Presented to:

RAM Training Summit

TriVector SERVICES INC.

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MBSE Applications

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A Huntsville Area Small Business

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Agenda

- **Introduction**
- MBSE Application – System Model Development
- Summary and Path Forward

Introduction
System Engineering Challenges

- **When speaking of overcoming past engineering failures, Dr. Mike Griffin (*How do we Fix Systems Engineering*) stated, "We need to rise above process, to examine the technical, cultural, and political mix that is 'system engineering', and to examine the education and training we are providing to those who would practice this discipline."**
- **Challenges of engineering complex systems - Dr. Michael Watson (*Engineering Elegant Systems: Theory of Systems Engineering*)**
  - "While at its core system engineering is concerned with the interfaces between and among separable system elements, it should be realized that the more important understanding concerns the dynamic behavior of the interactions between these elements.."
  - Gentry Lee who stated, "it's about the partials, not the values". Properly understood, system engineering is concerned with context over structure, with interactions over elements, with the whole over the sum of the parts.

Tools available to System Engineers greatly enhance the ability to develop elegant (robust, efficient, effective) complex systems

Model-Based Systems Engineering (MBSE)

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Text-Based

Evolving our Approach to Acquisition

Model-Based

The MBSE Puzzle

MBSE is a Systems Engineering paradigm that puts emphasis on applying visual modeling principles

MBSE Benefits

Communication

- Enhances consistency of documentation
- Enables highly interactive reviews
- Used as a tool to solicit feedback from stakeholders

Integration

- Establishes team integration through developing the model and requirements (Systems, Software, Requirements, Test) with a Battle Rhythm
- Reduces stove piping with a single source of truth

Requirements Analysis

- Specification/requirements development, requirements validation (with emphasis on functional requirements)
- Assists in requirements leveling and gap analysis
- Requirement orphans and widows quickly identified

The Ability to "Visualize" the System and Integrated Component Architecture proves valuable in Revealing Undesired and/or Unexpected Behavior

Systems Modeling Language -SysML-

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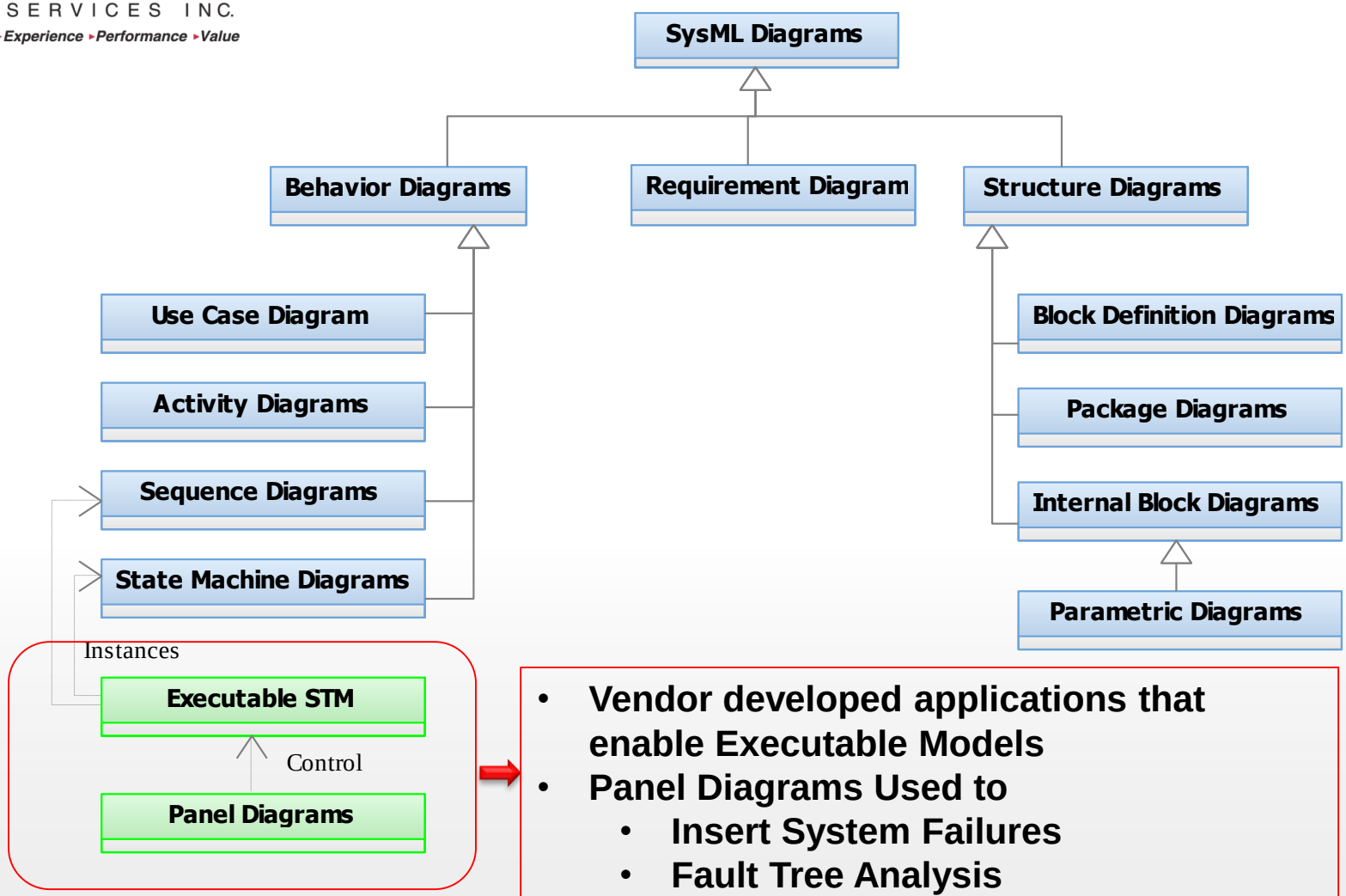

- Vendor developed applications that enable Executable Models
- Panel Diagrams Used to
  - Insert System Failures
  - Fault Tree Analysis
  - Alternate Flows
  - Event Visualization

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Up Front Questions to Ask Before any MBSD Project

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- What resources (dollars, skills, tools, time) are available for this project?
- What is the purpose of this modeling effort?
- What are the customers expectations?
- What are the expected deliverables?
- Does this system already exist?
- Who are the stakeholders and will you have access to them on a regular basis?
- Where will this effort primarily take place?
- Has this system ever been modeled before? By whom? Can we get that model?
- Are there any DoDAF views and/or an Operational Concept that can be leveraged?
- Are there any existing requirements?

