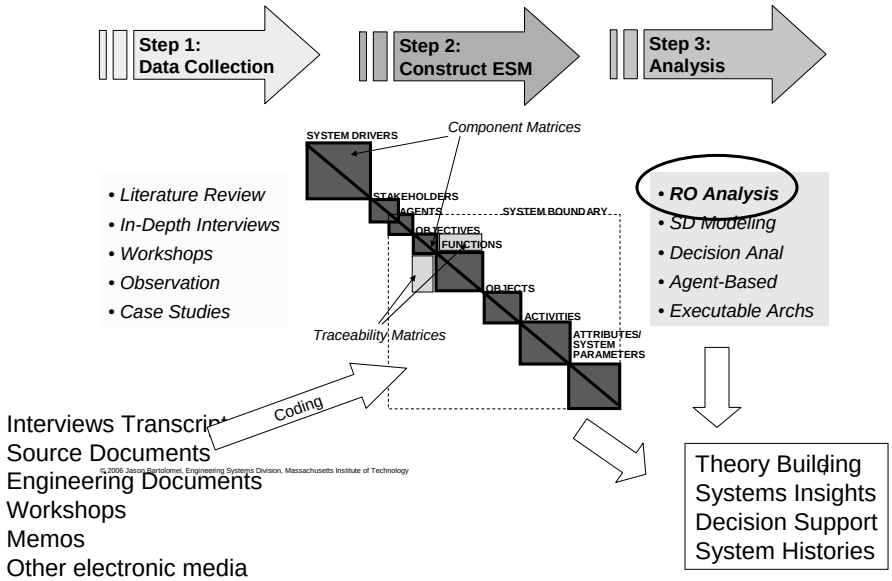
Jason's Insights from Silbey's Course

- Researching complex socio-technical systems
  - Modified Grounded Theory—using qualitative coding with DSM
- Issue:
  - Systems engineering/product development community does not have a transparent method for creating design structure matrices (DSMs)
    - Knowledge experts sit around table and start filling in boxes or drawing arcs
    - Nodes and links are abstractions that summarize and mask content
    - Often disagreements as to the nature of relations because the data is buried
    - Documentation process (if any) often loses detail gleaned in the knowledge elicitation process
- Socio-Technical Systems Decomposition Methodology (My research)
  - Repeatable process for reconstructing/decomposing qualitatively a complex system
  - Not classical grounded theory (however, methodology is useful for theory building)…because, it provides a "deliberately biased" approach for identifying system variables, defining relationships, and abstracting systems boundaries
    - Theoretically, grounded:
      - Design theory…systems exist to deliver value to stakeholders.
      - Design theory…Stakeholder value proposition can be decomposed functionally
      - Design theory…objects and processes are/must be functionally allocated to create system
      - Open Systems Theory…engineering systems exist in a great context that experiences exogenous interactions
      - Management Theory….Limits of human control is a useful as a system boundary identified

Basic Methodology

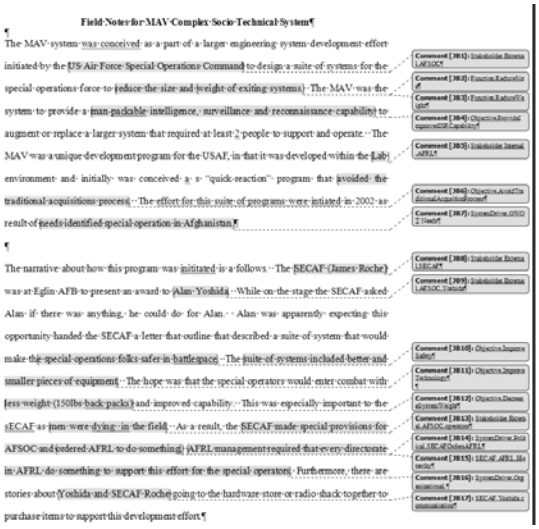


Thus…

- If we accept previous slide, then we might say:
  - Salient aspect of engineering systems can be described with the following codes

