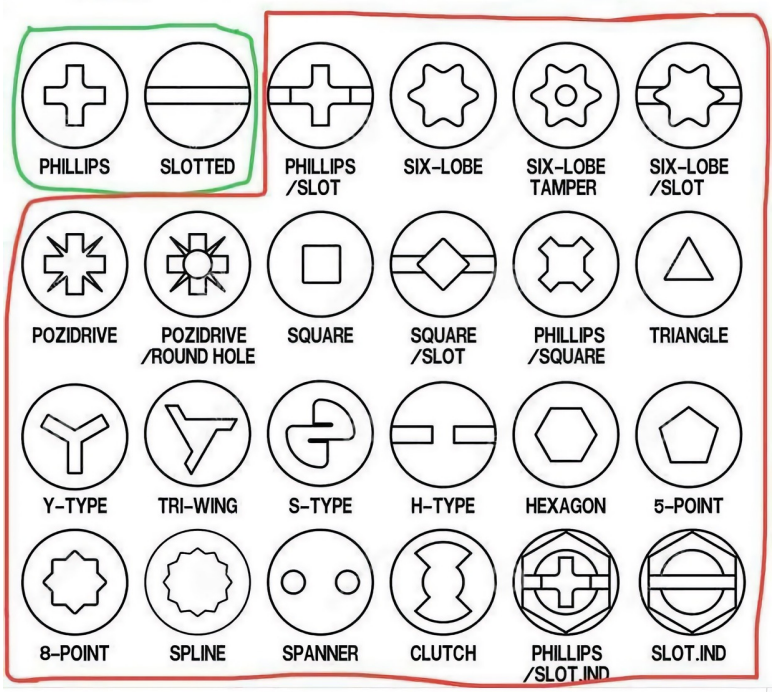
- Every engineering decision has a *price tag*.
- Cost isn't just the price of parts; it's a multi-variable equation that dictates whether a product is viable or sustainable.
  - **Fixed vs. Variable**: You must account for one-time research and development (R&D) costs versus the recurring cost of materials and labor.
  - **Life-Cycle Costs**: Modern engineering looks beyond the "shelf price" to include maintenance, energy consumption, and eventual disposal or recycling.
  - **The Trade-off**: Reducing costs often impacts quality or performance, a constant tug-of-war known as "value engineering."

Constraints/Boundaries

- Constraints are the non-negotiable limits within which the solution must exist.
- If the design process is a sandbox, the constraints are the wooden walls.
  - **Physical**: Limits on size, weight, material properties, and power consumption.
  - **Environmental**: Requirements for temperature resistance, humidity, or operating in a vacuum.
  - **Resources**: Limited time (deadlines), available manpower, and specific manufacturing equipment.

Standards (A Universal Language)

- Standards are the agreed-upon rules and technical specifications that ensure safety, reliability, and interoperability. Without them, your lightbulb might not fit into a socket made by a different company.
- **Safety & Compliance**: Regulatory bodies (like OSHA or the FAA) mandate standards to prevent catastrophic failure and protect the public.
- **Interchangeability**: Standards like ISO or ASME ensure that parts from different global suppliers work together seamlessly.
- **Quality Benchmarks**: Following established standards provides a baseline for "what good looks like," reducing the risk of design flaws.



Screw standards define the dimensions, thread pitch, and tolerances for fasteners to ensure interchangeability and strength, with the two primary systems being the Unified Thread Standard (UTS/Imperial) in North America and ISO Metric worldwide. Key standards include ISO 68-1 for metric, and ASME B1.1 for unified inch threads (UNC/UNF).

