# *Biometrics Enterprise Architecture*

Team Biometrics Enterprise-Architecture (BM-EA)

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# Bottom Line Up Front and Agenda

- Bottom Line: Current Architecture for Biometric Applications is outmoded and antiquated.
- Team BM-EA is pleased to present their OR 680/SYST 798 Capstone Project to the OR/SE faculty for the Fall 2009 semester
- Agenda
  - Problem Statement and Team Mission
  - Systems Engineering Processes and Modeling Tools
  - Results and Findings

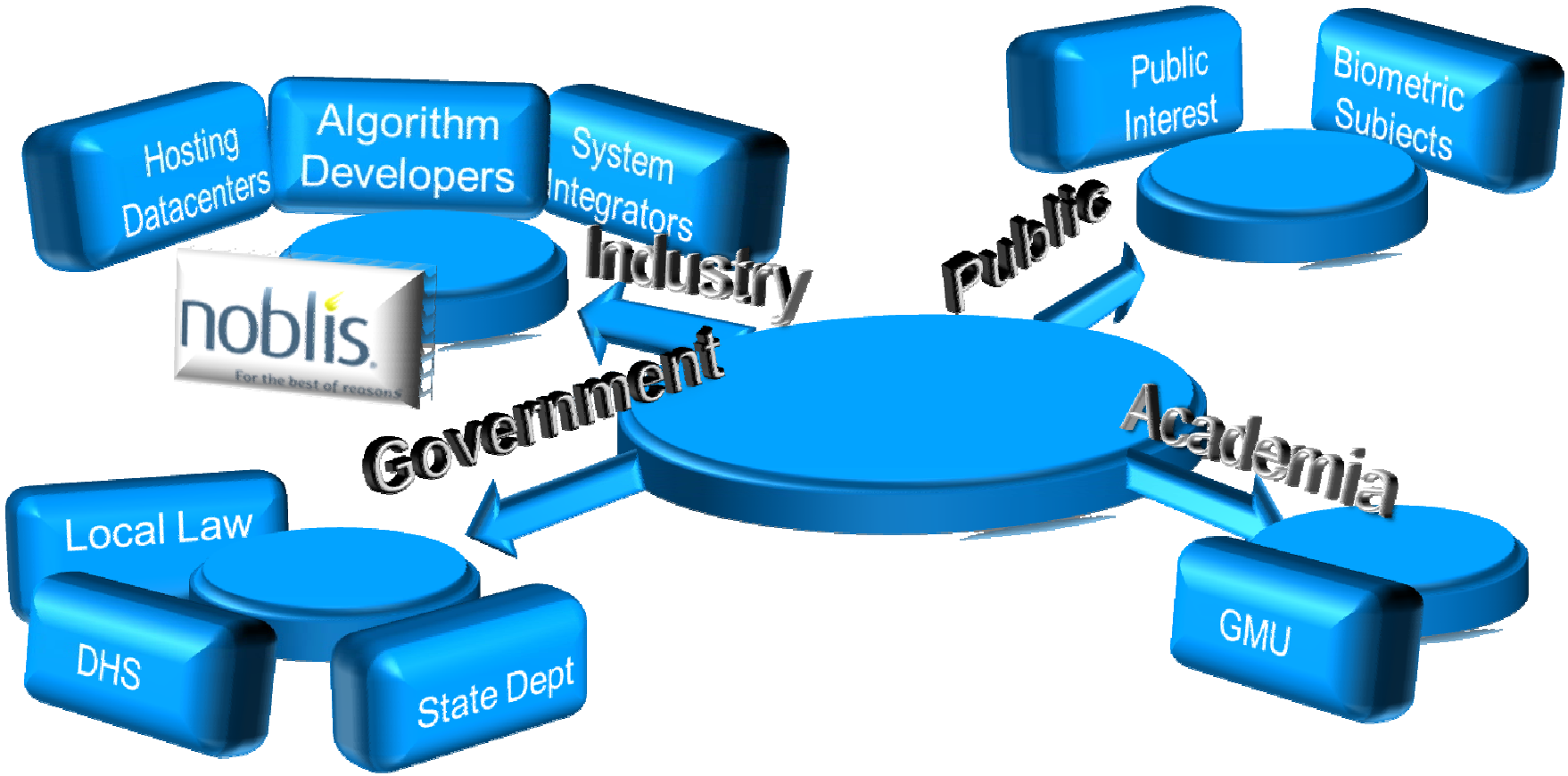
# Problem Statement

- Current large-scale biometric systems are generally inflexible and not optimized for their applications.
  - Stovepipe System Architectures
  - Proprietary solutions
  - Poor integration with enterprise systems
- The biometric algorithm market is trending towards less competition risking less innovation and higher prices although open-source initiatives are showing performance improvements.

# Mission Statement and Sponsor

- Team BM-EA is chartered to investigate existing biometric implementations to assess barriers to biometric enterprise integration. Team BMEA will produce “As-Is” biometrics systems architecture along with technical and financial (economic) performance models. Results are compared to prospective “To-Be” technical and financial (economic) models and results.
- Our sponsor is Noblis, Inc., is a nonprofit science, technology and strategy organization helping clients solve complex systems, process and infrastructure problems to benefit the public. We have partnered with them through Mr. Nat Hall, a Noblis employee and has colleagues interested in engaging our team for biometric systems architectural analysis.

# Stakeholder Community



# Stakeholder Needs Assessment and Value Mapping

1. Flexibility
2. Interoperability
3. Match Performance
4. Open Architecture

| Requirement Objectives \ Stakeholder Weights | SEOR Faculty | Noblis, Inc. | Govt Agencies | Criminal Investigators | Public Interest | Large Scale Biometric System | Image Acquistion System Developers | Biometric Match Algorithm Developers | Biometric System Managers/Administrator | Biometric Match Reviewers/Analysts | Requirement Value | Requirement Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 18 | |
| Increased Scalability | 2 | 3 | 3 | 3 | 1 | 4 | --- | --- | --- | --- | 2.6 | 8 |
| Increased Interoperability | 3 | 4 | 4 | 4 | 2 | 3 | --- | --- | --- | --- | 3.5 | 2 |
| Increased Flexibility | 4 | 4 | 4 | 3 | 3 | 4 | --- | --- | --- | --- | 3.7 | 1 |
| Improved biometric match performance | 3 | 3 | 3 | 4 | 2 | 3 | --- | --- | --- | --- | 3.1 | 4 |
| Transaction throughput | 3 | 2 | 3 | 3 | 3 | 3 | --- | --- | --- | --- | 2.8 | 7 |
| Transaction response times | 3 | 2 | 3 | 4 | 3 | 3 | --- | --- | --- | --- | 2.9 | 6 |
| Increased use of open source algorithm solutions | 3 | 4 | 4 | 0 | 4 | 3 | --- | --- | --- | --- | 3.1 | 4 |
| Multibiometric fusion Performance | 2 | 2 | 2 | 3 | 1 | 2 | --- | --- | --- | --- | 2.1 | 11 |
| Cost reduction | 1 | 3 | 3 | 3 | 3 | 1 | --- | --- | --- | --- | 2.4 | 9 |
| Ease of use | 2 | 2 | 2 | 4 | 3 | 2 | --- | --- | --- | --- | 2.4 | 9 |
| Standardization | 2 | 4 | 3 | 3 | 2 | 3 | --- | --- | --- | --- | 2.9 | 6 |
| Continuous improvement to algorithm performance | 3 | 4 | 3 | 4 | 2 | 2 | --- | --- | --- | --- | 3.2 | 3 |

Interoperable System

Flexible System

Encourage Open Source Solutions

Enable And Encourage Continuous improvement

| Value Scale Key | |
|---|---|
| Critical to stakeholder satisfaction | 4 |
| Highly recommended for stakeholder satisfaction | 3 |
| Provides moderate value to stakeholder satisfaction | 2 |
| Provides minimal value to stakeholder satisfaction | 1 |
| Provides no added value to stakeholder satisfaction | 0 |

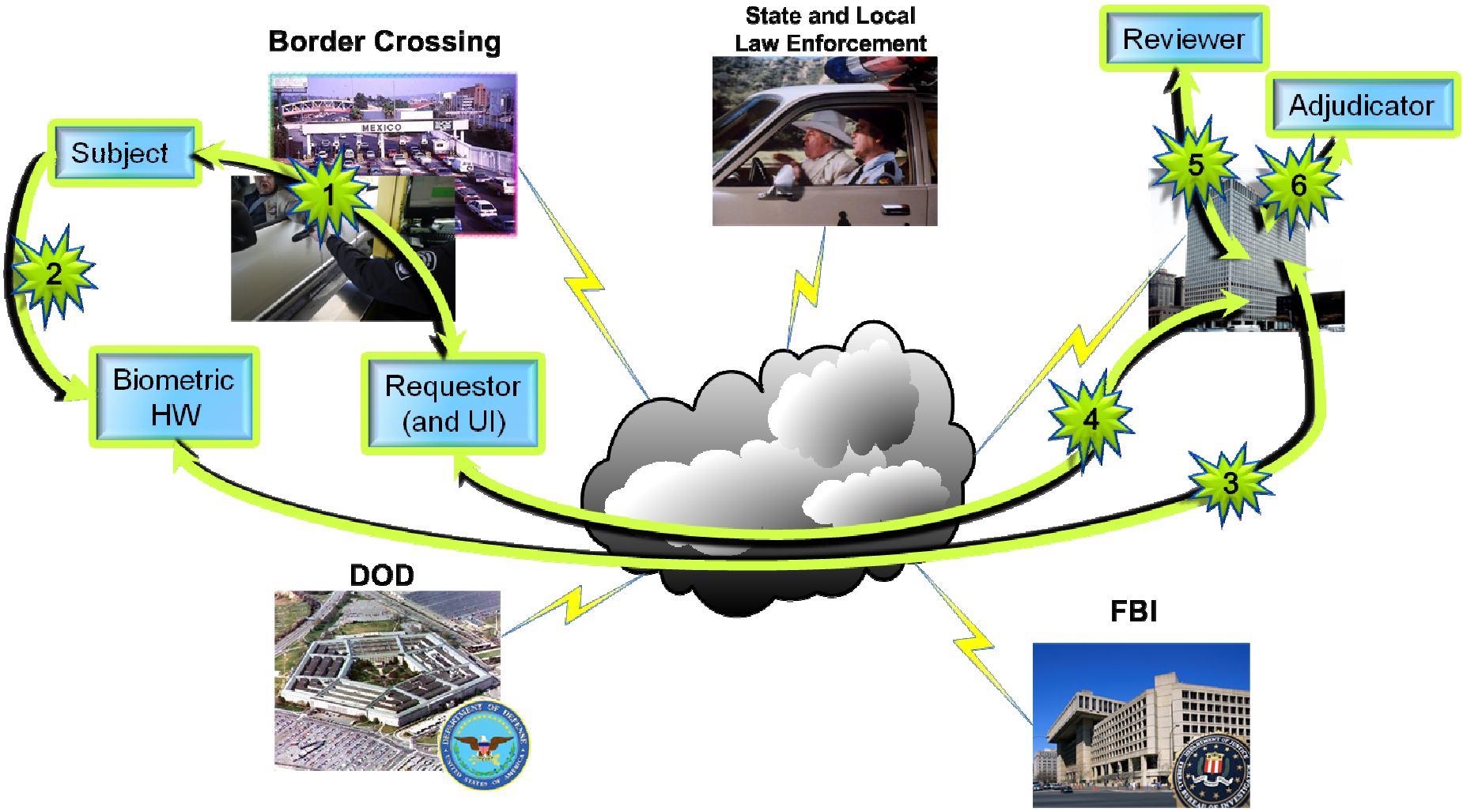
# Top Priority “ilities”

1. *Flexibility* – The architecture shall enable control of accuracy, throughput, response time, and technology used.
2. *Interoperability* – The architecture shall provide simple, decoupled transition interfaces allowing plug-n-play designs.
3. *Match Performance* – The architecture shall enable high match accuracy in large-scale, high volume biometric transaction systems and encourage research towards continued improvement.
4. *Open Architecture* – The architecture shall encourage non-propriety solutions and discourage Monopolistic behaviors to continually improve RO Algorithm Flexibility – The architecture shall provide low cost transitions among match algorithms.
5. Security – Biometric and other identifying data shall remain secure
6. Acceptability – Proven technology shall be used
7. High Availability – Architecture shall enable 99.9% (“three nines”) or Approximately 8 hours per year maximum downtime

