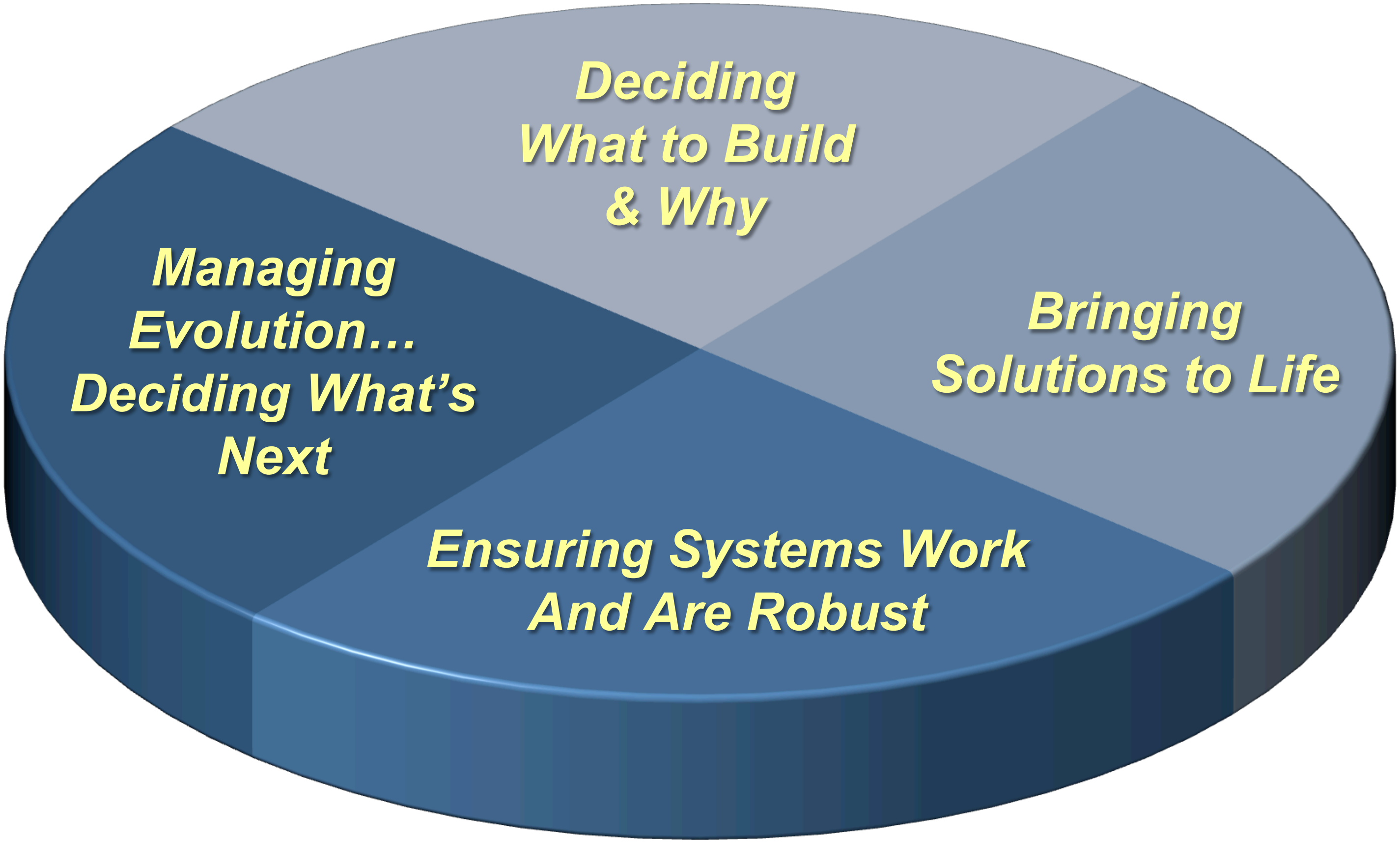
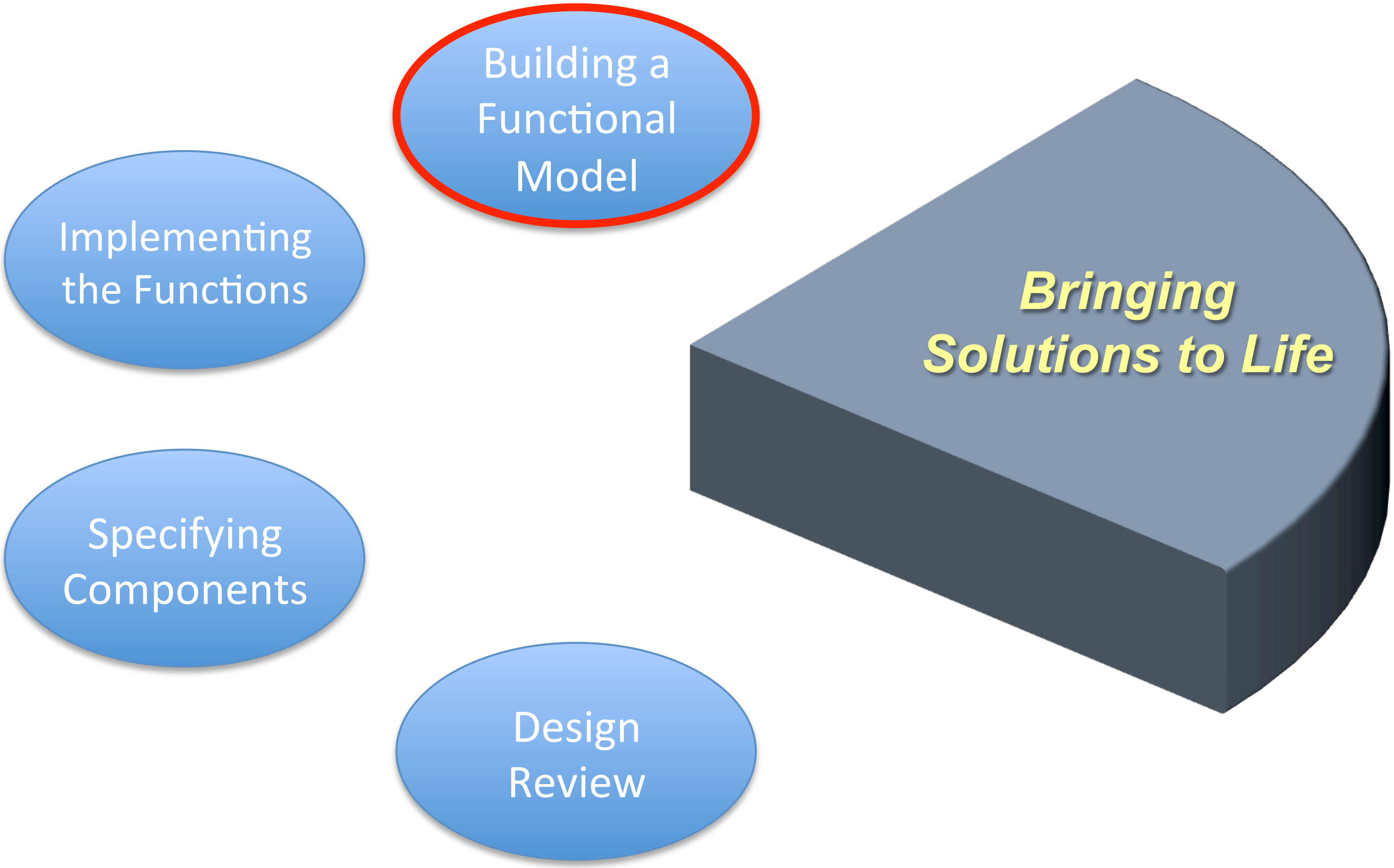
Building a Functional Model

"How will the system work?"

Course Design



Course Design



Class Schedule (1 of 2)

Date	Week	Topic
Feb 1	1	• Thinking in Terms of Systems
		Deciding What to Build and Why
Feb 8	2	• Defining the Problem
Feb 16	3	• Developing a Solution
Feb 22	4	• Formulating a Proposal
Feb 29	5	• Concept Review
		Bringing Solutions to Life
Mar 7	6	• Building a Functional Model
Mar 14	7	• Implementing the Functions
Mar 28	8	• Specifying Components
Apr 4	9	• Design Review

Class Schedule (2 of 2)

Date	Week	Topic
		Ensuring the System Works and Is Robust
Apr 11	10	• Integration and Test
Apr 18	11	• Modeling and Simulation
Apr 25	12	• Designing for the Lifecycle
May 2	13	• Test Readiness Review
		Managing Evolution…Deciding What's Next
May 9	14	• Technology and Innovation
May 16	15	• No Class – Final Project Submission

Deciding How the System Will Work
Key Questions:

1. What top-level functions will your system have to perform in order to accomplish it's mission?
2. How else could you have partitioned the system functionality and why did you choose to partition it the way you did?
3. How will the top-level functions interact with each other and with their external environment?
4. How well will your functional architecture perform and what evidence can you provide to support that assessment?