Establish & Evaluate

- **Define measurable evaluation criteria**
- **Score solutions, prioritize feasibility**
- **Consider cost, efficiency, & scalability**

Analyze & Select

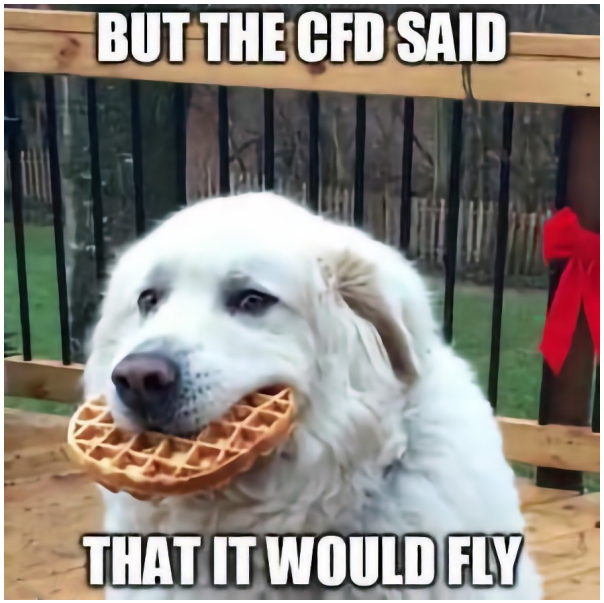
- Conduct trade-off analysis: Performance, cost, & risk analysis
- Adjust for scenario & assumption changes
- Select solution, justify with criteria

Document & Present

- Document process & findings clearly
- Use visuals with salient results

Concept Evaluation

- Evaluate concepts based on criteria
  - **Score and/or rank them** (PUGH Chart, WDM, …)
  - **Include trade-off analysis** (advantages/disadvantages)
- Select a best concept to move forward with detailed design and analysis



PS. Computational Fluid Dynamics (CFD)

Establish & Evaluate

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Solution Concept Identification

- Create a Summary Table

	Concept 1	Concept 2	Concept 3
Description	Playbook	Pivot Table	Database
RN Data Collection	None	Minimum	Maximum
Orientation Time	Static	Slow-Dynamic	Dynamic
Development Time	Little to none	Medium	Will take lots of time
Cost Per Facility	$300	$1000	$15000
Risk	Low	Moderate	High
Performance	High	Moderate	Low

Cost Analysis

Year	Depreciation Rate	Depreciation Charge	Net Book Value
0	---	---	$ 5,800.00
1	20.00%	$ 1,160.00	$ 4,640.00
2	32.00%	$ 1,856.00	$ 2,784.00
3	19.20%	$ 1,113.60	$ 1,670.40
4	11.52%	$ 668.16	$ 1,002.24
5	11.52%	$ 668.16	$ 334.08
6	5.76%	$ 334.08	$ -

Cost per cart: $290
Number of carts: 20

Year	Depreciation Rate	Depreciation Charge	Net Book Value
0	---	---	$ 6,400.00
1	20.00%	$ 1,280.00	$ 5,120.00
2	32.00%	$ 2,048.00	$ 3,072.00
3	19.20%	$ 1,228.80	$ 1,843.20
4	11.52%	$ 737.28	$ 1,105.92
5	11.52%	$ 737.28	$ 368.64
6	5.76%	$ 368.64	$ -

Cost per cart: $320
Number of carts: 20

Year	Depreciation Rate	Depreciation Charge	Net Book Value
0	---	---	$10,000.00
1	20.00%	$ 2,000.00	$ 8,000.00
2	32.00%	$ 3,200.00	$ 4,800.00
3	19.20%	$ 1,920.00	$ 2,880.00
4	11.52%	$ 1,152.00	$ 1,728.00
5	11.52%	$ 1,152.00	$ 576.00
6	5.76%	$ 576.00	$ -

Cost per cart: $500
Number of carts: 20

Costs				
Critical Quality	***Weight*** *(1 being least important, 10 being most important)*	**Playbook**	**Pivot Table**	**Database**
Upfront Investment	7	-1	0	1
Maintenance	6	-1	0	1
Personnel	5	0	0	-1
Technology	3	-1	0	1
Administrative	6	0	0	1
Regulatory & Compliance	9	-1	-1	1
Insurance Coverage	6	-1	-1	1
Improvements	3	0	0	1
Miscellaneous Expenses	3	-1	0	1

Summary Table			
Total "1s"	0	0	8
Total "0s"	3	7	0
Total "-1s"	6	2	1
Total	-34	-15	38

This could be presented, but there must be analysis to back up the assigned values

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Avenues for Economic Analysis

- Opportunity Cost Exploration
- Sensitivity Analysis
- Cost-Benefit Analysis
- Break-Even & Payback Period

The options for analysis shown in this presentation are by no means an exhaustive list.