SystemDriver.Economic.Name: A economic constraint or enabler beyond the control of the internal stakeholders for the system that interacts/affects other nodes within the system
SystemDriver.Policy.Name: A perceived "policy" driven constraint or enabler beyond the control of the internal stakeholders for the system that interacts/affects other nodes within the system.
SystemDriver.Technology.Name: A perceived technologically driven constraint or enabler beyond the control of the internal stakeholders for the system that interacts/affects other nodes within the system.
SystemDriver.Political.Name: A perceived politically driven constraint or enabler beyond the control of the internal stakeholders for the system that interacts/affects other nodes within the system.
SystemDriver.Environment.Name: A perceived environmental driven constraint or enabler beyond the control of the internal stakeholders for the system that interacts/affects other nodes within the system.
SystemDriver.Social.Name: A perceived social/organizational driven constraint or enabler beyond the control of the internal stakeholders for the system that interacts/affects other nodes within the system.
External.Stakeholder.Name: The individuals/organizations who define the objectives and/or value proposition of the system but do not directly control the elements within the system
Internal.Stakeholder.Name: The individuals/organizations who define the objectives and/or value proposition of the system and directly control the elements within the system
Agent.Name: *The individuals/organizations responsible for executing the processes achieved within the system.*
Objective.Name: The value propositions, or goals, that the system seeks
Function.Name: Functions represent WHAT needs to be done by the stakeholders to achieve their objectives. The functions can be described using **noun-verb pairs.**
Object.Name: The physical elements and infrastructure needed to carry out the functions.
Activity.Name: The activities and processes that support the function of the system. These activities might include coordination process, manufacturing line, design process, acquisitions process.
Parameter.Name: The mathematical measures, levels, describing the nodes above.
Characteristic.Name: The mathematical relations between parameters.
Attribute.Name: The quantitative measure of performance used to describe the objectives of the system.

Link Codes:
Name.Name.Relation


Field Notes for MAV Complex Socio-Technical System

The MAV system was conceived as a part of a larger engineering system development effort initiated by the US Air Force Special Operations Command to design a suite of systems for the special operations force to reduce the size and weight of exiting systems). The MAV was the system to provide a man-packable intelligence, surveillance and reconnaissance capability to augment or replace a larger system that required at least 2 people to support and operate. The MAV was a unique development program for the USAF, in that it was developed within the Lab environment and initially was conceived as a "quick-reaction" program that avoided the traditional acquisitions process. The effort for this suite of programs were initiated in 2002 as result of needs identified special operation in Afghanistan.

The narrative about how this program was initiated is a follows. The SECAF (James Roche) was at Eglin AFB to present an award to Alan Yoshida. While on the stage the SECAF asked Alan if there was anything he could do for Alan. Alan was apparently expecting this opportunity handed the SECAF a letter that outline that described a suite of system that would make the special operations folks safer in battlespace. The suite of systems included better and smaller pieces of equipment. The hope was that the special operators would enter combat with less weight (150lbs back packs) and improved capability. This was especially important to the sECAF as men were dying in the field. As a result, the SECAF made special provisions for AFSOC and ordered AFRL to do something) (AFRL management required that every directorate in AFRL do something to support this effort for the special operators). Furthermore, there are stories about Yoshida and SECAF Roche going to the hardware store or radio shack together to purchase items to support this development effort.

