

# Model Based Capability Assessment

By

**Matthew Carey**

B.S. Robotics & Electrical Engineering  
Worcester Polytechnic Institute, 2011

SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION  
AT THE  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2017

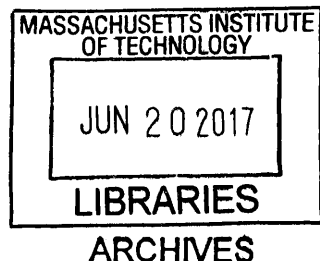
© Draper Laboratory

The author hereby grants to MIT permission to reproduce  
and to distribute publicly paper and electronic  
copies of this thesis document in whole or in part  
in any medium now known or hereafter created.

Signature of Author: **Signature redacted** \_\_\_\_\_  
MIT Sloan School of Management  
May 22, 2017

Certified by: **Signature redacted** \_\_\_\_\_  
Dr. Michael Whinston  
Sloan Fellows Professor of Management  
Thesis Supervisor

Accepted by: **Signature redacted** \_\_\_\_\_  
Maura Herson  
Director, MBA Program  
MIT Sloan School of Management



# Model Based Capability Assessment

By

**Matthew Carey**

Submitted to MIT Sloan School of Management  
on May 22, 2017 in Partial Fulfillment of the  
requirements for the Degree of Master of Business Administration.

## **ABSTRACT**

As processing, modeling software and design experience become more advanced, the idea of designing a system through models has gained traction in numerous Department of Defense programs. The efficiency gains piloted through implementation of models in the engineering process have also prompted the movement of incorporating models into the acquisition process. While initiatives have been started to incorporate models into the acquisition process (model-based acquisition), there is no publicly documented assessment to determine if an acquisition office possesses the needed skills. This paper explores the purpose of model-based acquisition and assessment structures, and proposes a CMMI like generalized quantitative method by which to assess the readiness of a government acquisition office for model-based acquisition.

**Thesis Supervisor:** Dr. Michael Whinston

**Title:** Sloan Fellows Professor of Management

UNCLASSIFIED

# Model-Based Acquisition Capability Assessment Thesis

**D R A P E R**



**Author: Matthew Carey**

**Expected Graduation Date: June, 2017**

(Last Update: 5/23/2017)

# 1. Contents

1.	Contents .....	2-4
2.	Table of Figures .....	2-7
3.	Cover Information .....	3-8
3.1	Title: .....	3-8
3.2	Abstract: .....	3-8
4.	Acknowledgements .....	4-9
5.	Introduction .....	5-10
5.1	Thesis Outline .....	5-10
6.	Purpose .....	6-11
6.1	Why does model-based acquisition matter? .....	6-11
6.1.1	Flexible, Quantifiable Metrics .....	6-11
6.1.2	Commonality and Re-use .....	6-12
6.1.3	Cost Reduction and Model Accuracy .....	6-13
6.1.4	Realistic Risk Quantification .....	6-13
6.2	Why Capability Assessment? .....	6-14
7.	Background .....	7-16
7.1	Overview .....	7-16
7.2	Thesis Definition of MBA/Digital Engineering .....	7-16
7.2.1	Thesis Definition of Acquisition: .....	7-16
7.2.2	Thesis Definition of Model: .....	7-17
7.2.3	Simulation (and modeling) .....	7-18
7.3	Background of System Modeling .....	7-19
7.3.1	History .....	7-19
7.3.2	System Modeling Today .....	7-21
7.4	Department of Defense Decision Support Systems .....	7-23
7.4.1	Overview .....	7-23
7.4.2	The Big 'A' .....	7-23
7.4.3	Joint Capabilities Integration and Development System .....	7-23
7.4.4	Planning, Programming, Budgeting, and Execution (PPBE) Process .....	7-24
7.4.5	Defense Acquisition System .....	7-25
7.5	Department of Defense Contract-Acquisition Process .....	7-26

7.5.1	Acquisition/Contract Process Overview .....	7-26
7.6	Background of Capability Maturity Models (Assessment Systems).....	7-28
7.6.1	General CMM .....	7-28
7.6.2	CMMI .....	7-28
8.	MBA Capability Assessment System .....	8-30
8.1	Overview.....	8-30
8.2	How the MBA Capability Assessment Functions .....	8-30
8.3	Who Performs the MBA Capability Assessment? .....	8-30
8.4	Structure of MBA Capability Assessment .....	8-30
8.5	Future Development .....	8-31
8.6	Graphical Overview of Assessment Results.....	8-32
8.7	Defining the Assessment System .....	8-33
8.7.1	Management Organization .....	8-33
8.7.2	Model Management.....	8-37
8.7.3	Model Validation and Assessment .....	8-40
8.8	Example of the MBA Capability Assessment System .....	8-42
8.8.1	Overview:.....	8-42
8.8.2	Process.....	8-42
8.8.3	Result.....	8-42
9.	Assessment Validation .....	9-45
9.1	Overview.....	9-45
9.2	Interviews .....	9-45
9.3	Industry Comparison .....	9-45
9.3.1	Automotive Industry Comparison .....	9-46
9.3.1.2	Assessment Scoring: .....	9-47
9.3.2	Industry Comparison Results .....	9-48
9.3.3	Comparison Breakdowns .....	9-48
9.4	System Dynamics Overview.....	9-49
9.4.1	System Dynamics Overview .....	9-49
9.4.2	Justification/Purpose .....	9-49
9.4.3	Process Breakdown .....	9-49
10.	Next Steps and Follow-on Work .....	10-55

11. Glossary..... 11-56

## 2. Table of Figures

Figure 1: Non-Linear Performance Reward Curve .....	6-11
Figure 2: Subsystem Breakdown of Generalized Model.....	6-13
Figure 3: Strategy, Benchmarking and Planning .....	6-14
Figure 4: The "Big A" Acquisition Definition .....	7-17
Figure 5: Thesis Definition of "Model" .....	7-17
Figure 6: Scale Model For Training Cargo Captains (Scale 1/25) .....	7-19
Figure 7: ENAC – Among First Modern Modeling Computer.....	7-20
Figure 8: 2016 Ford Model Concept Display.....	7-21
Figure 9: USS Ford; Carrier Built With Digital Modeling.....	7-22
Figure 10: Big "A" Acquisition Overview.....	7-23
Figure 11: JCIDS Interaction with Defense Acquisition System .....	7-24
Figure 12: PPBE Process.....	7-24
Figure 13: Defense Acquisition System Framework Per DoD 5000 .....	7-25
Figure 14: Contract-Acquisition Process.....	7-26
Figure 15: CMMI Overview .....	7-29
Figure 16: MBA Capability Assessment Tool.....	8-32
Figure 17: MBA Assessment Example .....	8-43
Figure 18: MBA Automobile Industry Comparison .....	9-46
Figure 19: Requirements Definition Modeling System Impacts .....	9-50
Figure 20: Acquisition Strategy Modeling System Impacts .....	9-51
Figure 21: RFP Modeling System Impacts.....	9-52
Figure 22: Evaluation Modeling System Impacts .....	9-53
Figure 23: Award Modeling System Impacts .....	9-54

### **3. Cover Information**

#### **3.1 Title:**

Model-Based Acquisition Assessment Tool

#### **3.2 Abstract:**

As processing, modeling software and design experience become more advanced, the idea of designing a system through models has gained traction in numerous Department of Defense programs. The efficiency gains piloted through implementation of models in the engineering process have also prompted the movement of incorporating models into the acquisition process. While initiatives have been started to incorporate models into the acquisition process (model-based acquisition), there is no publicly documented assessment to determine if an acquisition office possesses the needed skills. This paper explores the purpose of model-based acquisition and assessment structures, and proposes a CMMI like generalized quantitative method by which to assess the readiness of a government acquisition office for model-based acquisition.



#### **4. Acknowledgements**

This research was funded by the United States Air Force. I thank the Air Force for their support that greatly assisted this research, although they may not agree with all of the interpretations/conclusions of this paper.

I would like to thank the Massachusetts Institute of Technology, Sloan School of Business. The time spent getting my MBA at Sloan provided an invaluable experience that allowed me to pursue my thesis as a field of work within the Institute, despite the difficulties of building the framework of a sponsored thesis. I especially want to thank Josh DeMaio and Rod Garcia for working with the school to make it happen.

There were numerous people that allowed me to interview them in the midst of their very busy schedules to provide some of the content and ideas for this paper. I thank them for their time and contributions to this research.

I would also like to express my appreciation for my faculty advisor, Dr. Michael Whinston. Dr. Whinston accepted my thesis despite his extremely busy schedule and the content being outside of his normal area of study. He also kindly reviewed several versions of the thesis while on sabbatical.

I am grateful for the opportunity to do this paper through Draper Laboratories, a remarkable place of cutting edge research and development. I have been privileged to participate in the Draper Fellow Program with the guidance of Sheila Hemami who has made the program what it is today.

In particular, I would like to thank my industry advisor, Dr. Brenan McCarragher. Without him persistently working on funding, contacts and opportunities, this thesis never would have happened. I am extremely thankful for his mentorship and conversations over the past two years.

Finally, I would like to thank my family, especially my wife who put up with numerous late nights and too many proof reads over the past two years to count. I love you.

## **5. Introduction**

This thesis is designed to help Department of Defense Acquisition offices assess their current model-based acquisition process status. The goal is for people that have little to no background in modeling to understand the benefits, limitations and challenges they will face as they add or transition model-based processes to their current work.

This thesis covers basic definitions of modeling and acquisition, and presents a brief history of the origins of modeling as well as its future to inform the reader of how assessments might change. An overview of alternative assessment systems is given to provide the reader with an understanding of what systems the author has worked to incorporate.

The assessment model is laid out with a fictional application to help the reader understand not only what the system is, but also the beginnings of how an assessment would work.

The remainder of the thesis is spent covering the validation processes used to ensure the assessment metrics are appropriate. System dynamic models, interviews and a cross-industry comparison are all used to show convergence on selected metrics.

### **5.1 Thesis Outline**

This thesis will first cover the justification for model based acquisition, followed by the need for an assessment system to provide feedback to said models. The thesis will then spend time defining broad terms such as model, acquisition and simulation to ensure the diverse audience is using shared terms. A background will be provided giving the reader an understanding of how model-based acquisition will fit within acquisition and the role of the assessment process, before finally defining and giving an example of the assessment process itself.

The paper will then turn towards the verification and analysis of the assessment system presented through dynamic system models, industry comparisons and provided research. The thesis will close with the next steps that should be taken in the research as well as a glossary.

## 6. Purpose

This thesis is meant for acquisition offices looking to assess their model-based capability. However, before this assessment can be performed, it is important to understand not only the motivations of model-based acquisitions but also the reasons for capability assessment systems.

### 6.1 Why does model-based acquisition matter?

There are many reasons why a successful model-based acquisition process can benefit the end customer, acquisition office and contractor with little to no downside to complex programs. A selection of advantages is listed below:

#### 6.1.1 Flexible, Quantifiable Metrics

Current proposals are extremely difficult to score, requiring immense skill on behalf of the people making determinations. Decisions (especially large ones such as the replacement refueling aircraft contract) are consistently contested on the basis of politics, improper judgements and lack of information.

By using model-based acquisition, teams can provide quantifiable metrics to award different contracts. This not only protects the acquisition office, but also provides clearer expectations to the contractors bidding on a proposal.