Part 1: Introduction to System Architecture

Architecture as a Metaphor

- "…the systems engineer resembles an architect, who must generally have adequate substantive knowledge of building materials, construction methods, and so on, to ply his [or her] trade.

- "Like architecture, systems engineering is in some ways an art as well as a branch of engineering. Thus, aesthetic criteria are appropriate for it also. For example, such essentially aesthetic ideas as balance, proportion, proper relation of means to ends, and economy of means are all relevant in a systems-engineering discussion. Many of these ideas develop best through experience. They are among the reasons why an exact definition of systems engineering is so elusive."

Ref: Hendrik Bode, "The Systems Approach," Report to the Committee on Science and Astronautics, U.S. House of Representatives by the National Research Council (U.S.), Panel on Applied Science and Technological Progress, 1967.

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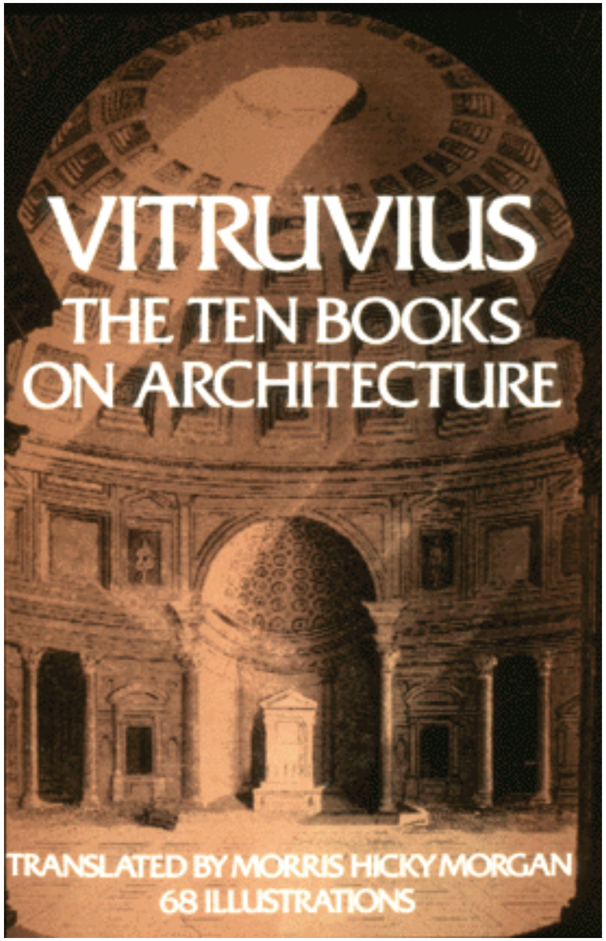
The Classical Architect



"The ideal architect should be a man [or woman] of letters, a skillful draftsman, a mathematician, a diligent student of philosophy, acquainted with music, not ignorant of medicine, learned in the responses of jurisconsults, and familiar with astronomy and astronomical calculations"

– *Vitruvius, 25 B.C.*

Classical Virtues of Architecture

- ***Utilitas*** **–** usefulness; appropriate spatial accommodation
- ***Firmitas*** **–** structural soundness; robustness toward change
- ***Venustas*** **–** aesthetics and beauty; ability of a form to communicate its function and to fit into its environment

Ref: Vitruvius, De Architectura.

What Is an Architect?

A creative and respected mediator between a “client” and a “builder”

- Envisions solutions to the client’s need that are feasible and that satisfy all the client’s requirements
- Communicates the vision to the client in a way that is compelling and leads to a decision to implement
- Communicates the vision to the builder in a way that results in its successful implementation
- Inspects and manages the implementation process to ensure that it is brought to a successful conclusion

What Is a *System* Architect

A creative and respected mediator between a "client" and a "***design team***"

– Envisions solutions to the client's need that are feasible and that satisfy all the client's requirements

– Communicates the vision to the client in a way that is compelling and leads to a decision to implement

– Communicates the vision to the ***design team*** in a way that results in its successful implementation

– Inspects and manages the implementation process to ensure that it is brought to a successful conclusion

The Role of a System Architect

Challenges

- Determine user needs & how value is created
- Effectively manage complexity
- Accommodate change
- Work within organizational constraints
- Balance all of the above

Required Skills

- Technical – To make it work
- Communication – To persuade others
- Political – To gain access to scarce resources necessary for the project’s success

Perspectives of a Classical Architect

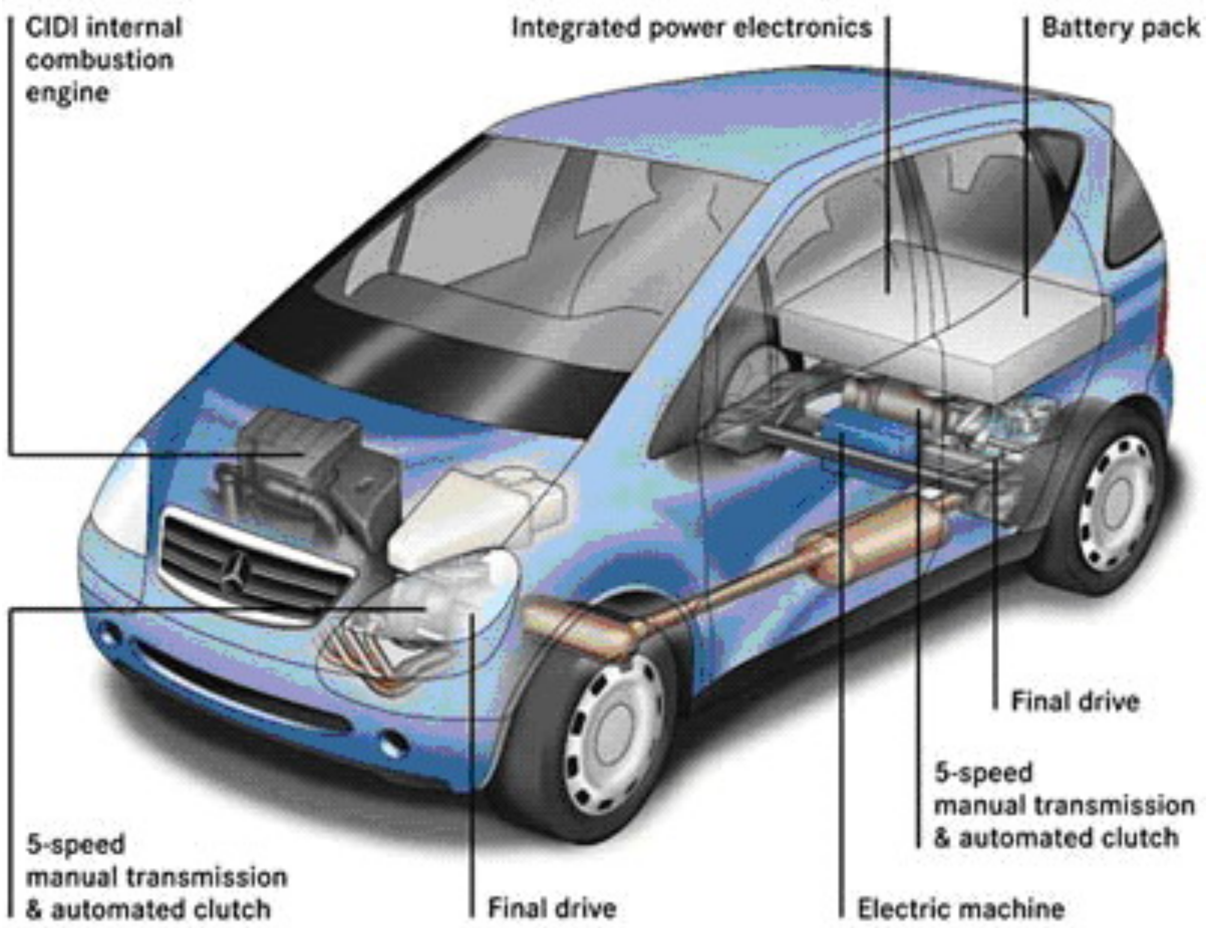
- **Objective:** Achieve a good "fit" between the form to be designed and its context
  - Form – that over which we have control
  - Context – that which puts demands on the form
- **Challenge:** "We seek to produce harmony between a form we have not yet designed and a context we cannot fully describe."
- **Process:**
  - Define the context as a set of requirements
  - Partition the requirements into clusters that are richly connected internally and as independent of each other as possible
  - Design a form that meets each cluster of requirements
  - Integrate the low level forms to produce the desired whole

Ref: C. Alexander, Notes on the Synthesis of Form, Harvard University Press, 1964.