General Questions for Data Collection

QUESTIONS ABOUT ENGINEERED SYSTEM:
What elements in the engineered system are your responsibilities?
What elements in the engineered system are affected by your elements?
What elements in the engineered system affect you elements?
Describe the nature of these interactions?
What are the key system parameters for the elements under your responsibility?
What are the attributes of engineered systems?
How has the engineered system changed over time?
What was the impetus of these changes?
Thinking back through the design iterations of previous systems…which elements in the physical structure has changed most (least)? Why was the driving force behind the changes (customer needs, innovation, architectual philosphy, other)

QUESTIONS ABOUT SYSTEM DRIVERS:
What are the factors beyond your control have the greatest impact on the system objectives?
What are the factors beyond your control have the greatest impact on the organization?
What are the factors beyond your control have the greatest impact on the engineered system?
What are the factors beyond your control have the greatest impact on the activities?
What is the nature of these interactions?
How rapidly is the technology supporting the system changing?
How have the operational requirements for the system changed, likely to change?
What was the impetus of these changes?
What are your greatest cost risks? Schedule risks? Performance risks?
What do you consider the greatest impediments to your program's success? (FAR, Cost Instability, Organization)
What do you consider the greatest enablers?

QUESTIONS ABOUT SYSTEM STAKEHOLDERS:
Who are your stakeholders/customers inside the organization?
Who are your stakeholders/customers outside the organization?
How have the stakeholders changed over time?
What are the impetus for these changes?
Who are the future stakeholders of the system?
What capabilities do they desire?
Are they different from existing capabilities?

QUESTIONS ABOUT ORGANIZATION:
Who in the organization requires information from you?
Who in the organization requires product from you?
Who in the organization requires money from you?
Who in the organization delivers information to you?
Who in the organization delivers product to you?
Who in the organization delivers money to you?
(Follow on questions seeking to describe the nature of these interactions)
How has the organization changed over time?
What was the impetus for these changes?

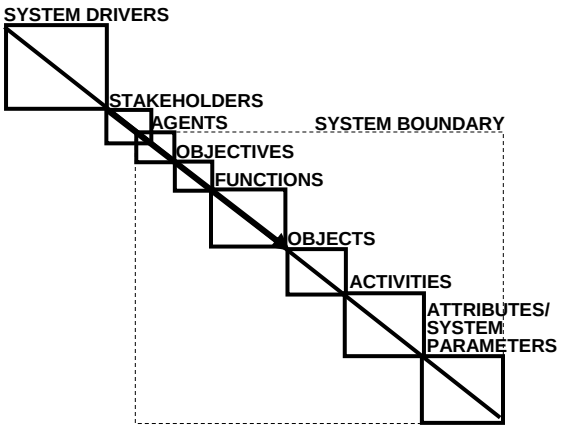
QUESTIONS ABOUT SYSTEM OBJECTIVES:
Are the objectives for the system defined/documented? If so, may I see them?
What do perceive are the objectives for the stakeholders you described above?
What are your objectives for the system?
What do you perceive are your customer's objectives?
What are the organization's objectives?
How have system objectives change over time?
What was the impetus for these changes?

QUESTIONS ABOUT SYSTEM ACTIVITIES:
Do you have a work breakdown structure/documents that describe your activities?
If so, (may I see them) are these documents accurate? What are the deviations? Explain.
What activities do you perform for your job?
What activities do you perform to support your objectives?
What activities do you perform to support your internal customers' objectives?
What activities do you perform to support your external customers' objectives?
What activities are required in order for you to perform your activities?
What activities are affecting your activities?
Describe the nature of these affects/interactions
What activities are affected by your activities?
Describe the nature of these interactions
What are the attributes/measures of performance for your activities?
How have the activities changed over time?
What was the impetus for these changes?

Grounded Theory of Real Options

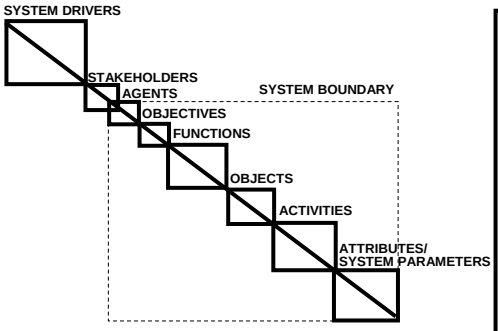
- Couple qualitative data with quantitative modeling
  - Multiple sources (minimize bias)

