Information Flow and Decision-Making in Advanced Vehicle Development

Presented by:

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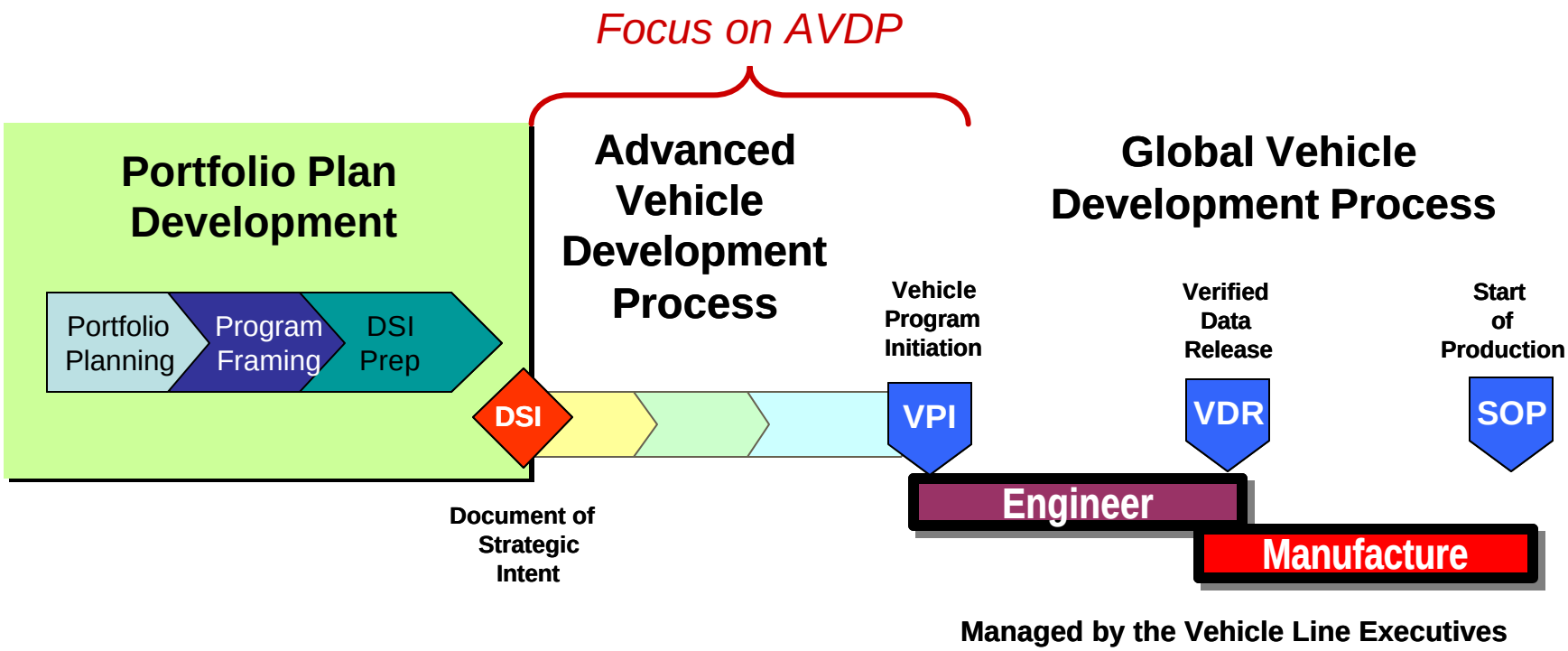
General Motors Research & Development Center

GM's Vehicle Development Process



Motivating Questions

1. To what extent can iteration be removed from the design process?
2. What are the triggers for generation, storage, and distribution of information in product development?
3. How can uncertainty be characterized and managed throughout the execution of the product development process?
4. What is the role of the engineer in decision-making?

Approach

- Apply leading-edge methods to model GM's Advanced Vehicle Development Process (AVDP)
  - Design Structure Matrix (DSM)
  - Decision Analysis (DA)
- Analyze models to gain insight into AVDP execution
  - Insights from individual models
  - Composite insights from both models

Contributors

DSM Model

GM R&D Center

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MIT CIPD

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DA Model

GM R&D Center

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Stanford University

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- Christopher Han
- John Feland
- Ronald Howard
- Ross Shachter

The Design Structure Matrix (DSM)

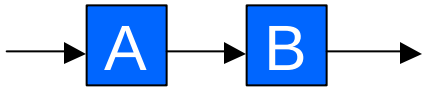
What is a Design Structure Matrix?

- A Design Structure Matrix (DSM) is a compact, matrix representation of a system/project.
- The matrix contains a list of all constituent subsystems/activities and the corresponding information exchange and dependency patterns.

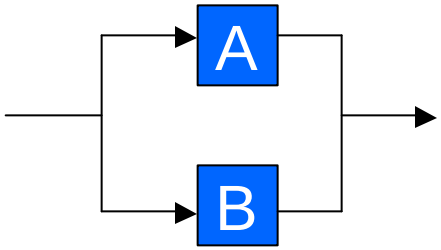
	A	B	C	D	E	F
A						
B	X					
C	X	X				
D		X				
E	X	X		X		X
F					X	

Information Flows & Task Sequencing

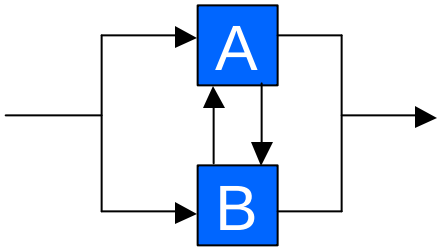
Three possible sequences for two tasks:



Dependent
(Series)

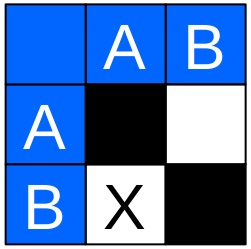


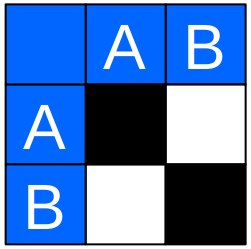
Independent
(Parallel)

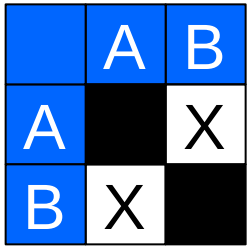


Interdependent
(Coupled)