[Time // Quality // Quantity] are dependent on one another

The Answers to above questions are related to each other and will influence the usefulness of any modeling effort

Model-Based System Definition (MBSD) Process

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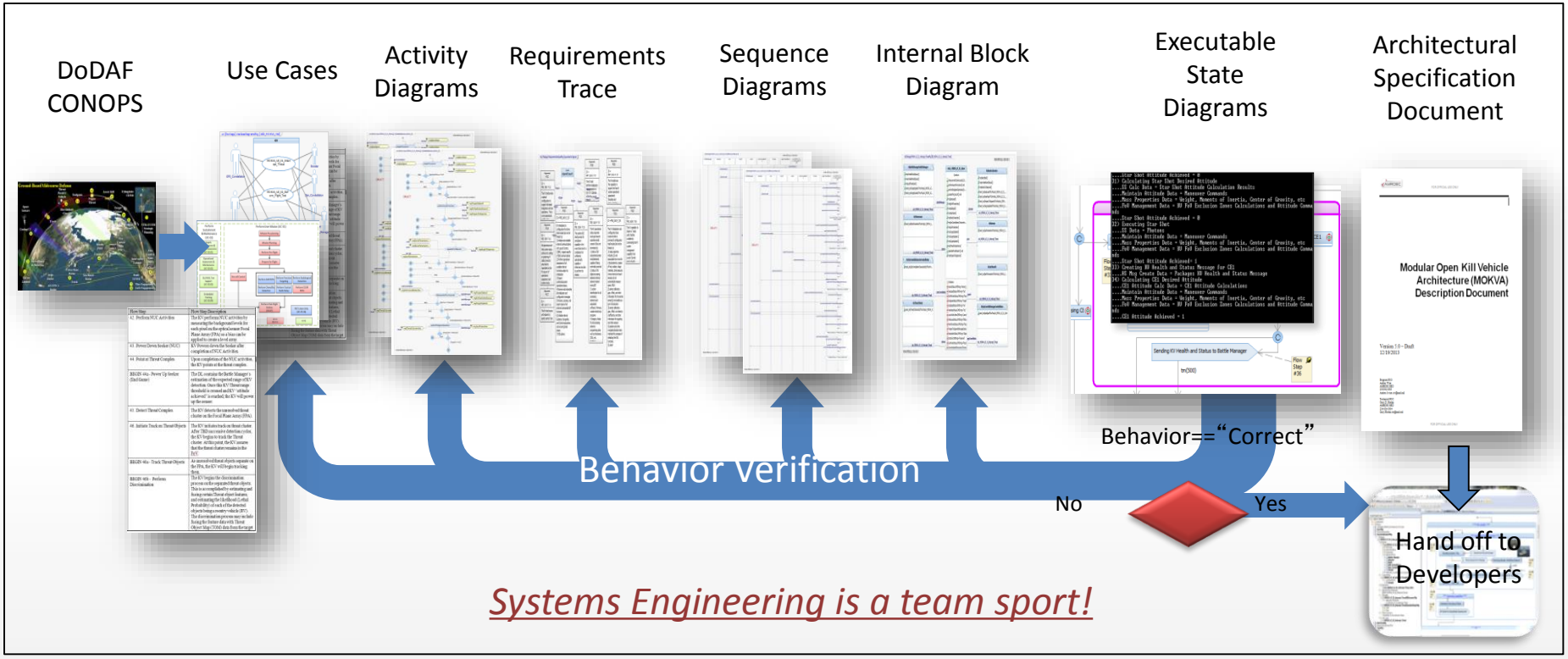

Model-Based System Definition (MBSD) Process

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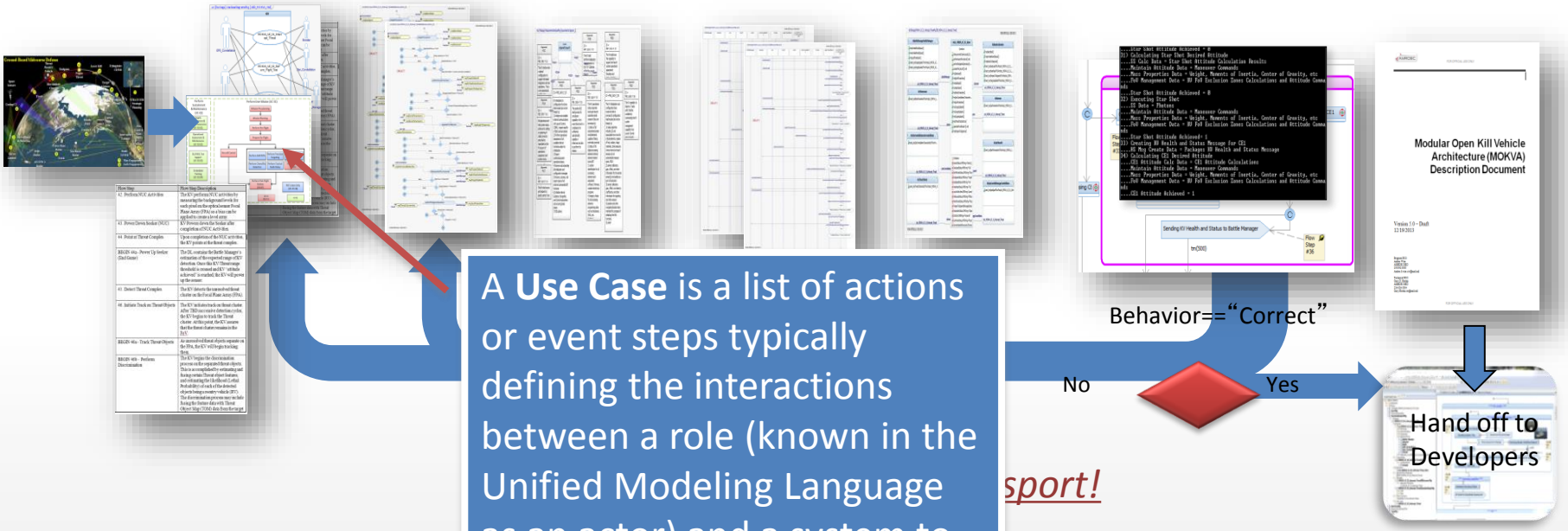
DoDAF CONOPS | Use Cases | Activity Diagrams | Requirements Trace | Sequence Diagrams | Internal Block Diagram | Executable State Diagrams | Architectural Specification Document



A **Use Case** is a list of actions or event steps typically defining the interactions between a role (known in the Unified Modeling Language as an actor) and a system to achieve a goal.

sport!

Model-Based System Definition (MBSD) Process

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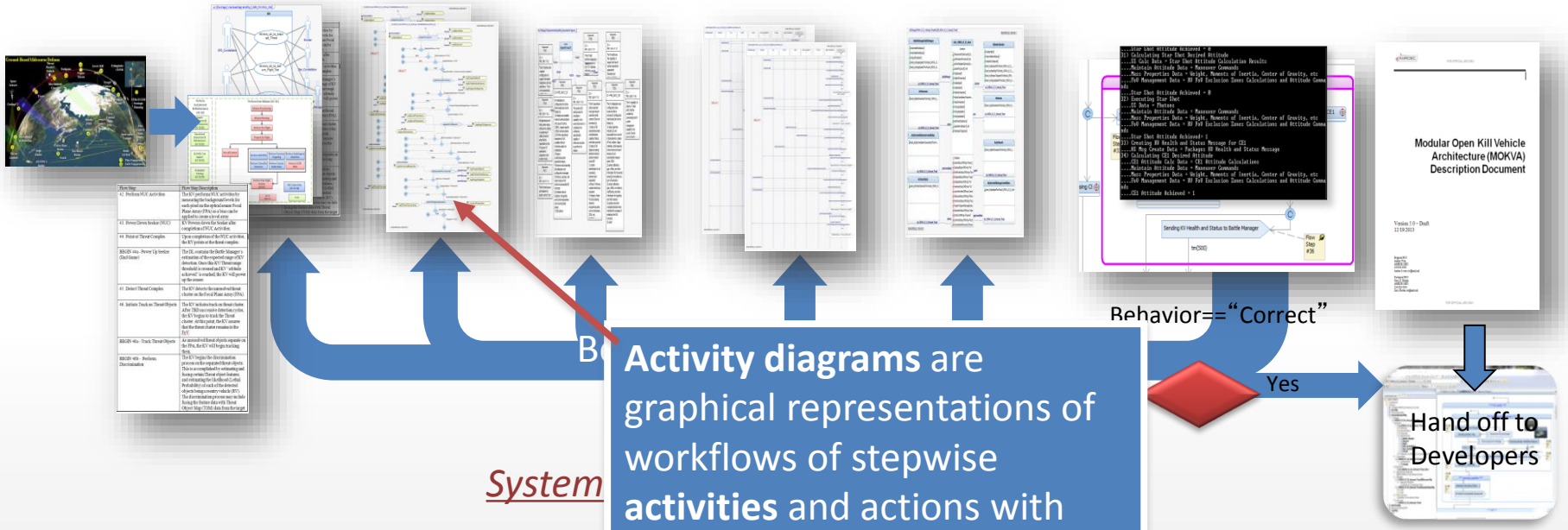

Activity diagrams are graphical representations of workflows of stepwise **activities** and actions with support for choice, iteration and concurrency.