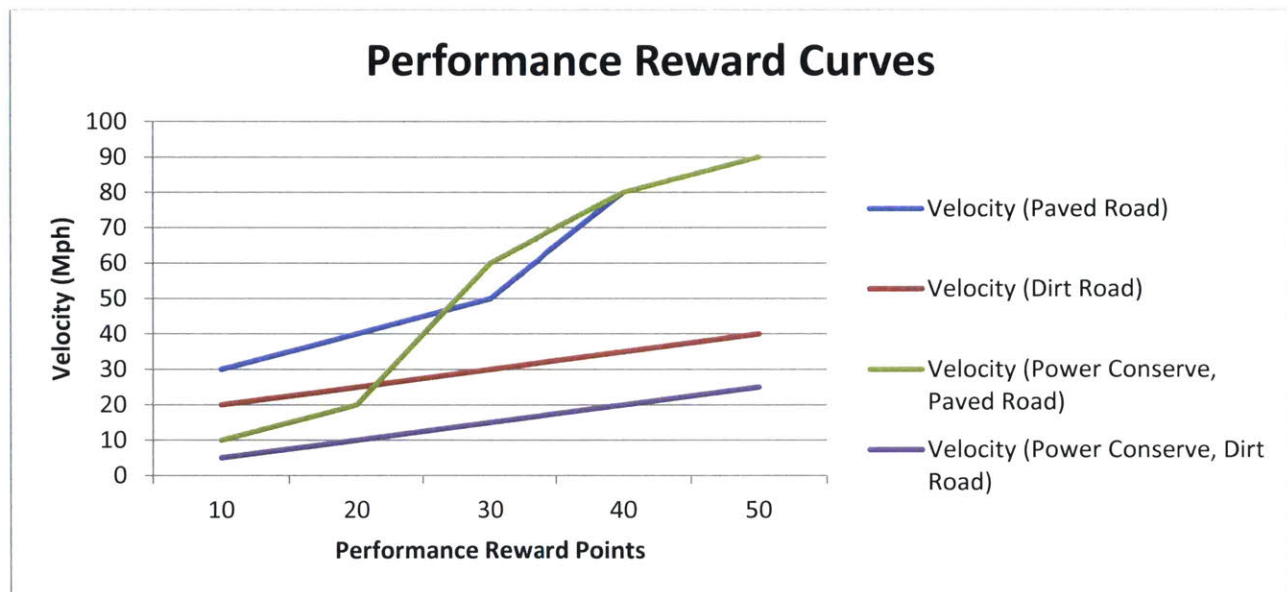


Figure 1: Non-Linear Performance Reward Curve

Model-based acquisition also enables new types of incentives to be offered within a contract that can further improve performance. Figure 1 demonstrates this, pairing performance (in this case, an arbitrarily defined speed of a product being bid on) to points rewarded for performance.

For instance, defining requirements through a System Requirements document takes form as:

***“The product SHALL have a velocity of 40 MPH on a paved road”***

Instead, performance reward curves can be given. This allows a contracting office to incentivize additional performance to a contractor. One of the key advantages of this approach is the fact that the curve does not have to be linear, but can provide key elbow points based in desirability. This can be applied to any measurable metric (environment, obsolescence and cost).

Figure 1 illustrates this capability. The performance increase required to go from twenty to thirty points is dramatic for a power conserved paved road application, allowing the contractor the visibility to know that the customer does not need that ability much at all. Instead, a much shallower curve is assigned to dirt roads, giving a much higher incentive for a contractor to focus on that particularly capability, while still balancing the rest.

This ability can be broadened to any aspect of the contract or any reward system. For instance, financial incentives can be provided on a non-linear scope, changing the behavior of the contractor. This can be used if the acquisition office wants to give emphasis on large cost savings, rather than having a linear scale for smaller ones. The acquisition officer might have in mind a particular price for a particular use case of a product (and incentivize accordingly). However, if the contractor was able to lower the price by a factor of ten, then the value to the acquisition office could well exceed the 10X multiple.

### **6.1.2 Commonality and Re-use**

One of the current Congress-mandated initiatives for acquisition offices<sup>1</sup> within the United States military is exploring how to better leverage the technology, systems and information between branches. This is a non-trivial problem, as if too many conflicting requirements are placed on a system, then complexity and cost rise rapidly.

Nevertheless, modeling provides a unique opportunity to validate and reuse subsystems for generalized use between departments or branches. Take for example Figure 2, where a bid was put out in the form of a government provided model (containing environments, sensor inputs and interfaces for outputs).

---

<sup>1</sup>Flip the Table on Procurement, Washington Technology. Retrieved 2017.  
<https://washingtontechnology.com/articles/2017/01/18/insights-soloway-procurement-reform.aspx>

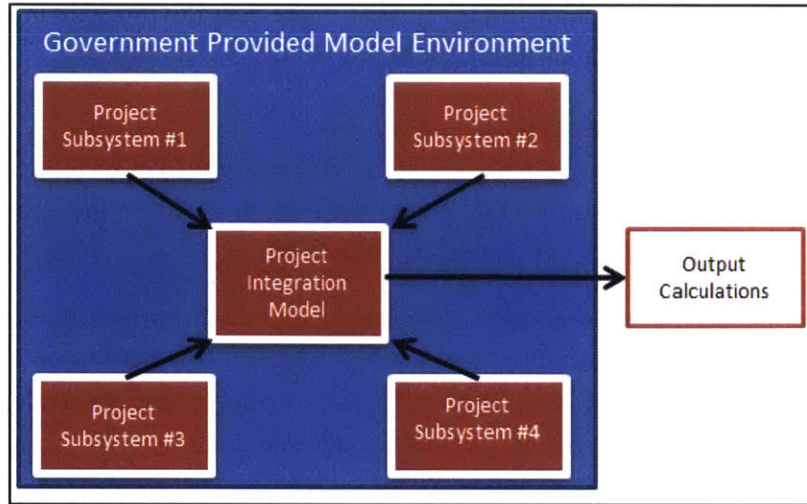


Figure 2: Subsystem Breakdown of Generalized Model

With model-based-acquisition, opportunities present themselves for designed subsystem reuse. While some of the subsystems might be different between branches or programs (say subsystem #2), other subsystems (#3 and 4) can be jointly developed to decrease cost and risk. Additional subsystems can be reused from older programs, allowing for legacy verification of otherwise unique systems. This concept of reuse and legacy is extremely important, greatly reducing cost, risk and complexity.

The same idea can apply to mid-development programs, when different programs or branches can pool resources to lower the risk a component might have, especially as if 80-90% of the requirements are common to each other. Rather than create new software from scratch, adaptive models can be created to tailor the functionality to a particular program.

### 6.1.3 Cost Reduction and Model Accuracy

Model-based acquisition allows for new levels of visibility into the costing projects submitted by contractors. Due to the fidelity of the subsystems interaction that must be shown to pass the external model interface, cost estimates can be performed with higher accuracy based on the performance desired versus past programs.

If desired, the acquisition office can also require a costing model to be run for the entire length of the program, allowing for systems that might have a high upfront cost to succeed over systems that might cost less during the development phase, but actually are more expensive over the life of the program.

### 6.1.4 Realistic Risk Quantification

Similar to the visibility for cost realism, model-based acquisition allows for increased visibility into the risks associated with a particular subsystem. While these sub-systems might be contracted out to sub-contractors, the interface definitions remain the same, allowing for independent verification and validation parallel to the rest of the technical development. Should a contractor not produce a sub-system meeting the model 'hole' that it was designated for, the requirements specifications (in the form of the model interfaces) will exist for another contractor to pick up. Agile development can be used in

conjunction with models to allow for steady progress to be made over the program lifetime, rather than having to complete the entire system and troubleshoot afterwards.

## 6.2 Why Capability Assessment?

It is important to note that organizations have understood the importance of benchmarking their skills throughout recent history. With the advent of modern systems engineering in the mid-1900s, the idea of organization skills and capabilities became critically important.

Model-based engineering has only recently gain popularity due to the promised efficiency gains. While it has showed promise, there are still substantial developments to be made in the tools and processes to fully take advantage of all the capabilities it offers. Acquisition is further behind in adopting these new processes due to the relatively short timeline, budget and additional scrutiny that come with awarding literally billions of dollars in a contract decision.

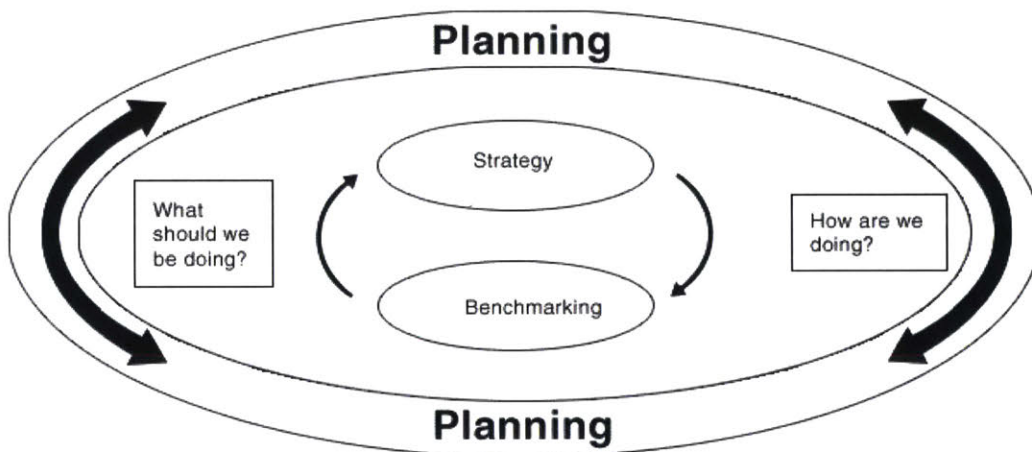


Figure 3: Strategy, Benchmarking and Planning

To reduce the amount of problems in adopting these new processes, acquisition offices must be aware of where the vulnerabilities within their own organizations lie. Without the proper tools and instructions to rule a model-based acquisition, valuable resources will be wasted in defective organization, as shown in Figure 3. Organizations must have a precise measuring system before feedback can be incorporated into planning. Furthermore, it will discourage positive change and innovation within this space for years to come.

Allowing acquisition offices to understand their weaknesses to counteract through training and resources lowers the risk of the program. Assessments like this one allow for an uncovering of the 'unknown unknowns' for the acquisition office to succeed.

A modeling capability assessment is critical to providing the first resource for an acquisition office to examine to understand the position of its tools, people and processes regarding digital models. The goal is not to provide the answers within the assessment model. Rather, the goal is to reduce the amount of

“unknown unknowns” that an acquisition office has regarding not only their current capability, but also the capability required for proficiency.

Once an acquisition director is armed with this information, then concrete, measurable steps can be taken to enhance the capability of an office and the ability to make educated decisions about how to ease into this difficult but promising idea of model-based acquisition. Until this paper, no public acquisition assessment guides exist for using models within the acquisition process.

## 7. Background

### 7.1 Overview

To understand the application of model-based acquisition, a foundation must be established. This background consists of relevant thesis specific definitions (i.e. Model-based Acquisition) and a history of various topics.

### 7.2 Thesis Definition of MBA/Digital Engineering

A singular understanding of what the author means by model-based acquisition must be understood before an assessment can begin. There are many different terms being used for the idea of models in conjunction with acquisition. While each term comes from a different area of defense or research and means slightly different things, this paper is focused on particular instances of both definitions. Other, similar definitions include:<sup>2</sup>

- Model-based Engineering
- Model-based Acquisition (small A)
- Digital Engineering
- Digital Acquisition
- Next-Generation-Acquisition
- Simulation Based Acquisition
- Data based Design
- Data based Acquisition

Depending on the parties being interviewed, the meanings of each can change quite dramatically in scope. To ensure that the reader is on the same page, below is the definition of model and acquisition for how it will be used in this thesis. The author makes no claims to superior or overwriting definition authority.

#### 7.2.1 Thesis Definition of Acquisition:

Before this thesis can go into an assessment of model-based acquisition, one must first define acquisition for this thesis. The definition of acquisition being used is referred to as the 'Big A'<sup>3</sup> of acquisition, as Figure 4 demonstrates.

---

<sup>2</sup> Office of the Deputy Assistant, Phil Zimmerman, Retrieved 2017.

[http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:07-iw14-mbse\\_workshop-mbse\\_in\\_government-zimmerman-v2.pdf](http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:07-iw14-mbse_workshop-mbse_in_government-zimmerman-v2.pdf)

<sup>3</sup> Congressional Research Service, Moshe Schwartz. Retrieved 2017.

<http://www.defenseinnovationmarketplace.mil/resources/RL340261.pdf>



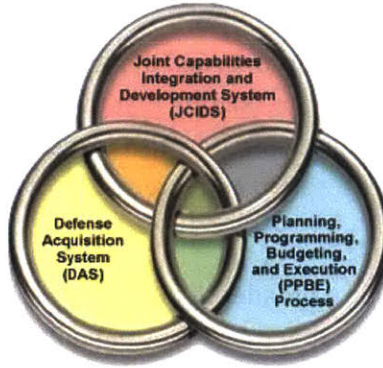


Figure 4: The "Big A" Acquisition Definition

This definition of acquisition encompasses not just the Defense Acquisition System, but also the entire capability development, planning, budgeting and execution along the entire lifecycle process. This includes technology development as well as operations and support. Further explanation of these processes can be found in 7-23.