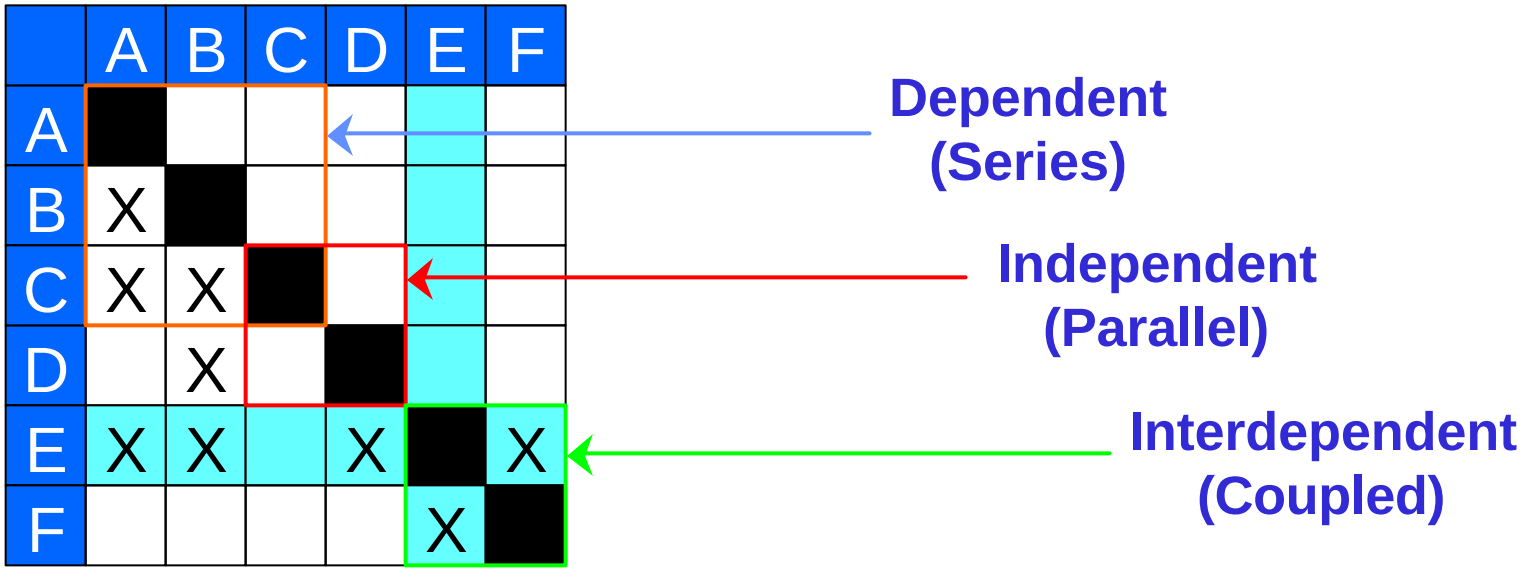
In DSM notation:







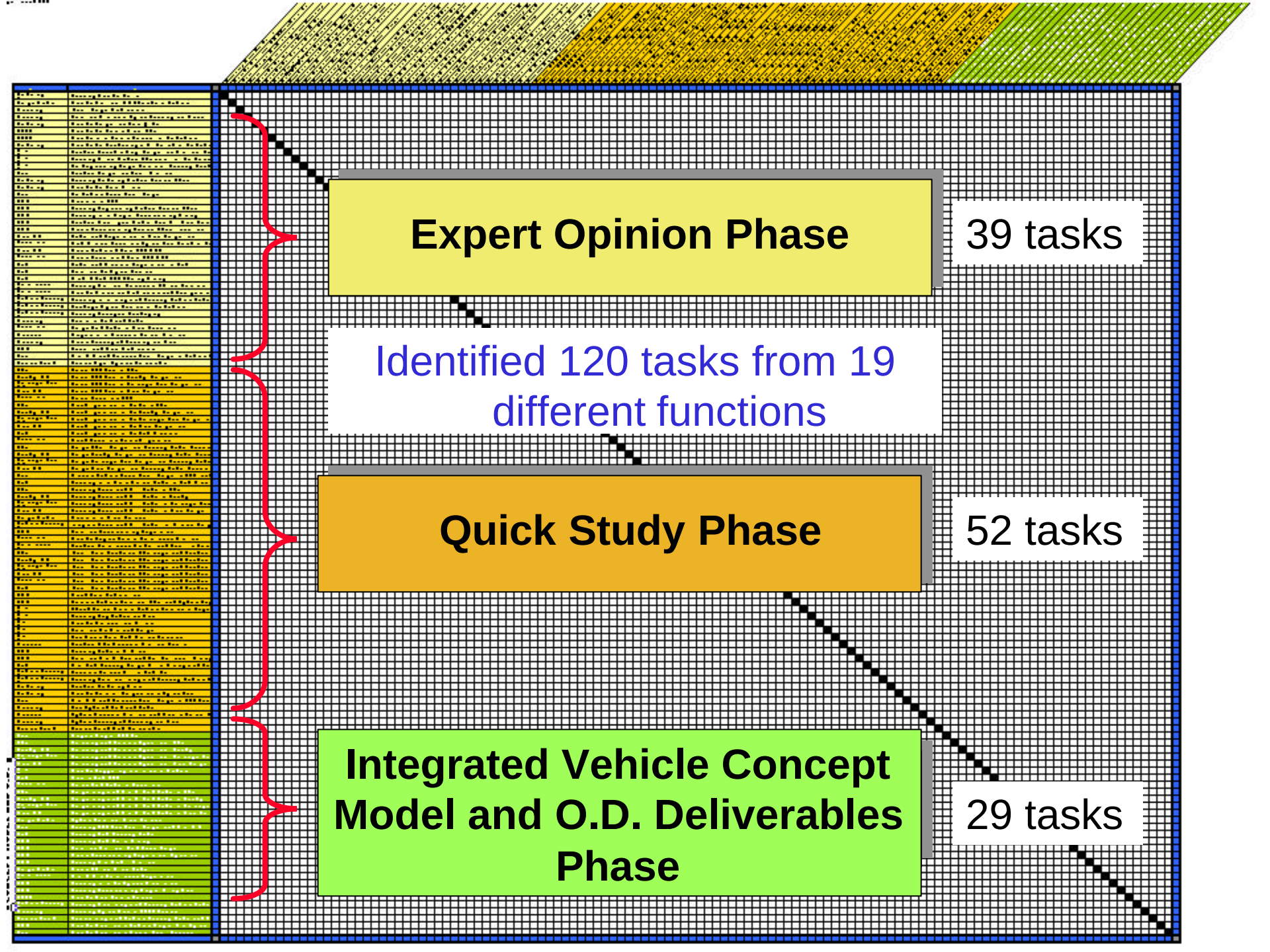
Reading the DSM

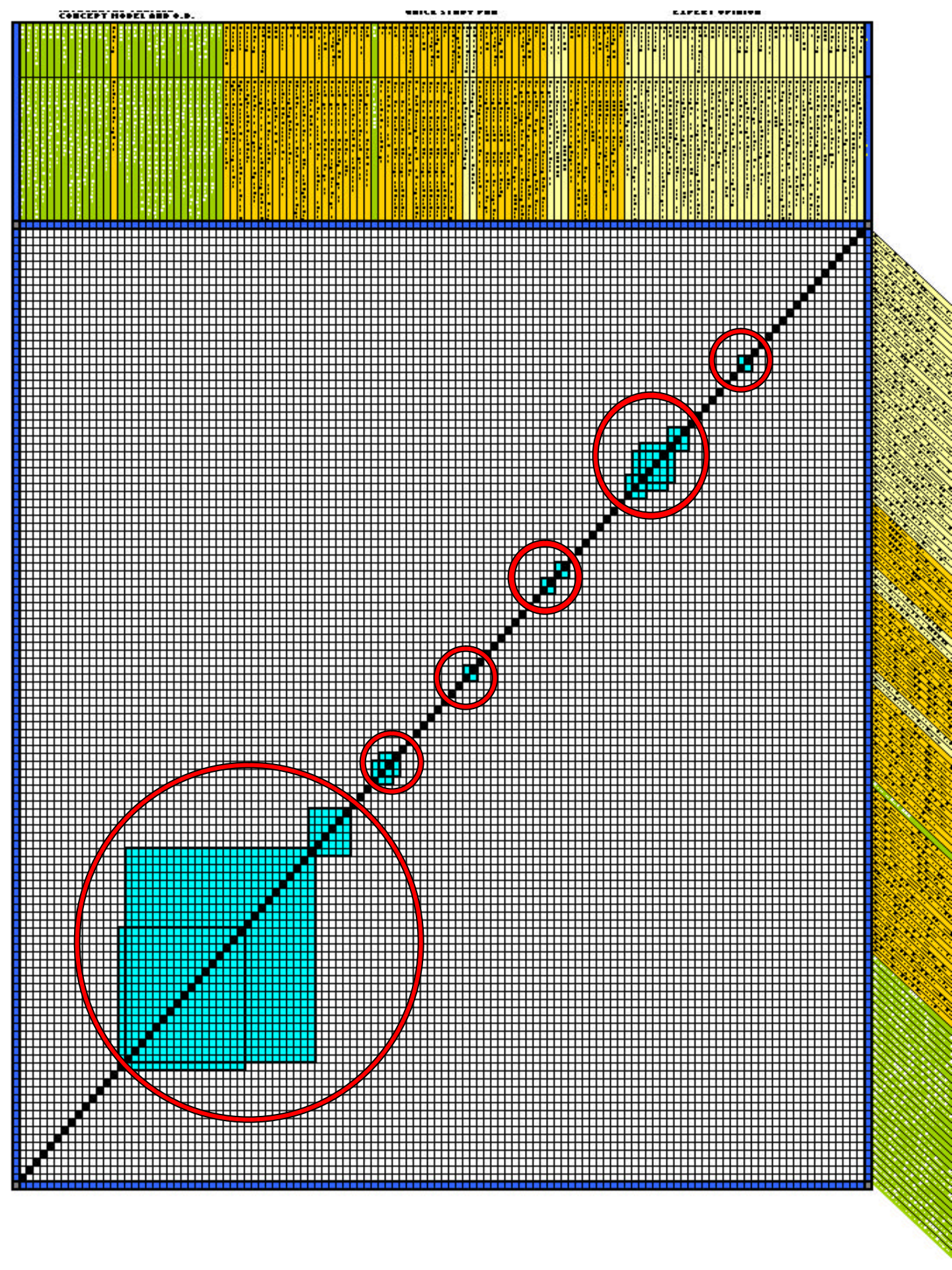


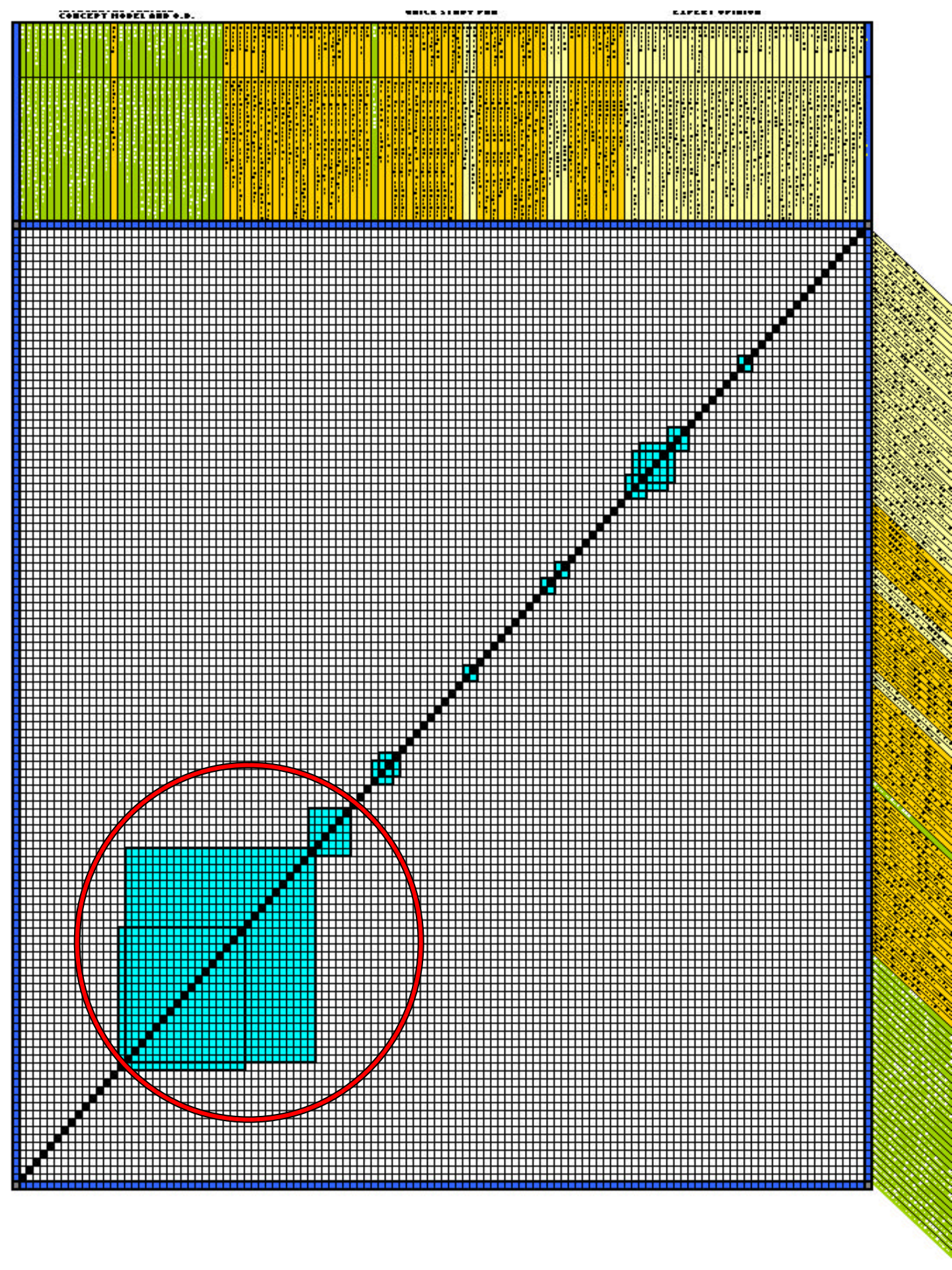
- Marks along the ***rows*** indicate ***inputs***
  (i.e. Task E receives inputs from tasks A, B, D and F)
- Marks along the columns indicate outputs
  (i.e. Task E provides an output to task F)

Key Functions Interviewed:

- Product Planning
- Marketing
- Finance
- Design Studio
- Program Management Team
- Quality
- Vehicle Integration Engineering
- Manufacturing Engineering
- Packaging Engineering
- Systems Engineering
- Body Engineering
- Chassis Engineering
- Powertrain Engineering


Expert Opinion Phase
39 tasks
Identified 120 tasks from 19 different functions
Quick Study Phase
52 tasks
Integrated Vehicle Concept Model and O.D. Deliverables Phase
29 tasks