Search for the methods which best utilize the dimensions in which you'll be comparing your alternatives.

For Capstone Context

- **Lower bound**: typical prototype or academic implementation using managed cloud services and limited data.
- **Upper bound**: closer to small production pilot projects with stronger infrastructure and security.
- Cost components typically include:
  - Cloud infrastructure (storage, compute)
  - Data ingestion tools
  - Engineering labor
  - Data governance / compliance
  - Visualization or ML integration

Typical Cost Components

- These ranges usually reflect several major categories:

Cost Component	Typical Share of Budget
Engineering Labor	40–60%
Cloud Compute	15–25%
Storage	10–20%
Data Pipeline & Orchestration Tools	5–15%
Monitoring, Security, Governance	5–10%

Associated Project Costs by Industry

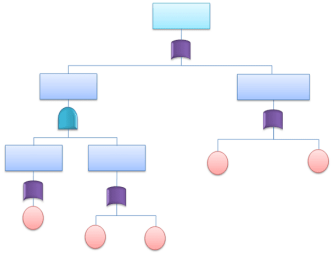
Industry	Example Data Engineering Project	Typical Data Sources	Infrastructure Needs	Estimated Project Cost (USD)
Healthcare	Patient data integration & analytics pipeline	EHR systems, lab records, insurance claims	Secure storage, HIPAA-compliant cloud, ETL pipelines	$20,000 – $80,000
Finance / Banking	Fraud detection data platform	Transaction logs, customer accounts, market feeds	Streaming ingestion, real-time processing, high security	$30,000 – $120,000
Retail / E-Commerce	Customer behavior & recommendation pipeline	Website logs, purchase history, inventory data	Data warehouse, streaming analytics, ML integration	$15,000 – $70,000
Manufacturing	IoT predictive maintenance pipeline	Sensor data, machine logs, maintenance records	Edge ingestion, time-series storage, streaming ETL	$25,000 – $90,000
Transportation / Logistics	Fleet tracking and route optimization data system	GPS data, vehicle telemetry, delivery records	Real-time pipelines, geospatial processing	$20,000 – $85,000
Energy / Utilities	Smart grid or energy usage analytics pipeline	Smart meter data, weather feeds, grid telemetry	Large-scale time-series processing, distributed storage	$30,000 – $100,000
Telecommunications	Network performance monitoring platform	Call detail records, network logs, usage metrics	High-volume ingestion, distributed processing	$40,000 – $150,000
Social Media / Marketing	Social sentiment and engagement analytics	Social APIs, campaign metrics, clickstream data	Data lake, NLP pipelines, batch + streaming	$10,000 – $50,000
Government / Public Sector	Open data integration and transparency dashboards	Census data, city infrastructure data, public records	Data lakehouse, visualization layer	$15,000 – $60,000
Education	Student performance analytics pipeline	LMS logs, enrollment data, course performance	Data warehouse, batch processing, BI dashboards	$8,000 – $40,000

Dataset Size vs. Estimated Data Engineering Project Cost

Dataset Size	Example Scale	Typical Technologies	Infrastructure Complexity	Estimated Project Cost (USD)
< 1 GB	Small structured datasets, CSV files, API pulls	Python, Pandas, SQLite, simple ETL scripts	Very Low	$1,000 – $5,000
1 – 10 GB	Small relational databases, multiple APIs	Python ETL, PostgreSQL, basic orchestration	Low	$3,000 – $12,000
10 – 100 GB	Moderate analytics datasets, event logs	Airflow/Prefect pipelines, cloud storage, data warehouse	Medium	$8,000 – $30,000
100 GB – 1 TB	Clickstream data, IoT telemetry, transaction logs	Spark, cloud data lake (S3/Azure/GCS), orchestration tools	Medium–High	$20,000 – $80,000
1 – 10 TB	Large enterprise datasets, multi-source integration	Distributed compute (Spark/Databricks), streaming pipelines	High	$50,000 – $200,000
10 – 100 TB	Enterprise-scale historical analytics	Data lakehouse architectures, scalable orchestration	Very High	$150,000 – $600,000
100 TB+	Large-scale platforms (telecom, social media, finance)	Distributed storage, real-time ingestion, advanced governance	Enterprise	$500,000 – $2M+