**7.2.2 Thesis Definition of Model:**

The definition of model differs radically from person to person depending on the background and branch to which a user belongs. It's important to note that the definition used by this author is not referring to a single representation of the real world. The concept of model (as used here) is also not referring solely to simulation.

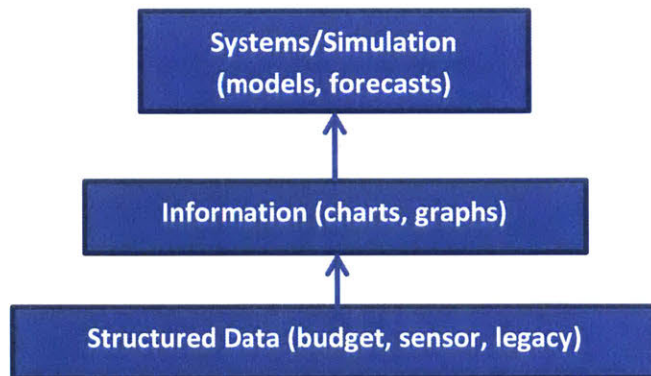


Figure 5: Thesis Definition of "Model"

Rather (seen in

Figure 5), the term model is being used for a collection of structured collected data from the real world, simulated data and the semantic models used to describe or generate it. In the world of 'model', there is an underlying network of data from both simulated and real inputs. The information layer is built on top of this data layer, allowing for viewing and interpretation of the data. Finally, systems in the forms of specific models or forecasts allow useful forward looking projections based on the information content.

The author is not referring to a file structure, rather a data centric structure that is continually built over time.

### **7.2.3 Simulation (and modeling)**

Modeling and simulation are commonly used terms<sup>4</sup> that are used together, representing several important offices within the DoD relating to skillsets that overlap with Model-based Acquisition. It's important to note that under the definition used by this particular department that modeling and simulation are focused on the representation and forecasting of physics, cost or risk based areas of a program.

On the other hand, this thesis is using a broader definition of model to encompass the structured data, the inferences that can be drawn from that data (information) and the physics based models (with relevant simulation that can be run). Therefore, simulation falls under the definition of 'model' used by this body of work.

---

<sup>4</sup> Modeling and Simulation Directive, DoD, Retrieved May 2017.  
<http://www.dtic.mil/whs/directives/corres/pdf/500059p.pdf>

### 7.3 Background of System Modeling

To better understand the nuances of the assessment system, as well as some of the language used, it is important to understand how modeling was first used, the transformation modeling has undergone over the past twenty years and where modeling is today. It is also important to note that while the definition of modeling for this thesis is data-centric (see 7-16), the first approximations of this model were mostly physical.

#### 7.3.1 History

Understanding the modern loaded definition of “model” and its influences is important to understand this thesis. The idea of being able to model complex systems to experiment and develop proven results has been around for hundreds of years. One of the more well-known early examples of establishing physical models was in the 1860s when the nautical engineer William Froude published several papers<sup>5</sup> about maximizing the stability and performance of naval vessels (including the Froude Number). To provide experimental results without having to invest the resources required to build large amounts of unique ships, he built scale models to validate his theories. He also identified and solved problems that are scale dependent, incidentally creating the field of model validation and verification.



Figure 6: Scale Model For Training Cargo Captains (Scale 1/25)

Numerous other ship (and later aircraft) companies copied the idea of scale-models, leading to faster, lower-cost design methods that produced superior, tested results. Previously classified designs of propellers (reduced cavitation), rudders (better flow profiles) and ice breaking (structural longevity) were all created with scale models in the early 1900s<sup>6</sup>. This method is still used today for training different crews on handling ships through simulation, as you can see in Figure 6. Until the past 50 years, the majority of these models were simpler, lower cost physical constructions of the finished product itself. All of these models were based in the physical world, rather than using stored digital data.

<sup>5</sup> Navies in Transition, Phil Russel. Retrieved 2017.

<https://web.archive.org/web/20010226150706/http://www.btinternet.com/~philipr/froude.htm>

<sup>6</sup> The NRG, Stuart McKenna. Retrieved 2017. <http://www.thenrg.org/resources/articles/58-2%20NRJ%20The%20Two%20Clydes%20-%20article.pdf>

The notable exception to this was the Manhattan Program, where analog computers (as well as hand-operators) simulated the size and shape of neutron collisions using Monte Carlo simulation.<sup>7</sup> ENIAC (one of the first general purpose digital computers shown in Figure 7) was then built to model and simulate artillery firing tables. The idea of modeling systems in flexible, dynamic methods using digital systems was pioneered by Professor Jay Forester from MIT Sloan. Prof. Forester leveraged his existing relationship with General Electric to discover why employment cycles within General Electric involved cyclical characteristics.<sup>8</sup> The Apollo program also heavily used early methods of simulation as it introduced digital controls (and corresponding algorithms) on the race to the moon. However, these expensive controllers cost far beyond what was needed for ubiquity.<sup>9</sup> For the first time, models now encompassed more than just simple digital representations: they were a collection of data that could be used to generate useful information, representation and simulation – a modern model.

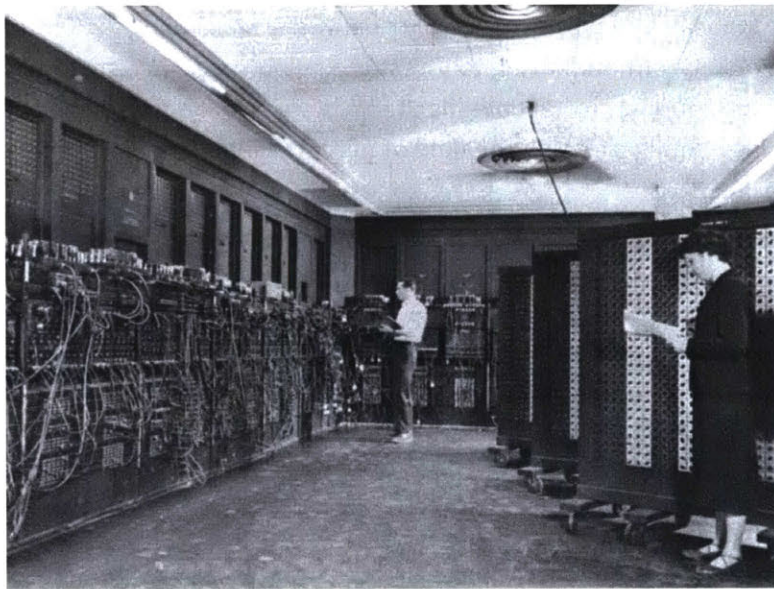


Figure 7: ENAC – Among First Modern Modeling Computer

It wasn't until the advent of programmable logic controllers that simulation and modeling could take place outside of the laboratory or highly funded space program. Personal computers (however rudimentary by today's standards) were now capable of running the same basic software found in a

<sup>7</sup> Atomic Heritage Foundation, Retrieved 2017. <http://www.atomicheritage.org/history/computing-and-manhattan-project>

<sup>8</sup> MIT Technical Review. Retrieved 2017. <https://www.technologyreview.com/s/538561/the-many-careers-of-jay-forrester/>

<sup>9</sup> David Mindell, Digital Apollo. 2014.

<https://books.google.com/books?id=gXYltzQARVoC&pg=PA139&lpg=PA139&dq=apollo+spacecraft+digital+controls&source=bl&ots=24mHMn2Z45&sig=N7u2EavPqCzJeCueva9I2DaUduw&hl=en&sa=X&ved=0ahUKEwjH57PBknTAhVCRCKHeJ2AaIQ6AEIRTAI#v=onepage&q=apollo%20spacecraft%20digital%20controls&f=false>

factory or design settings, paving the way for more advanced models, algorithms and development processes.<sup>10</sup>

### 7.3.2 System Modeling Today

Modern use of modeling has and continues to grow outside of the Defense Department. Because this thesis uses areas like automobile manufacturing to validate part of the assessment process, a background on where modeling is used elsewhere is important for the reader to understand.

System modeling is primarily used for training, engineering and science. The introduction of the modern PC and low-cost digital processing unit allows almost any engineer to run moderately advanced models at their work desk. Modeling has allowed for collaboration and testing in unprecedented ways (specifically speed and situation variety), laying the groundwork for easier construction of previously exhaustive systems.<sup>11</sup>

A good example of this is car manufacturing, where car companies now not only build models about their car dynamics, but also about almost every facet. Detailed models and representations are made about the user interface, handling, fuel economy and breakdown parameters. A public demonstration is shown in Figure 8.



Figure 8: 2016 Ford Model Concept Display

All of the parts are created in computer-aided design software and evaluated prior to selection. Eventually, the goal is for car design to become almost entirely digital, with only verification and testing performed in the physical world.<sup>12</sup>

An example of modeling advances within the Department of Defense includes two of the most complicated systems within the United States Navy. The Ford class carrier (see Figure 9) and the Ohio

<sup>10</sup> Computer Weekly, Cliff Saran. . Retrieved 2017. <http://www.computerweekly.com/feature/Apollo-11-The-computers-that-put-man-on-the-moon>

<sup>11</sup> Model Driven Engineering, Douglas Schmidt. . Retrieved 2017. <http://www.cs.wustl.edu/~schmidt/PDF/GEI.pdf>

<sup>12</sup> Model Driven Architecture, John Poole. . Retrieved 2017. <http://ieeexplore.ieee.org/document/1530663/>

Replacement Submarine are both entirely digitally designed from the ground up, including the service lines, pipes, electricity and walkways.<sup>13</sup>



Figure 9: USS Ford; Carrier Built With Digital Modeling

Modeling and simulation has also produced optimal orders with which to assemble the machines, avoiding as much construction inefficiencies as possible. Models are also being used to generate the hardware and software integration needed for automatic defensive systems, as the response time must be faster than a human.

As programs and departments continue to build their capability and confidence in digitally modeling and simulating complex environments, the amount of model-based engineering (and the corresponding gains) will only continue to increase.

The processing power available to the standard worker, increasing efficiency of the modeling tools and potential huge cost savings from using models will continue to grow this field quickly in the future. Companies must adopt model-based design and/or acquisition to survive – yielding a greater need for assessment systems.

---

<sup>13</sup> Super Carrier 2015, Noah Shachtman. <http://www.popularmechanics.com/military/navy-ships/a4330/4321136/>

## 7.4 Department of Defense Decision Support Systems

### 7.4.1 Overview

The next part of this thesis covers the decision support systems for acquisition within the DoD. This is relevant to this thesis, as one of the key advantages of model-based acquisition is its ability to draw complex systems together for a long period of time. To understand how this advantage applies and what models (cost vs risk vs physics based) model to choose, the understanding of the various branches desires is critical.

### 7.4.2 The Big 'A'

Usually referred to as the 'Big A' acquisition framework, the defense decision support system covers the organizational lifetime of the program. This is critical, as most of the cost of an acquisition is much further down the timeline than what is typically considered "acquisition."<sup>14</sup> The framework below ensures that not only is the initial acquiring aspect of a program considered, but the full file-cycle, budget and existing capability is also considered.<sup>15</sup>

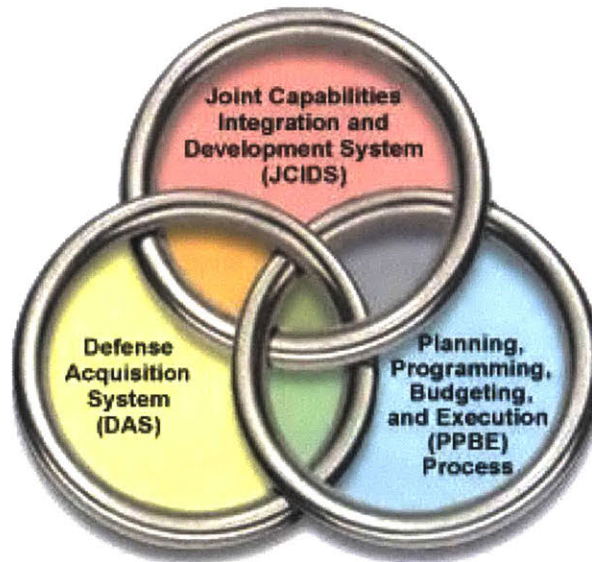


Figure 10: Big "A" Acquisition Overview

### 7.4.3 Joint Capabilities Integration and Development System

The purpose of the Joint Capabilities Integration and Development System (JCIDS) is to allow effective oversight to validate the capability requirements dictated for current and future systems.<sup>16</sup> To ensure accountability, reviews are held throughout the entire assessment; design, product and operation of a

<sup>14</sup> Congressional Research Service, Moshe Schwartz. Retrieved 2017.