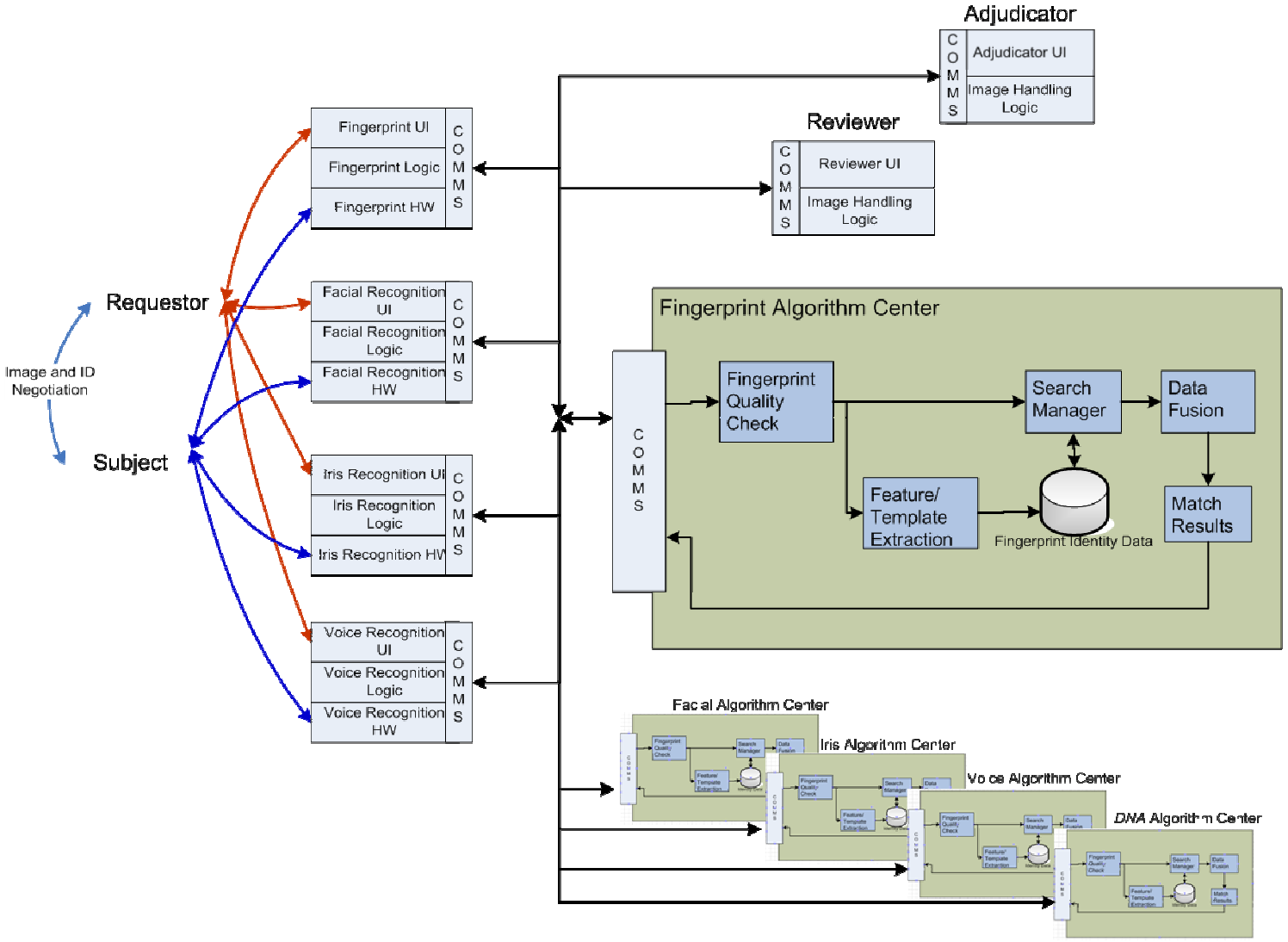
# Project Definition

- Team BM-EA's project provides results that serve to establish parameters for indicating non-vendor specific, non-proprietary flexible, scalable prospective biometric implementations within either an existing or prospective enterprise. Specifically Team BMEA:
  - Investigated alternatives to biometric system enterprise integration barriers
  - Investigated alternatives for flexible, interoperable, scalable and open solutions
  - Provides a pattern for non-proprietary open-standard based access to vendor match and search algorithms