Model-Based System Definition (MBSD) Process

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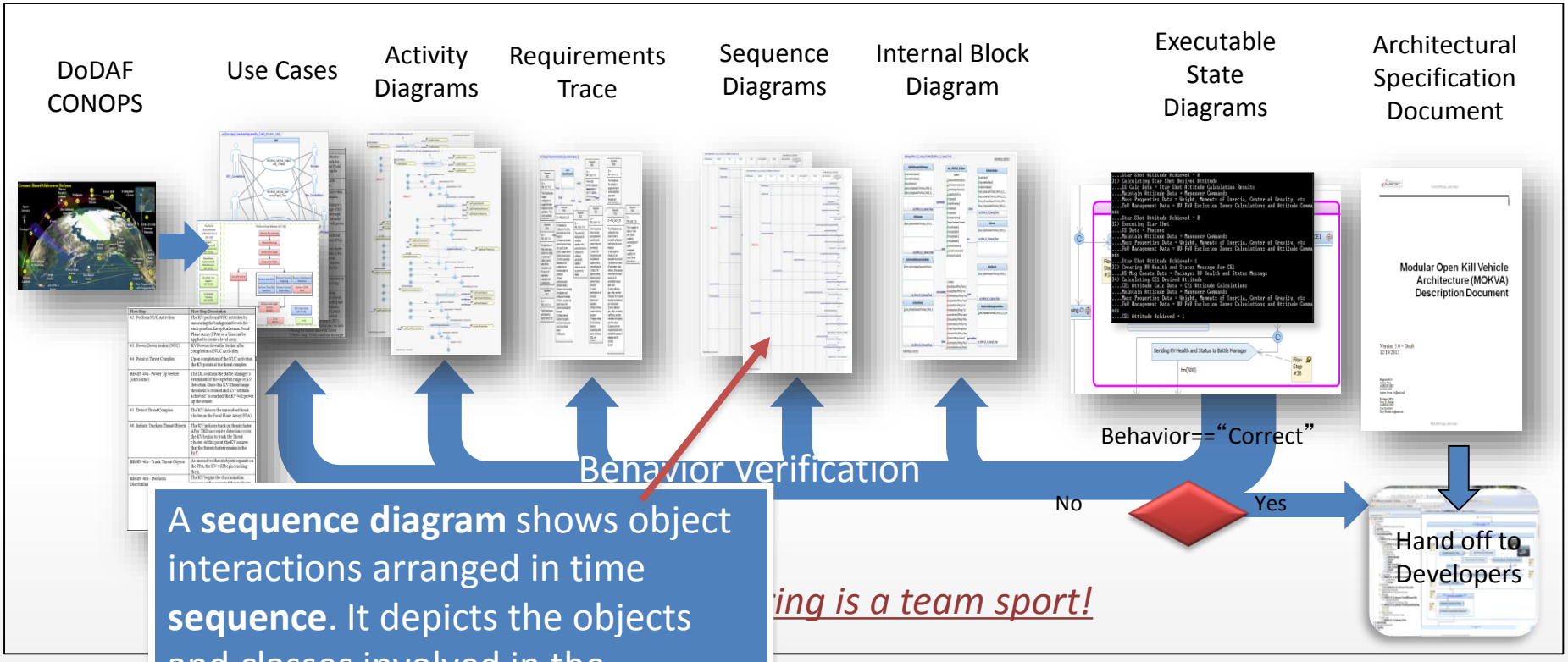

A **sequence diagram** shows object interactions arranged in time **sequence**. It depicts the objects and classes involved in the scenario and the **sequence** of messages exchanged between the objects needed to carry out the functionality of the scenario.

Model-Based System Definition (MBSD) Process

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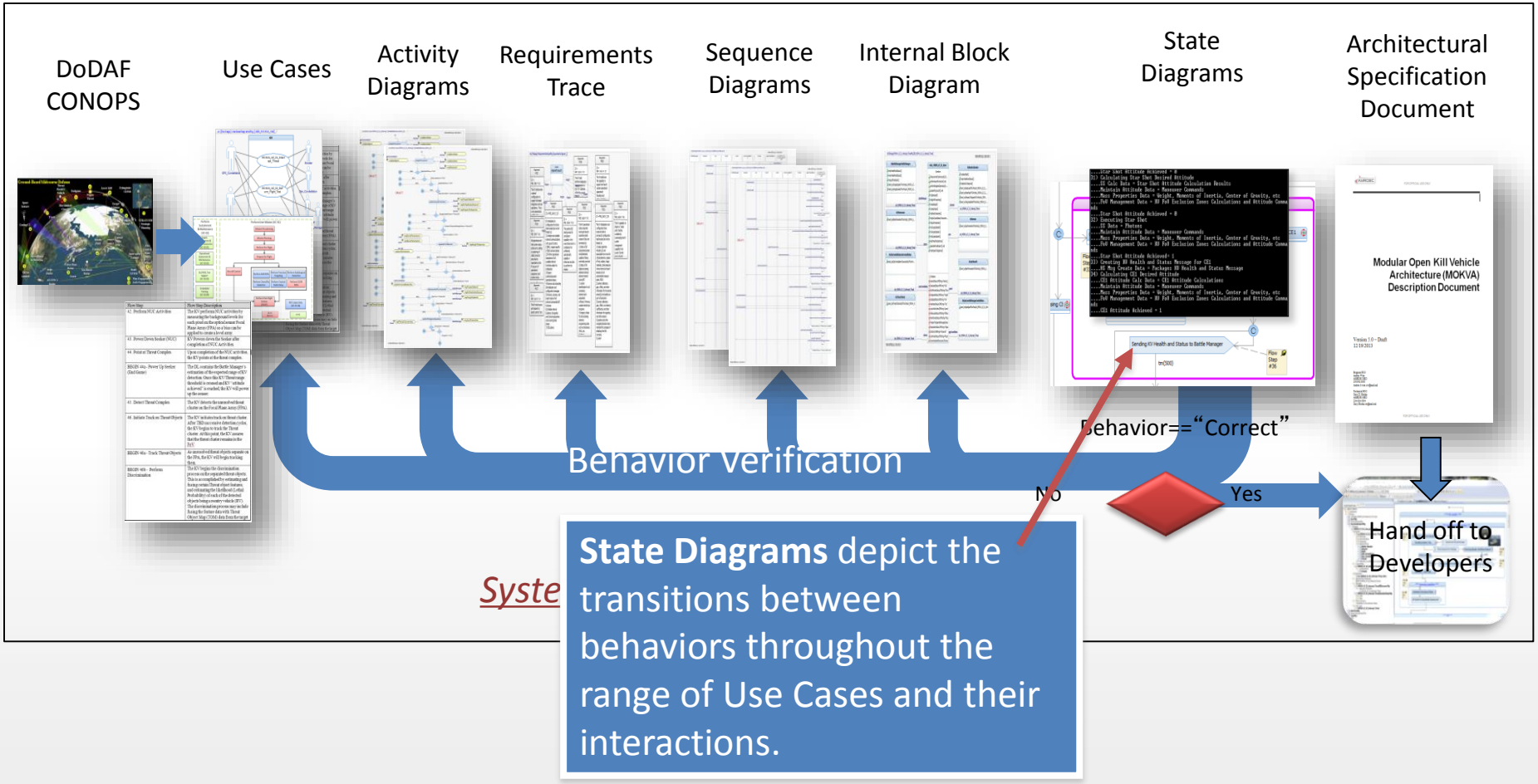

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Background – Example MBSD Development

- **A bank wants to improve its perception among younger customers and plans to introduce a card-less Automatic Teller Machine both at its branches and satellite locations. The Initial concept is for facial recognition software to be employed to analyze facial features of a user, compare it with a database, make a positive match and then allow the user to make a cash withdrawal.**

Operational Concept (1 of 2)

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User Desirement

The stakeholder says they want to develop a new ATM that will allow customers to make transactions based on facial recognition. After the machine makes a positive ID of the customer, they are able to make cash withdrawals from the machine.