<http://www.defenseinnovationmarketplace.mil/resources/RL340261.pdf>

<sup>15</sup> DoD Acquisition. Retrieved 2017. <https://dap.dau.mil/aphome/Pages/Default.aspx>

<sup>16</sup>JCIDS DoD Acquisition. Retrieved 2017. <https://dap.dau.mil/aphome/jcids/Pages/Default.aspx>

particular system (see Figure 11). The idea of incorporating models into this process allows for increased visibility and capability into active assessments.

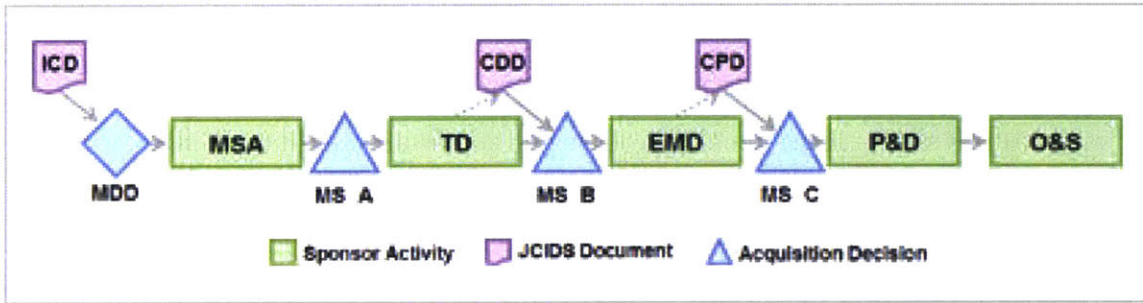


Figure 11: JCIDS Interaction with Defense Acquisition System

This system is flowed up to the highest levels of organization, with the Joint Chiefs of Staff and Requirements Oversight Counsel taking an active role in approving and supervising high level requirements through the JCIDS.

This process helps govern the responsibility of the acquisition provided model environment compared to the contractor provided model. Update times/frequency would be determined according to the different sponsor activities scheduled.

#### 7.4.4 Planning, Programming, Budgeting, and Execution (PPBE) Process

The Planning, Programming, Budgeting, and Execution (PPBE) Process governs where the money is spent for the duration of the program.

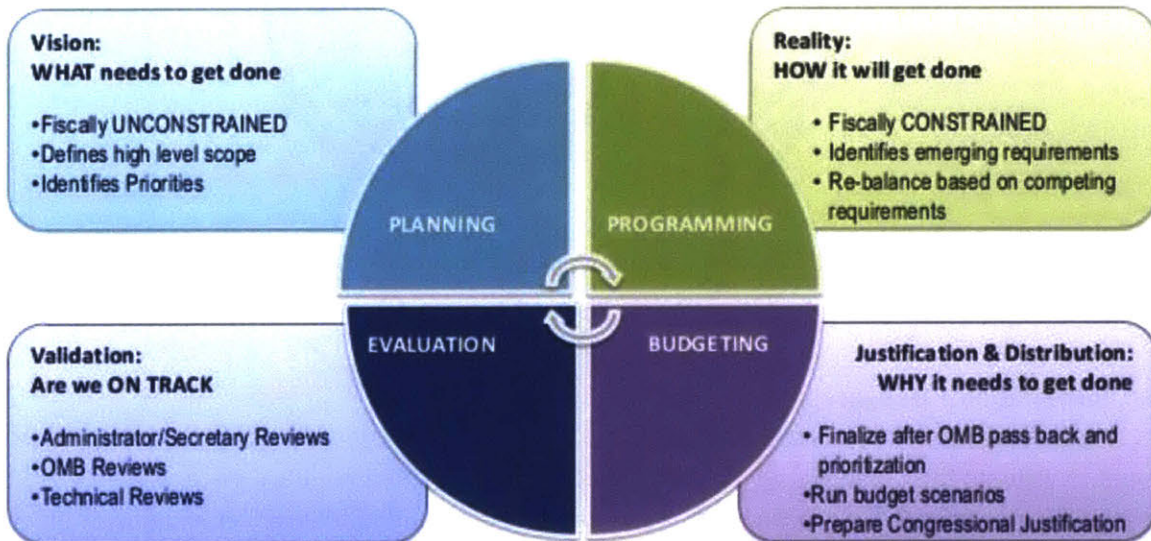


Figure 12: PPBE Process



Leveraging modeling through risk, cost and timelines tied to specific milestones (see Figure 12), this process can help hold programs accountable to the model-based plan that they are using to succeed.<sup>17</sup>

Each aspect (planning, evaluation, programming and budgeting) is information derived from the data structure of the model, building on the legacy of each program before it. Risk can be assessed based on the history of the contractor, technology or other risk profiles that can be simulated from model data.

#### 7.4.5 Defense Acquisition System

All of the acquisition process is kept in DoD document 5000, the comprehensive framework for all acquisition processes. While recent updates have begun to encourage the use of models and simulation, no current processes exist that incorporate or require models to be used in acquisition other than as a means to de-risk important areas of an acquisition.<sup>18</sup> See Figure 13 for a complete breakdown.

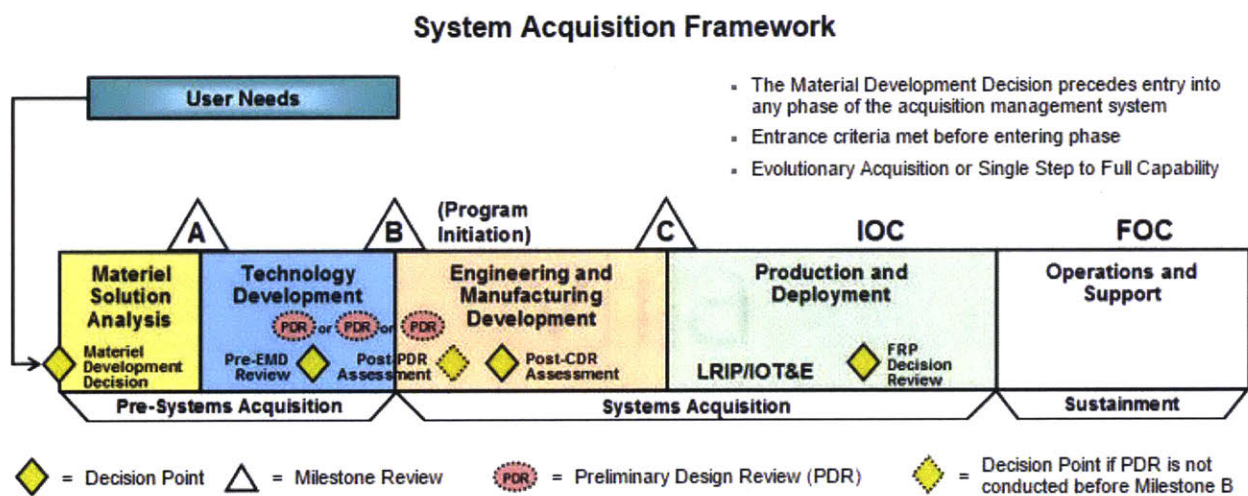


Figure 13: Defense Acquisition System Framework Per DoD 5000

##### 7.4.5.1 Material Solution Analysis

The first phase of any program acquisition, this stage identifies if a material solution is available for a pain point or specifically needed capability. Alternatives and technical feasibility are examined.

##### 7.4.5.2 Technology Development

This phase assesses the technological readiness level of the program, including preliminary design. Each configuration item is required to be broken down along with major subsystems. A preliminary design review must be held.

##### 7.4.5.3 Engineering and Manufacturing Development

Final design is completed in this stage, which is allowed to progress into manufacturing upon passing the critical design review. Initial manufacturing runs are created and all initial technical risk is eliminated.

<sup>17</sup> PPBE DoD Acquisition. Retrieved 2017. <https://dap.dau.mil/aphome/ppbe/Pages/Default.aspx>

<sup>18</sup> SAF DoD Acquisition. Retrieved 2017. <https://dap.dau.mil/APHOME/Pages/Default.aspx>

#### 7.4.5.4 Production and Deployment

Following successful milestone system acceptance, the program is put into either full-rate or low-rate production and deployment. The system is now handed off to the warfighter.

#### 7.4.5.5 Operations and Support

The fifth and final phase covers the extended deployment, maintenance and operation of the program. Often the most expensive, this phase covers the “long-tail” of weapons programs.

### 7.5 Department of Defense Contract-Acquisition Process

#### 7.5.1 Acquisition/Contract Process Overview

This acquisition process is followed any time a contract is sent out to bid. As a result, this thesis relies heavily on the categories to build later system dynamics models (for ensuring complete coverage) as well as perspective on how traditionally defined acquisition fits within the DoD ‘Big A’ plan.

There are five major parts (see Figure 14 to the contract/acquisition process for any piece of the system acquisition framework).<sup>19</sup> These are:



Figure 14: Contract-Acquisition Process

##### 7.5.1.1 Requirements Definition:

The beginning stage of any acquisition/contract process, the requirements definition is where the statement of work (SOW) is first identified. The proposed set piece of work is identified from the contract officer on behalf of the customer for future evaluation. This high-level body of work is what the contractor is ultimately judged against and paid for.

Part of this process is responsible for taking qualitative statements from the warfighter (“I need to carry lots of equipment quickly”) to quantitative “shall” statements used for requirements (“The unit SHALL carry 200lbs at 40mph”). The contracting and project officer will also identify the market, vendors and current commercial practices for similar contracts to gain knowledge of requirement realism.

Finally, a Statement of Objectives (SOO) is created that provides high level guidance for the request for proposal process (RFP).

<sup>19</sup> Acquisition/Contracting Progress. Retrieved 2017. <https://acc.dau.mil/communitybrowser.aspx?id=520847>

**7.5.1.2 Acquisition Strategy:**

The acquisition strategy follows the requirements definition closely, providing a larger scope to the method by which the requirements will be fulfilled. Unit definitions, exit criteria and phase gates are defined at this stage. Cost and schedule are determined based on technical complexity and calculated risk.

Sources of materials, industrial processes and equipment and existing technologies are all investigated at this stage for potential leverage. While most contracts do not stipulate the details on sources, program requirements are defined using their guidance from market forces. The level of Commercial off the Shelf (COTS) items is assessed to gain an understanding of potential costs and complexity. Life cycle costs are considered against all aspects.

**7.5.1.3 Request for Proposal:**

The Request for Proposal (RFP) is a formal solicitation issued by the Department of Defense to potential contractors (and the public depending on the contract sensitivity). A complete set of the requirements, projected costs, schedule and grading complexity is transferred within the RFP.

Typically, a contractor(s) will have between ninety to one hundred days to respond to a standard RFP, after which thirty to sixty days are set aside for evaluation. Depending on the complexity and classification of the contract, bidding is open to all the world, or select contractors. In the case that only one contractor can produce the product, and then a sole-source selection process is conducted with an RFP to maintain accountability.

**7.5.1.4 Evaluation Phase:**

The proposals are evaluated using a weighted set of previously published criteria. Each proposal is broken down by cost, risk and capability.

The first step of evaluation is to select the team responsible for the evaluation through nomination, briefing and training. The team must possess a wealth of experience in both technical fields and business case domains.

The team utilizes the defined criteria to determine if the RFP meets the minimum threshold required to be considered, then how it exceeds it. This team is responsible for carefully examining the language in the contract to ensure no unjust cost increases are in store. The team is also charged with documenting all finds to back up the contract award.

**7.5.1.5 Contract Award:**

Once a decision has been made, the results (and winning bid cost and capability) are announced. The contractor awardee is then allowed to sub-contract a predetermined percentage to the losing bids if desired.