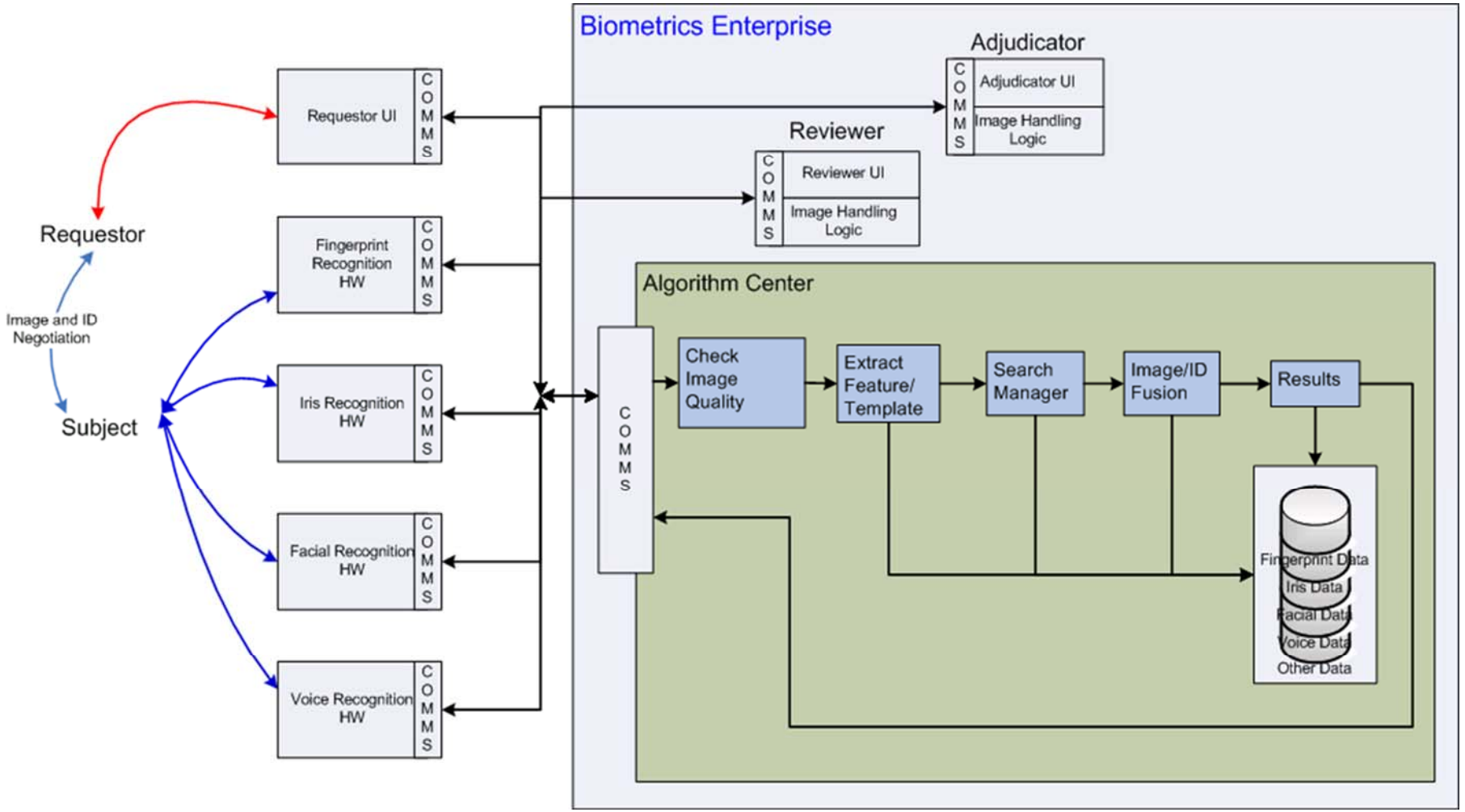
# Operational Context



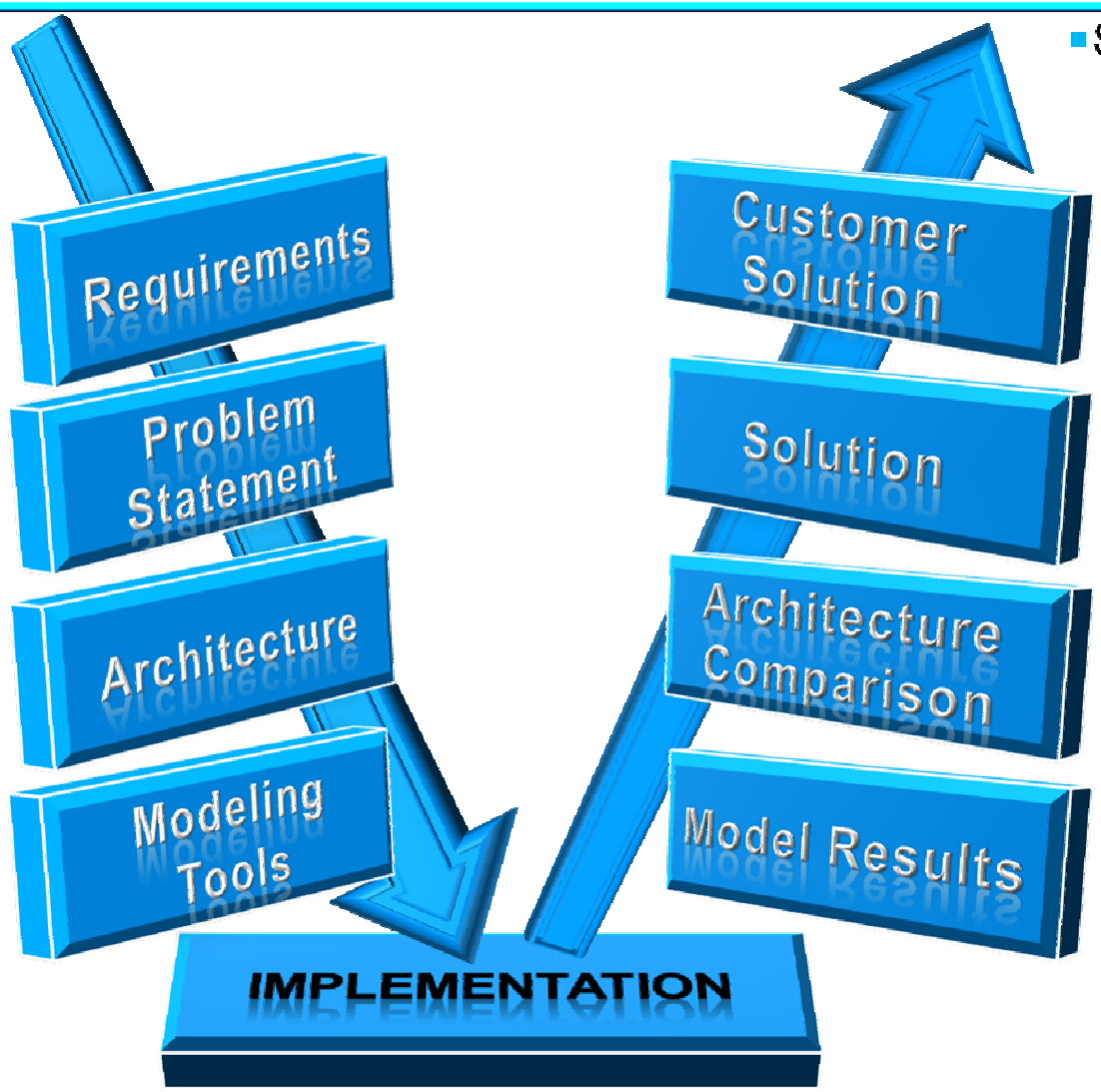
# BMEA As-Is Implementation Diagram



# BMEA To-Be Implementation Diagram

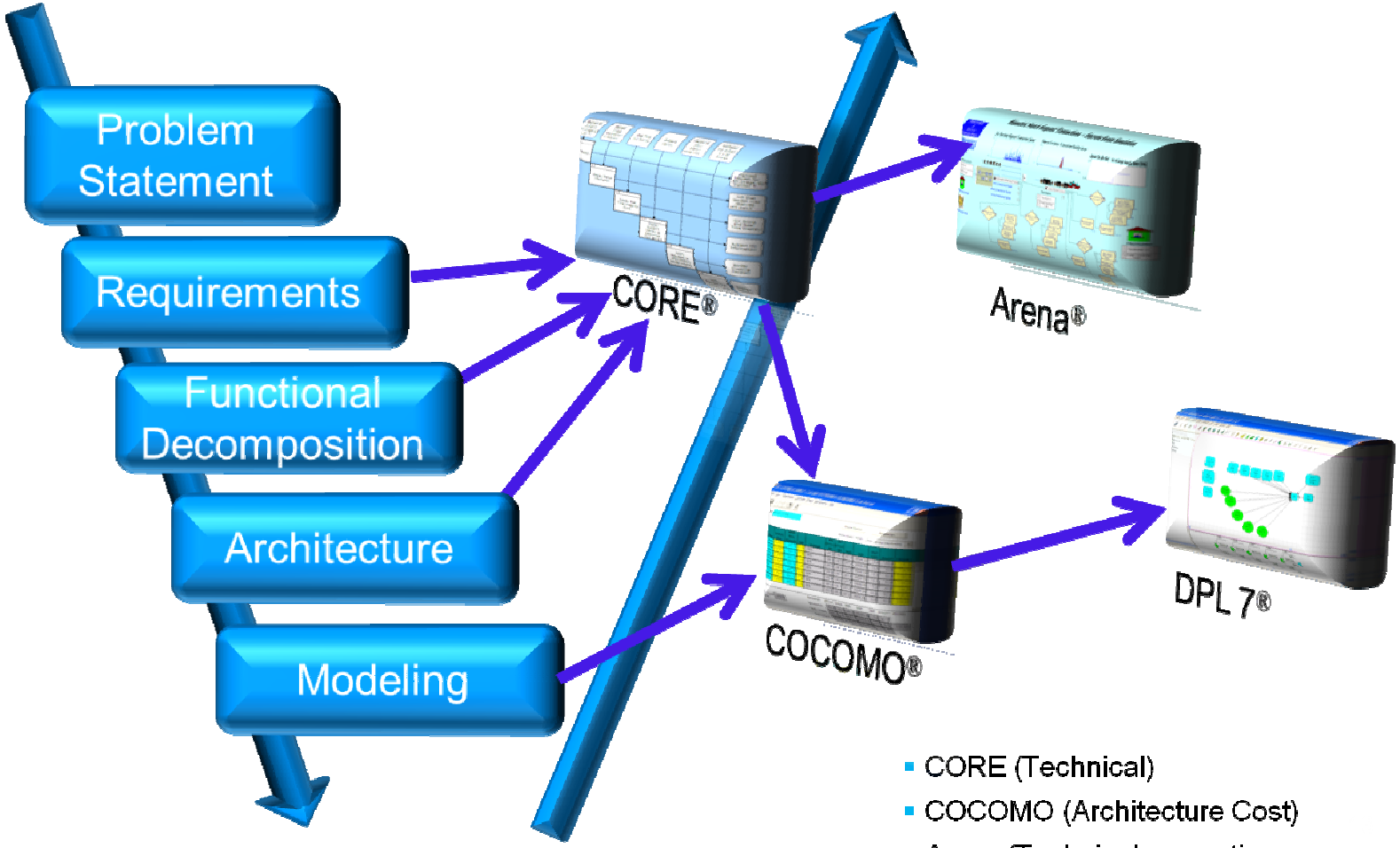


# System Engineering Approach



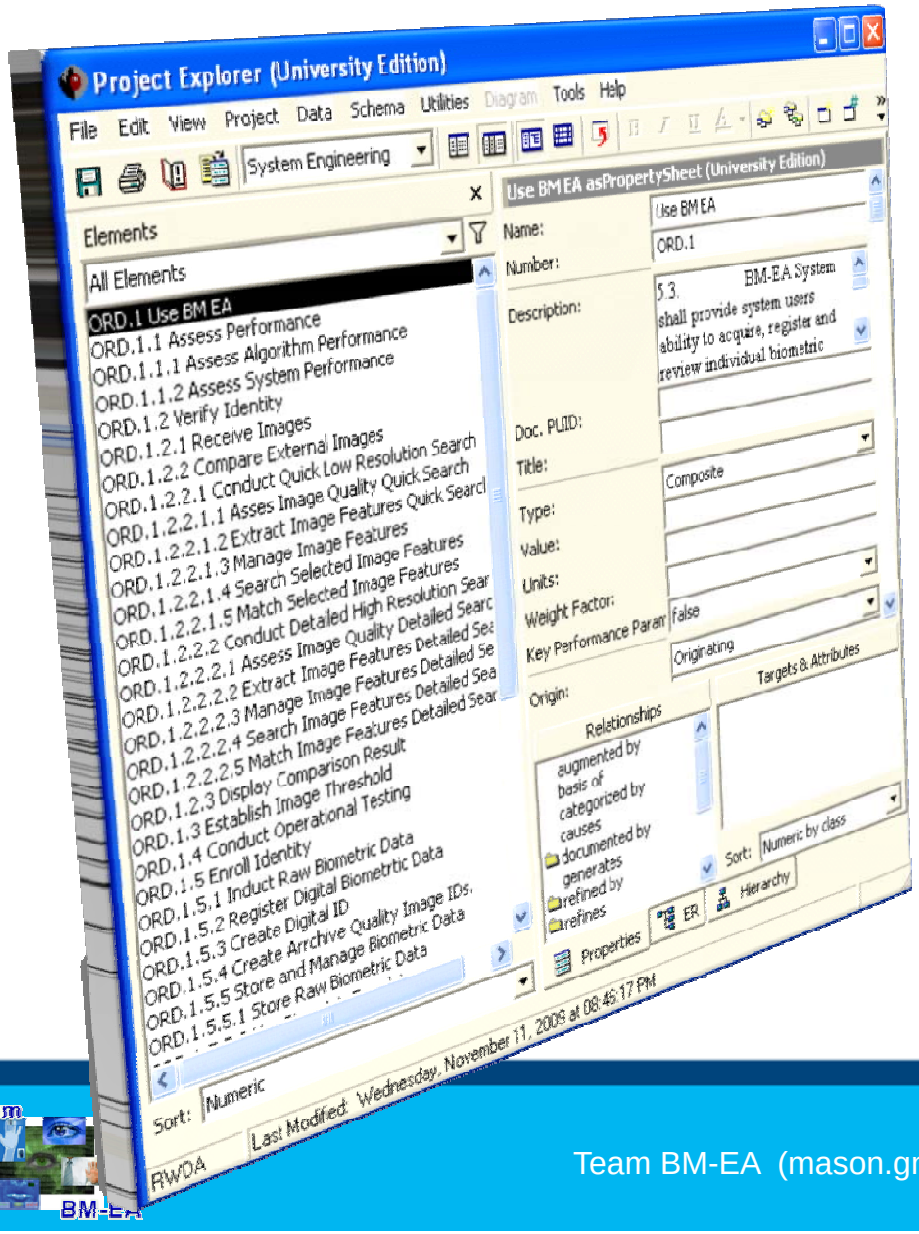

- Systems Engineering Approach
  - Documented an "As-Is" implementation of BMEA Architecture
  - Developed a technical model for a proposed "To-Be" implementation of BMEA Architecture
  - Developed a technical performance model to simulate the operational concept of the "To-Be" Architecture
  - Developed a Cost Model comparing NPV of As-Is and To-Be
  - The results from the technical performance model provide an analysis showing the various performance characteristics for resolving selected, various biometric enterprise business requirements.

# Modeling and System Engineering



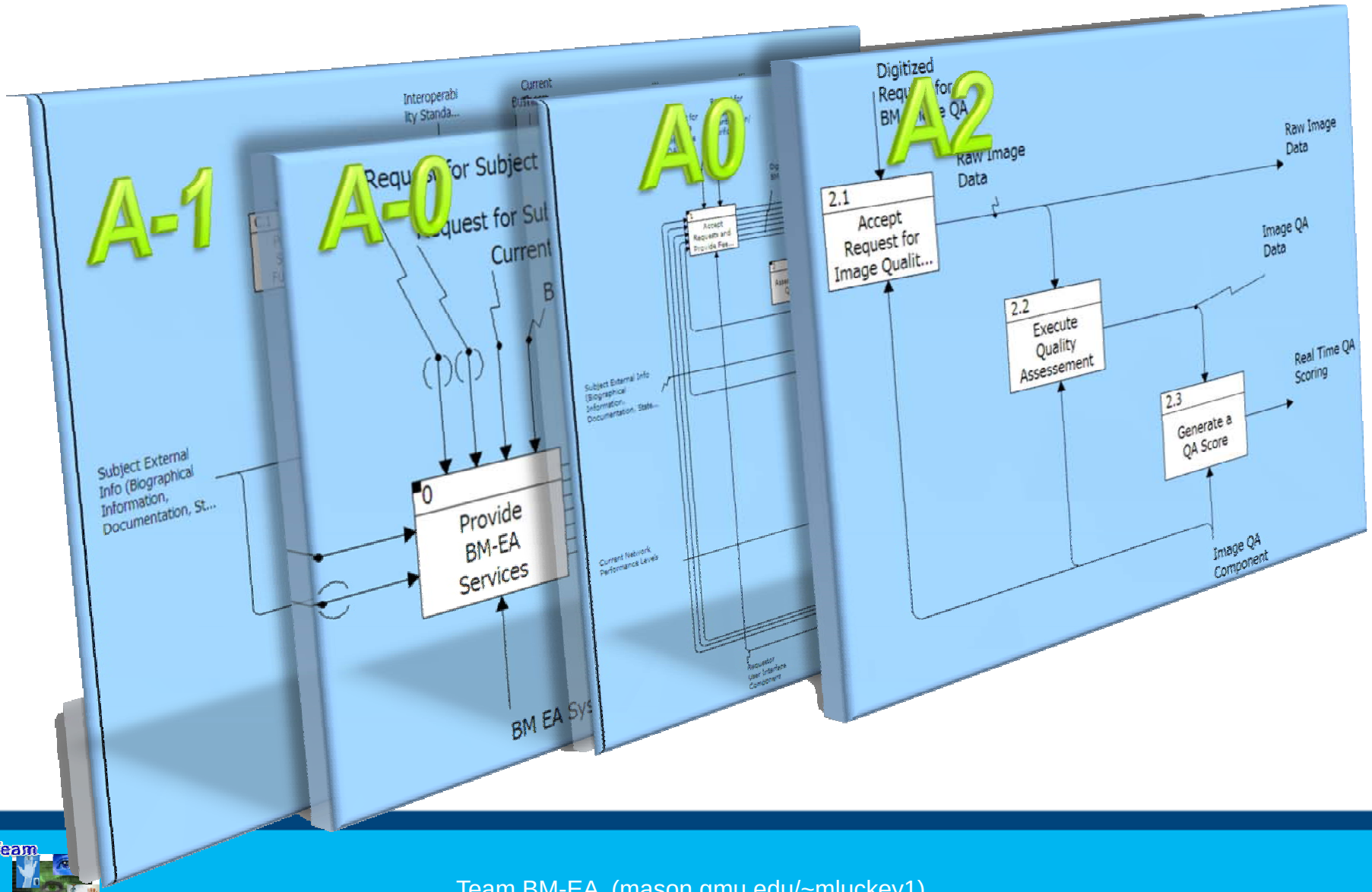

- CORE (Technical)
- COCOMO (Architecture Cost)
- Arena (Technical, execution assessment)
- DPL (LifeCycle Cost)

# CORE (Technical Model)

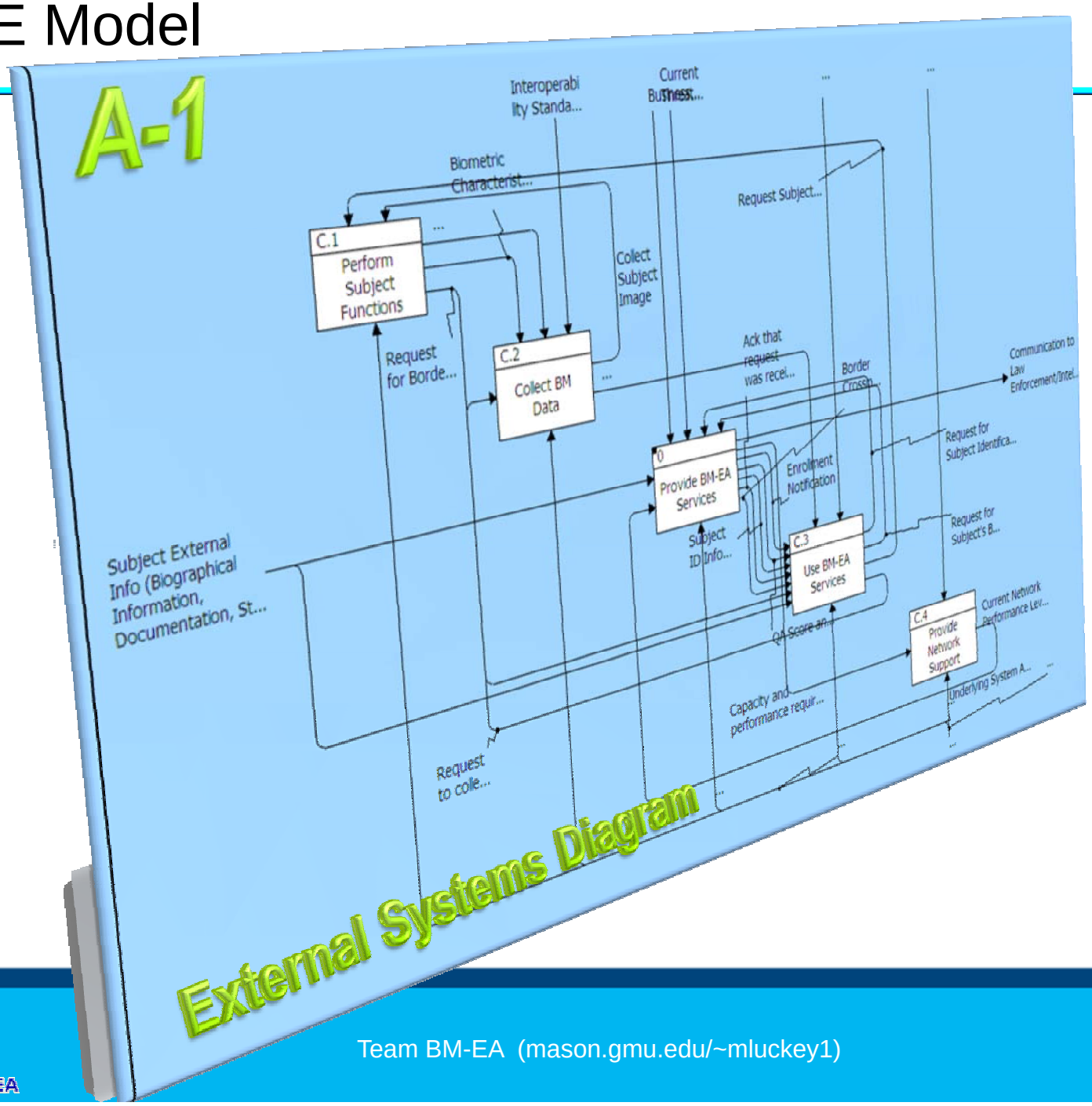



- Utilized CORE to document requirements and generate architectural products/diagrams
  - Establish Requirements
  - Develop Context Diagram
  - Create Functional Flow Block Diagrams
  - IDEF0 Models
  - Create Draft System Description Document

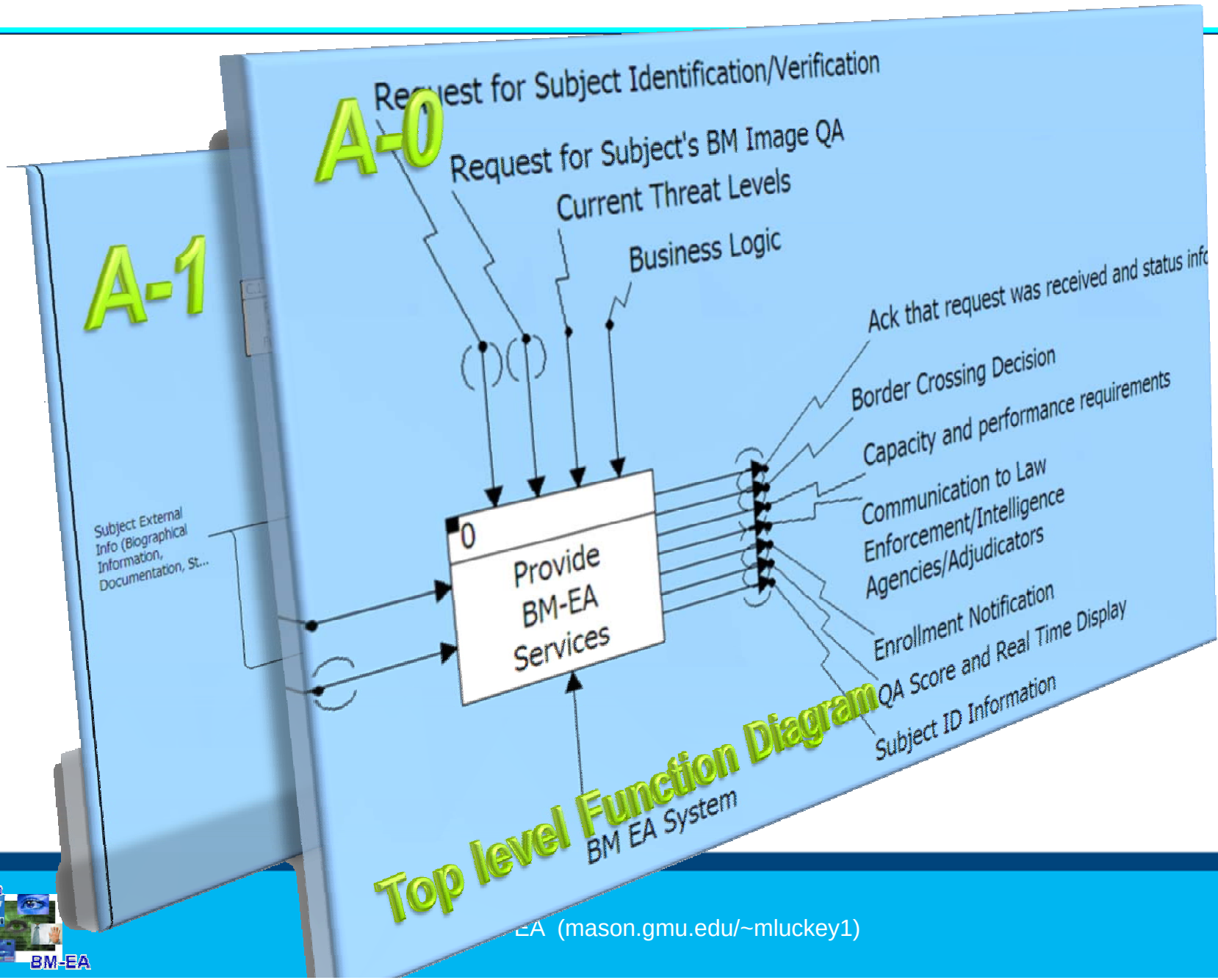
# CORE Model


A-1
A-0
A0
A2
Subject External Info (Biographical Information, Documentation, St...
0
Provide BM-EA Services
2.1
Accept Request for Image Qualit...
2.2
Execute Quality Assessement
2.3
Generate a QA Score
Raw Image Data
Image QA Data
Real Time QA Scoring
Image QA Component