System Architecture

- **System** – A set of components that work together to accomplish a common purpose
- **System Architecture** – The fundamental structure of a system: its elements, the roles they play, and how they are related to each other and to their environment

What are the key components? How do they work together?



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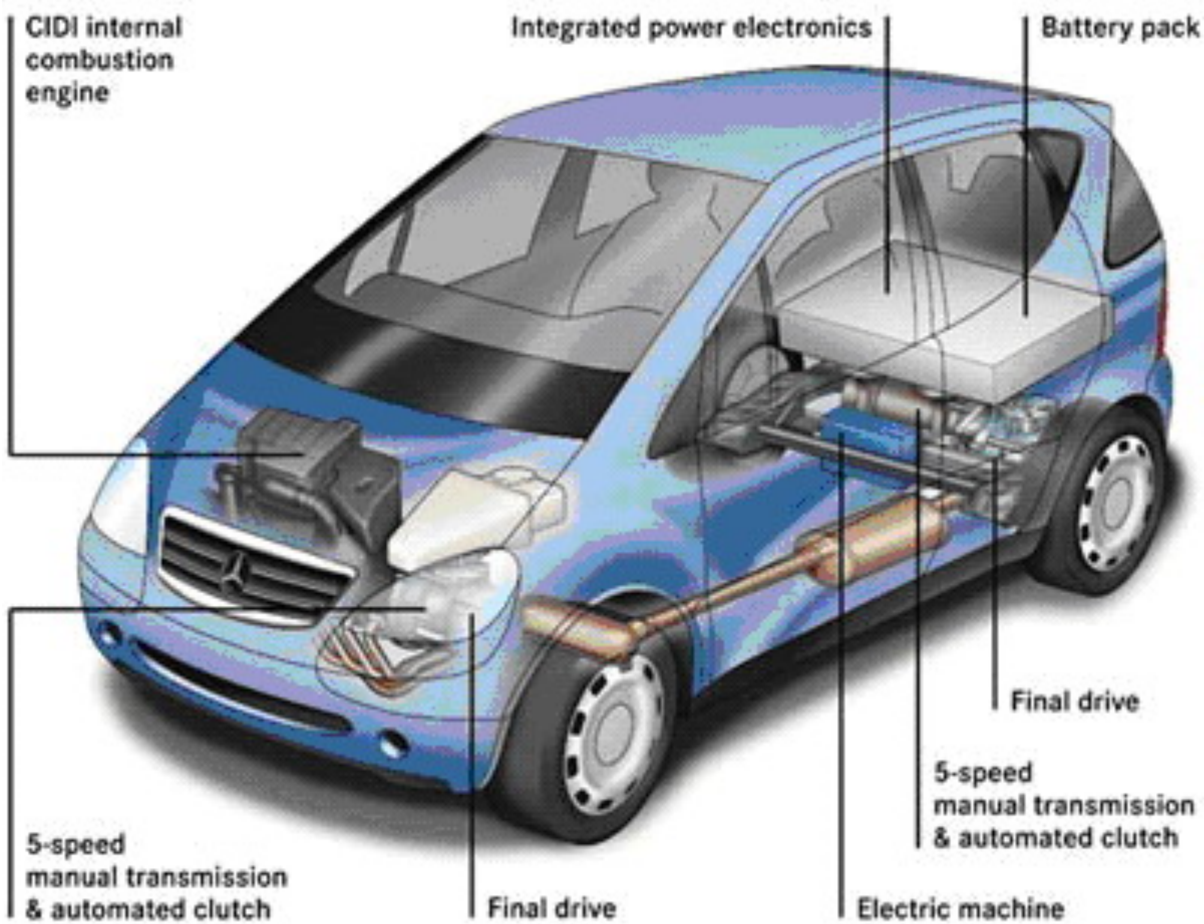
How else could this be done? Why was it done this way?



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System Architecture and Design

- **System -** A set of components that work together to accomplish a common purpose
- **System Architecture -** The fundamental structure of a system: its elements, the roles they play, and how they are related to each other and to their environment
- **System Design** – an instantiation of the system architecture

All architecture is design; not all design is architecture.

	Design	Architecture
Scope	For a specific implementation	Can guide multiple designs and therefore implementations
Goals	Ensures the specific implementation meets specified requirements (functional, non-functional, and project)	Ensures a number of implementations meet wider business targets and strategies
Decision Points	Rationale for decisions is driven by implementation parameters (time to market, cost, features, resourcing, etc.)	Rationale for decisions is driven by business strategies (market responsiveness, competitive positioning, etc.)
Detail	Defines all elements and interfaces to an implementation level of detail	Defines some elements of the system as abstract types, and some interfaces at an implementation level of detail

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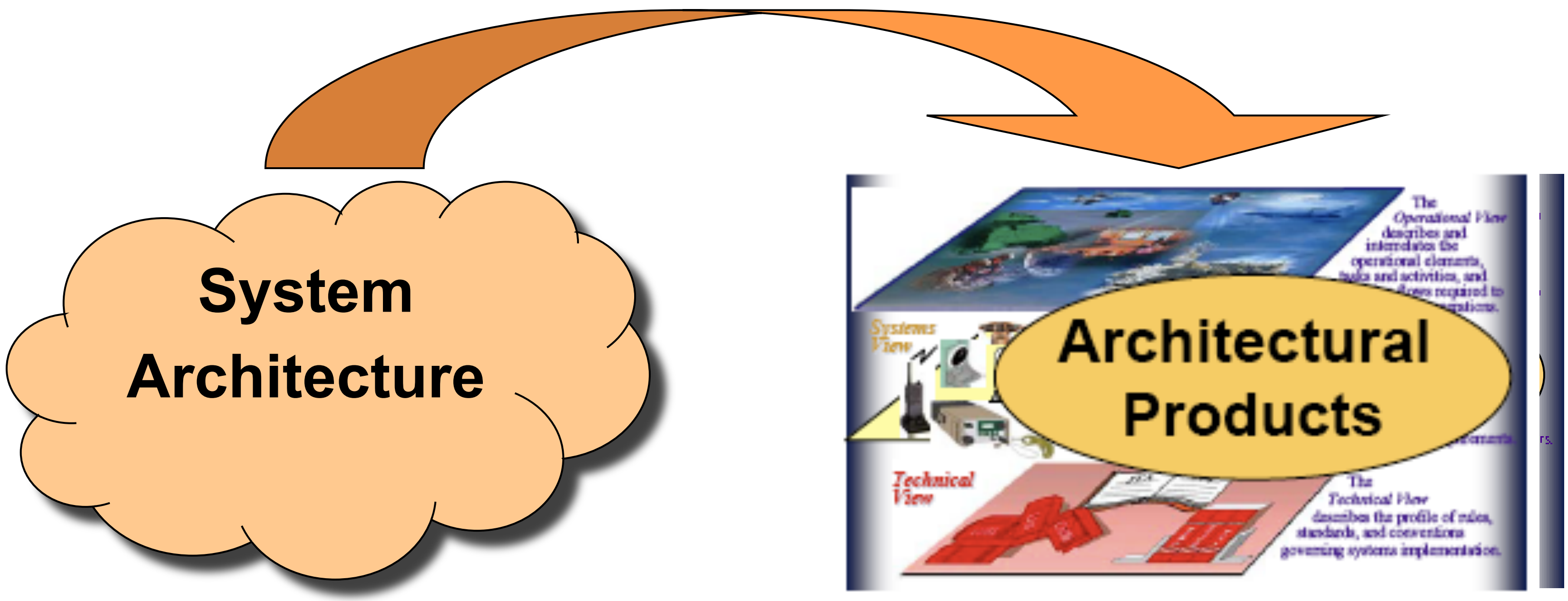
System Architecture

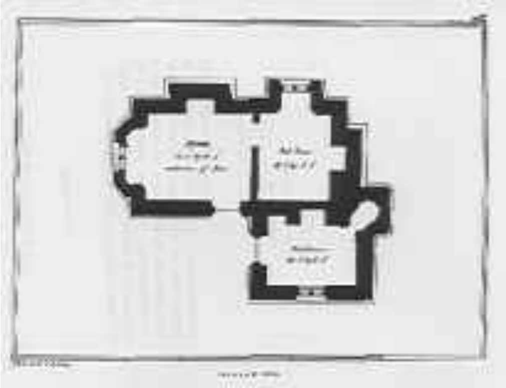
- **System –** A set of components that work together to accomplish a common purpose