Just based on this graphic, and the lead in, what are your observations on system expected behavior?

Operational Concept (2 of 2)

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Observations on Operational Concept

- Is the camera integral to the ATM, or is it a separate external component?
- How will the stakeholder build/maintain a facial database?
  - Should this even be considered in this system?
- Where will the database be stored/queried?
- Why is a stamp included in the operational concept?
- What is the desired behavior when a Unauthorized User Attempts to Access the System
- Should the user be connected to the withdrawal function?
- Others?

…Translated into Initial Stakeholder Requirements…

•The System shall perform facial recognition of users
•The System shall determine the identity of the User
•Upon positive identification of the user, the System shall allow the user to input the desired amount of money
•The system shall dispense a User-defined amount of money
•The System shall prevent use by Unauthorized Users

Operational Concept (2 of 2)

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So lets Scope the Initial Use Case

- **What is the system under consideration, what do we call it?**

  → *System name needs to be something easily recognizable. Let's go with the obvious: Facial Recognition ATM (FR-ATM)*

- **Can we define the "Goal" of the System**

  → *Allow the Authorized User to withdrawal money from the ATM*

- **What "Actors" will the system have to interface with?**

  → *Customer*

- **What does a successful day look like for the System?**

  → *A customer approaches the FR-ATM, the FR-ATM correctly Identifies the customer, and allows the customer to withdrawal money from their account*

Initial Use Case Diagram for "Execute Cash Withdrawal"

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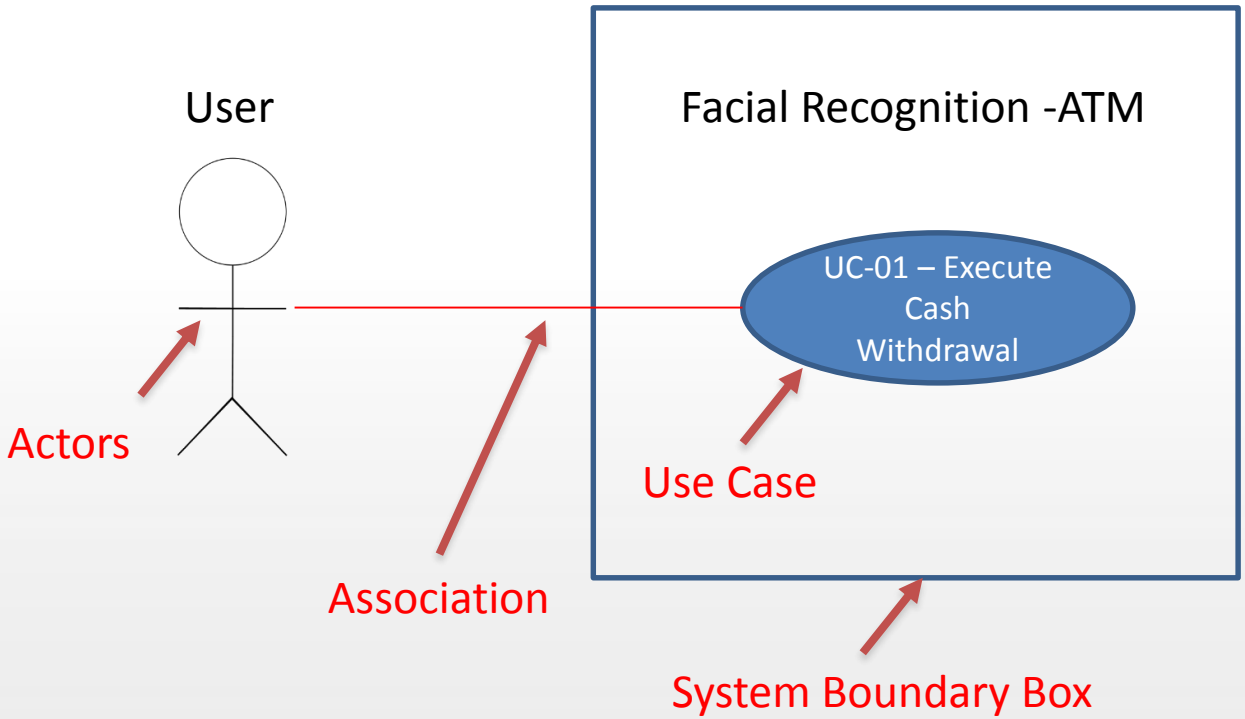
Pre-Conditions:
1) The system is powered on
2) A customer is in view of the camera

Post-Conditions:
1) The Authorized User has made a cash withdrawal



Activity Diagram for "Execute Cash Withdrawal" (1 of 3)

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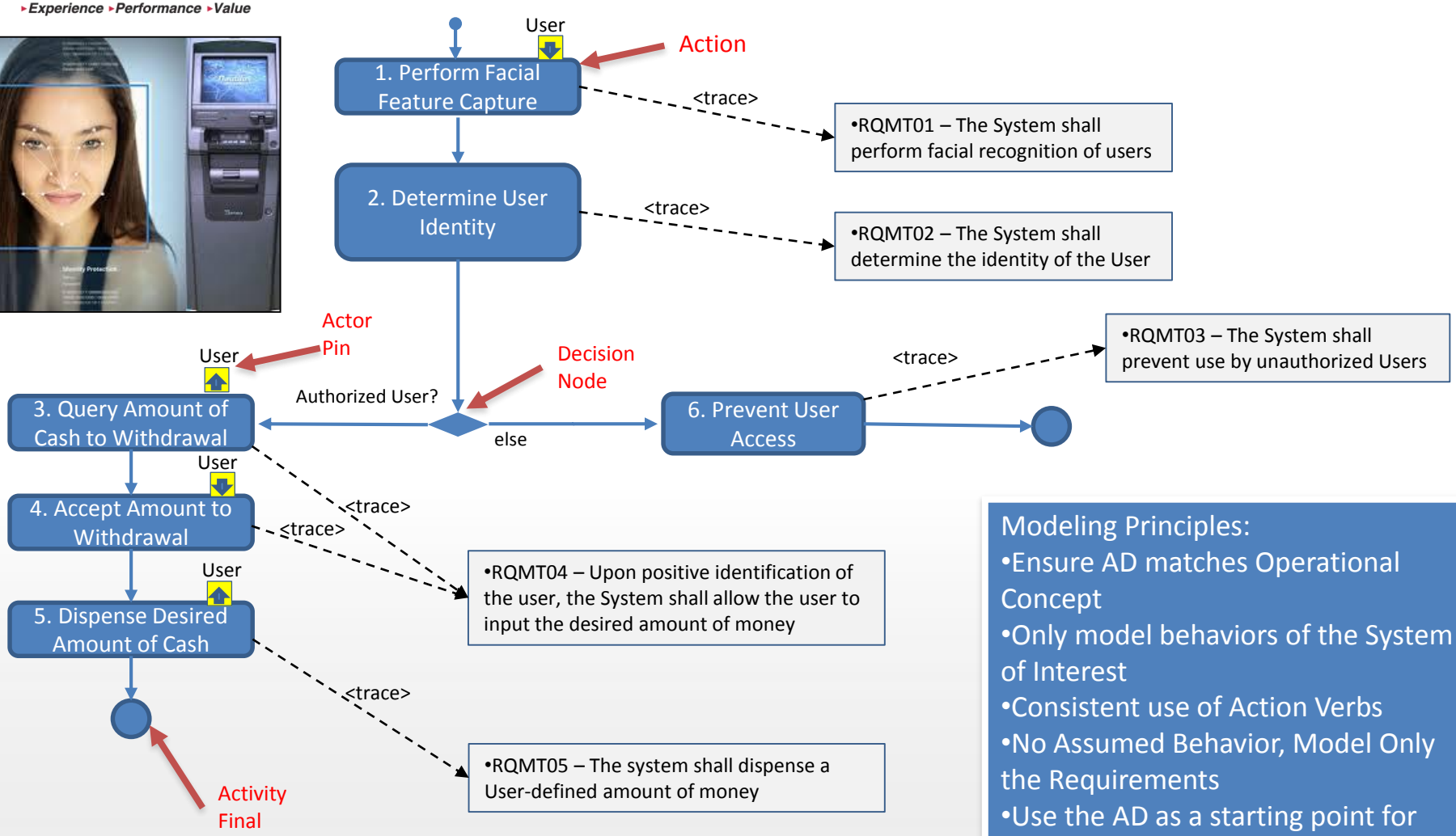