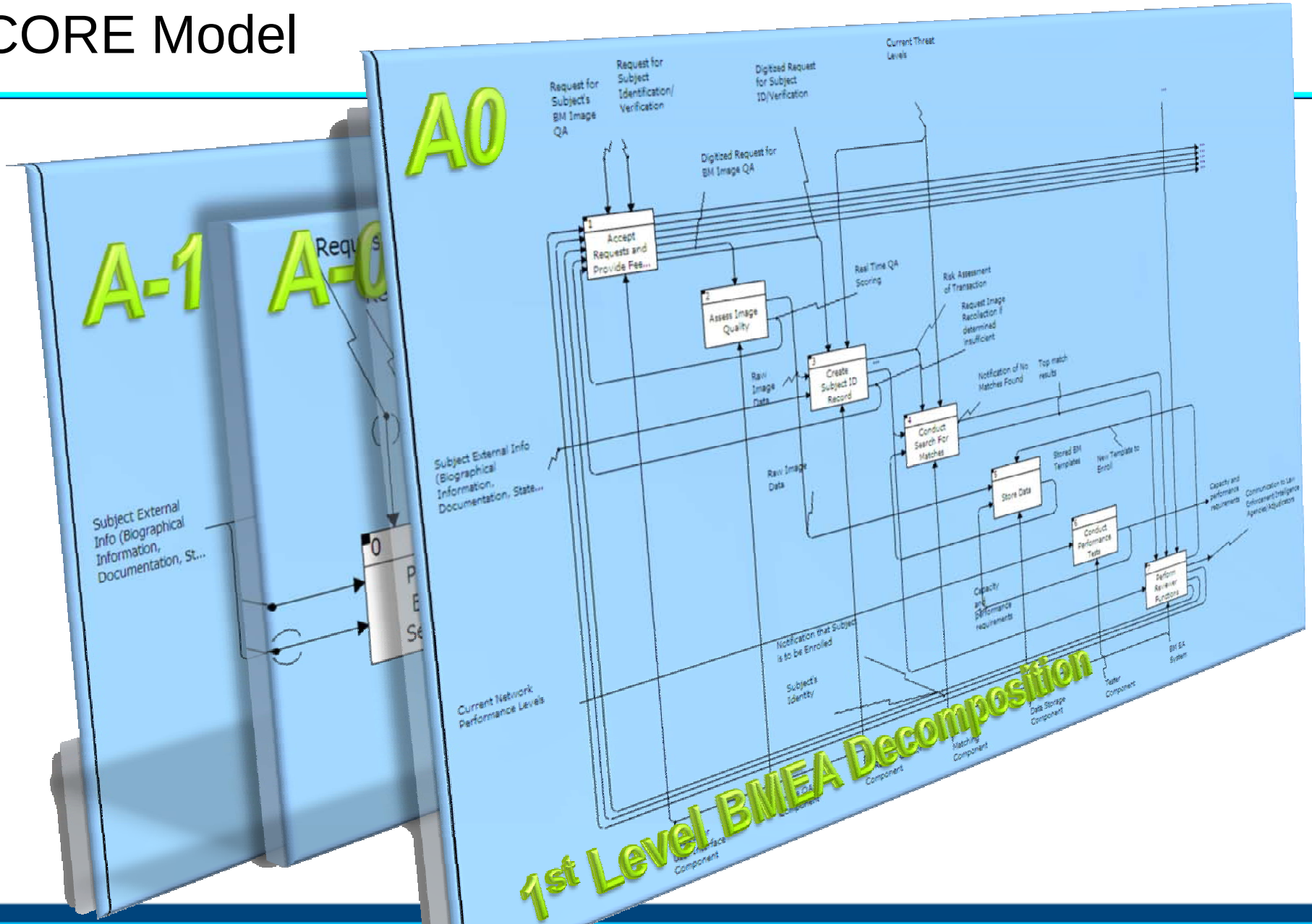
# CORE Model


A-1
Interoperability Standa...
Current Business...
Biometric Characterist...
Request Subject...
C.1
Perform Subject Functions
Collect Subject Image
Request for Borde...
C.2
Collect BM Data
Ack that request was recei...
Border Crossi...
Communication to Law Enforcement/Intel...
0
Provide BM-EA Services
Enrollment Notification
Request for Subject Identifica...
Subject External Info (Biographical Information, Documentation, St...
Subject ID Info...
C.3
Use BM-EA Services
Request for Subject's B...
C.4
Provide Network Support
Current Network Performance Lev...
QA Score an...
Capacity and performance requir...
Underlying System A...
Request to colle...
External Systems Diagram

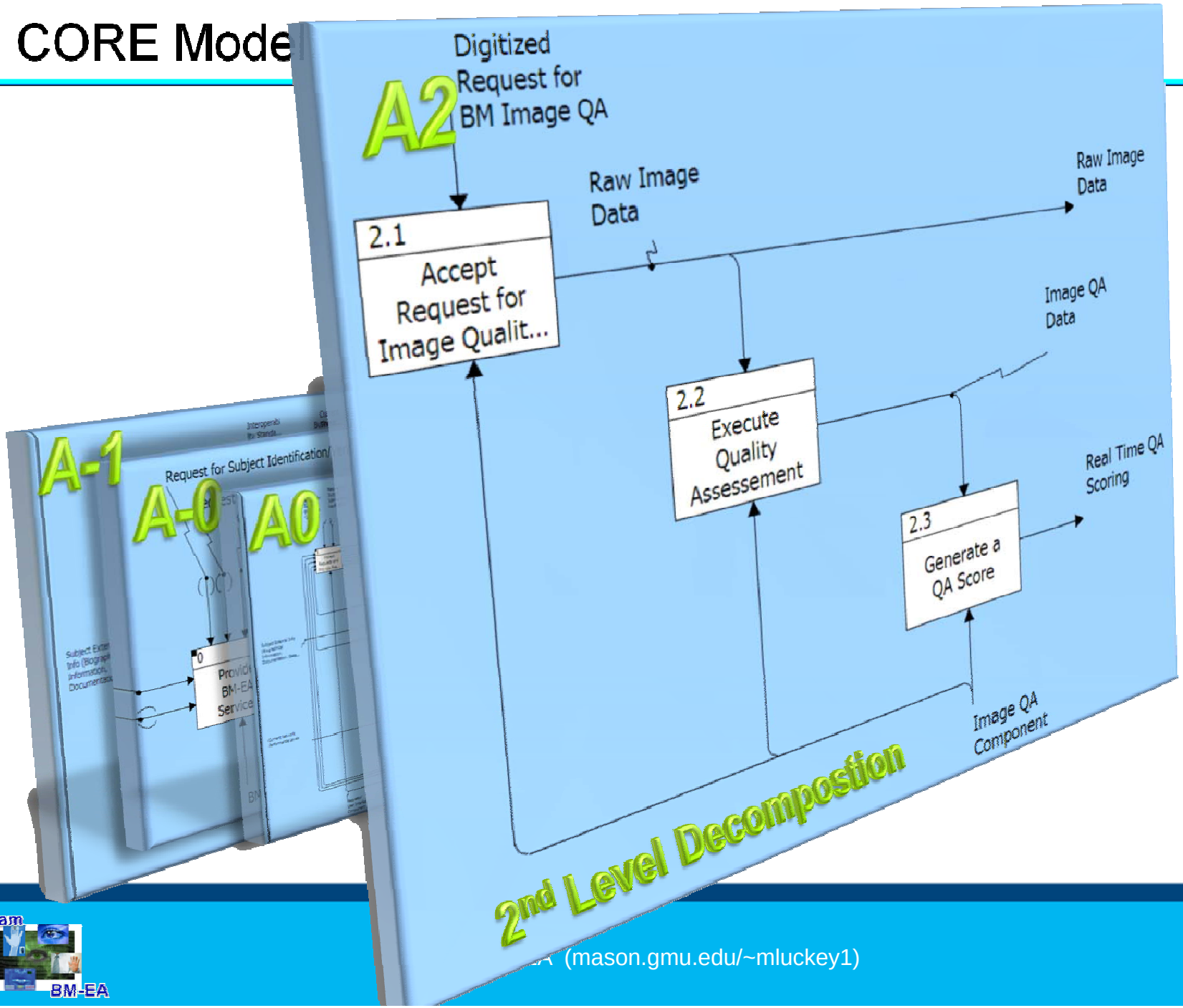
# CORE Model


A-0
Request for Subject Identification/Verification
Request for Subject's BM Image QA
Current Threat Levels
Business Logic
A-1
Subject External Info (Biographical Information, Documentation, St...
0
Provide BM-EA Services
Ack that request was received and status info
Border Crossing Decision
Capacity and performance requirements
Communication to Law Enforcement/Intelligence Agencies/Adjudicators
Enrollment Notification
QA Score and Real Time Display
Subject ID Information
Top level Function Diagram
BM EA System

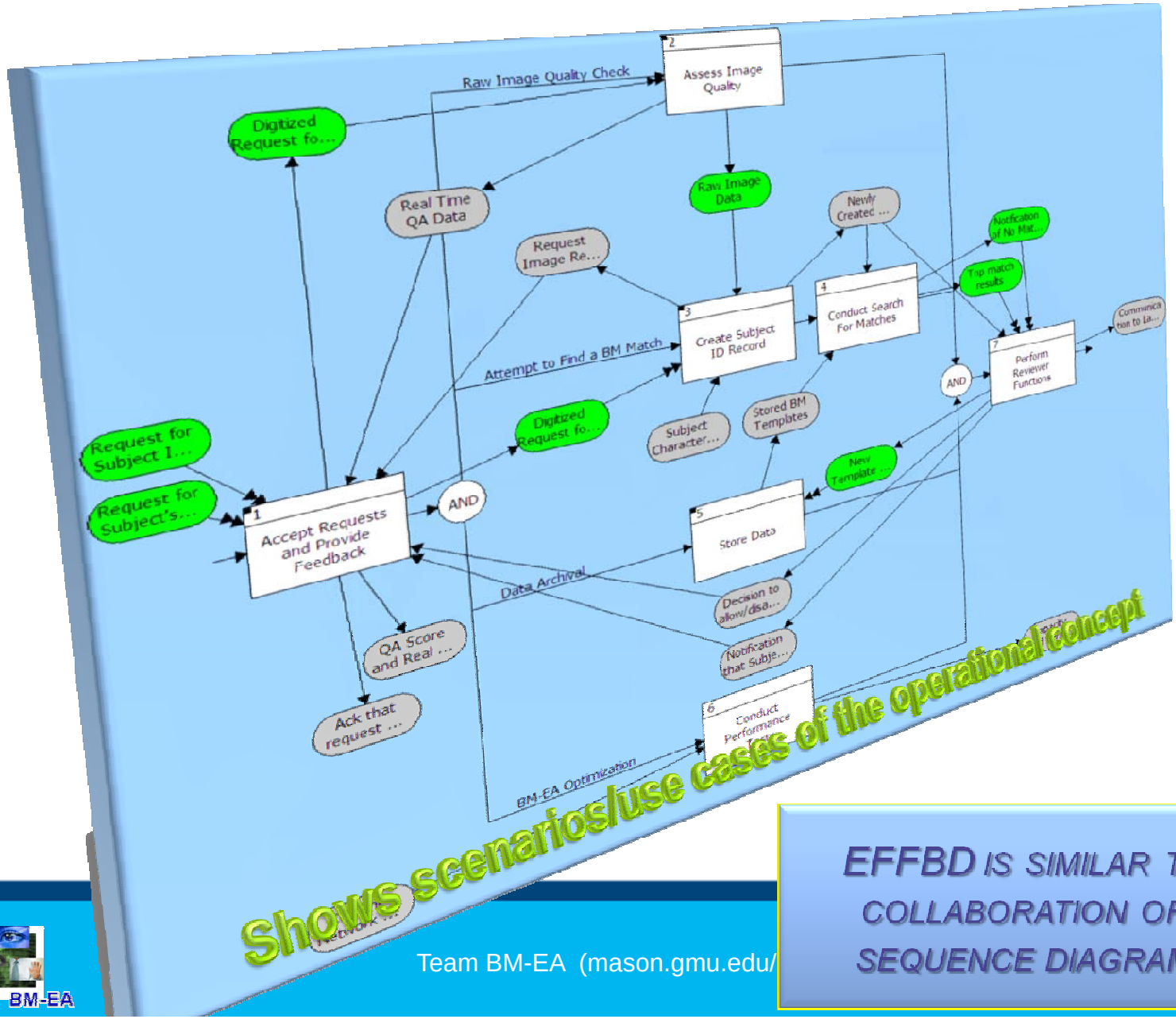
# CORE Model


A-1
A0
Request for Subject's BM Image QA
Request for Subject Identification/ Verification
Digitized Request for Subject ID/Verification
Current Threat Levels
Digitized Request for BM Image QA
Accept Requests and Provide Fee...
Assess Image Quality
Create Subject ID Record
Conduct Search For Matches
Store Data
Conduct Performance Tests
Perform Reviewer Functions
Real Time QA Scoring
Risk Assessment of Transaction
Request Image Recollection if determined insufficient
Raw Image Data
Notification of No Matches Found
Top match results
Stored BM Templates
New Template to Enroll
Capacity and performance requirements
Communication to Law Enforcement Intelligence Agencies/Adjudicators
Subject External Info (Biographical Information, Documentation, State...
Current Network Performance Levels
Notification that Subject is to be Enrolled
Subject's Identity
Interface Component
Data Storage Component
Matching Component
Tester Component
BM EA System
Subject External Info (Biographical Information, Documentation, St...
1st Level BMEA Decomposition