The number of bids, offers, names, prices and reasons for acceptance/rejection are all made public following the contract award.

## **7.6 Background of Capability Maturity Models (Assessment Systems)**

Since this thesis proposes a maturity assessment model, it's important to understand the primary digital assessment processes on the market today. While each assessment is different, the end result of this thesis leverages previous experience within Capability Maturity Model Integration to ensure validity. Understanding the background and current status of CMM/I is critical to understanding the created assessment model.

### **7.6.1 General CMM**

The idea behind Capability Maturity Model was developed primarily in the 1960s, with the advent of reprogrammable computers. Little organization process had formed to help guide how software should be conceptualized, developed and ultimately coded.

As a result, numerous software-hardware integration programs failed, primarily due to poorly developed software. This poorly developed software was underscored by the failed demonstration of Sgt. York, an automated anti-aircraft turret that pointed to its operators rather than the target on several high-profile situations. No commercial solutions existed to help organize and budget the code development that was exponentially increasing in complexity. When the cost-overruns and program failure started impacting important military programs, the United States Air Force commissioned a study at Carnegie Mellon to understand why this was occurring.<sup>20</sup>

Development of a maturity model began in earnest in 1986, at first focusing on evaluating existing software to assist the United States military in awarding government software contracts. This eventually grew into an objective evaluation of process capability assessment focusing on subcontractors.

Unfortunately, the Capability Maturity Model was never widely adopted due primarily to its requirement of applying diverse, integrated models throughout an organization. This requirement drained resources and made the system extremely heavy (process-wise) to implement, even on smaller tasks. To resolve these issues, Capability Maturity Model Integration was developed.

### **7.6.2 CMMI**

Capability Maturity Model Integration (CMMI) was developed in partnership with government, industry and academia to improve the processes associated with software development while correcting problems introduced by CMM.

---

<sup>20</sup> Software Engineering Institute, Richard Lynch. Retrieved 2017.  
[http://www.sei.cmu.edu/newsitems/Humphrey\\_obituary.cfm](http://www.sei.cmu.edu/newsitems/Humphrey_obituary.cfm)

## Characteristics of the Maturity levels

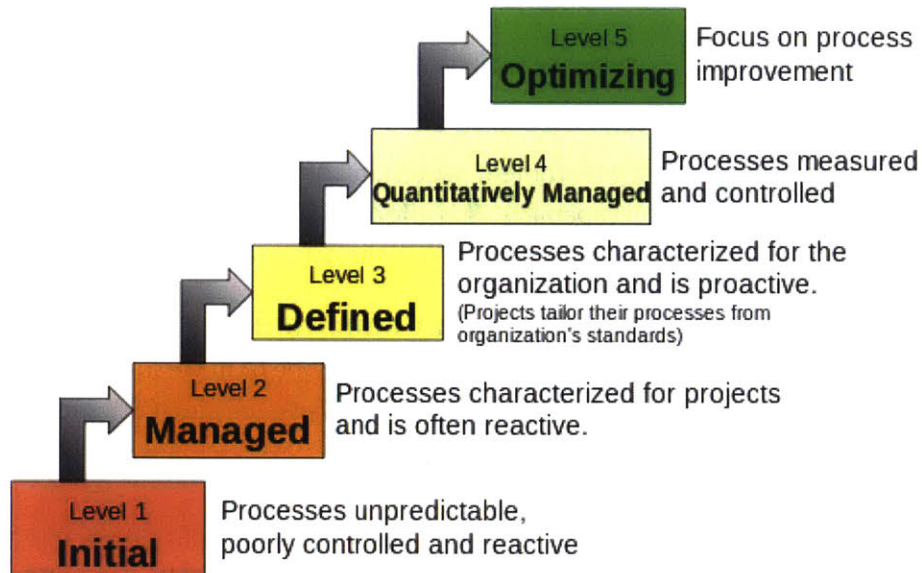


Figure 15: CMMI Overview

Carnegie Mellon funded the development of the process, until spinning it out to a private audit and consulting company. In 1997, the first version was released, quickly followed by 1.1 in 2002, 1.2 in 2006 and finally 1.3 in 2010. CMMI 1.3 incorporated and provided process improvement for multiple levels and styles of software development, including the up and coming Agile development process.<sup>21</sup>

Due to its well-documented, process driven methodology, CMMI quickly rose in popularity. Rather than being certified in CMMI, organizations were now being required to be appraised by CMMI auditors on a regular basis, ensuring quality of service. Most software development contracts require CMMI appraisal if they relate to external systems concerning safety.<sup>22</sup>

The approach (see Figure 15) focuses on five different stages, each with clear criteria. While originally designed for software development, CMMI has been spread to many different applications including manufacturing, e-commerce and hardware engineering.

<sup>21</sup> CMMI V1.3 Process Area. Retrieved 2017. <http://www.benlinders.com/tools/cmmi-v1-3-process-areas/>

<sup>22</sup> Popularity of CMMI. Retrieved 2017. <http://www.cmmiconsultantblog.com/certification/popularity-of-cmmi-performance-improvement-framework-is-increasing-at-global-level-and-rising-continuously/>

## **8. MBA Capability Assessment System**

### **8.1 Overview**

This section will discuss the actual modeling capability assessment system, as well as provide concrete examples as to its application.

The purpose of this tool is to provide a government acquisition office a clear method by which to evaluate their model-based acquisition capability. This information will produce actionable steps forward with which to augment, train or otherwise de-risk the acquisition team.

### **8.2 How the MBA Capability Assessment Functions**

The evaluator receives written material, conducts interviews (phone or in person) and consults with outside professionals to arrive at a quantitative score in all of twelve metrics. Each metric is scored 1-5, with five being the most proficient and one being the least.

The output of this assessment is a quantitative score of an acquisition office's model based acquisition proficiency. The output should also include a report of what aspects should be fixed first and how the training/capability gap should be reduced.

Finally, a new assessment should be scheduled if areas were not satisfactory to ensure skill areas are being addressed.

### **8.3 Who Performs the MBA Capability Assessment?**

The evaluator (or evaluation team) is expected to be proficient with model based engineering. Without this critical skill, the evaluator will find it extremely difficult to assess the team skill, tooling and quantitative measurement.

In order to incorporate the model based functioning into the existing DoD acquisition process, the evaluation team must also be proficient within the current acquisition framework. This is not only to be able to verify and suggest proper process, but also to understand the daily pressures and acquisition team and its contractors face.

Finally, the evaluation team should belong to a separate unit (or independent sub-contractor) to avoid improper measurement pressures.

### **8.4 Structure of MBA Capability Assessment**

There are twelve major metrics that are assessed during this process. Each metric is broken into one of three categories to allow for performance trends to be detected easily. The evaluator can then to understand the root of the problem if most of the deficiencies are focused on people (Management Organization), the model (Model Management) or the way people are assessing the model (Model Validation and Assessment).

While there are numerous other categories that this area could be inserted to cover the twelve different metrics, the author found that the feedback received from separating on the model implantation, people and the actual measurement allowed for the greatest understanding of how to assess properly. Future versions with additional metrics could adopt new categories if desired.

## **8.5 Future Development**

While extensive research in the form of system models, industry comparisons and relevant interviews has been completed to validate this assessment model to the maximum extent possible, there will be modifications and additions that additional parties will want to include learning from application experience.

The author expects additional versions [such as 1.2 or 1.3] to emerge as this process gets applied over the next year. Eventually, more versions that encompass more detail in modeling efforts (such as the digital twin) might supplant the current approach, leading to 2.0 or 3.0 versions of this assessment effort. This similar progress occurred with CMM and CMMI over a period of twenty years, leading organizations to the detailed system it has today.

### 8.6 Graphical Overview of Assessment Results

Located in Figure 16 is the spider chart with which to visualize this evaluation. Note that the twelve components are broken into three major categories depending on relevance for ease of organization.

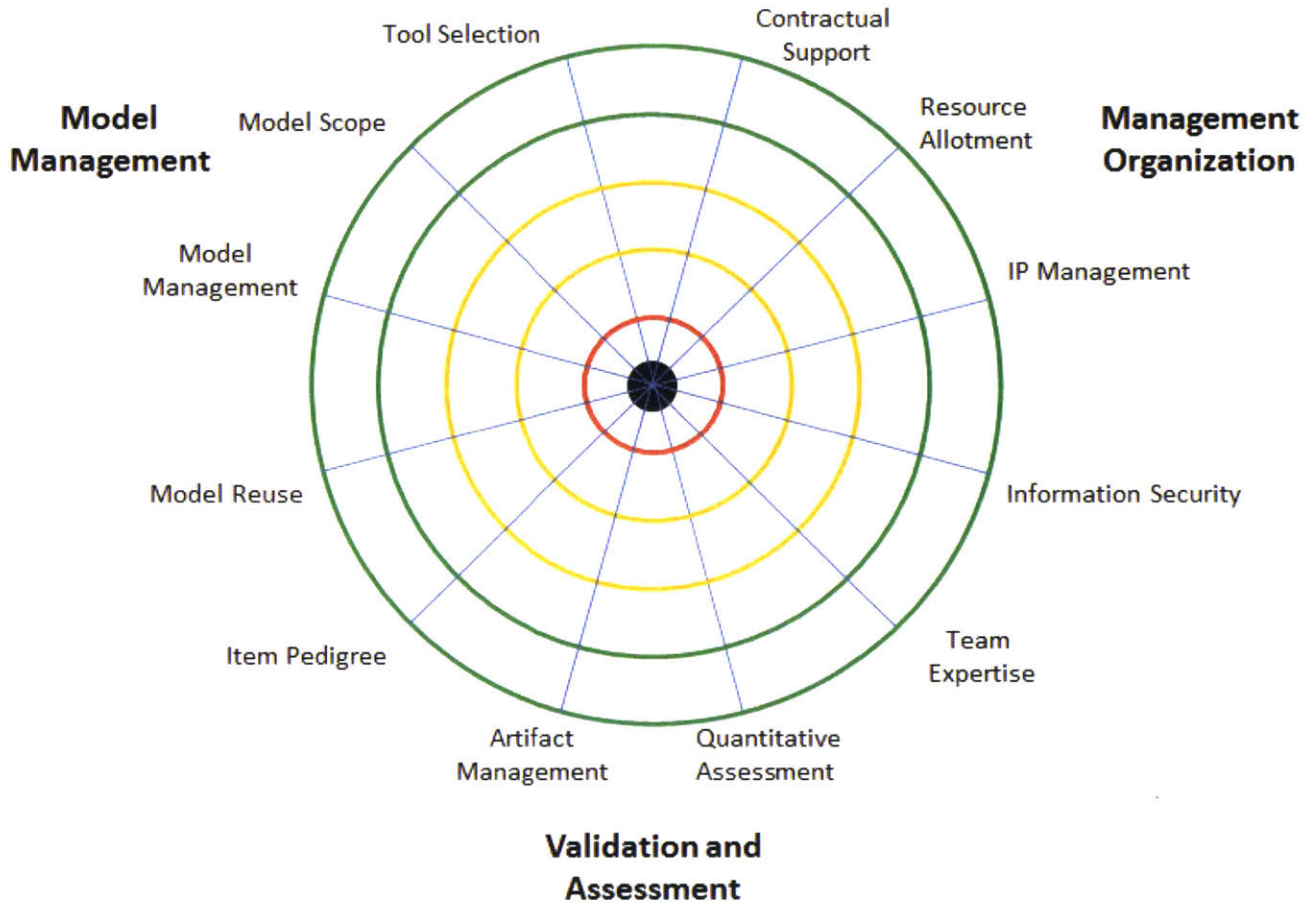


Figure 16: MBA Capability Assessment Tool



## 8.7 Defining the Assessment System

Below are explanations of the evaluation criteria. To be able to implement and exercise the content in this thesis, a thorough understanding of each of these terms, their various levels and possible overlap that might occur must take place.

### 8.7.1 Management Organization

This aspect of the assessment focuses on people. A low score in this category means that the processes surrounding people must change.