Modeling Principles:
- Ensure AD matches Operational Concept
- Only model behaviors of the System of Interest
- Consistent use of Action Verbs
- No Assumed Behavior, Model Only the Requirements
- Use the AD as a starting point for 'What-If?' Conversations with Stakeholders

Activity Diagram for "Execute Cash Withdrawal" (2 of 3)

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User
1. Perform Facial Feature Capture
<trace>
•RQMT01 – The System shall perform facial recognition of users
2. Determine User Identity
<trace>
•RQMT02 – The System shall determine the identity of the User
Authorized User?
else
<trace>
•RQMT03 – The System shall prevent use by unauthorized Users
6. Prevent User Access
User
3. Query Amount of Cash to Withdrawal
<trace>
User
4. Accept Amount to Withdrawal
<trace>
•RQMT04 – Upon positive identification of the user, the System shall allow the user to input the desired amount of money
User
5. Dispense Desired Amount of Cash
<trace>
•RQMT05 – The system shall dispense a User-defined amount of money

Observations:
- What triggers the FR-ATM to perform feature capture?
- Does the FR-ATM determine the User ID or is that an external function?
- Does the System notify the User they are an Unauthorized User?
- Does the FR-ATM determine if the User has the required amount of money in their account?
- Appears that the Ops Concept & Use Case Needs to be updated…

Updated Use Case Diagram for "Execute Cash Withdrawal"

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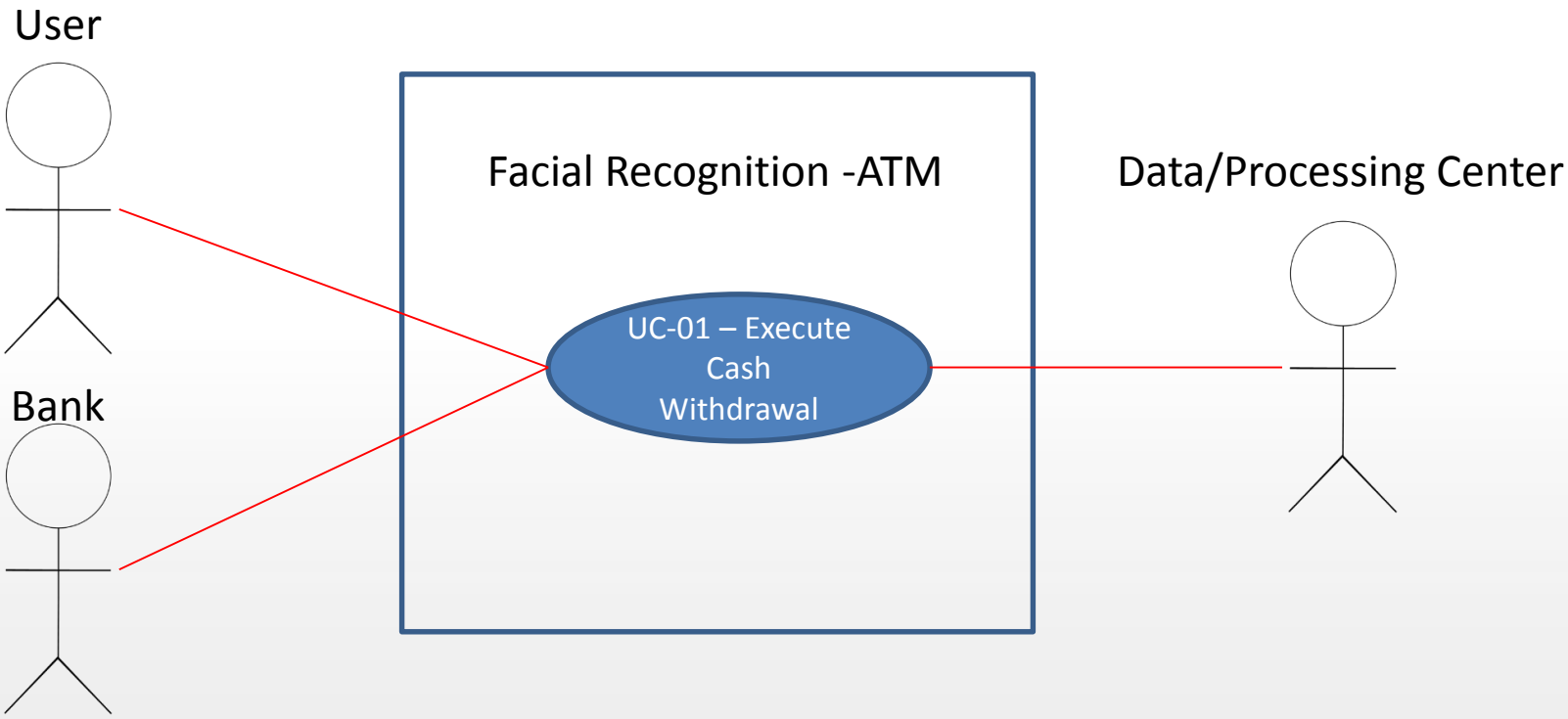
Revisions to Use Case
- Data Processing is performed at an external facility
- The 'Bank' maintains the amount of Cash available for withdrawal
- If a User cannot be identified, they are prompted if they want to 'Try Again'



Updated Activity Diagram for "Execute Cash Withdrawal"

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~~•RQMT02 – The System shall determine the identity of the User~~
•NOT A FR-ATM FUNCTION

•RQMT07 – The System shall continuously search for Users

~~•RQMT01 – The System shall perform facial recognition of users~~
•RQMT06 – The System shall capture facial features of the User

•RQMT09 – The System shall provide User facial feature data to the Data Center

•RQMT10 – The System shall receive User Identification data from the Data center

•RQMT04 – Upon positive identification of the user, the System shall allow the user to input the desired amount of money

•RQMT11 – Upon determination of an Unauthorized User, the System shall allow the User to attempt an additional log-in