- **System Architecture –** The fundamental organization of a system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution. *Ref: ANSI/IEEE 1471-2000*
  - Also, the artifacts that describe this structure

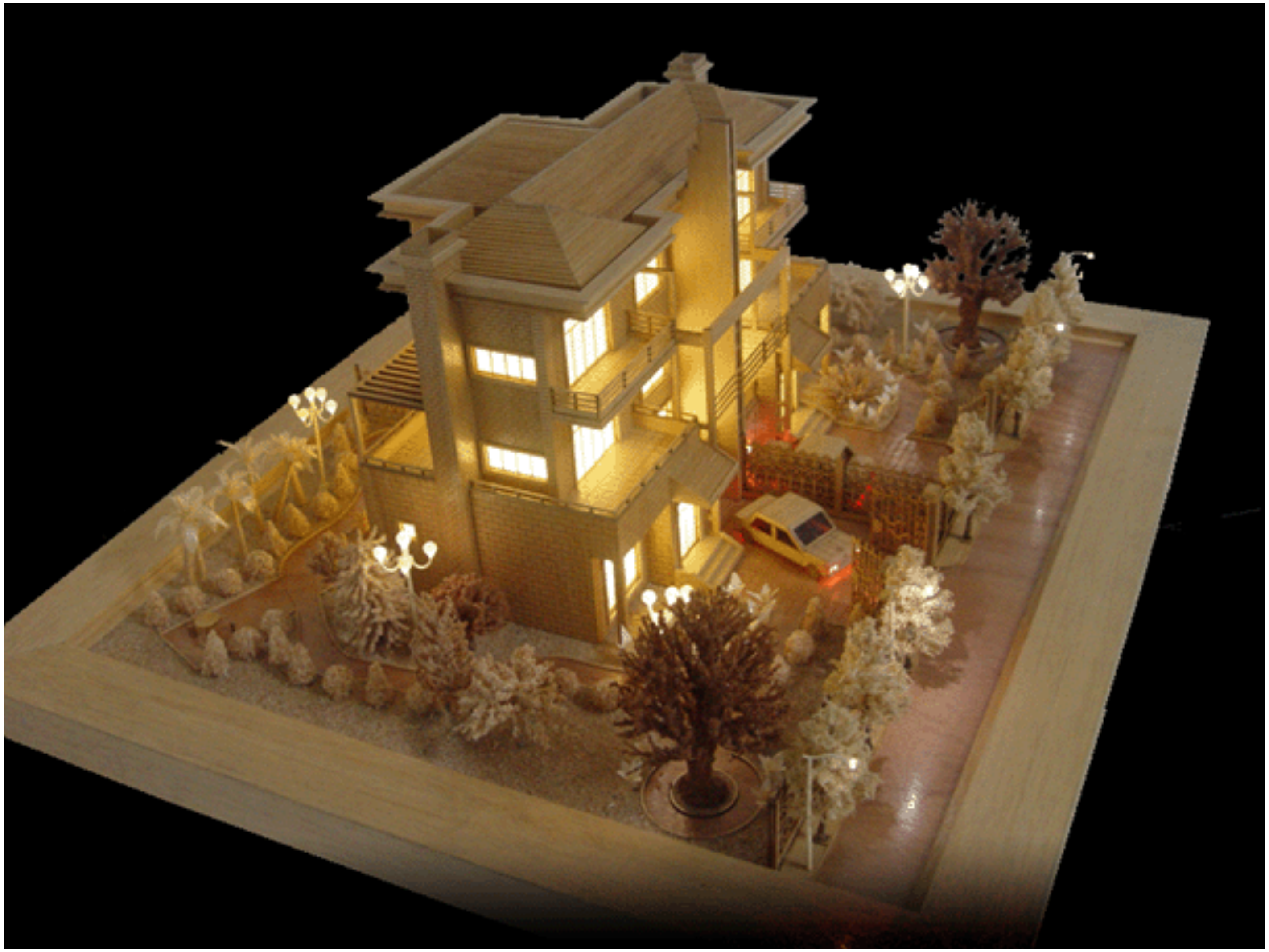
System Architecture – “The Map Is Not the Territory”



Traditional Views of a Building Architecture

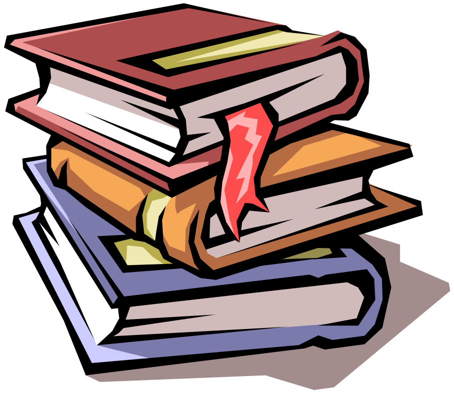
Plan View	Front Elevation View	Side Elevation View
		

Today's architects don't just create documents, they build models.



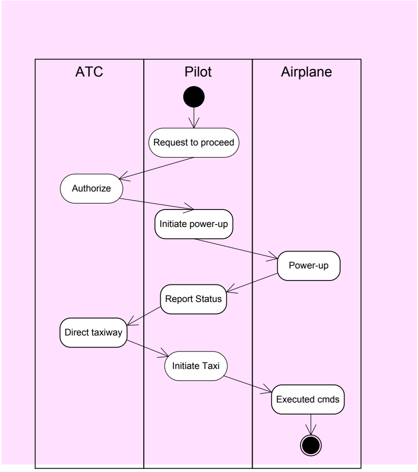
SE Practices for Describing Systems

Past



- **Specifications**
- **Interface requirements**
- **System design**
- **Analysis & Trade-off**
- **Test plans**