CONCEPT MODEL AND 4.0.
EXPERT OPINION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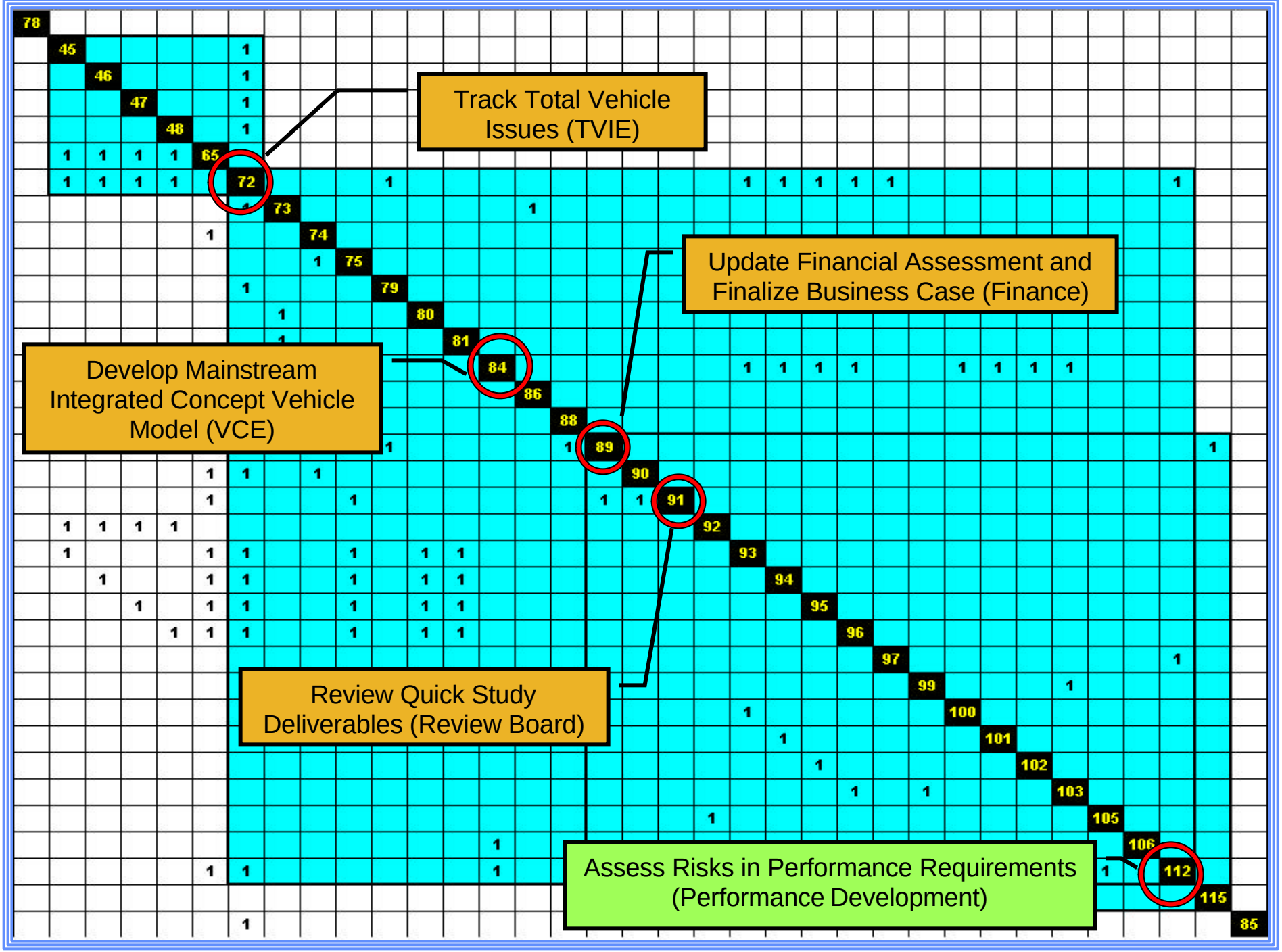
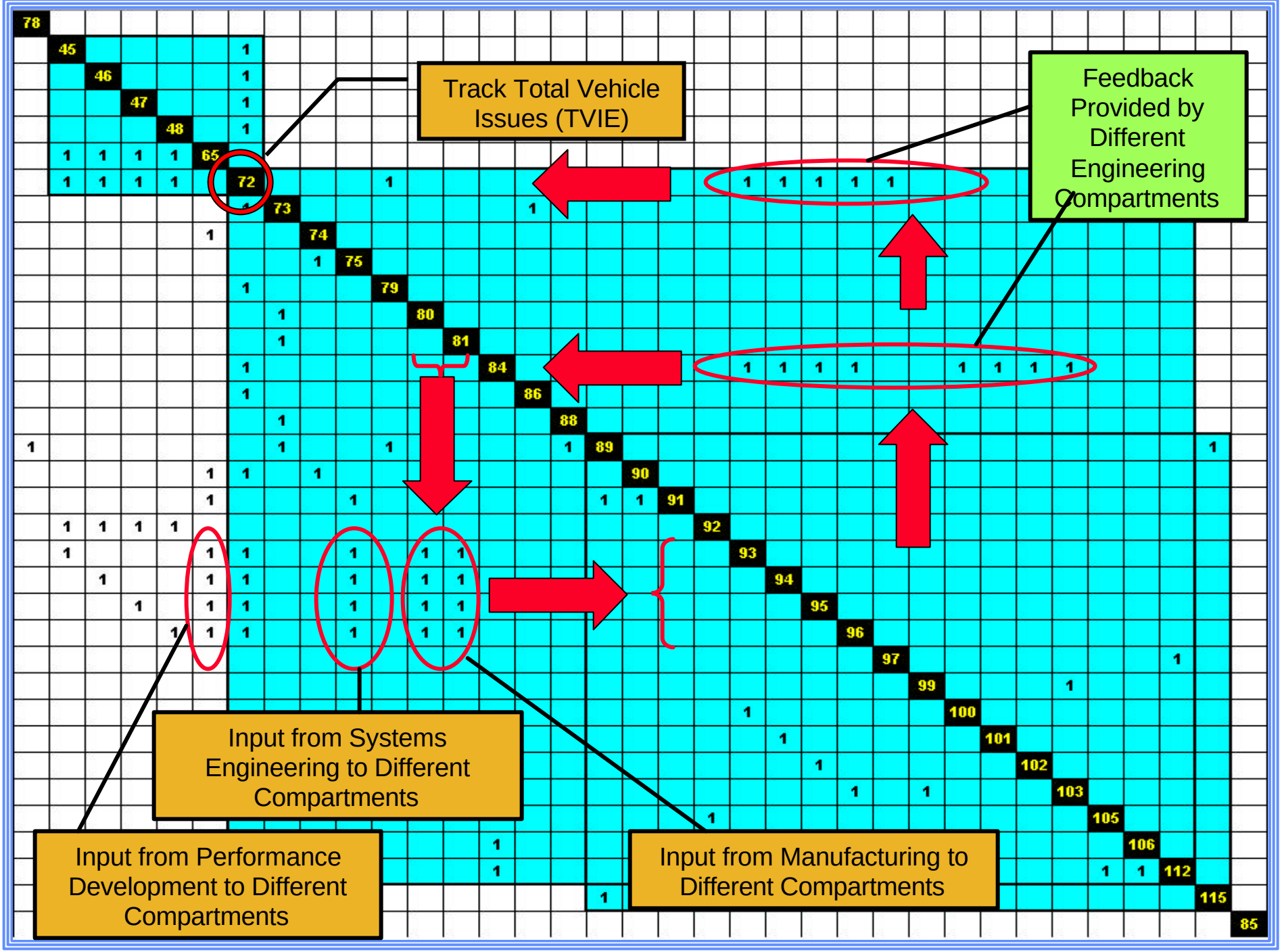
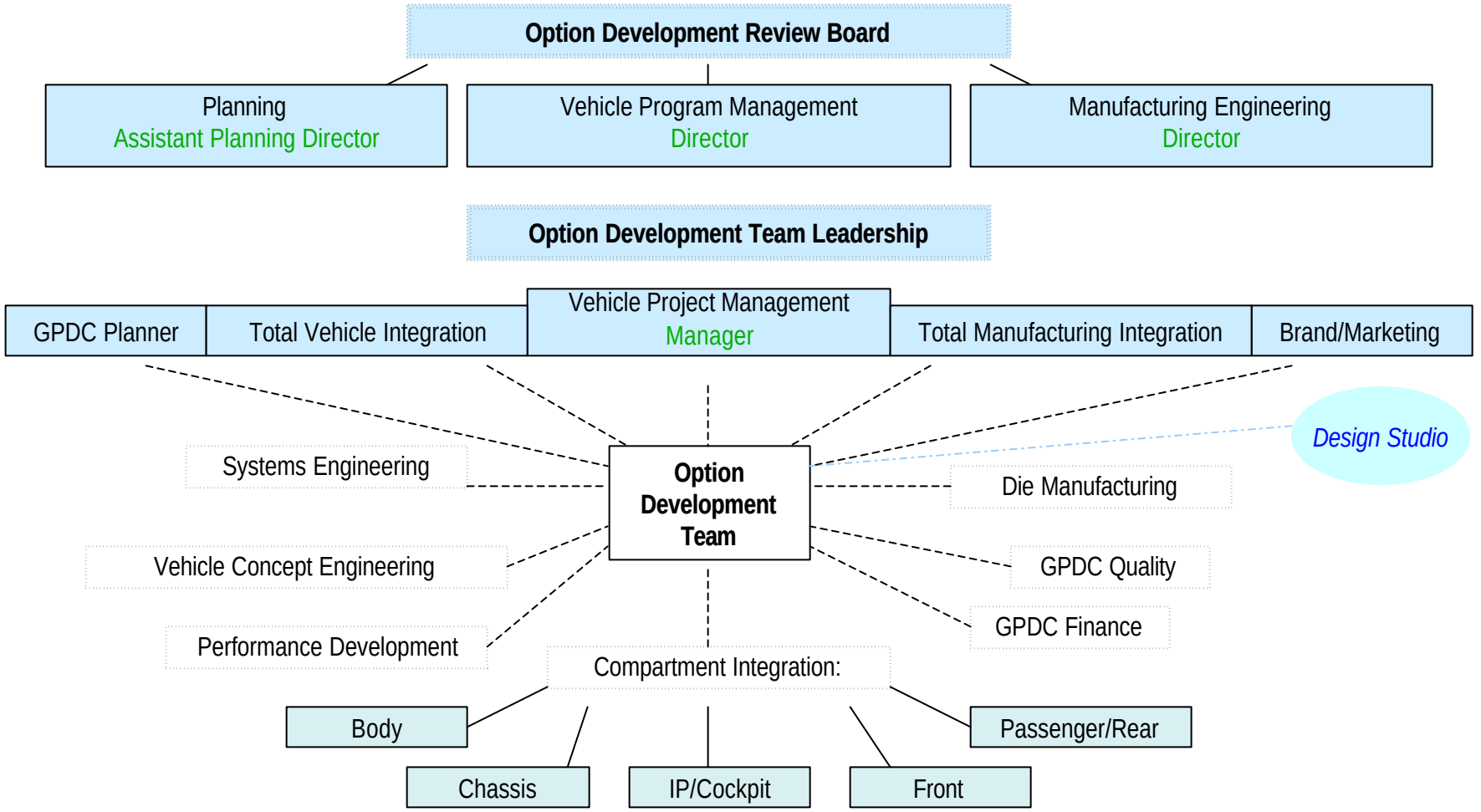