•RQMT12 – The System shall receive a confirmation from the Bank that cash is available

•RQMT03 – The System shall prevent use by unauthorized Users

•RQMT08 – The System shall provide User desired withdrawal amount to the Bank

•RQMT05 – The system shall dispense a User-defined amount of money

User
1. Search for Users
Find Anything?
else
Yes
No
Yes
Merge Node
2. Perform Facial Feature Capture
Data Center
3. Provide Feature Data
Data Center
4. Receive User Identity Determination
Authorized User?
else
User
9. Accept User Input Try Again
User
8. Display Error Message
User
5. Query Amount of Cash to Withdrawal
User
6. Accept Amount to Withdrawal
Bank
5. Query if Cash is Available
Bank
5. Receive Available Cash Confirmation
User
7. Dispense Desired Amount of Cash

Observations:
- All behaviors traced to requirements
- Questions from Initial AD Observations have been answered
- Visual Requirements Management
- Post-Conditions are satisfied
- Interfaces Identified

Sequence Diagram for "Execute Cash Withdrawal" (1 of 2)

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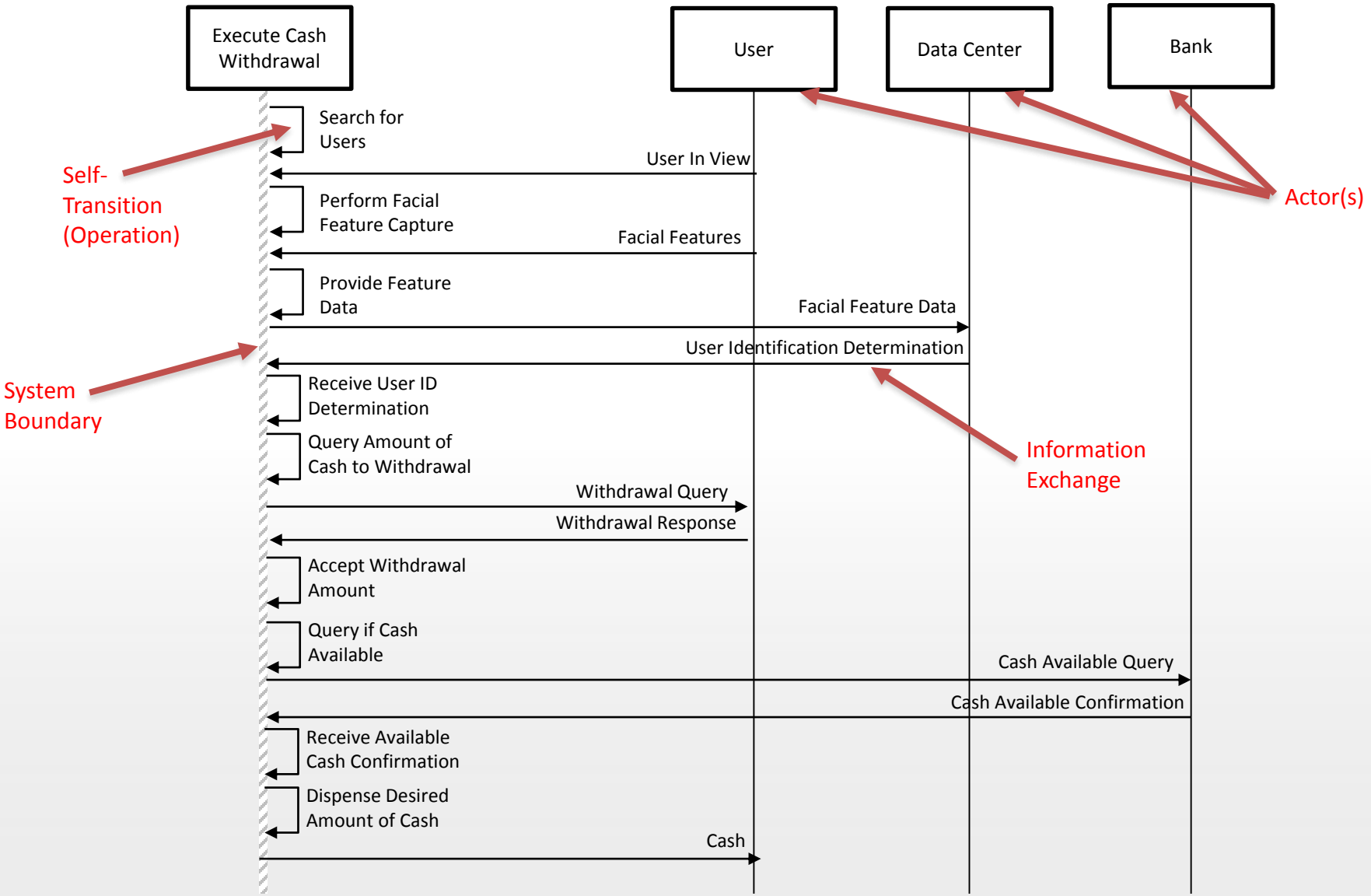

Sequence Diagram for "Execute Cash Withdrawal" (1 of 2)

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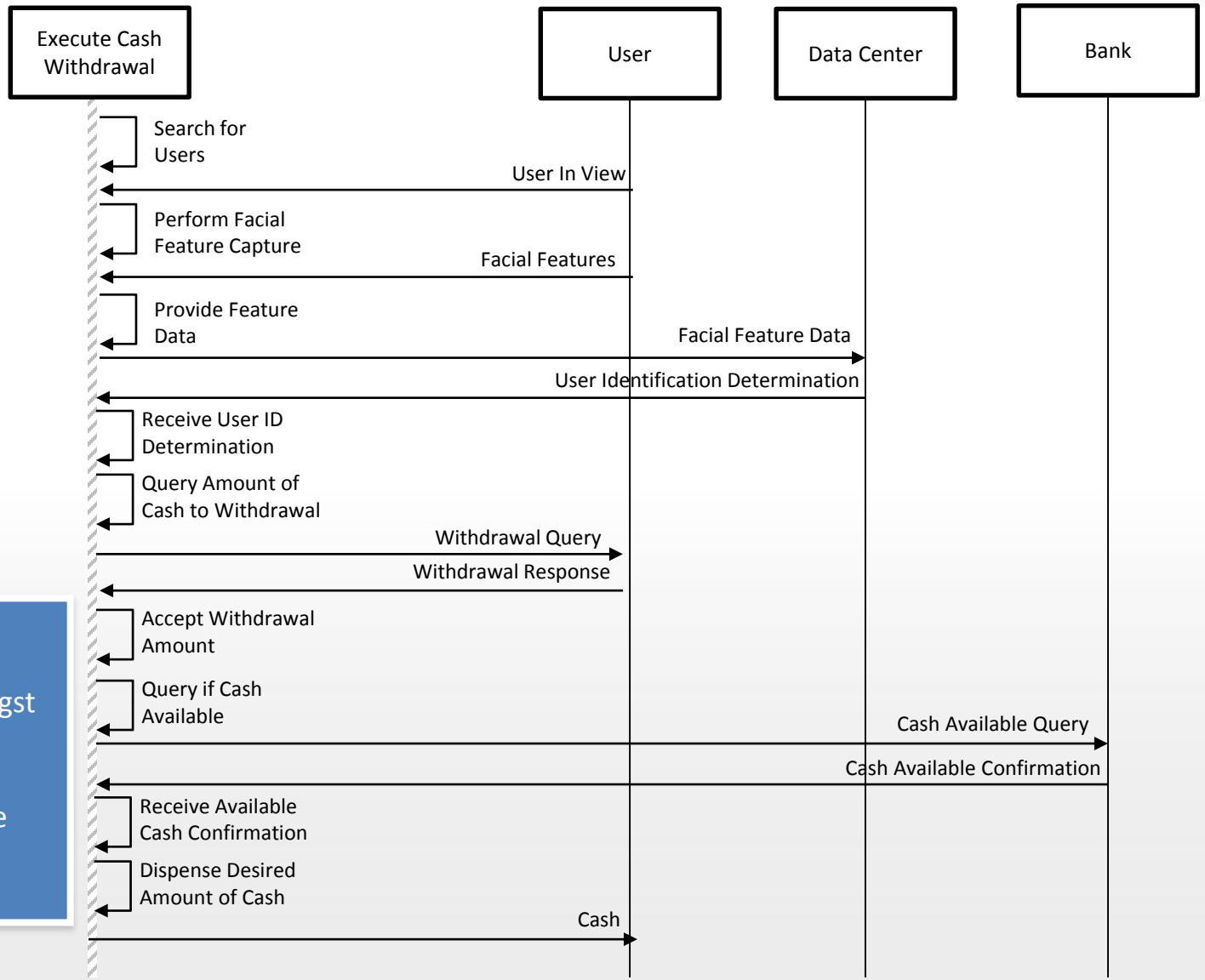