Present

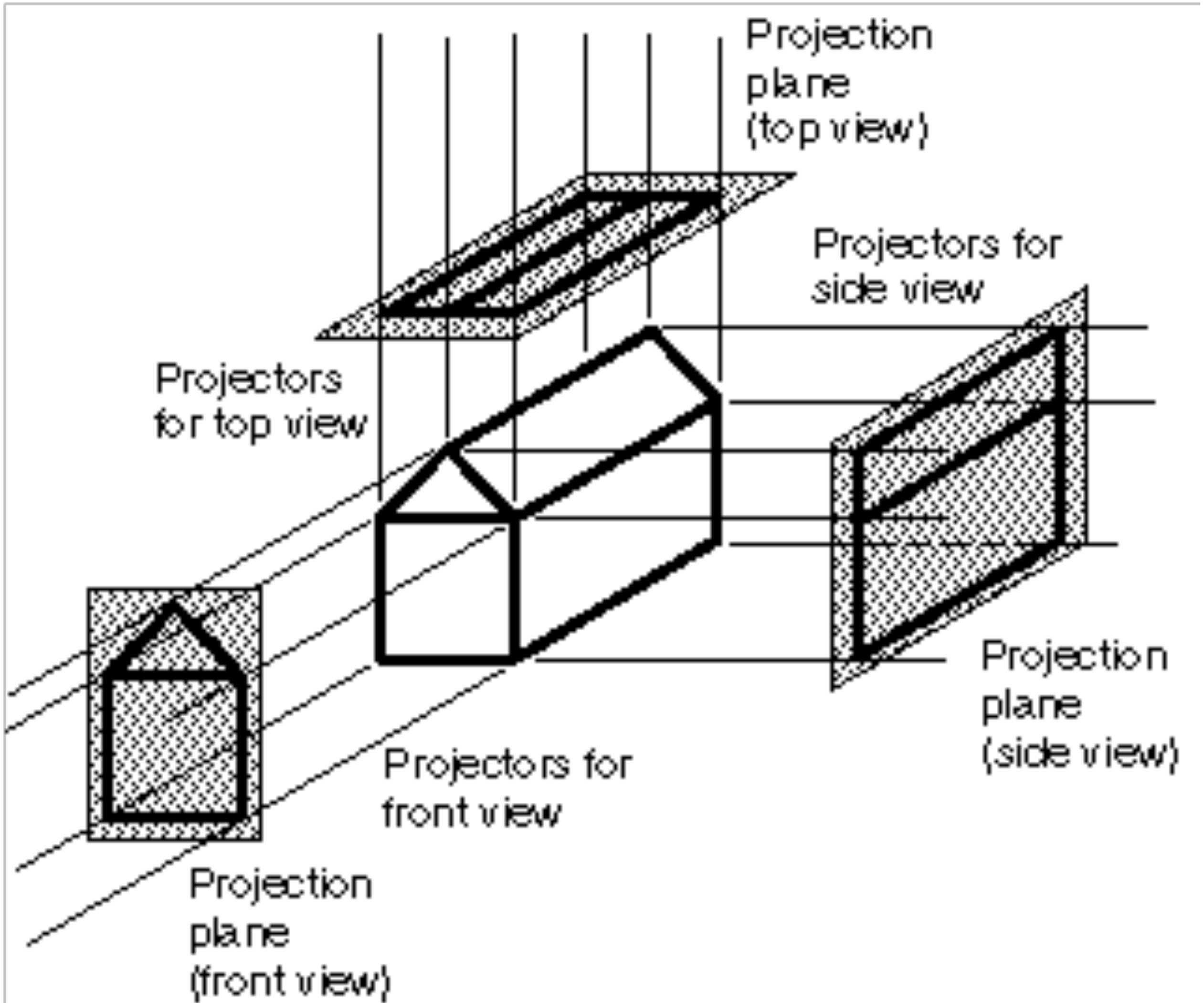


Moving from Document-Based to Model-Based Architecture

Model-Based Architecture

- A system model:
  - Is the primary product of model-based systems engineering
  - Incorporates all the system requirements, functional elements, physical components and the relationships between them in a single repository
  - Requires some sort of tool, since there is no way to represent all this information at a single time
  - Is able to provide consistent “views” required by the system designers and a wide range of stakeholders, all derived from the same source

Models and Views



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Traditional Views of System Architecture

- **Operational View**
  - Defines the system from the users' (or operators') point of view – how the users will interact with the system and how the system will interact with external systems
  - Shows the flow of data (inputs/outputs) between the system, its users and the external systems.

- **Functional View**
  - Defines what the system must do – the capabilities or services it will provide and the tasks it will perform
  - Shows the messages / data between functions

- **Physical View**
  - Defines the partitioning of the system* resources (hardware and software) needed to perform the functions. Also shows the interconnections between the resources - usually defined by the SE to the configuration item level – Computer Software (CSCI) or Hardware (HWCI)

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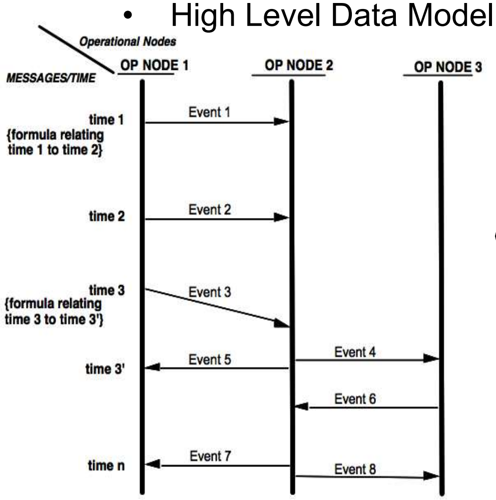
Traditional Views of System Architecture

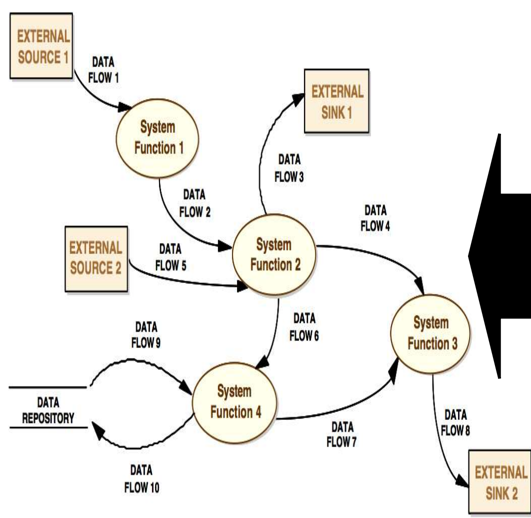
Operational View

- Shows how the operator will use the system.
- Shows inputs and outputs to users and other systems.
- Usually described by:
  - Operational Concept
  - Context Diagram
  - Use Case Scenarios
  - Sequence Diagrams
  - High Level Data Model



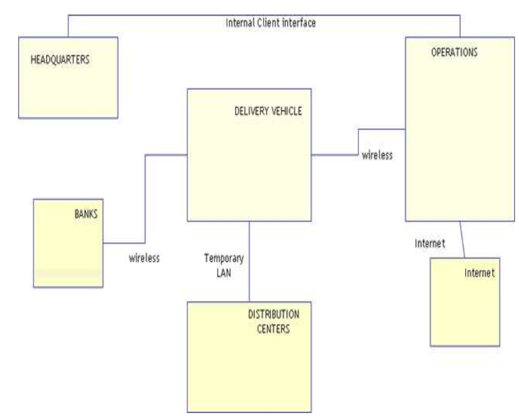
Functional View

- Defines the capabilities, the services, or the functions provided by the system.
- Shows the messages / data between functions
- Usually described by:
  - IDEF0 Diagrams
  - Functional Flow Block Diagrams
  - N2 Diagrams



Physical View

- Defines allocated resources (hardware and software)
- Shows the interconnections between the resources.
- Usually described by:
  - Physical Block Diagrams
  - Physical Interface Definitions



Part 2: The Functional View

Functional View of a System

- **Elements** – functions; the tasks the system performs
- **Interrelationships** between the elements – the data, information, material or energy exchanged between functions in order to accomplish the tasks

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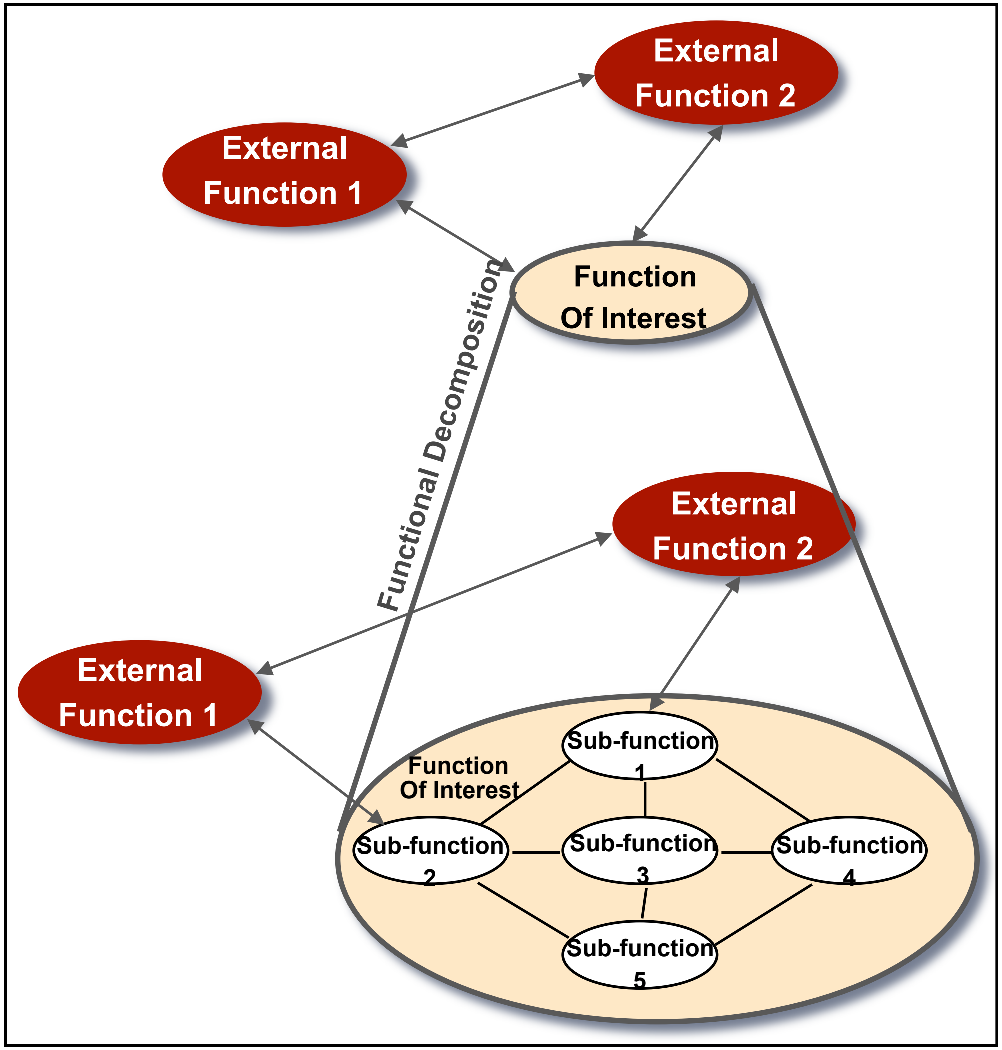
Functions in Systems Engineering