Track Total Vehicle Issues (TVIE)
Update Financial Assessment and Finalize Business Case (Finance)
Develop Mainstream Integrated Concept Vehicle Model (VCE)
Review Quick Study Deliverables (Review Board)
Assess Risks in Performance Requirements (Performance Development)


Track Total Vehicle Issues (TVIE)
Feedback Provided by Different Engineering Compartments
Input from Systems Engineering to Different Compartments
Input from Performance Development to Different Compartments
Input from Manufacturing to Different Compartments

Team Structure



Team Meetings

Option Planning Team

Performance Integration Team

VAPIR
(Vehicle and Process Integration Review)

Design Center Interface

Typical Section Team

Compartment Integration Teams

Front & Chassis | Body | IP/Cockpit | Passenger/ Rear

Supplier Design Reviews

Insights from DSM Model (1)

Iteration in design process

- Extensive in 2nd phase of AVDP
- Contributing factors:
  - Investigations of alternatives to mainstream design
  - Coordination of work across disciplines
  - Tremendous complexity in subsystem interactions

Generation and distribution of information

- Highly structured - Largely driven by templates
- Centrally stored
- Often reviewed in “town hall” meetings
- Ad-hoc networks arise as needed

Insights from DSM Model (2)

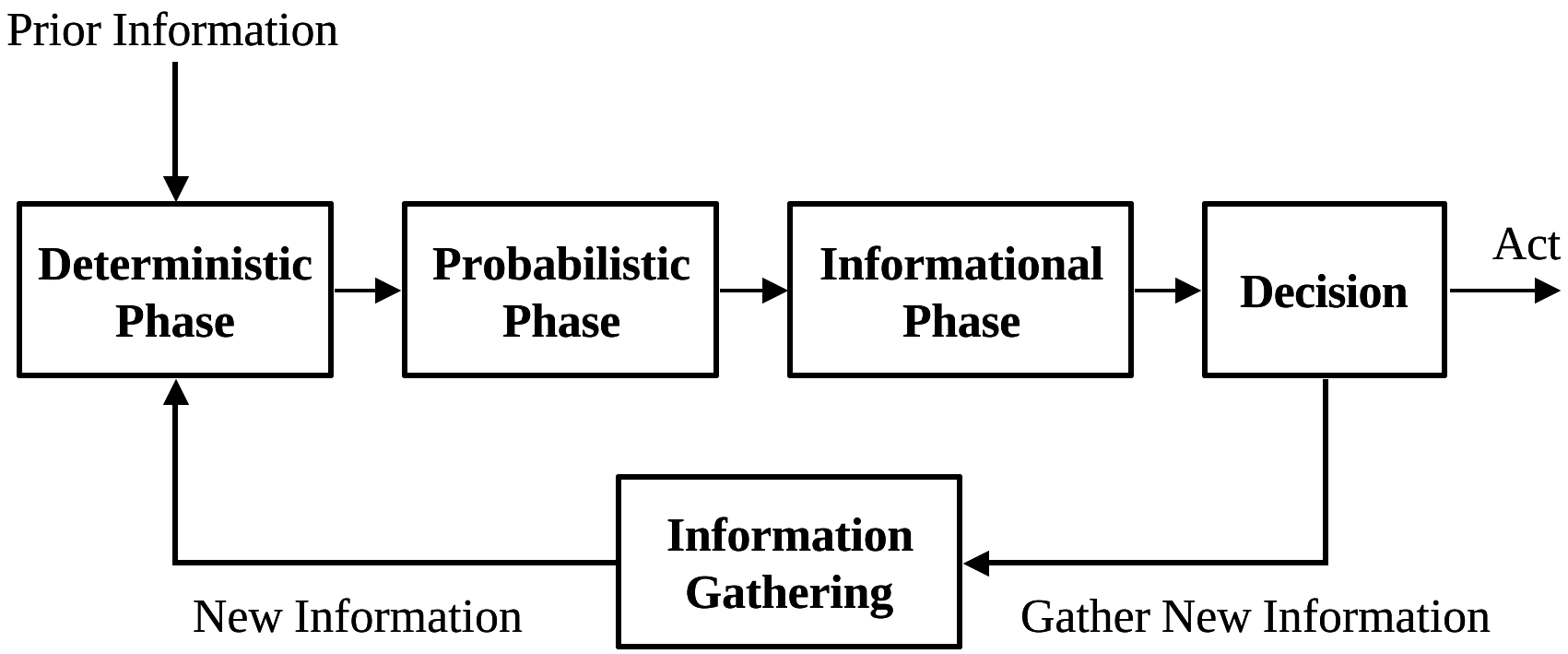
Management of uncertainty

- Allocate all available resources to reducing uncertainty
- More model detail → Less perceived uncertainty