#### 8.7.1.1 Contractual Support

Contractual support defines the amount of support written into a contract or proposal request by the acquisition office for a model-based acquisition approach. While contractors currently provide the output of their simulations to prove topic feasibility, the goal would be that such decisions could be based on variable models to better allow for analysis of performance. Contractual support occurs when the incentive is provided to demonstrate these models, as well as a timeline of model delivery throughout the program.

Key aspects include: whether a model is required as a deliverable; the scope of said model and how heavily a model's performance; flexibility and completeness.

<i>Type: Contractual Support</i>	<i>This defines how much model driven processes are mandated by the proposal or contract.</i>
<i>Level 1:</i>	Internal model work is suggested by the acquisition office; contractor model output supports submission material.
<i>Level 2:</i>	Contractor model work is suggested by the acquisition office as supplemental evaluation material. Acquisition office will perform basic assessment of standalone model to assist in award decision.
<i>Level 3:</i>	Project requirements and performance is demonstrated by contractor based models that are required to be submitted as part of the proposal/submission.
<i>Level 4:</i>	Acquisition office creates and provides contractors with developed use case models to work with on proposal for 1-2 select at-risk areas. These particular areas are evaluated primarily based on model performance and flexibility. Completed contractor models are required for valid proposal/submission. The rest of the areas are driven by standard requirement language documents.
<i>Level 5:</i>	Project requirements are driven by established models provided by the acquisition office. Contractors create their respective models in scopes defined by risk profiles including cost, technical solution and timeline. Completed contractor models are required for valid proposal/submission.

#### 8.7.1.2 Resource Allotment

Resource allotment defines the amount of summation resources provided by the acquisition office to promote the usage of models. Due to the nature of model-based acquisition, there are additional costs in designing and creating models to be used for evaluation. These costs are realized at the beginning of a contract stage, with the savings being realized throughout the entire process.

These resources are measured in both dollars and time, recognizing that good model development has schedule allowance in addition to staff resources to be accomplished correctly.

<i>Resource Allotment:</i>	<i>Captures how many resources are given to develop, maintain and effectively use the models.</i>
<i>Level 1:</i>	Minimal resources or schedule time to evaluate any potential models submitted by contractors. No models published by acquisition office.
<i>Level 2:</i>	Some resources and schedule time allocated to evaluate any potential models submitted by contractors. No models published by acquisition office. Model submission encouraged by acquisition office.
<i>Level 3:</i>	Resources and schedule provided by acquisition office to develop use case models for key at-risk areas around the system (<10% total model coverage). Models submitted by contractors are evaluated thoroughly and quantitatively.
<i>Level 4:</i>	Resources and schedule provided by acquisition office to develop a basic use case models for the desired system, focusing on at risk areas (<50% total model coverage). Resources cannot update the models during bid process. Models submitted by contractors are evaluated thoroughly and quantitatively.
<i>Level 5:</i>	Resources and schedule provided by acquisition office to develop the use case models for the desired system. Resources are provided during the bid process to update models based on new requirements. Models submitted by contractors are evaluated thoroughly and quantitatively.

### **8.7.1.3 IP Management:**

Managing intellectual property of both the government and its various contractors is a significant hurdle to model-based acquisition. This is due both to the rapid transition to digital media without time to create social and legal norms, as well as the fluid and efficiency that digital information can travel. Complex objects (such as models and the data they create) do not naturally create easy lines to differentiate what aspects should be shared or kept secret.

IP management concerns the systems in place to properly share relevant technical, cost and schedule models while also preventing abuse of those ideas by other contractors. Similar to current practices such as personnel firewalling, IP must be separated or obfuscated to prevent abuse.

<i>IP Management:</i>	<i>IP management covers the effectiveness (or existence) of policies that allow for information sharing without compromising the sensitive models between contractors.</i>
<i>Level 1:</i>	No IP management plan in place specifically addressing models or model sharing
<i>Level 2:</i>	IP management plan published ahead of bidding process. Contractors only submit 'blackbox' output models with acquisition office. Limited sharing by specific permission only between contractors.
<i>Level 3:</i>	IP management plan published ahead of bidding process. Models can be shared openly with acquisition office; only raw output can be shared between different contractor model systems of different levels.
<i>Level 4:</i>	IP management plan published ahead of bidding process. Models can be shared openly with acquisition office, with blackbox, firewall and other initiatives governing model

	and data sharing between contractors and sub-contractors. There is no sharing between prime contractors.
<i>Level 5:</i>	IP management plan published ahead of bidding process. Contractors feel comfortable with IP management through extensive prior validation work. Models can be shared openly with acquisition office, with blackbox, firewall and other initiatives governing sharing and stacking models between all contractors.

### 8.7.1.4 Information Security

Information Security encompasses both internal and external threats and classification standards. As various parts of a major system possess different classification levels (power management might be unclassified versus a highly classified control algorithm). Creating and understanding the classification of data management to various systems as a result of simulation will be critical for synergies to be leveraged in acquisition.

Information security also covers external threats outside of the Department of Defense. As one of the key advantages of a model-based acquisition program is to allow for flexibility and optimization through a cyber-based medium, hostile external actors can also use this factor to the detriment of national security.

<i>Information Security:</i>	<i>Information security defines the interfaces between sub-components and personnel, while also maintaining integrity against outside threats.</i>
<i>Level 1:</i>	No information security plan is defined. No cyber security plan for external players has been defined.
<i>Level 2:</i>	Information security plan is defined; no data sharing is permitted between subsystems of different classifications.  All relevant organizations are in accordance with NIST 800-171 or higher for pertinent classified material to protect against outside hostile cyber intrusions.
<i>Level 3:</i>	Information security plan is developed with contractor buy-in, clear interfaces are installed. Only methods that allow for similarly classed data is allowed to be shared intersystem.  All relevant organizations are in accordance with NIST 800-171 or higher for pertinent classified material to protect against outside hostile cyber intrusions.
<i>Level 4:</i>	Information security plan is developed with contractor buy-in, clear interfaces are installed. Only methods that allow lower classified materials to move to higher classified systems are allowed to be shared intersystem.  All relevant organizations are in accordance with NIST 800-171 or higher for pertinent classified material to protect against outside hostile cyber intrusions.
<i>Level 5:</i>	Information security plan is developed with contractor buy-in, clear interfaces are installed and a method to raise/low classification of data is created and approved.  All relevant organizations are in accordance with NIST 800-171 or higher for pertinent classified material to protect against outside hostile cyber intrusions.

### 8.7.1.5 Team Expertise

Team expertise is defined as the amount of experience and skill an acquisition team has in model building, management and evaluation. This can be built through training, as well as experience with model-based engineering principles or other resources. While this thesis treats all modeling expertise the same, it's important to understand that there are several different modeling methods that could be useful for different types of contracts – each with its own partially overlapping skillset.

Due to resource constraints, the acquisition office can outsource some of the building and evaluation to independent contractors. For the purposes of this thesis, the independent contractors are considered to be part of acquisition team, although careful thought should be given to manage internal versus independent acquisition modeling team skill.

<i>Team Expertise:</i>	<i>Defines the amount of experience an acquisition team has (can be augmented by contractors).</i>
<i>Level 1:</i>	Acquisition team has little experience with modeling concepts (little to no involvement with acquisitions utilizing models).
<i>Level 2:</i>	Acquisition team has some experience (at least two prior acquisitions utilizing models) with modeling concepts, primarily from outside independent contractors.
<i>Level 3:</i>	Acquisition team has some experience (at least two prior acquisitions utilizing models) with modeling, primarily from outside independent contractors. Training plan in place to establish domain expertise.
<i>Level 4:</i>	Acquisition team has extensive experience (at least five prior acquisitions utilizing models) in both modeling and the acquisition process.
<i>Level 5:</i>	Acquisition team has extensive experience (at least five prior acquisitions utilizing models and considered SMEs) in both modeling and the acquisition process. Team is clear on when to call in outside expertise and possesses needed, trusted contacts.

## 8.7.2 Model Management

This aspect of the assessment focuses on process. A low score in this category means that the processes surrounding the model must change.

### 8.7.2.1 Tool Selection

There are many tools available for model construction and management (Cameo, Rhapsody), all of which have strengths and weaknesses. Although this thesis is focused on the acquisition office, each contractor will also have a preferred software selection, forcing a hard look at compatibilities within tools (or directed messaging for certain tools). The clarity, messaging and systems used to get the contractors all using the same tools will prove critical to any model-based decisions.

Previous work through Krogstie (2001), Goodhue et al (1995) and Nysetvold (2006) have produced validated systems through which a model is chosen. There are six main areas identified in Goodhue's research, all leading to quantitative selection criteria to determine the best tools for the job. No singular tool can satisfy all the modeling requirements, but rather a toolset with a data-centric structure to link the data, information and simulations/representations together.

<i>Tool Selection:</i>	<i>This term defines how efficient (both from training and model completeness) the modeling tool in question is being used.</i>
<i>Level 1:</i>	No processes are done to select tools, each agency or contractor uses whichever tool is most comfortable for them.
<i>Level 2:</i>	Tool selection analysis is conducted before the bidding process, primarily focused on team expertise and type of project. Contractors are required to use either the same tool or compatible versions.
<i>Level 3:</i>	Tool selection analysis is conducted before the bidding process, taking into account the type of project, risks, contractor preferences and team expertise. Contractors are required to use either the same tool or compatible versions. Modeling method is not driven.
<i>Level 4:</i>	Tool selection analysis is conducted before the bidding process, taking into account the type of project, risks, contractor preferences and team expertise. Contractors are required to use either the same tool or compatible versions. A modeling method preference is dictated by the acquisition office without consulting with industry.
<i>Level 5:</i>	Tool selection analysis is conducted before the bidding process, taking into account the type of project, risks, contractor preferences and team expertise. A modeling method preference study is also conducted taking contractor input into account before being set by the acquisition office.

### 8.7.2.2 Model Scope

There is a huge range of modeling that can take place within a project. Some models follow a physics-based determinate flow, providing key details of how a physical object will relate to the real world.

Other types of models (such as risk assessments) allow an acquisition office predict the success of the program (and the largest risk contributors). Costing models can also be extremely beneficial, as they can help an acquisition office not only understand the current cost, but also the life cycle costs for a complex

program many years down the road. Determining the correct scope of the models is a critical part to any decision process based on said models. Two questions must be answered.

First, a determination must be made of the appropriate topics to be modeled, versus continuing with the standard acquisition practice. This decision must take into account the areas with the highest risks and mission critical performance as well as the resources available (including skill level).

Second, a decision must be made about which models cover which scope. For instance, is it best to have the radiation model be dependent from the electrical power draw, or is it better to keep those separate?

It's important to note that the representative models come in all forms of shapes, sizes and functionality. Occasionally overlooked is full costing and risk models, which can be critical to a well-run program. Costing models allow for the entire lifetime cost of a program to be modeled and looked at with sensitivity analysis based on previous program life. Considering that only a small fraction of the total program cost is present at acquisition, this information needs to play a role in selecting the long-term solution for a capability hole.

Risk is also an important model. Since technology and complexity are inherent in almost any acquisition process, not conducting a risk analysis can leave the acquisition office open to potential capability shortfalls. Instead, risk assessments (and adjustments) can be done to reduce capability, mandate a second technical approach or delay a program altogether until the risk is deemed appropriate.

<i>Model Scope:</i>	<i>Determines the scope of the models in question.</i>
<i>Level 1:</i>	Model scope is dictated by contractors based on their preference/risk assessment.
<i>Level 2:</i>	At risk-areas are requested by acquisition office to be covered within the scope of the modeling.
<i>Level 3:</i>	At risk-areas are required by acquisition office to be covered within the scope of the modeling.
<i>Level 4:</i>	Model scope covers a significant portion (+50%) of the complete framework of acquisition, all required by bidding process. Full coverage is suggested.
<i>Level 5:</i>	Model scope covers complete framework of acquisition, all required by bidding process.

**8.7.2.3 Model Reuse**

Due to the resource intensive nature of designing and building models, acquisition offices must leverage previous artifacts, systems and methodologies to develop the best model frameworks possible to reduce resource constraints. This metric refers to the degree to which reuse of any of those factors can be implemented in a particular program.

This measure also refers to the systems set in place to help existing programs catalog and leverage existing programs work.