- A function is a ***process*** that transforms inputs into outputs
- A function describes an ***action*** taken by the system or by one of its elements
- A function is represented by a ***verb*** or *verb-noun phrase*

Functional Decomposition



Decomposition vs. Composition

- Decompositon (top-down)
  - Partition system function a level at a time
  - Need sound definition of all inputs & outputs
- Composition (bottom-up)
  - Define many functionalities (bottom-level functions)
  - Synthesize functional hierarchy from many bottom-level functions
- Use both to develop the best solution

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Functional Building Blocks

- Signal functions – generate, receive, transmit, convert or distribute signals
- Information functions – analyze, interpret, query, store or convert information
- Material functions – support, enclose, store, reshape or transport matter
- Energy functions – generate, transform, or control: thrust, torque, power, heat or motion

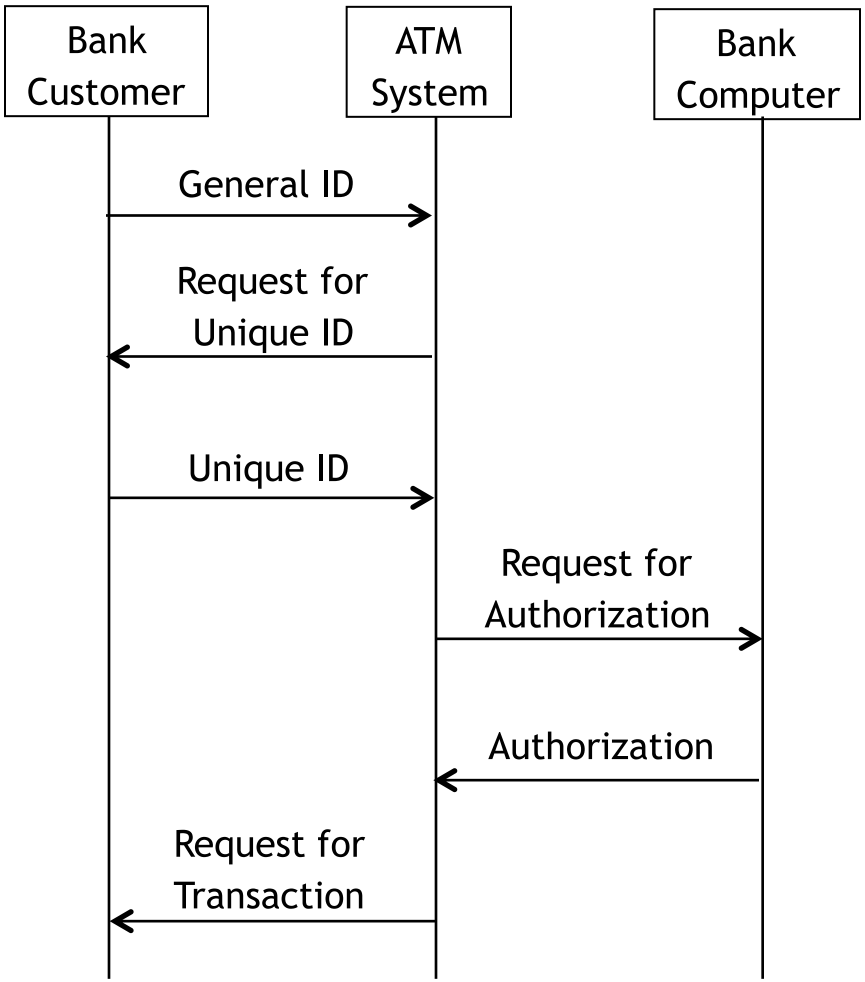
More examples?

Question – Are these elements hardware or software?