# CORE Model


A2
Digitized
Request for
BM Image QA
Raw Image
Data
Raw Image
Data
2.1
Accept
Request for
Image Qualit...
Image QA
Data
2.2
Execute
Quality
Assessement
Real Time QA
Scoring
2.3
Generate a
QA Score
Image QA
Component
2nd Level Decompostion
A-1
A-0
A0
Request for Subject Identification/
0
Provide
BM-EA
Service

# CORE (Enhanced Functional Flow Block Diagram)




**EFFBD** IS SIMILAR TO COLLABORATION OR SEQUENCE DIAGRAM

# Architectural Choices

## Client Server Architecture

- Two computer programs in which one program makes a service request from another program fulfilling the request
- Generally requires deployment of software
- Transactions are structured to behave in very specific ways
- Such applications are highly brittle and prone to default

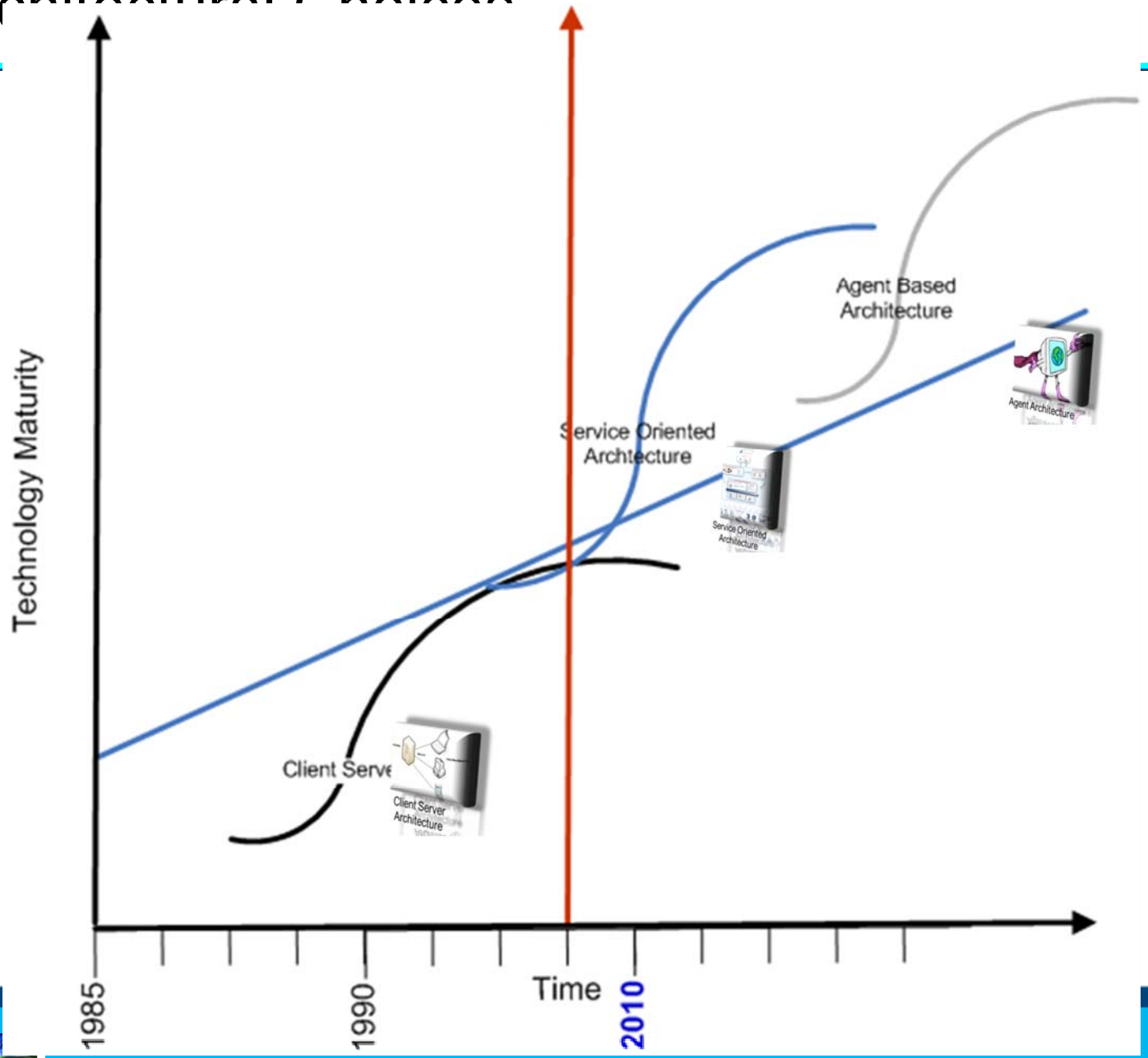
## Service Oriented Architecture

- Architectural framework with reference implementations where software is described as an interoperable set of services
- Software is built to serve along business process lines
- Releases computing platform from business context
- Allows wider use of domain (business) logic in a more flexible and aggressive ways

## Agent Architecture

- Software entity capable of acting with a certain degree of autonomy in order to accomplish tasks on behalf of its user
- A complementary and FUTURE capability to SOA
- Requires highly available and efficient infrastructure
- Requires SOA and cloud computing maturity

# Architectural Choices



# Modeling Tools: COCOMO

- ***CO***nstructive ***CO***st ***MO***del II (COCOMO II): A parametric modeling tool useful for planning and estimating software development:

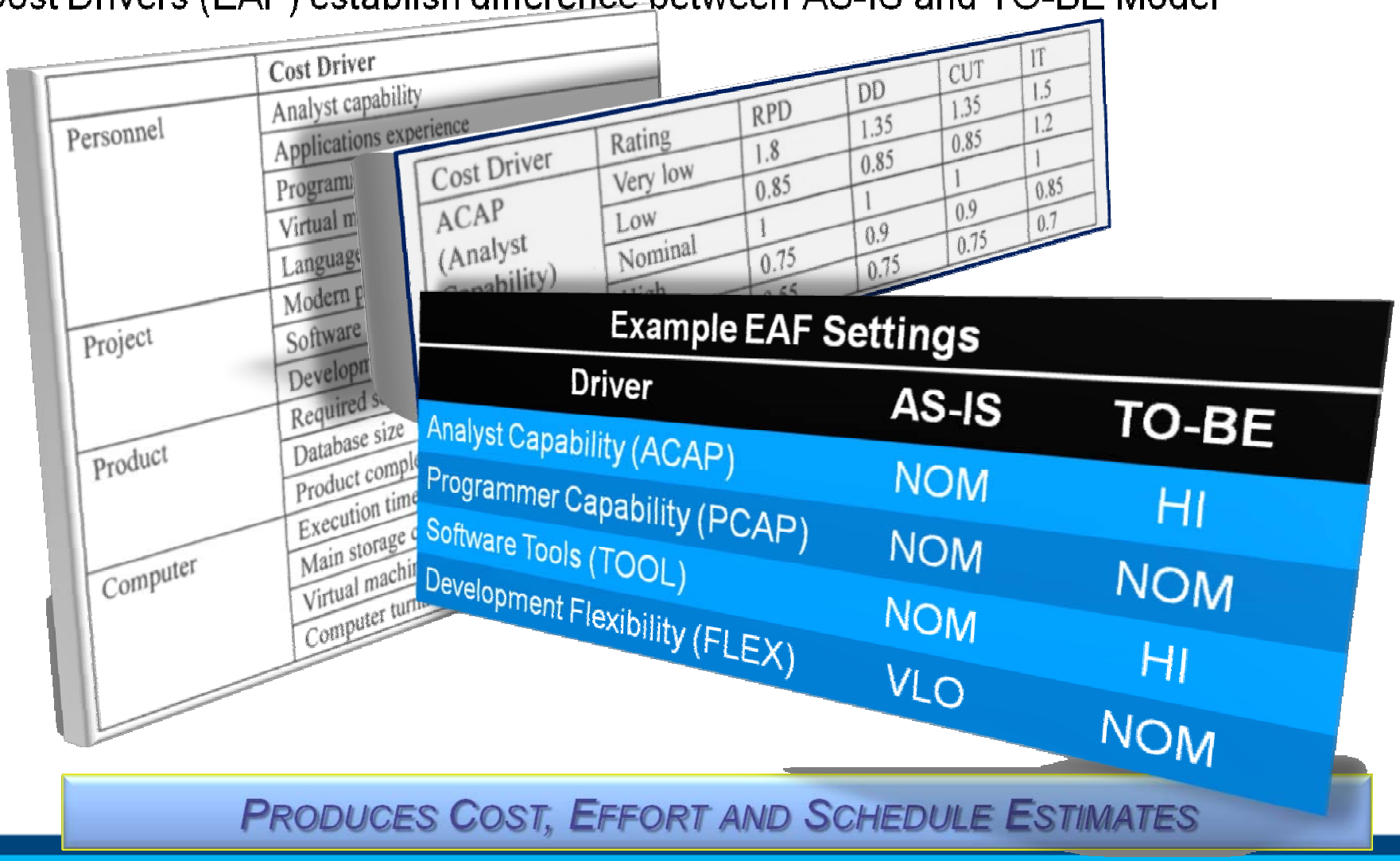
$$EstimatedEffort = a\,EstSizeNewproj^{b}\,EAF$$

- **EstimatedEffort**: Development in Person-Months
- **EstSizeNewproject**: Lines of Code or Function Points
- **EAF**: Effort Adjustment Factor (Cost Drivers)
- Used to compare As-Is and To-Be architecture based on Function Points
- Result is a Development and Maintenance Cost Estimate

PRODUCES COST, EFFORT AND SCHEDULE ESTIMATES

# Modeling Tools: COCOMO

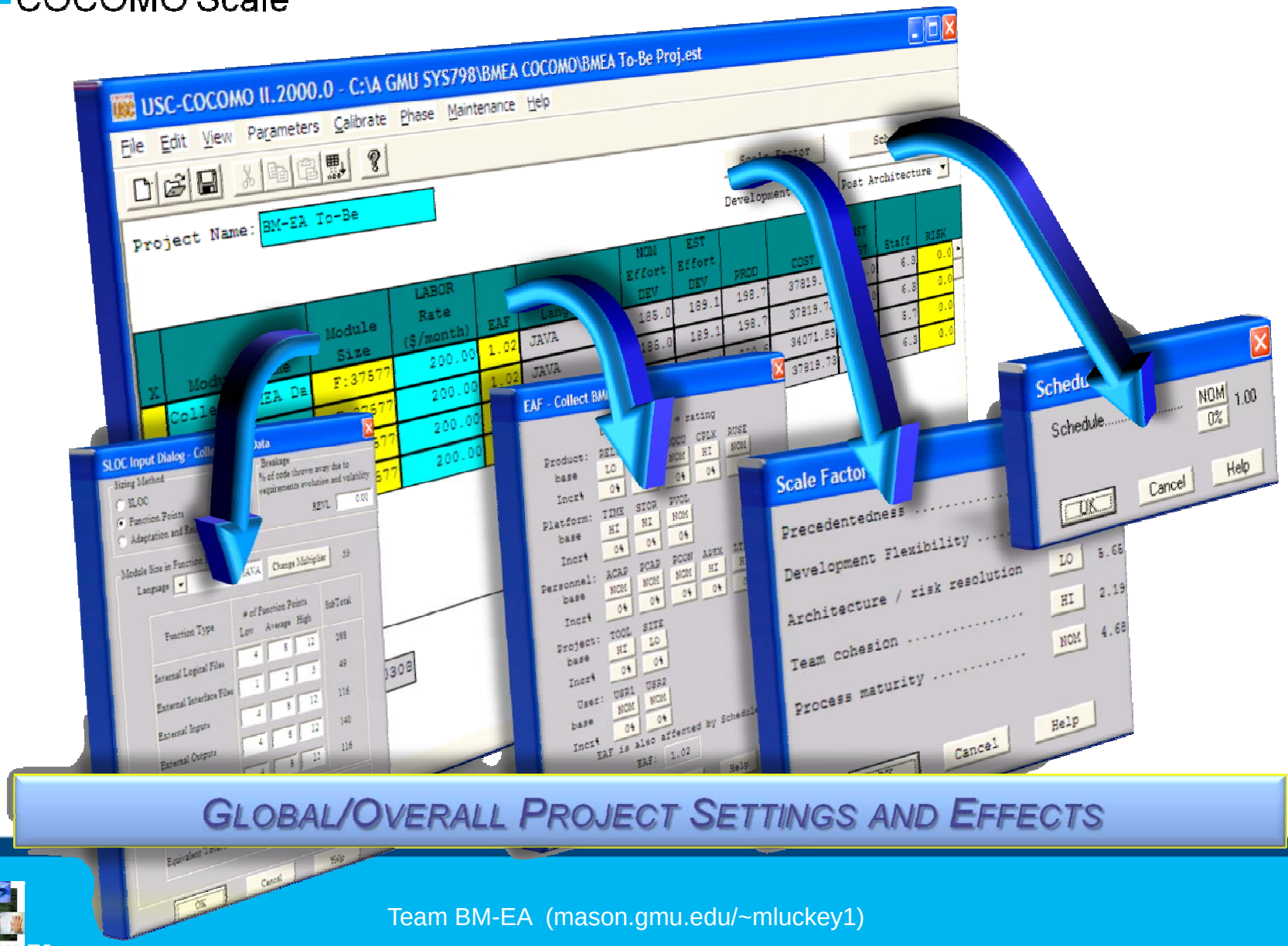
- Cost Drivers (EAF) establish difference between AS-IS and TO-BE Model