Risk Analysis Resources

- **Fault Tree Analysis** (FTA)
  https://sixsigmastudyguide.com/fault-tree-analysis/



- **Pugh Analysis**
  https://sixsigmastudyguide.com/pugh-analysis/

	Baseline		A	B	C	D
Criteria						
1	0		+1	-1	0	+1
2	0		0	-1	0	+1
3	0		+1	-1	+1	0
4	0		-1	0	0	+1

- **Failure Mode Effects Analysis** (FMEA)
  https://sixsigmastudyguide.com/failure-mode-effects-analysis-fmea/

Process step	Potential failure mode	Potential effects of failure	Cause of failure	Severity	Occurrence	Detection	RPN
Get details from Level 1 support team.	Customer details not passed on correctly	Decreased service rating	Operator error	5	2	7	70
	Support ticket delayed	Increased call time	Network failure	4	3	9	108
Ask customer to run a diagnostic test and email the results.	Customer doesn't understand instructions	Increased call time	Lack of automation	8	6	10	480
	Customer refuses	Decreased service rating	N/A	8	2	10	160
	Customer fails to send results	Lost/inconclusive support case	N/A	6	4	9	216
Analyze results to find any issues.	Incorrect analysis	Decreased service rating	Insufficient training	9	3	4	108
	Can't find any issues	Lost/inconclusive support case	N/A	5	6	10	300
Explain analysis to customer.	Customer doesn't understand explanation	Increased call time	Lack of clear explanation?	5	5	8	200
	Customer refuses results	Decreased service rating	N/A	7	2	9	126
Fix problem if it's within Level 2 abilities. If not, refer up to Level 3 support team.	Support ticket not filled out correctly	Decreased service rating	Operator error	5	1	6	30
	Customer angry about delay	Decreased service rating	N/A	7	2	8	112

Engineering Standards

- **Data Quality & Governance**
  - ISO/IEC 8000 – **Data Quality Standard**: Defines requirements for reliable and accurate data across systems.
  - **ISO/IEC 11179 – Metadata Registry Standard**: Governs how data elements and metadata should be defined and documented.
  - **ISO/IEC 38505 – Data Governance Framework**: Defines governance practices for managing organizational data.
  - **General Data Protection Regulation** (GDPR)
- **Data Management Body of Knowledge**
  - DAMA International Data Management Framework (DMBOK): Widely used reference covering: data governance, data architecture, data quality, master data management, metadata management
- **Data Architecture**
  - The Open Group TOGAF Enterprise architecture framework often used in data platform design.
  - World Wide Web Consortium standards (JSON, XML, RDF, etc.) that govern structured data exchange.
  - ISO/IEC 9075 – SQL Standard: The formal specification behind relational databases.
- **Data Security Standards**
  - **ISO/IEC 27001 – Information Security Management**
  - National Institute of Standards and Technology Cybersecurity Framework

  These can govern encryption, access control, auditing, breach management.