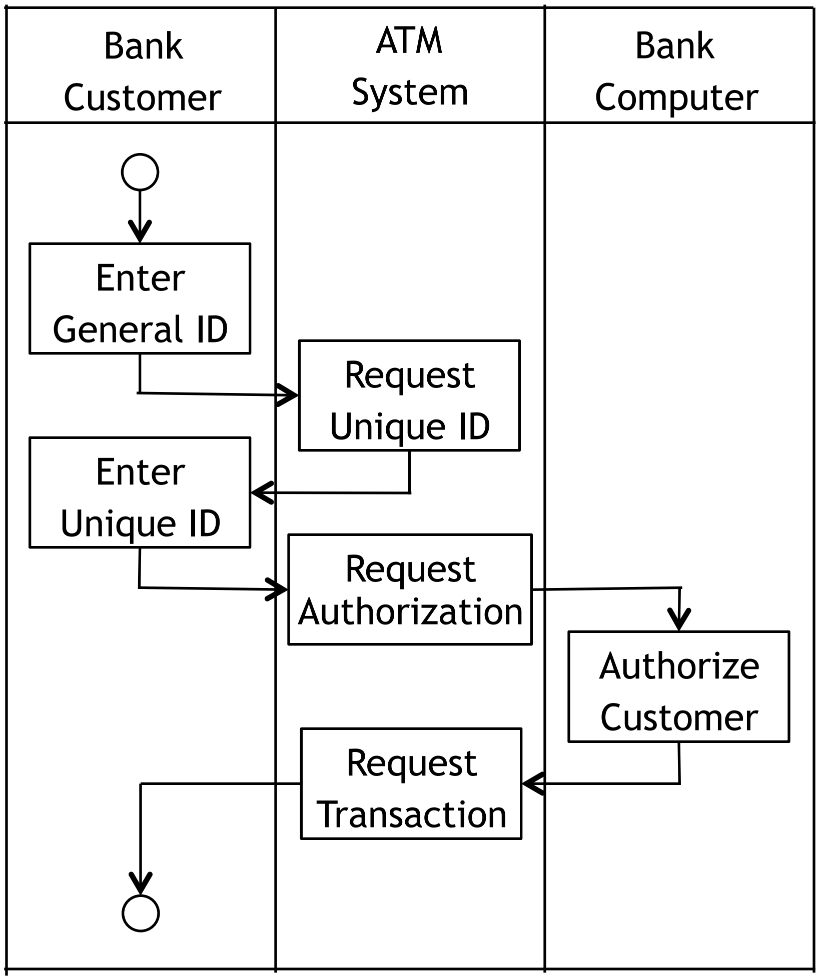
Part 3: ATM Example

ATM Example: Scenario Descriptions

Sequence Diagram

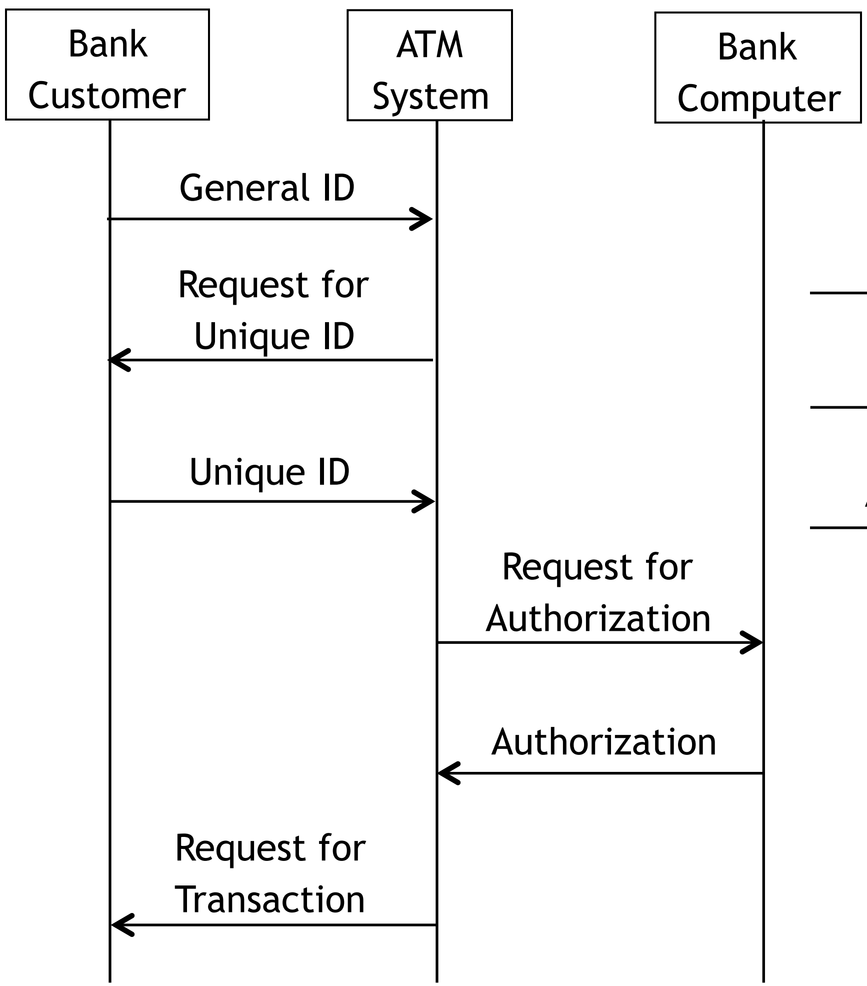


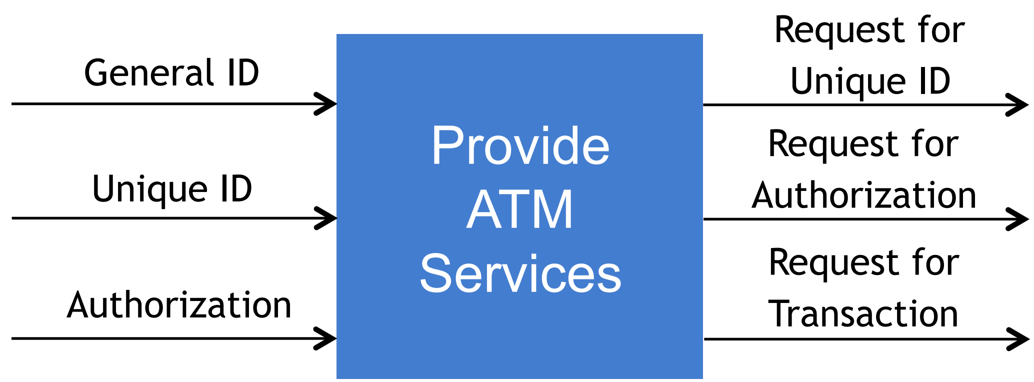
Activity Diagram



ATM Example: Inputs and Outputs

Sequence Diagram

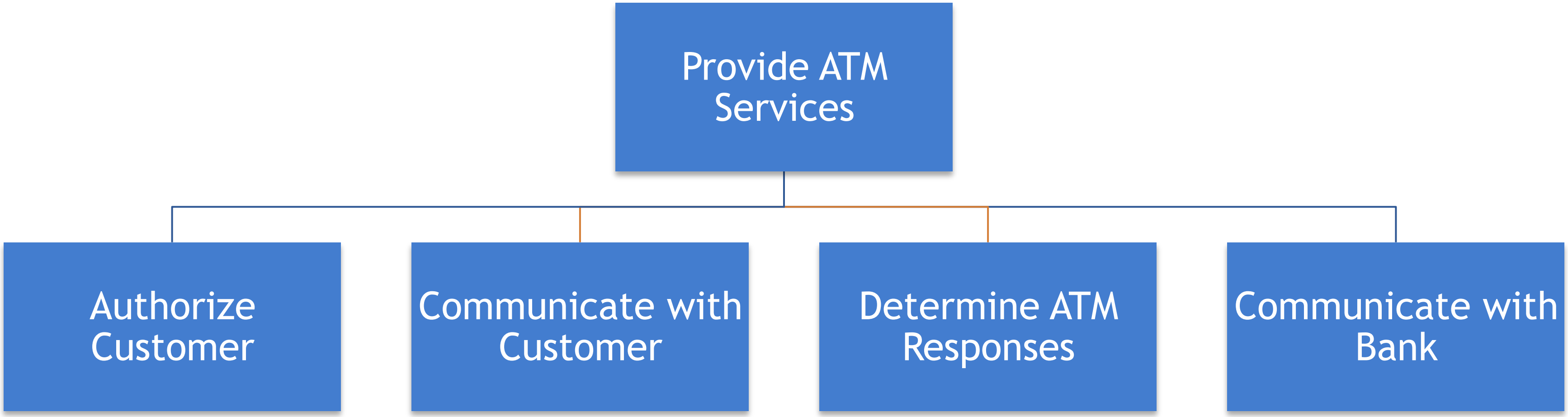




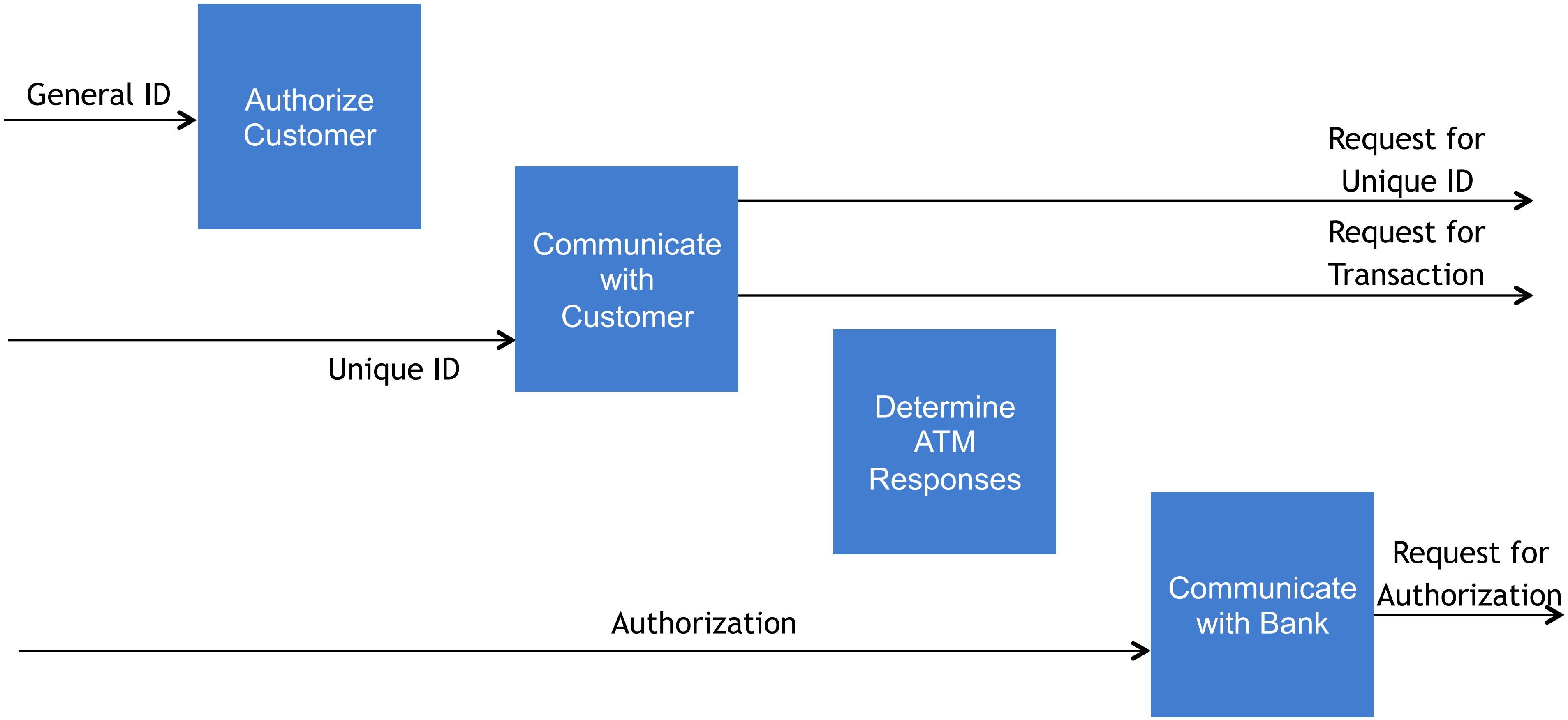
ATM Example: First-Level Functional Decomposition