Roles in decision-making

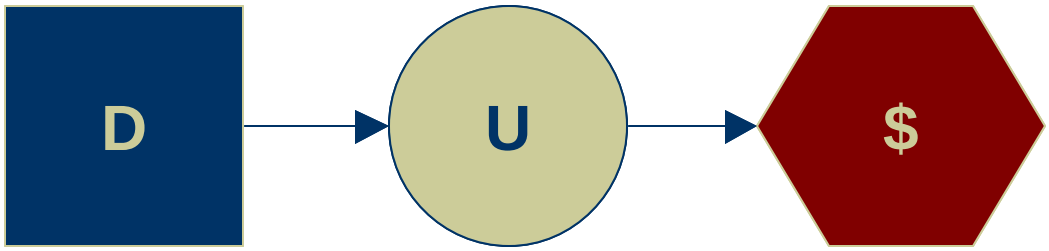
- Engineers:
  - Develop alternatives
  - Provide information
- Managers:
  - Make decisions

The Decision Analysis Cycle



Matheson, J.E. and Howard, R.A., An Introduction to Decision Analysis (1968), from Readings on The Principles and Applications of Decision Analysis, Strategic Decisions Group , 1989.

Decision Diagrams



D - Decision Node

Multiple decisions *non-deterministically* affect the value

U - Uncertainty Node

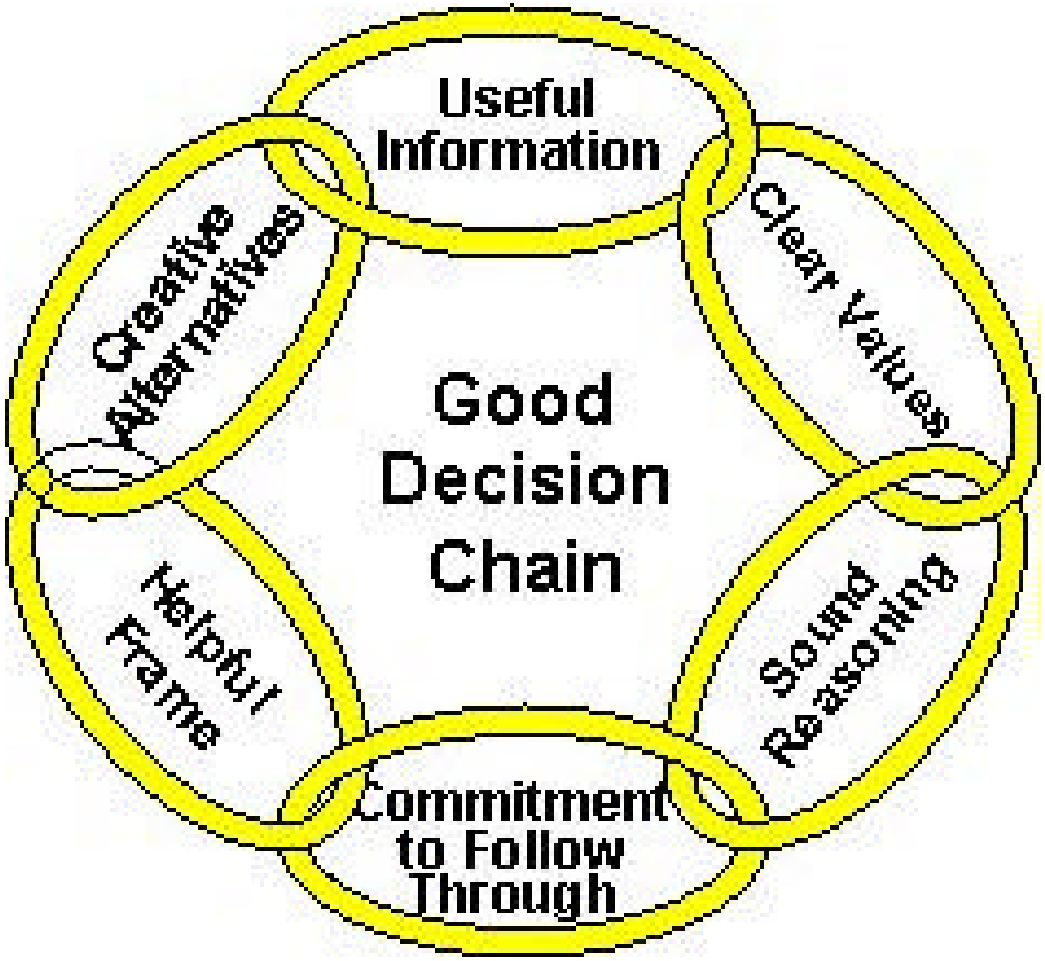
Multiple non-deterministic relationships represent the knowledge of how decisions affect the value

$ - Value Node

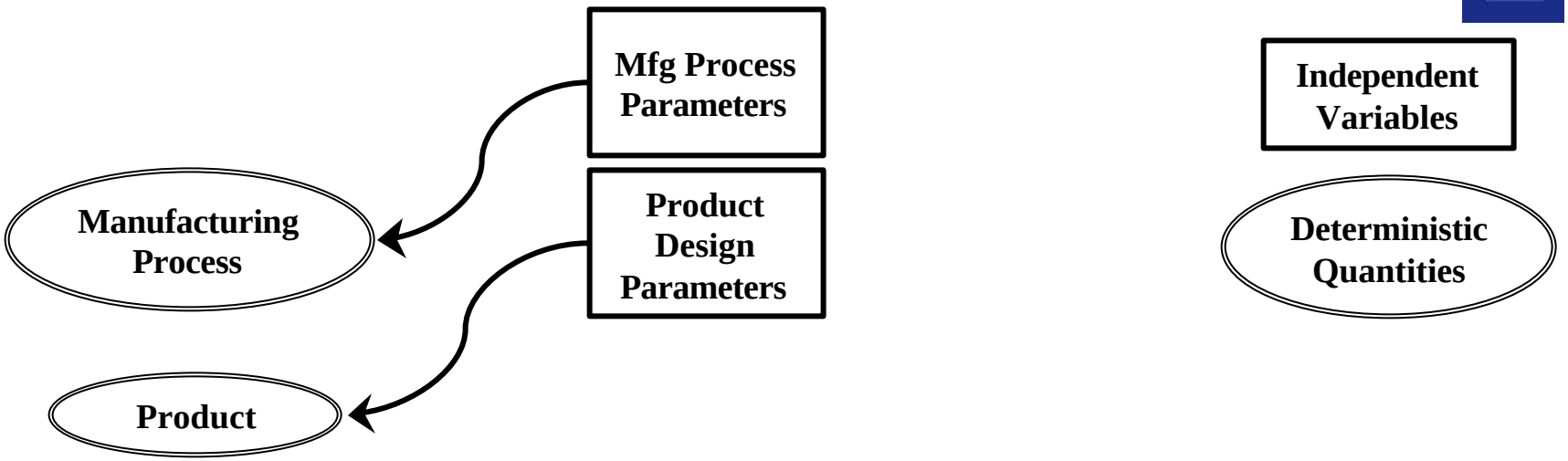
Value captures the preference under uncertainty among various prospects

The Elements of Decision Quality

(courtesy of Strategic Decisions Group)