PRODUCES COST, EFFORT AND SCHEDULE ESTIMATES

# Modeling Tools COCOMO

- COCOMO Scale



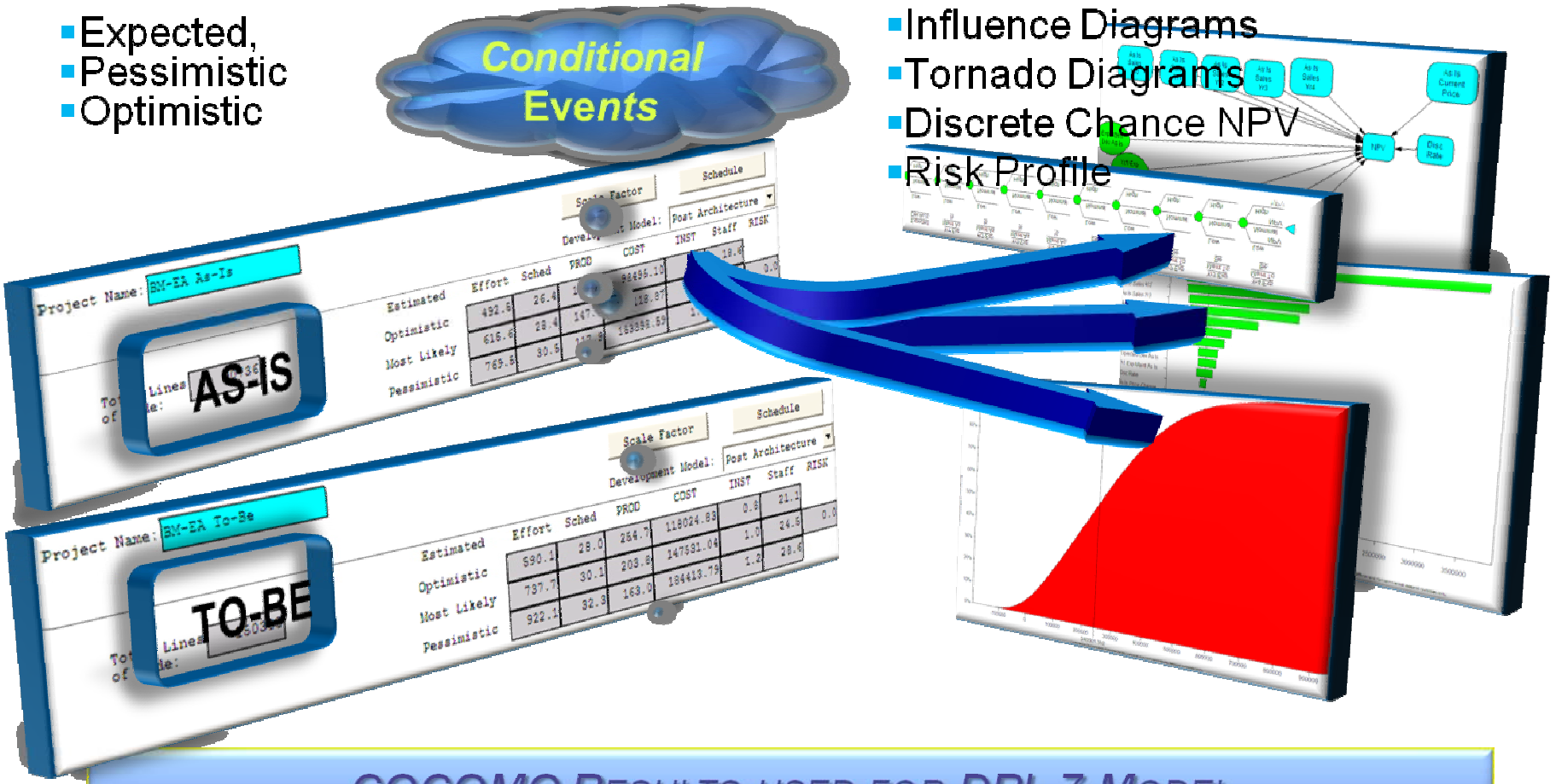
# Modeling Tools COCOMO

COCOMO generates Development and Maintenance Estimates. :

- Expected,
- Pessimistic
- Optimistic

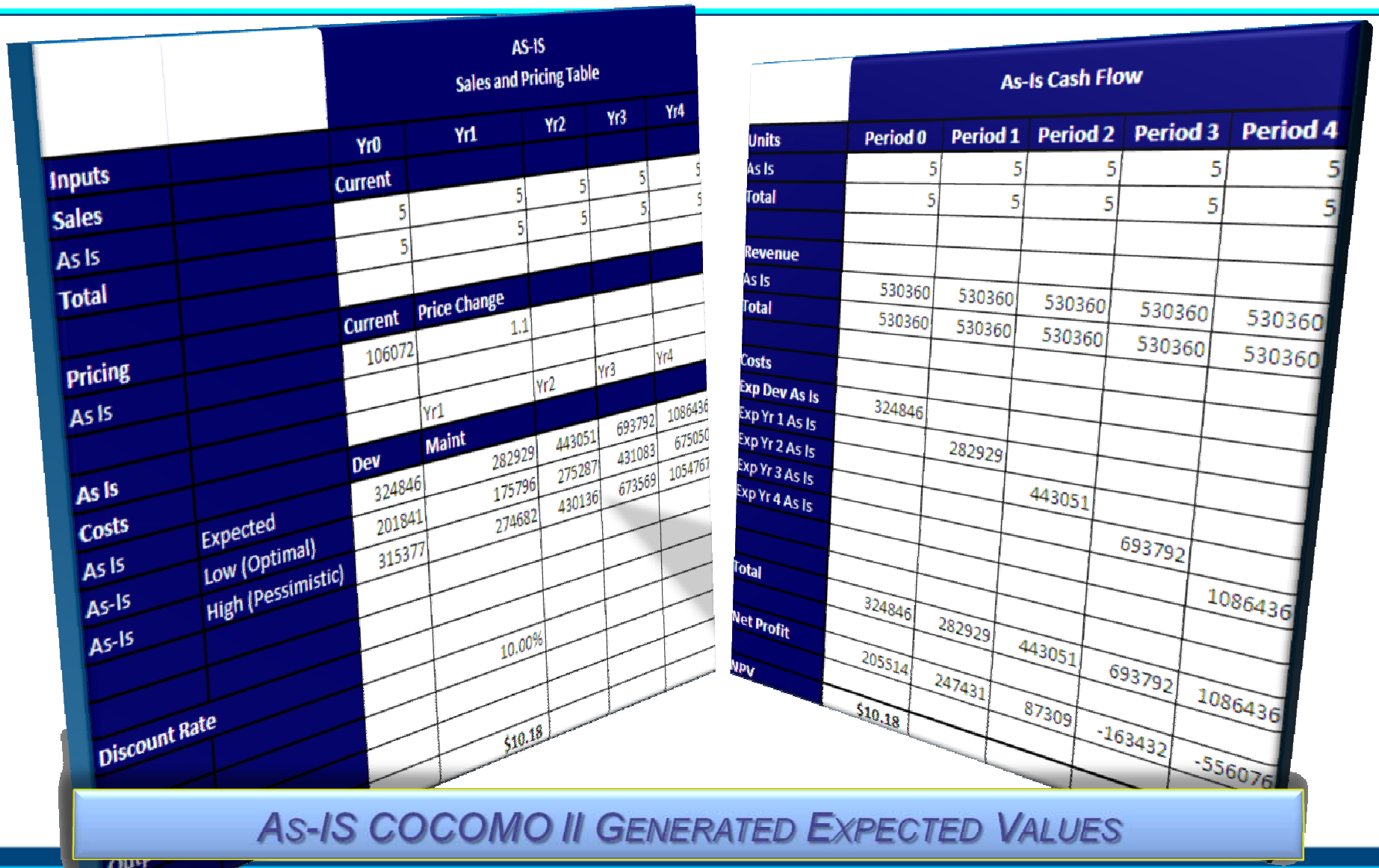
Estimates used to develop DPL 7 based models to compare AS-IS and TO-BE