Provide ATM Services

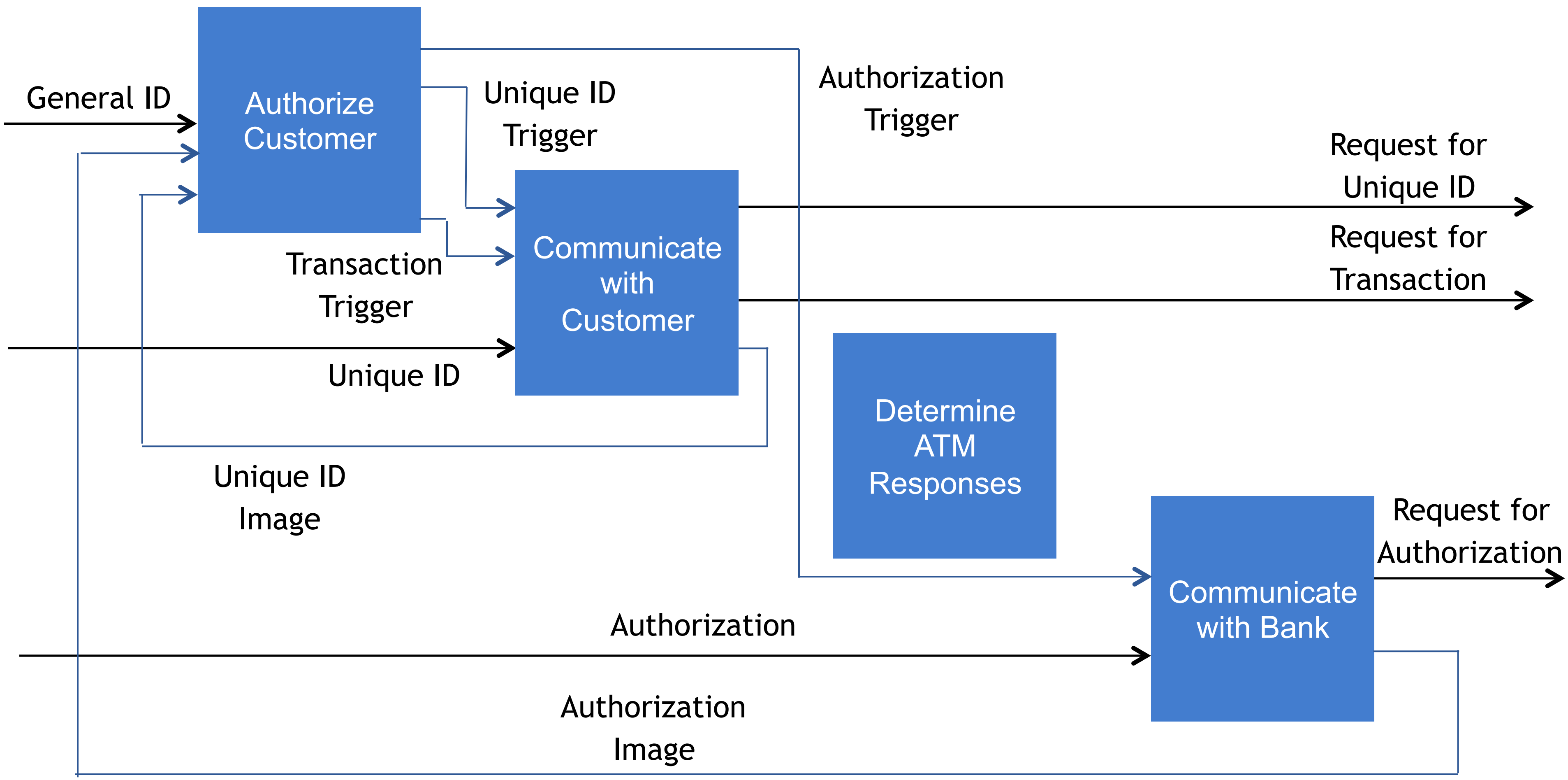
ATM Example: First-Level Functional Decomposition



ATM Example: Input and Output Assignment



ATM Example: Sample Functional Flow



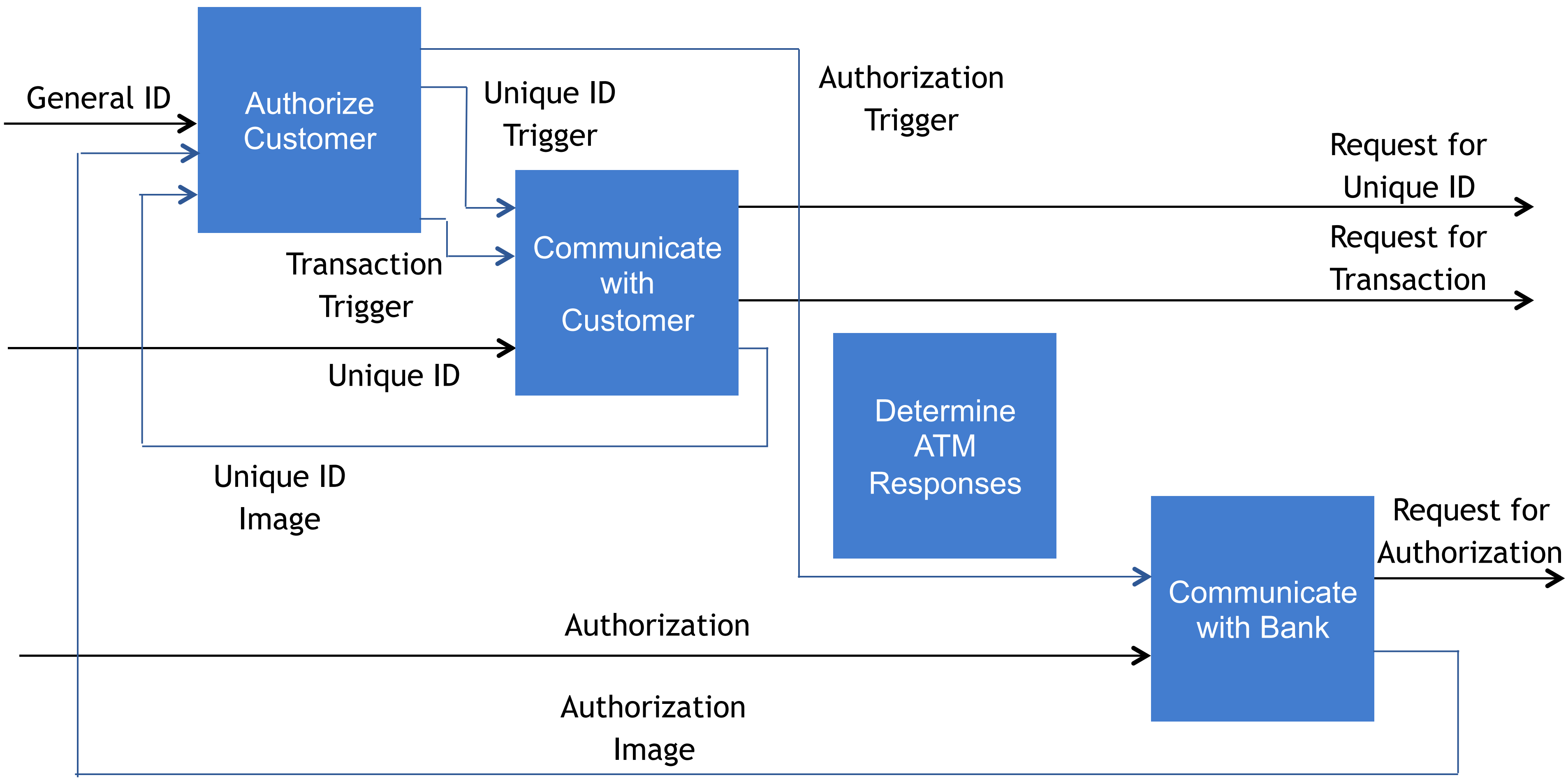
ATM Example:
N^2 CHART – EXTERNAL I/O

GENERAL ID	UNIQUE ID		AUTH	
AUTHORIZE CUSTOMER				
	COMMUNICATE WITH CUSTOMER			REQ FOR UID REQ FOR TRANS
		DETERMINE ATM RESPONSES		
			COMMUNICATE WITH BANK	REQ FOR AUTH

ATM Example:
N^2 CHART - COMPLETE

GENERAL ID	UNIQUE ID		AUTH	
AUTHORIZE CUSTOMER	UID TRIGGER TRANS TRIGGER		AUTH TRIGGER	
UID IMAGE	COMMUNICATE WITH CUSTOMER			REQ FOR UID REQ FOR TRANS
		DETERMINE ATM RESPONSES		
AUTH IMAGE			COMMUNICATE WITH BANK	REQ FOR AUTH

How well does the architecture work? How do you know?



Deciding How the System Will Work
Key Questions:

1. What top-level functions will your system have to perform in order to accomplish it's mission?
   - *<u>Assessment Criteria</u>: Top-level functions are few in number (3-6) and fully represent the required system functionality.*
2. How else could you have partitioned the system functionality and why did you choose to partition it the way you did?
   - *<u>Assessment Criteria</u>: Alternative decomposition is plausible and the rationale for selecting the chosen partition is sound.*
3. How will the top-level functions interact with each other and with their external environment?
   - *<u>Assessment Criteria</u>: Key operational scenarios can be traced through the top-level functions.*
4. How well will your functional architecture perform and what evidence can you provide to support that assessment?
   - *<u>Assessment Criteria</u>: The functional architecture has been analyzed to verify that it achieves the key system requirements.*