<i>Model Reuse:</i>	<i>This defines how much of previous models can be reused to save time and lower risk.</i>
---------------------	--

<i>Level 1:</i>	Each model is developed from scratch; no reuse processes are used before or after the project.
<i>Level 2:</i>	Prior to model development, tribal knowledge is used to examine what parts can be reused.
<i>Level 3:</i>	Prior to model development, analysis is done with previous models to examine what parts can be reused.
<i>Level 4:</i>	Prior to model development, analysis is done with previous models to examine what parts can be reused. After the model development is in progress, documentation is done to ensure future projects can leverage model.
<i>Level 5:</i>	Prior to model development, analysis is done with previous models to examine what parts can be reused. After the model development is in progress, libraries are established of complete sub systems for future comparison and reuse.

#### **8.7.2.4 Model Management**

The metric of model management refers to the tactical care of the acquisition models. Model management governs the methodology of how a model is updated (with changes being pushed to contractors) and the change management process is developed.

Model management also dictates what organization is ultimately in control of the model. This understanding answers the operational questions about when an acquisition team's model will be updated, who holds the 'truth' model, and what the role/purpose of the model is. This aspect can become difficult when two or more acquisition teams are involved (such as multiple branches) with diverse requirements. To save costs and reduce confusion, determining the process for ownership is critical to a contract.

<i>Model Management:</i>	<i>Model Management refers to how effectively a model is updated and maintained to increase effectiveness.</i>
<i>Level 1:</i>	No use case model is published by the acquisition office.
<i>Level 2:</i>	Acquisition use case model is published with no support. No ownership plan in place between organizations; all organizations maintain their own version.
<i>Level 3:</i>	Acquisition use case model is published with explanation support to contractors, no updates are provided. Model ownership dictated by acquisition office for first use.
<i>Level 4:</i>	Acquisition use case model is published with support and ownership plan in place. Contractors have a clear path to update their models to acquisition office frameworks. Multiple acquisition departments keep their own versions of the model to ensure their requirements can be met. Updates are made on an ad hoc basis by acquisition office.
<i>Level 5:</i>	Acquisition use case model is published with support and ownership plan in place. Updates are made on a scheduled basis unless major changes are needed. Known process to get model updated with new or fixed aspects with notification to contractors. Multiple acquisition offices can work effectively together to understand which is responsible for the model. Model purpose clearly defined.

### 8.7.3 Model Validation and Assessment

This aspect of the assessment focuses on the critical aspect of quantitatively scoring a model system. A low score in this category means that the scoring system must be changed.

#### 8.7.3.1 Model Pedigree

Model validation is an expensive, time-consuming task. To reduce risk and build confidence in models, new models should take advantage of validated model parts. If similar parts are being developed, existing legacy data about previous work should be incorporated (compensating for any changes) to boost confidence. This same practice is applied to contractor models, to better assess the validity of claims relating to potentially risk technology.

Management of pedigreed parts should be structured in a way to allow maximum part compilations within all departments, so long as policy is approved by IP management.

<b>Model Pedigree:</b>	<i>Model Pedigree refers to the data on modeled components in real life. Having models with high pedigree means lower risk.</i>
<i>Level 1:</i>	Each model is developed from scratch, no legacy data is used before or after the project.
<i>Level 2:</i>	Prior to model development, tribal knowledge is used to examine what part data can be evaluated.
<i>Level 3:</i>	Prior to model development, analysis is done with previous models to examine what parts have existing, validated data.
<i>Level 4:</i>	Prior to model development, analysis is done with previous models to examine what data on various parts can be used for validation. After the model development is complete, documentation is done to ensure future projects can leverage model.
<i>Level 5:</i>	Prior to model development, analysis is done with previous models to examine what data on various parts can be used for validation. After the model development is complete, libraries are established of complete subsystem data for future comparison and validation.

#### 8.7.3.2 Artifact Management

Throughout the modeling process artifacts (errors) will be found on both the acquisition office and contractors models. These errors must be tracked and eventually fixed for the model to be dependable. The artifact management process must remediate all errors while keeping in mind the sensitive nature of various company proposals.

An advanced artifact management process will also be able to process and update upgrades to the model as well, capturing ideas or incentives as contractors are exploring new methodologies to better satisfy the customer.

<b>Artifact Management:</b>	<i>During the acquisition process, contractors will create and find errors in the modeling processes. Artifact Management refers to the efficiency of the error capture,</i>
-----------------------------	--



	<i>documentation and remediation.</i>
<i>Level 1:</i>	No artifact management process is set in place for models.
<i>Level 2:</i>	Contractors are notified if their models contain artifacts, little remediation is allowed. Process not published.
<i>Level 3:</i>	Process is published. Contractor model artifacts found are documented and remediated (if contract language allows).
<i>Level 4:</i>	Process is published. Major acquisition model artifacts are updated through an unscheduled, undocumented process. Contractor model artifacts found are documented and remediated (if contract language allows).
<i>Level 5:</i>	Two-way artifact management process is published and used. Contractors can petition acquisition office to change model aspects, while contractor model artifacts found are documented and remediated (if contract language allows). Timeline goals of artifact closure are set and met.

**8.7.3.3 Quantitative Assessment**

One of the most important parts of contract decisions is evaluating the proposals with a quantitative assessment. This metric governs the process by which the assessment/incentives are designed within the model, distributed to the contractor, and used to make a decision.

This quantitative assessment should be entirely numerically-based with appropriate weighting based on the wishes of the acquisition office. Appropriate performance point bonuses should be established, along with penalties for less desired model behavior.

<b>Quantitative Assessment:</b>	<i>Quantitative Assessment concerns the judgement of models in a quantitative way against know criteria. This is extremely important for evaluation.</i>
<i>Level 1:</i>	Contractor models are not assessed against quantitative metrics. No metrics are published prior to evaluation.
<i>Level 2:</i>	Physics-based contractor models are assessed against quantitative metrics. Qualitative measurements against other aspects are performed.
<i>Level 3:</i>	Most contractor models (+50%) are judged against the same quantitative measurements. Scope and measurements are published during the bidding process.
<i>Level 4:</i>	All contractor models are judged against quantitative measurements. Measurements are published during the bidding process.
<i>Level 5:</i>	All contractor models are judged against the same quantitative measurements. Measurements are published during the bidding process and are modified after a contractor petition process.

## **8.8 Example of the MBA Capability Assessment System**

To provide the reader with an example of how a completed assessment would look, a fictional, abbreviated case has been created to demonstrate the completed assessment process. This example will show not only what the assessments were arrived at based on the background of the case, but also provide an idea of the process.

### **8.8.1 Overview:**

An acquisition office has previously evaluated the idea of model-based acquisition. They recently were given direction by the acquisition chief to pilot a model-based approach on one of the new upcoming programs.

After taking some time to assess what program would be best, the acquisition office selected a five year, \$100 million USD program. This program has a supporting PM from both the military and civilian side. This acquisition project is starting one year ahead of schedule to accommodate the learning process required to drive an acquisition through models.

Sufficient funding was allotted to cover the modeling costs as well as to build a sustainable system for future use if the program succeeded in controlling costs. Before the program was kicked off, an assessment of the office was conducted to determine a risk assessment and possible allocation of new resources.

### **8.8.2 Process**

To facilitate this process, material about existing processes for this acquisition office was sent to the evaluating personnel. This process material included the current process at this office, but also the proposed changes that would be made as models continued to be incorporated into this program.

Following a process evaluation, the evaluation team conducted several interviews with on-site personnel in key positions. Structured interviews were conducted with a focus on the new processes that would be implemented to enable this model focus.

Following the data collection, determinations were made against the set criteria of the capability assessment system to ascertain status.

### **8.8.3 Result**

Below is an assessment example for model management, management organization and validation and assessment (Figure 17).

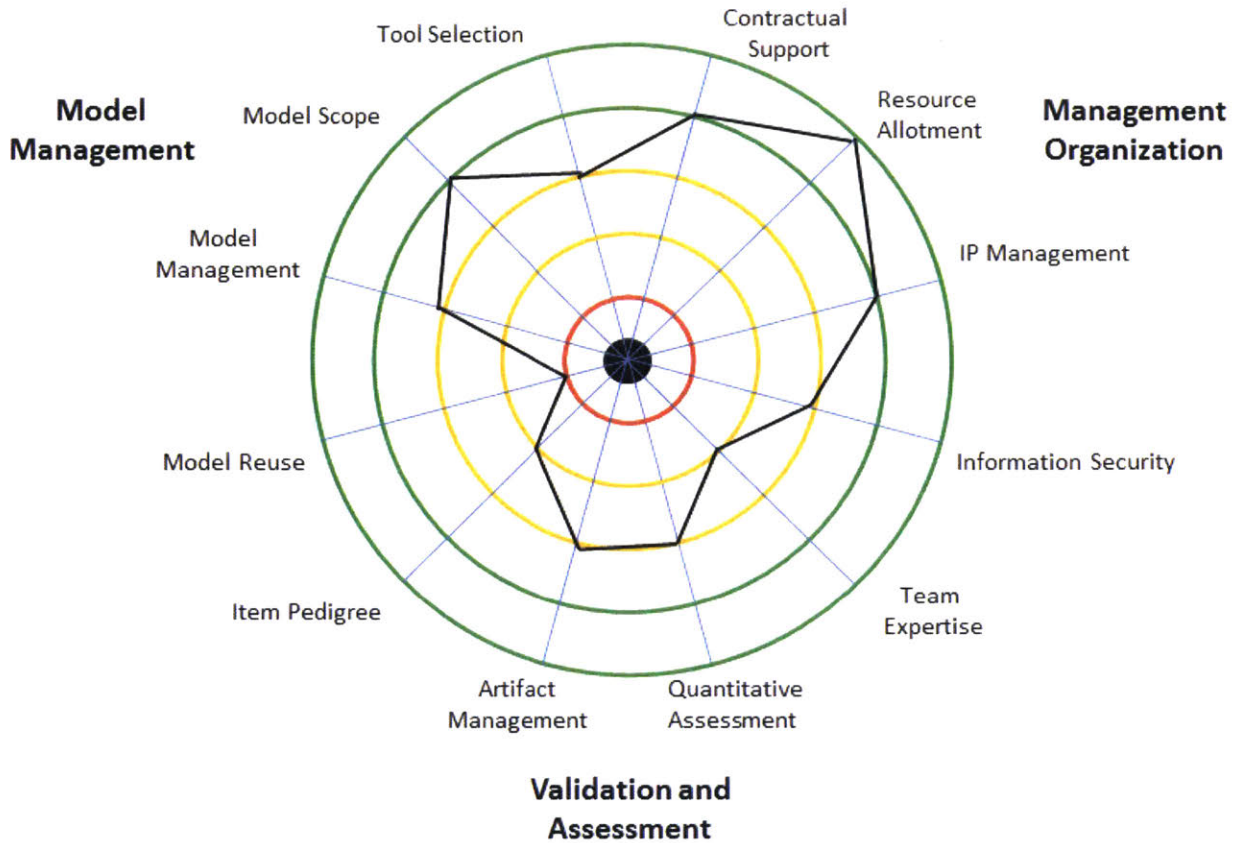


Figure 17: MBA Assessment Example

**8.8.3.1 Model Management**

Assessment Topic	Score (1-5)	Reasoning
Tool Selection	3	Tool selection was declared, but contractors are not used to the tool-set
Model Scope	4	The model scope is clearly defined in the contract for various points along the process. No trade space study was conducted, however.
Model Management	3	Model management process is planned and conducted, but little process is in place to determine superiority.
Model Reuse	1	No previous models exist or are being used.

Table 1: Model Management Assessment Example

**8.8.3.2 Validation and Assessment**

Assessment Topic	Score (1-5)	Reasoning
Item Pedigree	2	While no models have parts containing pedigree for validation,

		there is a process in place to start this.
Artifact Management	3	Acquisition office has an artifact management process in place and in use, but only periodically shared with contractors
Quantitative Assessment	4	Acquisition office has published a quantitative assessment plan, but no scenario testing has been established.
Team Expertise	5	Team is new, but training processes have been put in place.

Table 2: Validation and Assessment Example

**8.8.3.3 Management Organization:**

<b>Assessment Topic</b>	<b>Score (1-5)</b>	<b>Reasoning</b>
Model Ownership	3	Due to lack of expertise the ownership of the models is held by an outside contractor.
IP Management	4	IP management is strong with the acquisition office, with complete models shared. Sharing between prime and subcontractors is restricted to black-box interfaces only.
Resource Allotment	5	Sufficient resources and time have been allocated to properly develop the models throughout the entire process.
Contract Support	4	Significant pieces of the requirements will be validated by models, some additional requirements captured in a system-requirements-document.