Engineering Standards

- **Manufacturing**: ASME Y14.5 (GD&T), ASTM Standards, ISO 2768 (General Tolerances), ISO 9001, ANSI Standards, IPC Standards, API Standards
- **Aerospace & Defense**: AS9100, ASME Standards, ASTM F519, MIL-STD-810 (Environmental Engineering), MIL-STD-461 (EMC), RTCA DO-160 (Environmental Testing), SAE AS Standards, ISO 9100 Series
- **Healthcare**: ISO 13485, IEC 60601 (Medical Electrical Equipment), ISO 14971 (Risk Management), ASTM Standards (Medical Devices), FDA 21 CFR Part 820 (Quality Systems Regulation), ANSI/AAMI Standards
- **Food Industry**: ISO 22000 (Food Safety Management), 3-A Sanitary Standards, ANSI/NSF Standards, ASTM Food Packaging Standards, EHEDG (European Hygienic Engineering & Design Group), GMP Engineering Standards

Engineering Constraints

- **Manufacturing**: Cost, Production efficiency, Material availability, Manufacturing tolerances, Environmental regulations, Equipment limitations, Safety and ergonomics, Time constraints
- **Aerospace & Defense**: Weight constraints, Aerodynamics, Thermal management, Regulatory compliance (FAA, ITAR), Material strength and fatigue, Electromagnetic compatibility (EMC), Reliability and redundancy, Environmental resistance
- **Healthcare**: Biocompatibility, Sterilization requirements, Patient safety, Regulatory compliance (FDA, ISO), Ergonomics and usability, Reliability and maintainability, Data security (HIPAA), Precision and accuracy
- **Food Industry**: Hygienic design, Material safety and compatibility (food-grade materials), Regulatory compliance (FDA, HACCP), Temperature control, Shelf life, Sanitation and cleaning ease, Packaging integrity, Product contamination prevention

The whole point of …

1. Developing a To-Be CONOPS
2. Generating solution concepts
3. Conducting analysis of alternatives

… is to prove to your sponsor **why they can trust you!**

The work you've done in phases 1 and 2 show that you understand their system and what needs to be done.

Now, you're showing them that you're confident you've arrived at the best possible means of system transformation.

Phase 3 Guidelines

On Canvas

Project Recap

- In addition to displaying your problem statement in the introduction, provide a project recap.
- A slide or two (visuals are good) explaining the "why" of your project and your efforts to date.
- This is likely going to be included in your showcase video as a project introduction.
- Think of it as your "elevator pitch", but along with a minute or so to talk, you'll have visuals to back it up.

To-be Conops

- If your to-be system is a modification of the as-is system, briefly show the as-is (with limited explanation).
- Focusing on your system requirements, introduce where changes to the system will convert it from "as-is" to "to-be".
- Avoid too much detail here, keep it solution neutral.

Research Projects

- For research projects, your model may not change (significantly), but point out which parts of the as-is model that your research will potentially impact.
- Ensure that your projected research deliverables address the requirements you defined in Phase 2.

Solution Concepts

- With a solution neutral to-be model, you can generate various concepts to enable the desired changes.
- Even if you've already moved towards a solution, you need to present alternatives you considered.
- For research projects, you'll want to present areas of research you considered.

Analysis of Alternatives

- Using the criteria you defined (constraints and standards included), compare your alternatives.
- Present in a clear, non-technical way. Include any technical back-up in the appendix.
- For research projects, you'll want to analyze what you could gain from research you considered and use criteria to compare and decide the area(s) you decided to focus on.

Selection of Alternative

- End the Analysis of Alternatives with a clear indication of the concept you selected.
- Don't provide a bunch of design details, that'll follow in Phase 4.

Traceability

- Unless you've added or modified requirements or actions, traceability here will be the same as in Phase 2.
- If you've added, just note what you've added.
- More detail on traceability will be presented in Phase 4.

Research Project Decision Making

- Results and decision making for research projects may look different from applied projects.
- However, the process and decisions made should still reflect the initial information gathering and modeling process
  - Some decisions about areas to research should have been made.
  - Areas that can affect the "as-is" state should be the areas of focus.
  - Areas of research that indicates previous attempts to improve a process are important for comparisons.
  - Constraints and standards are important and specific research into them should be highlighted.

"You never achieve what you want without falling on your face a few times."

Steve Jobs

Nice reading: https://book.stevejobsarchive.com

Listen Well everyone
Great is the problem of Life and Death
No forever gone gone
Awake Awake each one
Dont waste your life

dd buddhist poem