Constructing the ESM



- All matrices are n^2— share the same column and row headings
- Decomposition begins northwest to southeast
- Off-diagonal cells represent relationships between variables
- Goal is to represent traceability between multiple views of the system
- The C-DSM maps represents physical and non-physical relations

Stakeholder Matrix



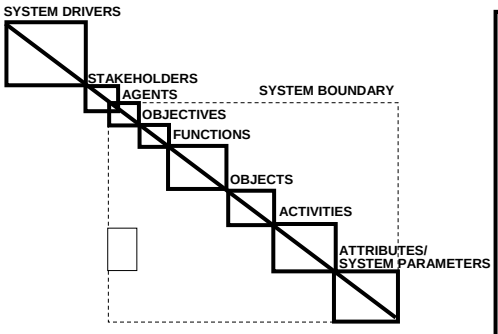
Rows and Columns

- **Stakeholders** are individuals or organizations define system objectives and/or the system value proposition
- **External stakeholders** (outside the dashed line) have no control over the aspects of the system
- **Internal stakeholders** (inside the dashed line) interpret the objectives for the system, control resources, manpower, and have decision making authority
- The extent of **internal stakeholders** control defines the **system boundary** of the system

Cells

- Can be used to represent several different types of relationships between stakeholders such as:
  - Hierarchy (put an X in a row cell if reports to a column)
  - Linkages could represent transfer of money, information, product, other
- The result is a social network of organization/individual stakeholder interactions

Agents Matrix



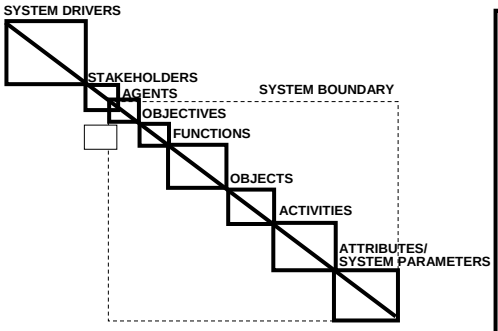
Rows and Columns

- Represent the human agents responsible for executing the activities within the engineering system
- Represents the organization in place to fulfill system objectives

Cells

- Can be used to represent links between agents (social network analysis)
- The light orange matrix represents traceability between the organization and the activities to be performed. An “X” signifies the specific agents associated to a particular task

Objectives Matrix



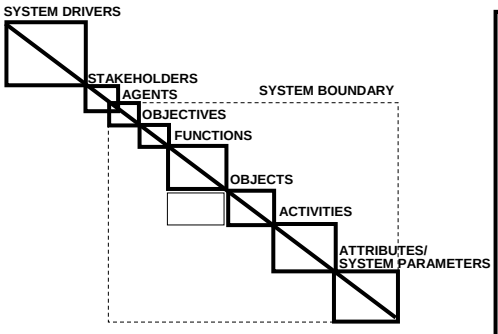
Rows and Columns

- The combined **objectives** of all stakeholders in the system otherwise known as their value propositions
- The objectives includes all articulated and unarticulated customer needs, system requirements, and goals/objectives

Cells

- Can be used to represent whether the row and column objectives are in competition (-), cooperation (+), or unrelated (0)
- An additional matrix under the stakeholders and to the left of objectives is formed with stakeholder columns and objectives rows. The cells in the matrix are marked with an "X" represent traceability between stakeholders and objectives. Also, each cells can be codes as the stakeholder view towards that objective, for instance: positive, negative, neutral

Functions Matrix



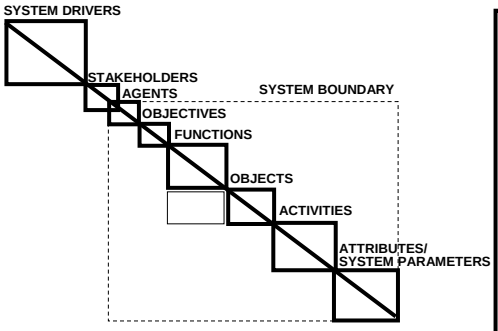
Rows and Columns

- Represent the functions required in order to achieve the objectives
- Functions represent the "What and Why" for the variables in an engineering system
- Traditional functional decomposition methods are used to create the functions matrix, such as: Functional Analysis Systems Technique, Quality Function Deployment, etc.