Observations:

- Operations consistent amongst AD and SD
- Information Exchanges define Interface Requirements

Expanding on the System Architecture

- **Investigate if Additional Use Cases Exist through What-If analysis with Stakeholders**
  - What-If:
    - …the System is low/out of money to dispense?
    - …the User has insufficient funds in their account?
    - …the System cannot connect to the Data Center or the Bank?
    - …the System is unable to perform operations due to a malfunction?
    - Others
- **Additional Use Cases are created and defined throught the MBSE Process to encompass the entire lifecycle of the System**
  - May identify additional external Actors
- **Functional behavior of the System is described in the State Diagram**

Example State chart Diagram for "FR-ATM"

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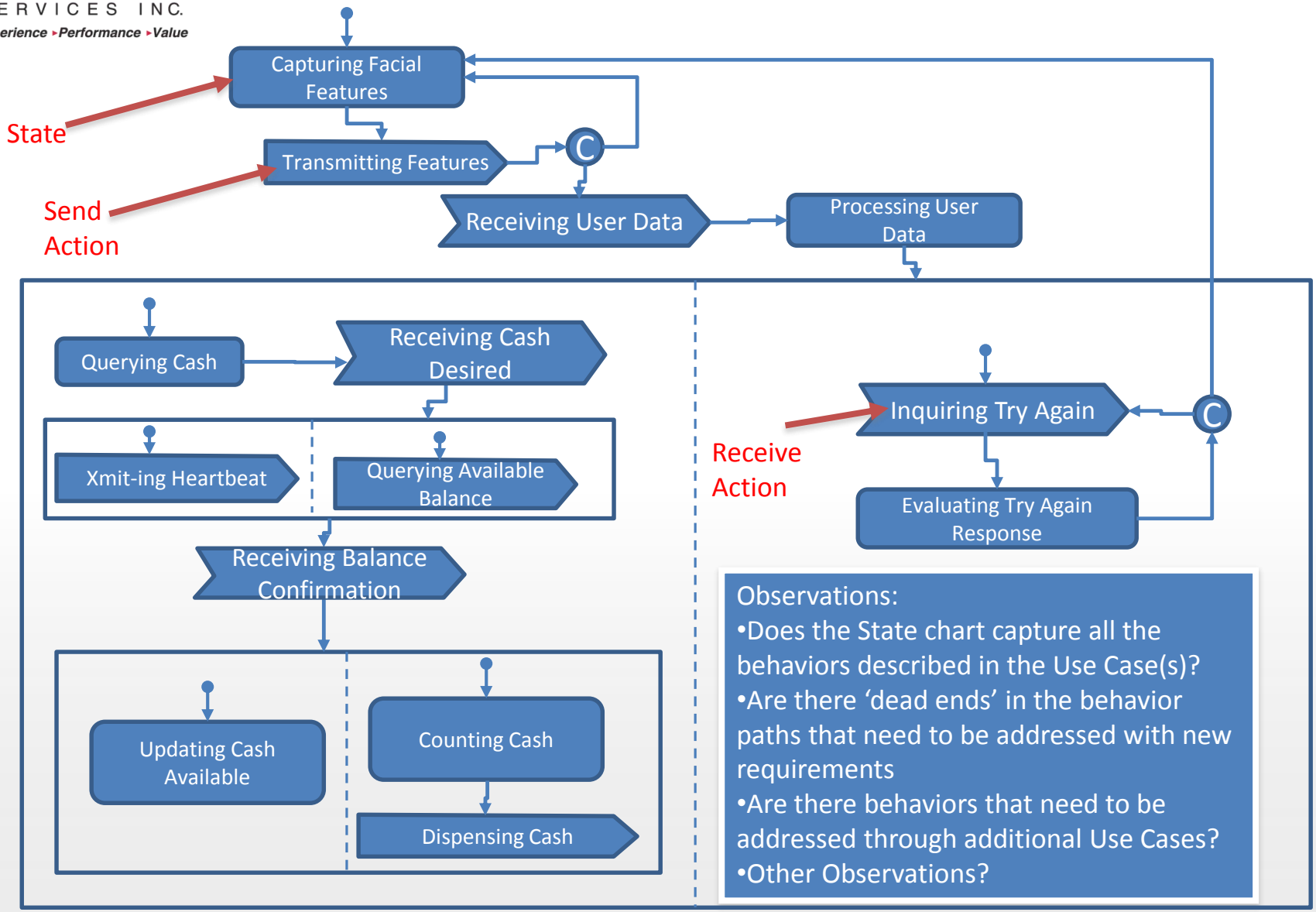

Observations:
- Does the State chart capture all the behaviors described in the Use Case(s)?
- Are there 'dead ends' in the behavior paths that need to be addressed with new requirements
- Are there behaviors that need to be addressed through additional Use Cases?
- Other Observations?

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Additional Considerations

- **Are there any applicapable laws/regulations that should be considered?**
- **Based on the System Architecture, are there areas/requirements that can be modified to increase system reliability?**
- **Are the interface requirments identified able to be performed by the External Actors?**
- **Tie Functional Requirements to Performance Requirements**
  - ‘Do This’ and ‘Do It This Fast’

Reliability Considerations for "Execute Cash Withdrawal" (1 of 2)