- Influence Diagrams
- Tornado Diagrams
- Discrete Chance NPV
- Risk Profile



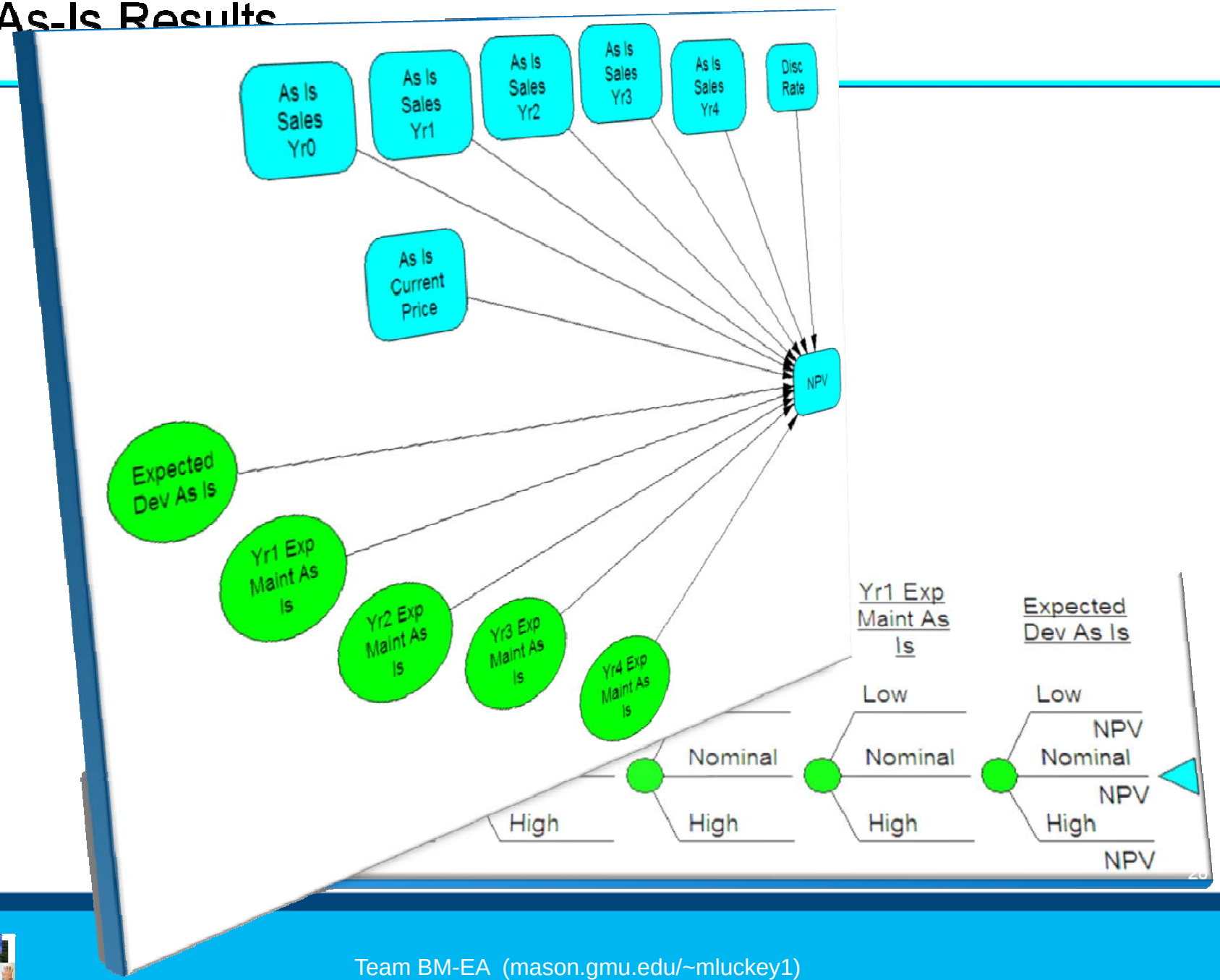

COCOMO RESULTS USED FOR DPL 7 MODEL

# Modeling Tools DPL 7

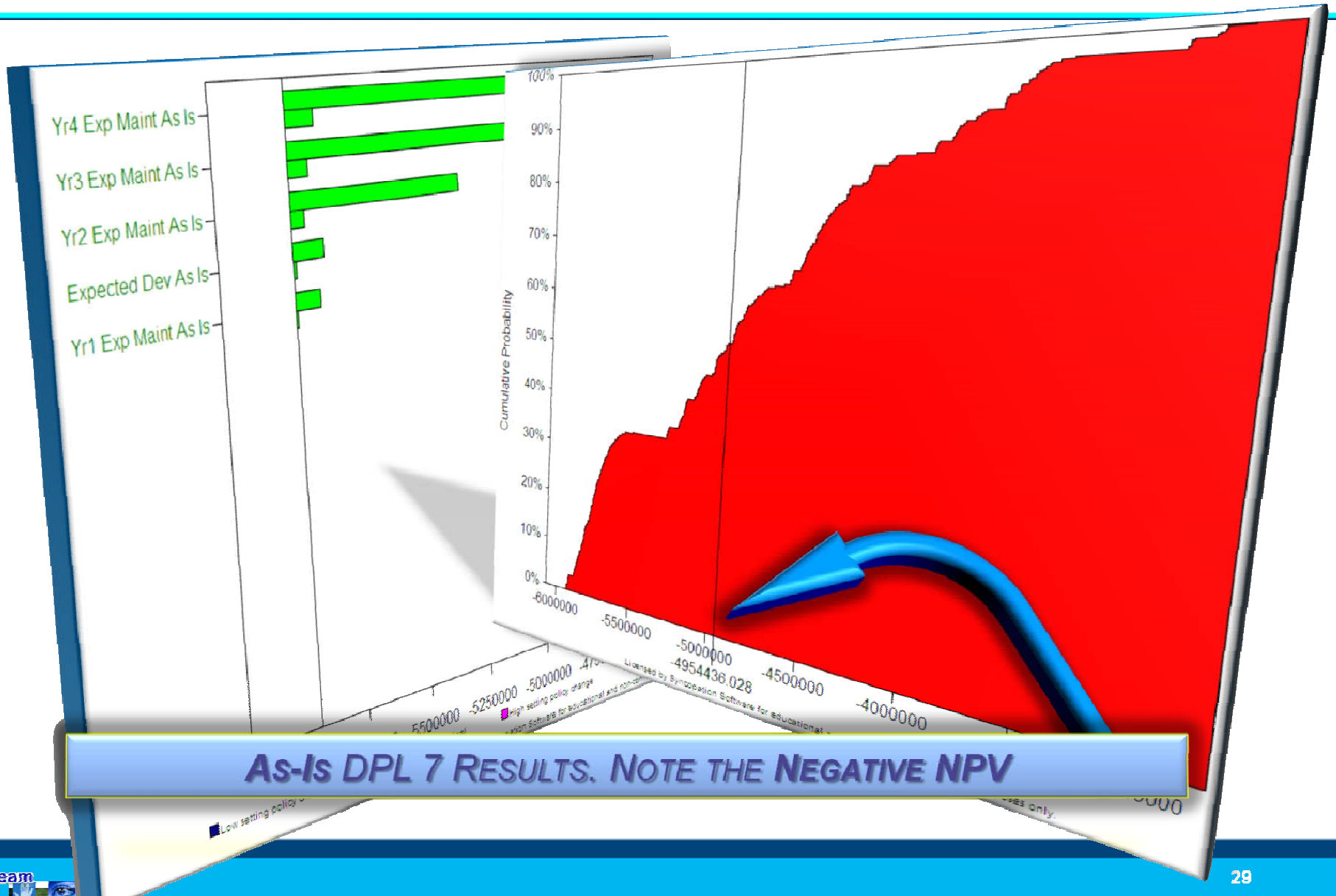



AS-IS COCOMO II GENERATED EXPECTED VALUES

# As-Is Results

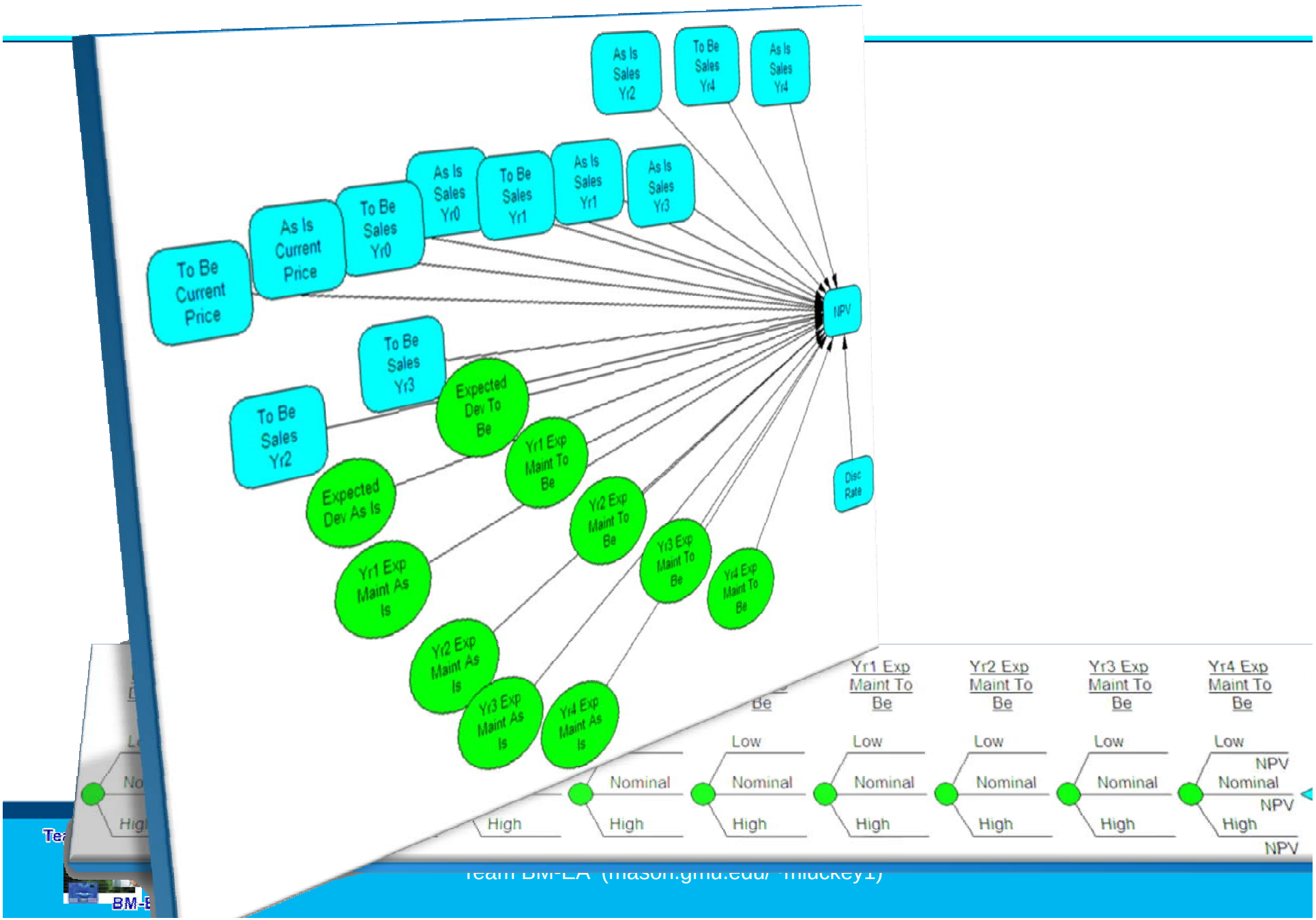


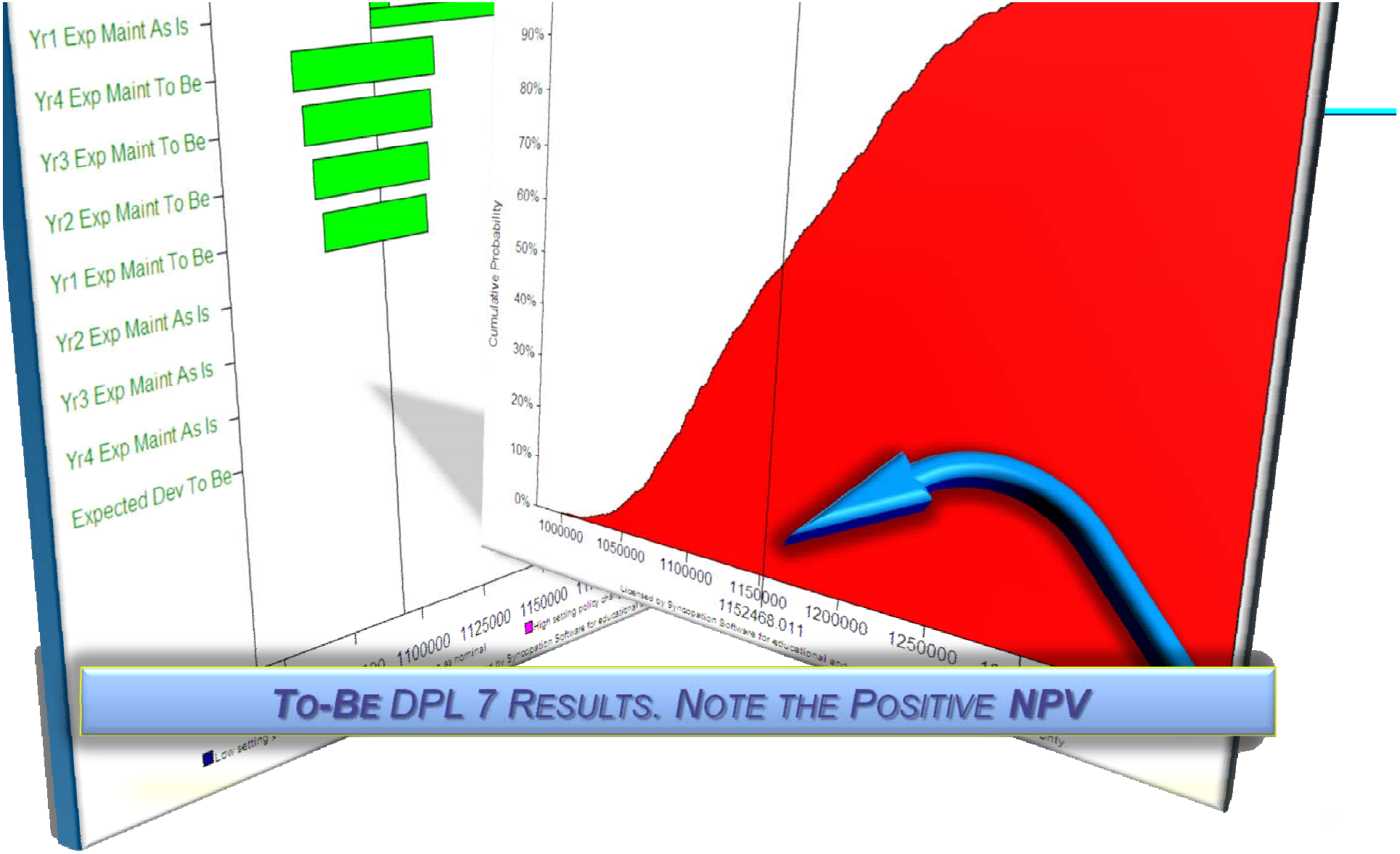
# As-Is Results




**AS-IS DPL 7 RESULTS. NOTE THE NEGATIVE NPV**

# To-Be Results






# To-Be DPL 7 Results. Note the Positive NPV

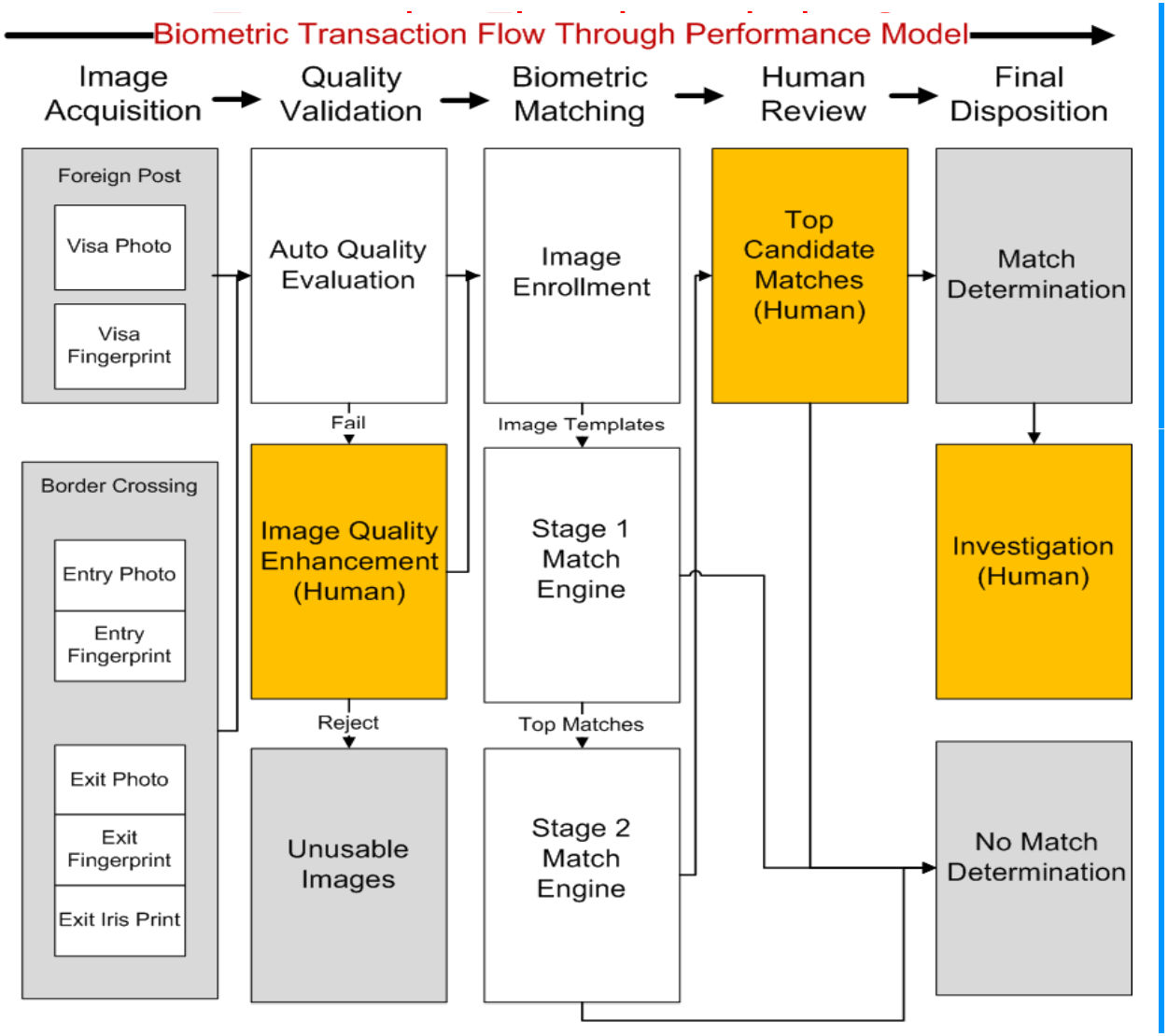
# Border Crossing (Hypothetical Biometric Application)

| Count | Application Parameters |
|---|---|
| 7,100,000 | US Visas Issued (2008) |
| 130,000,000 | US Border Enrolled Travelers (2008) |
| 35,000,000 | Foreign Visitors Entering U.S./Year |
| 35,000,000 | Foreign Visitors Exiting U.S./Year |
| 50 | Human Reviewers per Shift |
| 4750 | Total Hardware Chassis |

*APPLICATION COUNTS BASED ON OPEN-SOURCE RESEARCH*

- Baseline Volumes Determined from Open-source Literature
- Simulation Scaled to 10% of Transaction Volume
- Staff and Biometric Hardware sized to Obtain Reasonable Performance
- Each Run Simulated for Five Days