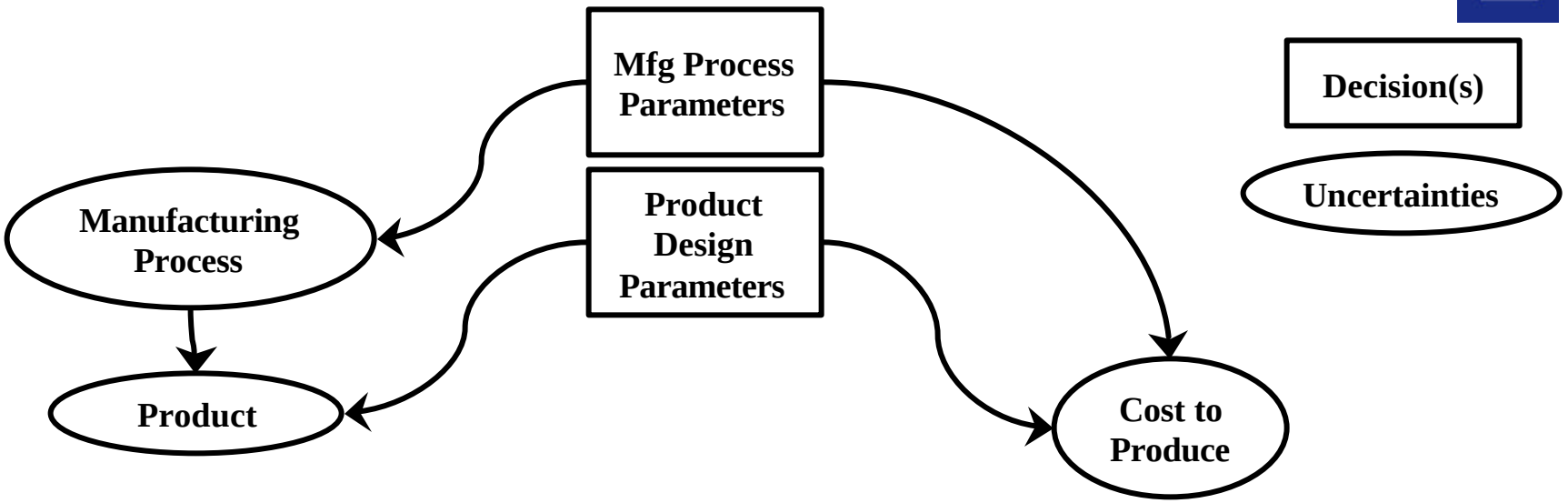


Decision Diagram for Design Alternatives (1)



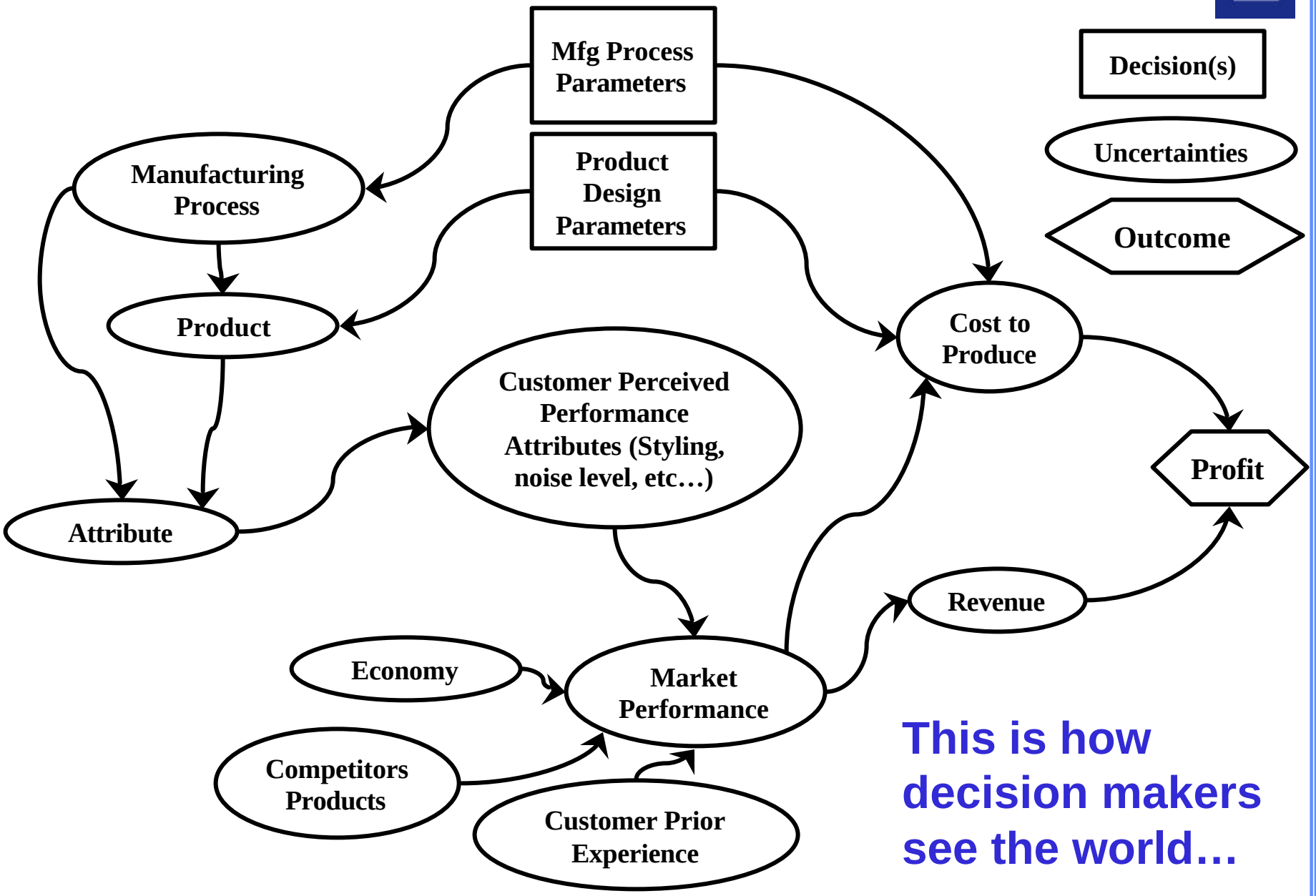
This is how new engineers see the world…

Decision Diagram for Design Alternatives (2)