Cells

- Can be used to represent a sub-hierarchical relationship between the functions with an "X" signifying if "row" falls under "column."
- The cells can be color codes to signify the type of relation between the functions, such as static, dynamic, information, or material
- The light orange matrices representing the mapping between function and form. Object-Process Methodology (OPM) relations can be captured in these matrices

Objects Matrix



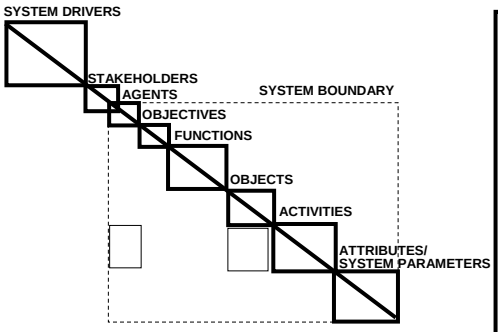
Rows and Columns

- The physical architectural entities required to carry out the functions
- The physical "form" of the system

Cells

- Can be used to represent a physical network between subsystem and components.
- The cells can also be colored codes to signify the type of relation between the functions, such as static, dynamic, information, or material
- The light orange matrices representing the mapping between function and form

Activities Matrix



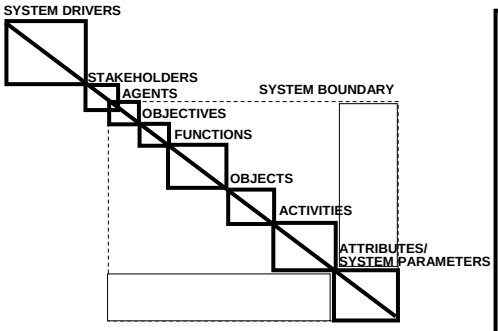
Rows and Columns

- The activities required to be performed by the system
- Activities flow from the functions and objects matrices
- Represents information generally found in a Work Breakdown Structure

Cells

- Can be used to represent if the activities are dependent/interdependent
- The light orange matrix below the agents matrix maps agents to tasks
- The light orange matrix below the objects matrix is used to represent if there is a relationship between an activity and a physical object

Attributes/System Parameters Matrix



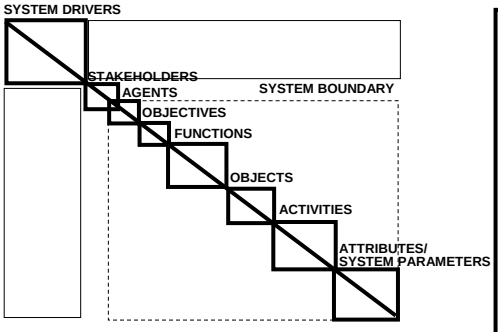
Rows and Columns

- Captures the system attributes and parameters
- Attributes are the measures for which the system objectives are measured
  - For example an objective for a Mini UAV might require the system to be man-packable. System weight is one attribute for this objective
- Parameters are the variables used to describe elements of a system
  - For example: Wing length and root chord length are examples of parameters that describe a wing

Cells

- Cells can be used to represent links between attributes and parameters
- The matrices to the left and right of the attributes/system parameters shows traceability with the variables in the other matrices
- Links can be represent causal and non-causal relations between nodes

System Drivers Matrix



Rows and Columns

- Captures the exogenous variables that influence the system or are beyond the internal stakeholders control
- In particular, these are the social, political, economic, and technical constraints, enablers that affect the system

Cells

- Can be used to represent links between drivers to show interrelationships
- More importantly, the additional matrix above the system drivers matrix represents how system drivers affect the parameters within the engineering system…the matrix to the left represents how the engineering system can influence the system drivers