# Simulation Process Flow (Border Use Case)




## Time Distributions

New Transactions:
- Poisson Event Distribution

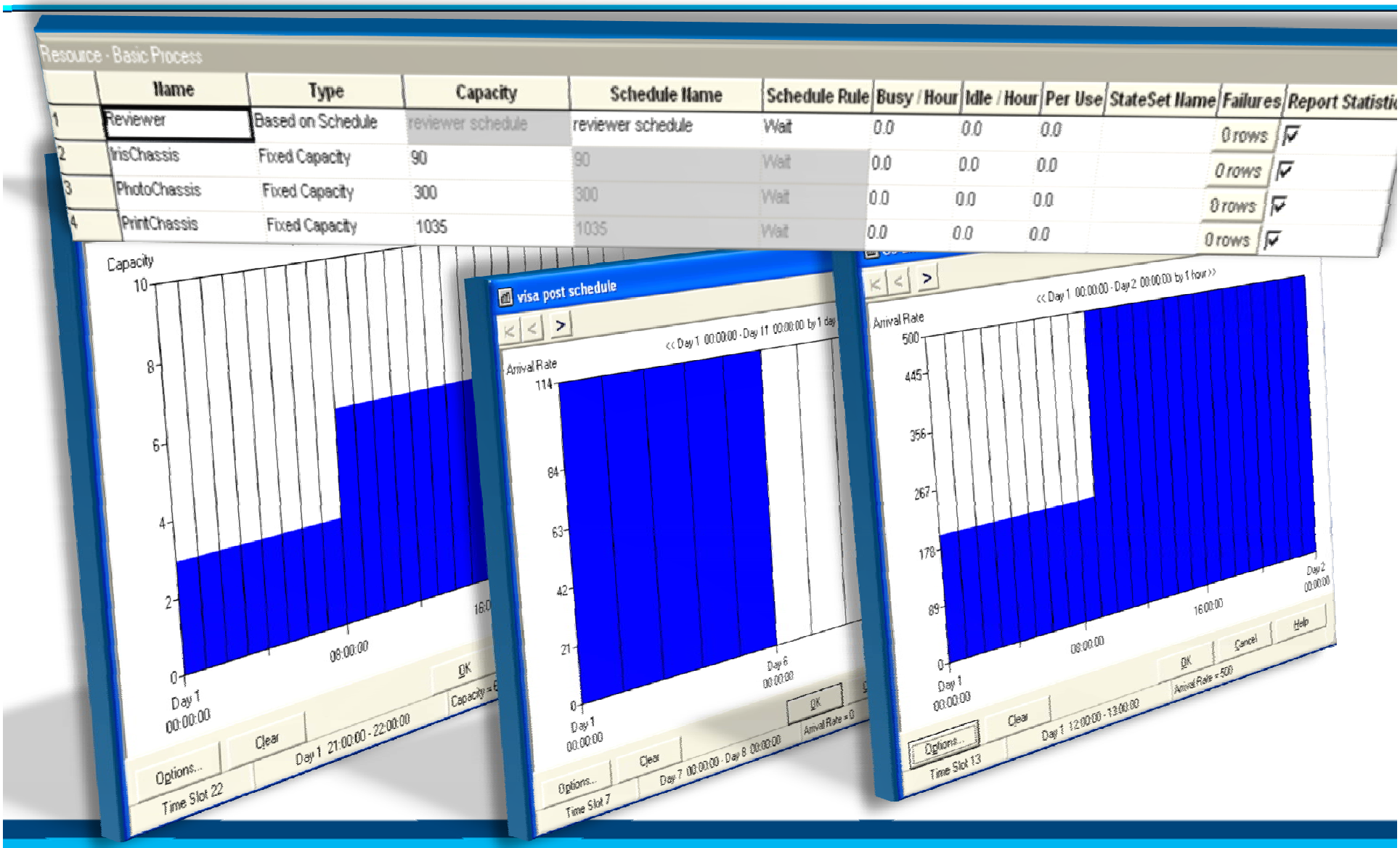
Automated & Human Processes:
- Gamma Distributions

## Performance Measures

1. Match Accuracy
   - % Unusable Images
   - % Matches Found
   - % False Matches
2. Match Transaction Throughput
3. Match Result Response Time
   - Average Response time
   - Maximum Response time
   - Priority Transaction Response

# Major Resources and Process Schedules -- Baseline Run

(Hypothetical Border Application)



# Process Transaction Queues w/ Priority Transaction Based Queuing
## (Gamma Distributions for all Processes)

Queue - Basic Process

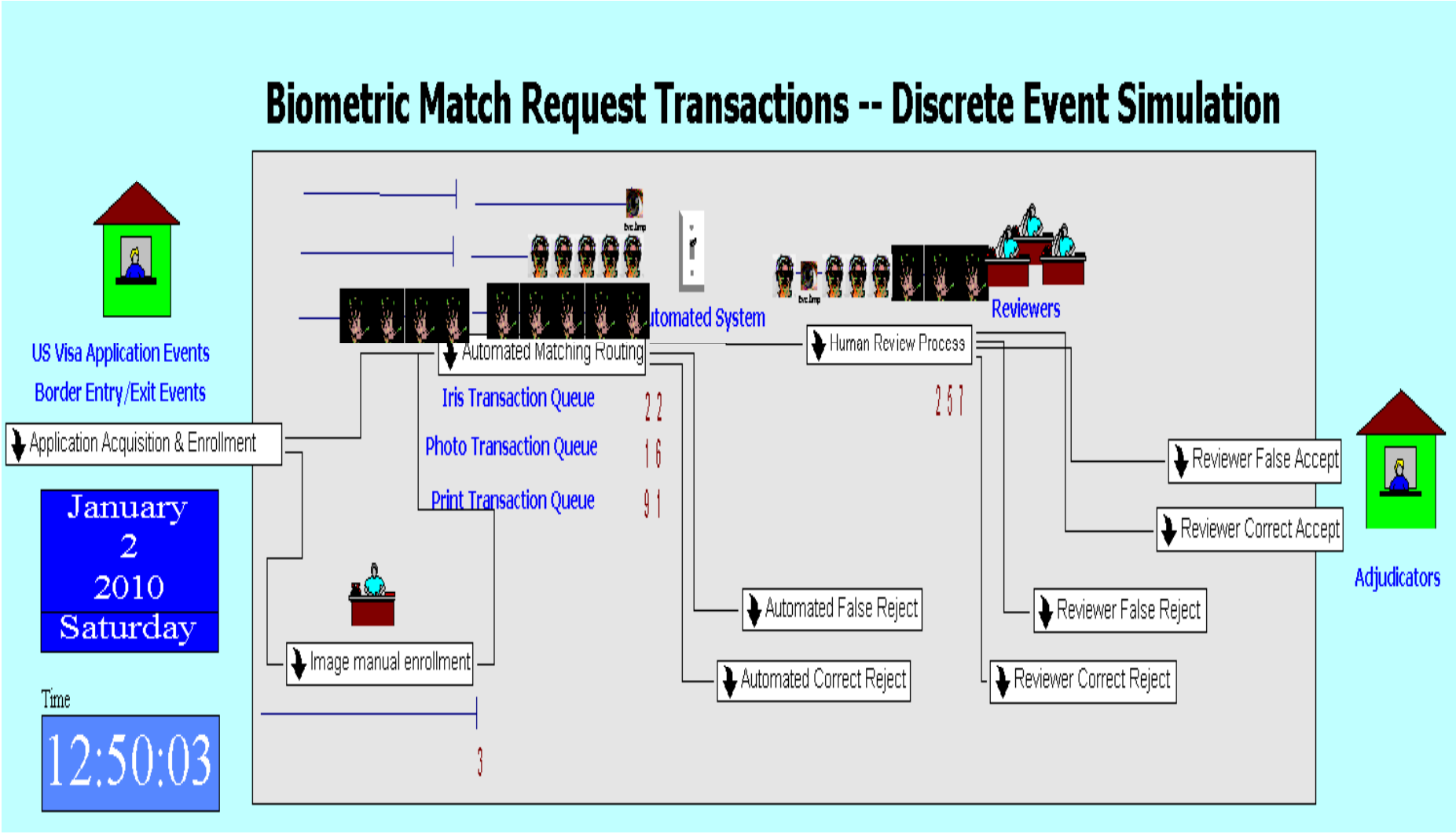
| | Name | Type | Attribute Name | Shared | Report Statistics |
|---|---|---|---|---|---|
| 1 | Human Review Process Queue.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 2 | Iris Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 3 | Photo Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 4 | Photo Slow Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 5 | Iris Slow Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 6 | TenPrint Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 7 | TenPrint Slow Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 8 | TwoPrint Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |
| 9 | TwoPrint Slow Matcher.Queue | Highest Attribute Value | Response | ☐ | ☑ |

Entity - Basic Process

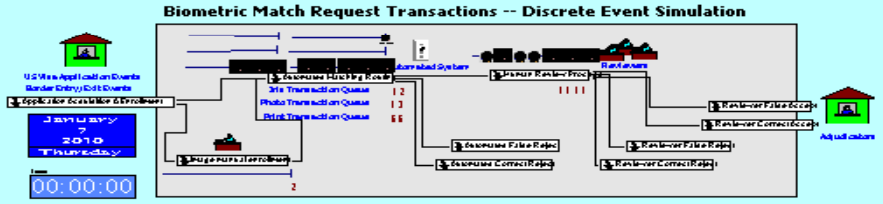
| | Entity Type | Initial Picture | Holding Cost / Hour | Initial VA Cost | Initial NVA Cost | Initial Waiting Cost | Initial Tran Cost | Initial Other Cost | Report Statistics |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Application | Picture.Yellow | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 2 | FraudApplication | Picture.Man | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 3 | Test | Picture.Red Page | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 4 | Application with Mate | Picture.Report | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 5 | Photo | face | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 6 | TenPrint | hand | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 7 | TwoPrint | hand | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 8 | Iris | eye | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 9 | EnterPhoto | face | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 10 | ExitPhoto | face | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 11 | VisitPhoto | face | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |
| 12 | Priority | Picture.Report | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ☑ |

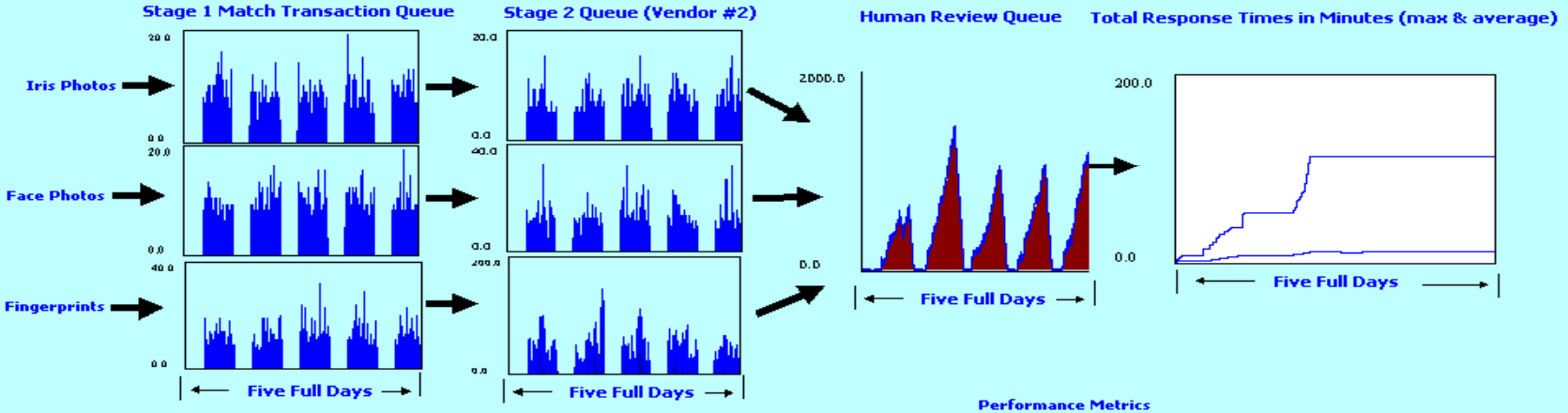
**Transaction Entity Types: Poisson Distributions for all Transaction Creation Events**

# Performance Simulation Overview Animation
(Hypothetical Border Application)



# Biometric Transaction Performance Modeling




**Performance Metrics**

| | All | Iris | Photo | Fingerprint |
|---|---|---|---|---|
| % of Matches Found: | 71.1 | 75.2 | 63.1 | 73.8 |
| % with False Match: | 6.0 | 0.4 | 11.6 | 2.7 |
| % of Unusable Images: | 2.98 | | | |
| Hourly Transaction Throughput: | 3249.1 | 581.0 | 1330.6 | 1337.5 |
| Non-priority Average Response Time (minutes): | 10.1 | 2.9 | 12.8 | 11.0 |
| Non-Priority Maximum Response Time (minutes): | 113.8 | 104.1 | 107.7 | 113.8 |
| Average Assigned Reviewers: | 7.00 | | | |
| Average Reviewers Busy: | 6.57 | | | |

**Priority Transactions Only (15% of all transactions require real-time responses)**

| All Priority Transactions | |
|---|---|
| Average Response Time (minutes): | 1.9 |
| Maximum Response Time (minutes): | 8.9 |

# Highlights of Performance Simulation Findings

| Stress Test # | Environmental Change | Significant Results |
|---|---|---|
| 1 | Increased Transaction Volume: 10% | Under transaction volume stress, our system's response time averaged 26% lower than for the traditional system. |
| 2 | Decreased Image Quality | Similarly poor results produced from both systems |
| 3 | Increased Threat-level for Five Days | Under the traditional system, hardware could not be increased in such short notice. In our system, the increased hardware sent the overall system out of balance but with increased human reviewers, overall match performance was increased slightly. |
| 4 | Increase in Transaction Volume: 50% Priority Transactions: 15% | Under the traditional architecture, transaction prioritization cannot be implemented and average response time was 7.2 minutes. Under our architecture, priority placement in queues allowed priority transactions to have an average response time of 1.9 minutes although at the same time non-priority transaction response time increased to 10.1 minutes. |

**CONCLUSION: FLEXIBLE ARCHITECTURE ADDRESSES SHIFTING GOALS**

# Future Activity

- Survey current and future large-scale biometric applications
- Implement our models to predict system performance  applications
- Provide additional guidance to designers seeking to size implementations
- Further explore agent-based architecture and compare performance
- Refine Cost model with real world enterprise cost data
  - Enter into COCOMO II or other estimating tool
  - Conduct Additional Sensitivity Analysis
- Create and stress test prototype reference environment

*THIS IS ONLY A START*