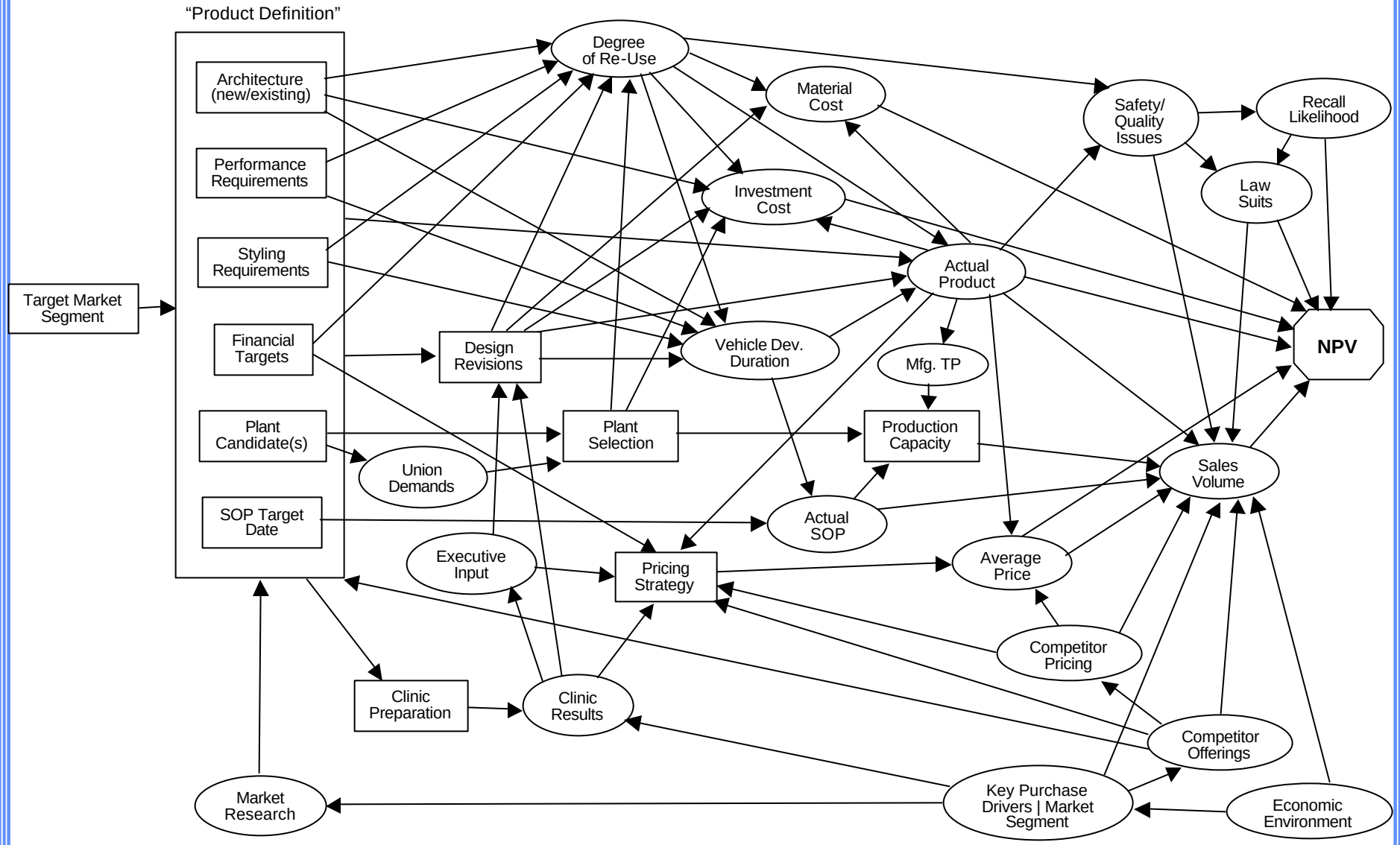
This is how experienced engineers see the world…

Decision Diagram for Design Alternatives (3)



This is how decision makers see the world…

A Decision Diagram for the AVDP



Insights from DA Model (1)

Iteration in design process

- Occurs naturally in the Decision Analysis Cycle
- Driven by information needs of decision-makers

Generation and distribution of information

- Analytical results supplement the decision-maker's ***State of Information***
- Analyses are performed when the results are material to decisions at hand

Insights from DA Model (2)

Management of uncertainty

- Decision-making under uncertainty and risk is INEVITABLE
  - Epistemic uncertainty can be reduced
  - Aleatory uncertainty CANNOT be reduced
- Uncertainty must be assessed by the decision-maker

Roles in decision-making

- Engineers develop alternatives and provide information
- Managers assess uncertainties and make decisions

Engineering Design: Parametric Design

An optimal determination of design parameters based upon pre-specified objective functions

- Current Perspective
  - Viewed as dimensional adjustments on the selected design
  - Formulate an optimization problem where the objective is to minimize the deviation from the specifications
- Decision Analytic Perspective
  - Formulate an optimization problem where the single objective is to maximize expected utility instead of deterministic value functions

Engineering Design: Design Selection

Selection of a design from a fixed set of alternatives based upon some stated criteria

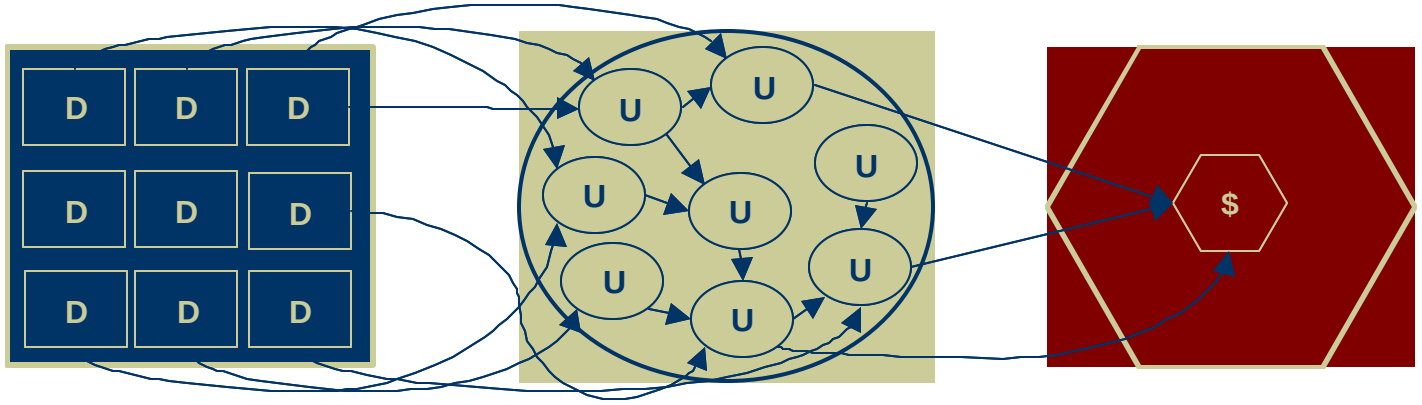
- Current Perspective
  - No creative process involved
  - Pick the design from the set that matches the requirements
- Decision Analytic Perspective
  - Pick the optimal design from the set based on the maximum expected utility criterion

Engineering Design: Design Synthesis

A creative configuration of entities to construct a system based upon some criteria

- Current Perspective
  - Ongoing process where final alternatives are never completely specified until the very end
  - End requirements are cascaded down as specifications in order to allow effective translation & guidance from abstract to detailed designs
- Decision Analytic Perspective
  - This is the focus of this research

Decision Diagram for Design Synthesis



Problem Characteristics

- Very large alternative space
- Extremely complicated relationships
- Organizational boundaries
- Time constraints
- Modeling complexity

Solution Characteristics

- Rational decision-making under uncertainty procedure
- Manageable modeling in terms of construction and implementation that recognizes the organizational and resource restrictions

Decisions in Design Synthesis

- Design Decisions
  - System-level decisions
    - Concept, architecture, interface among subsystems, etc
  - Subsystem-level decisions
    - Interface among components, etc
  - Component-level decisions
    - Components and parts, etc
  - Fine-tuning decisions
    - Parametric design decisions

Uncertainties in Design Synthesis

- Design Uncertainties
  - How current decisions affect the value
    - Evaluation of partially specified alternatives
  - How current decisions affect subsequent decisions
    - Evaluation of restrictions imposed on later decisions
  - How further refined designs will look like
    - Anticipation of various more-detailed designs
  - How those detailed designs will affect the value
    - Given detailed design, value is not known deterministically

Final Thoughts

On iteration in the design process

- Plan for “good iteration” (allow for exploration of design space and reduction of uncertainty)
- Reduce “bad iteration” (caused by lack of discipline, poor team or process structure, or miscommunication)

On generating and distributing information

- The primary challenge is focusing resources on the subset of information that is relevant and valuable

Final Thoughts

On characterizing and managing uncertainty

As beauty is in the eye of the beholder,
so is uncertainty in the eye of the decision-maker

On roles in decision-making

Engineers develop alternatives and provide information
Managers assess uncertainties and make decisions
Computers execute instructions