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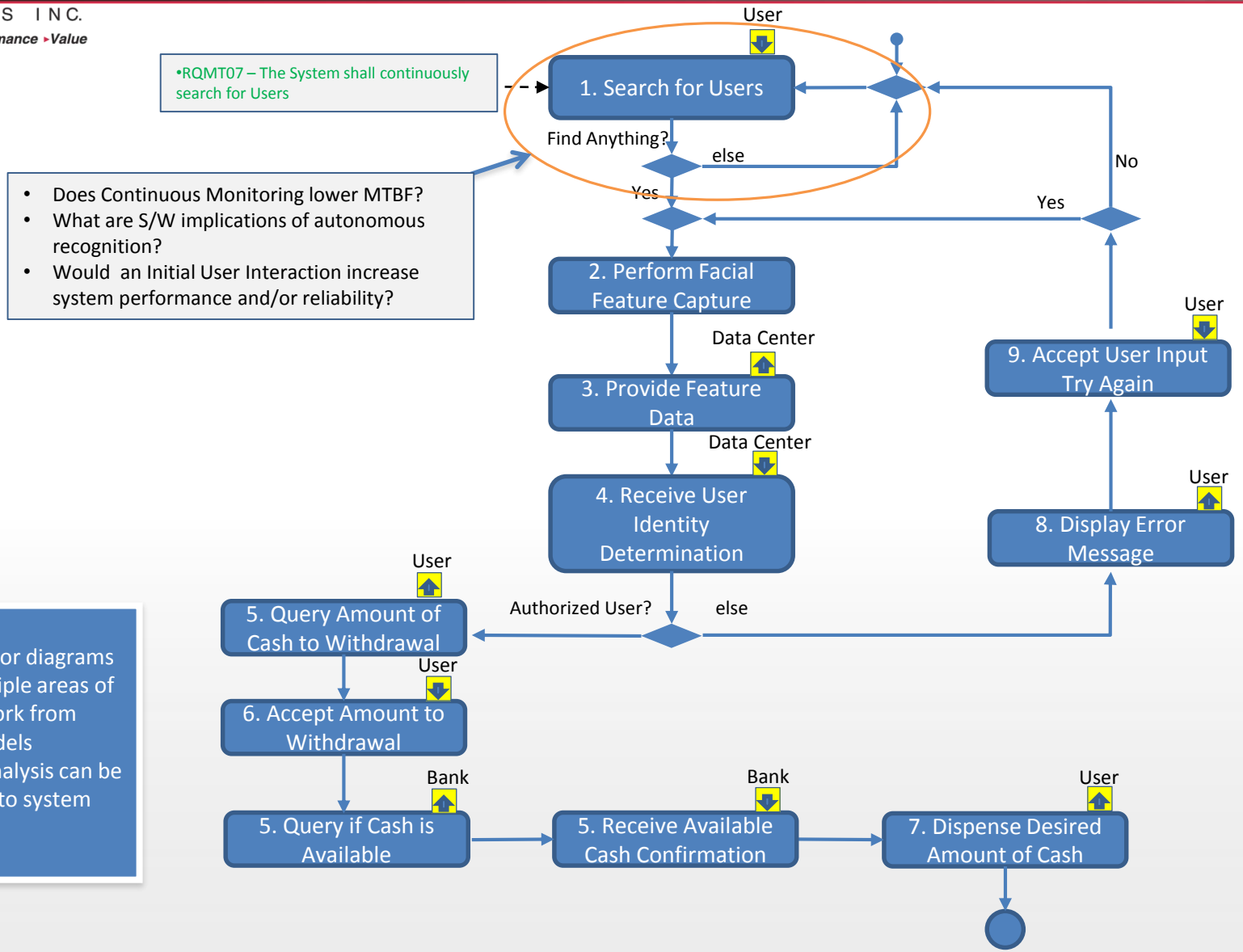

Observations:
- Concise behavior diagrams allow for multiple areas of engineering work from integrated models
- Failure Tree Analysis can be linked directly to system models

Reliability Considerations for "Execute Cash Withdrawal" (2 of 2)

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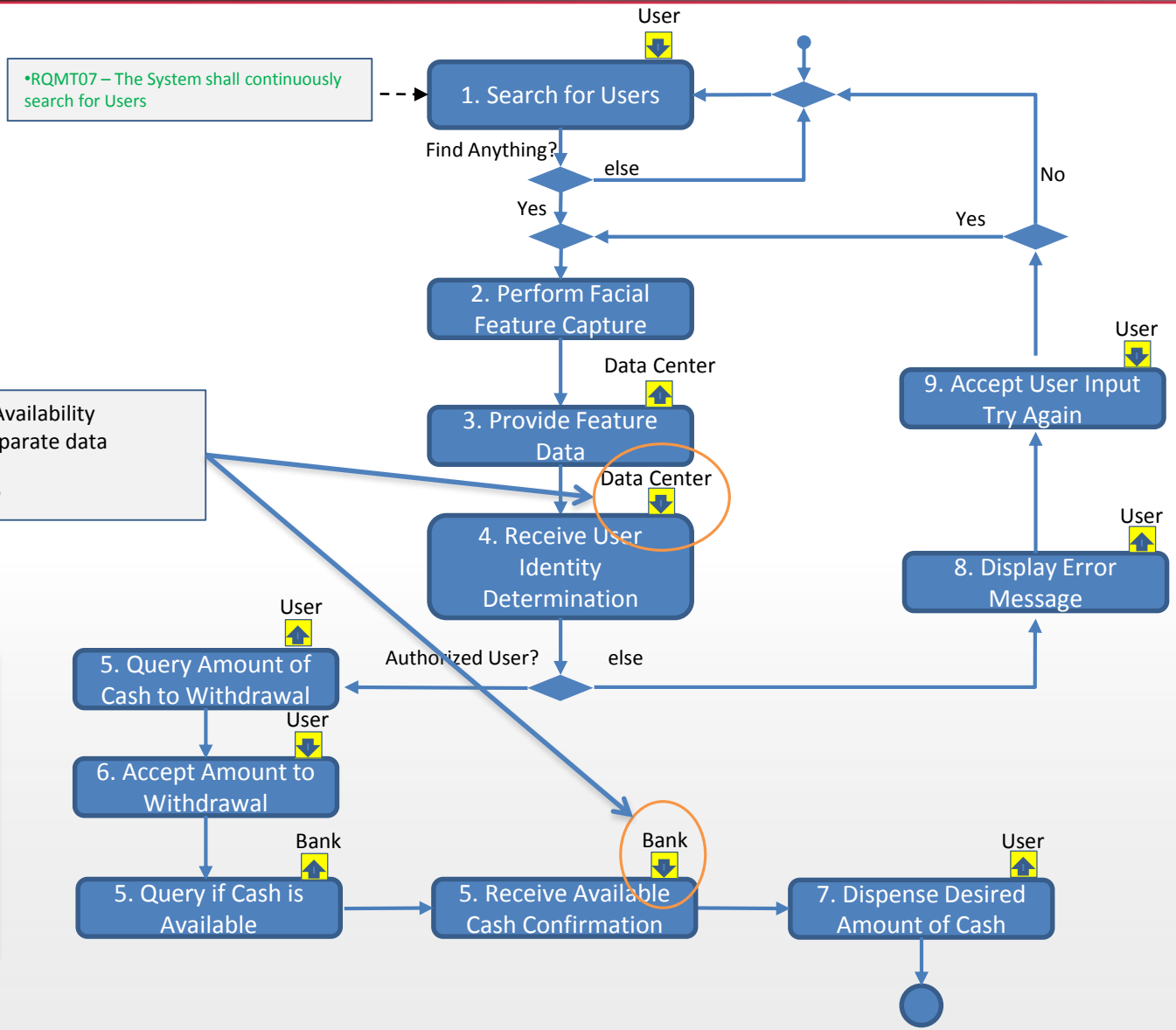

- What are the Reliability / Availability constraints for having 2 separate data interfaces?
- Could these be combined?

Observations:

- Concise behavior diagrams allow for multiple areas of engineering work from integrated models
- Failure Tree Analysis can be linked directly to system models

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- **Summary and Path Forward**

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MBSE Lessons Learned and Conclusions

- **Systems Engineering is a Team Sport**
  - If you don't have the right people you have the wrong solution
- **MBSE is a new paradigm for Systems Engineering and there is significant inertia to change**
- **MBSE is a SE Process, not an exercise in tool use**
- **Effective Communication over Model Intricacies**
- **Developing meaningful SysML models takes a lot of practice….i.e. epic fails**
- **Properly scoping a Use Case early will save a lot of rework time later.**
- **Each Behavior Diagram serves a unique purpose, don't try and make diagram show all conical forms.**
- **MBSE enhances traditional Systems Engineering principles, it doesn't eliminate them**

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Critical Customer Challenges

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