Table 3: Management Organization Assessment Example

## **9. Assessment Validation**

### **9.1 Overview**

Due to the open nature of this assessment tool, further work can always be done to validate the results. Similar to the twenty years, extensive funding and support that CMMI received before wide scale adoption, this assessment model will require further iteration will probably be needed to refine both the assessment model and the process/criteria used to arrive at certain scores. However, this does not remove the need for at least initial validation.

Some of this validation is being provided in the form of application of an actual analysis on an acquisition office pursuing model-based acquisition. Unfortunately, the notes and results will be both beyond the scope of this thesis and of a proprietary nature. The author expects that learnings from that process will continue to improve the model being shown.

This does not remove the need for comparison and validation, however. Three methods were used to accomplish this – interviews and an industry comparison and system dynamics models.

### **9.2 Interviews**

The author interviewed over thirty different individuals, all with extensive experience regarding acquisition, models/modeling, data management and department of defense structure. These interviews spanned across all three branches (including Missile Defense Agency), as well as numerous contractors, civilian acquisition specialists, academics, software and hardware vendors and the main Department of Defense office. Positions included:

- Deputy Director, Engineering Tools & Environments
- Program Managers
- Acquisition Officers (three branches)
- Modeling and Simulation Specialists
- Directors of academic institutions studying modeling
- Tool Vendors
- Retired Acquisition personnel

All provided unique perspectives that afforded the opportunity for a well-balanced result. Numerous iterations occurred to incorporate, moderate and weigh the importance of each judging factor. The breadth of interviews also served as a valuable screen against industry specific terms that might put off a beginning acquisition office.

### **9.3 Industry Comparison**

An industry comparison was also done to validate some of the criteria and findings within the assessment. Two industries stood out as ones that take model-based design, engineering and acquisition of systems to a superior level – aircraft and automobile design. Due to the diversity of automobiles (similar to the variety of programs within the Department of Defense), automobiles was chosen.

Interesting follow-on work can be done comparing how aircraft modeling and acquisition processes also compares to existing work within Defense.

### 9.3.1 Automotive Industry Comparison

#### 9.3.1.1 Overview:

The goal of this comparison is to provide feedback to the assessment process and model to provide some validation of criteria on the thesis. Since the automobile manufacturing now relies almost exclusively on model-based part acquisition<sup>23</sup>, design and engineering, the author both predicts and expects a very high score. This high score will allow for some validation that valuable and meaningful criteria have been chosen.

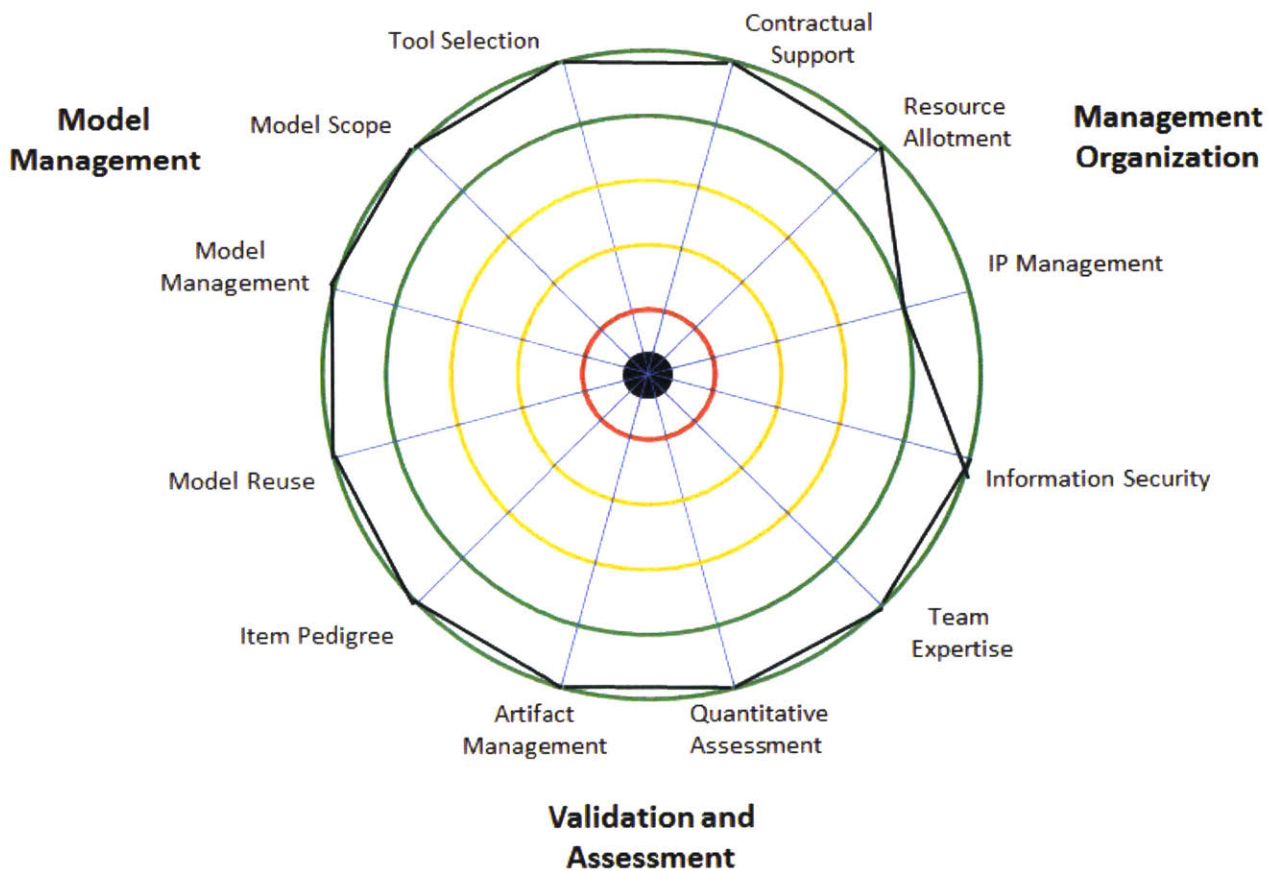


Figure 18: MBA Automobile Industry Comparison

<sup>23</sup> Modeling & Simulation in Automotive Industry, Retrieved 2017. [http://www.simultech.org/Documents/Previous\\_Invited\\_Speakers/2011/SIMULTECH2011\\_Gusikhin.pdf](http://www.simultech.org/Documents/Previous_Invited_Speakers/2011/SIMULTECH2011_Gusikhin.pdf)

### 9.3.1.2 Assessment Scoring:

Figure 18 is an assessment example for model management, management organization, validation and assessment. Areas with zero score represent an “NA” for meaningful transfer between automobile industries and the Department of Defense.

### 9.3.1.3 Model Management

Assessment Topic	Score (1-5)	Reasoning
Tool Selection	5	Tool Selection is mandated by the manufacturer after OEM input.
Model Scope	5	The model scope is clearly defined for all systems and subsystems, including service and support.
Model Management	5	Model is managed by specific departments within the manufacturing organizational.
Model Reuse	5	Model reuse is heavy even between manufactures, allowing for large datasets. Frameworks are heavily reused.

Table 4: Model Management Assessment Example

### 9.3.1.4 Validation and Assessment

Assessment Topic	Score (1-5)	Reasoning
Item Pedigree	5	Items are heavily pedigreed with defect, maintenance and lifetime cost data carefully stored.
Artifact Management	5	Defect (artifact management) mitigation and storage system in place.
Quantitative Assessment	5	Due to the known nature of each part interface, quantitative assessment of subsystems as well as the master system is definitive.
Team Expertise	5	Training is extremely robust, with numerous hires specifically devoted to model-based design and engineering.

Table 5: Validation and Assessment Example

### 9.3.1.5 Management Organization:

Assessment Topic	Score (1-5)	Reasoning
Information Security	5	Unclear, although there have been no known major cyber intrusions to mainstream auto manufacturers. No classification issues.
IP Management	4	Interfaces are carefully defined and available for all to see. Only the car manufacturer has access to all the data, rather than subsystem visibility.
Resource Allotment	5	Sufficient resources and time have been allocated to properly develop the models throughout the entire process.
Contract Support	5	Manufactures control individual contracts well, preventing Defense like complexity.

Table 6: Management Organization Assessment Example

### 9.3.2 Industry Comparison Results

As hypothesized, this assessment model captures the significant advancement that automobile manufacturing has benefited from over the past fifteen years. Nearly all areas are well above satisfactory, although some of the areas rely on far less complexity than their DoD counterparts.<sup>24</sup>

It is important to note the benefit car manufacturing industries have seen since the implementation of model-based processes. Meaningful design changes combined with fewer defects over a faster acquisition time has been achieved – a remarkable improvement<sup>25</sup>. Other industries (including the Department of Defense) could capture some of these same advantages.

### 9.3.3 Comparison Breakdowns

While the benefits are easy to see, mega organizations (such as the Department of Defense) will encounter difficulties not experienced by auto manufacturers due to size, complexity and variety. Unlike standardized moving vehicles, projects within the DoD are incredibly diverse, making it difficult to catalog and store information about classes of car parts. Auto manufactures are also able to leverage their relatively shallow command structures to implement new types of initiatives or requirements – such as focus on a particular toolset, process or interface specification. Incentives are easily seen for OEMs to fall within line to keep particular companies happy as well.

One of the largest differences is the amount of time a car takes to design, build and produce compared to some of the DoD programs. Serious car design (after concept) range from three to six years before they are released<sup>26</sup>, while some DoD programs require decades or more to emerge to the warfighter. The reason for the shorter cycle is that the car manufactures already have a good idea of the product they want to build, rather than building large amounts of new material for each program. While introducing models allow cars to get more complex and have slightly shorter build times, the improvements are not enough to expect military programs to cycle nearly as efficiently.

---

<sup>24</sup> Benefit of Model-Based Design. Retrieved 2017.

[https://www4.in.tum.de/~schaetz/papers/Benefit\\_of\\_MBEES.pdf](https://www4.in.tum.de/~schaetz/papers/Benefit_of_MBEES.pdf)

<sup>25</sup> Safer Cars from Simulating Crashes. Wired. Retrieved 2017. <https://www.wired.com/2015/04/gms-using-simulated-crashes-build-safer-cars/>

<sup>26</sup> How long does it take to Develop a Car? Retrieved 2017. <https://www.quora.com/Automobile-Design-How-long-does-it-take-to-develop-a-car-design-from-scratch>



## 9.4 System Dynamics Overview

### 9.4.1 System Dynamics Overview

A system dynamics model was developed to validate the assessment model. Without the system dynamics models, it would be difficult to validate that all the metrics needed have been covered.

Each system dynamics model has a stock representing the efficiency gain for a particular part of a contract award. The understanding is that the higher the stock, the more gains there are in speed, accuracy and cost for a particular contract stage. This stock is controlled by a gain and loss flow monitor to understand how the stock is affected. This flow in turn is controlled (positively or negatively) by outside factors. Remember that a decreasing negative flow results in the increase of a stock.

The focus of this modeling is solely on the modeling feedback that would occur, rather than other possible efficiencies to be gained. Further work could be accomplished by increasing the complexity and scope of these system dynamic models.

### 9.4.2 Justification/Purpose

One of the challenges faced when creating an assessment system of any kind is ensuring that a complete selection of the objects to be measured is captured. Because modeling encompasses so many components, analysis had to be performed to ensure coverage. System dynamics is an extremely useful tool to help understand all the factors for a given use case, which led to its selection to ensure metric coverage.

The dynamics model was not used in a predictive fashion; rather, it is a tool to better understand the inputs and outputs of the acquisition process when models are incorporated.

### 9.4.3 Process Breakdown

Below is a breakdown using system dynamics for acquisition/contract process overview that contributed to the assessment breakout selection. Due to the completeness of the standard contract process, no other categories are needed.

#### **9.4.3.1 Requirements Definition:**

Figure 19 shows the system dynamics model for the requirements definition stage of any contract process.

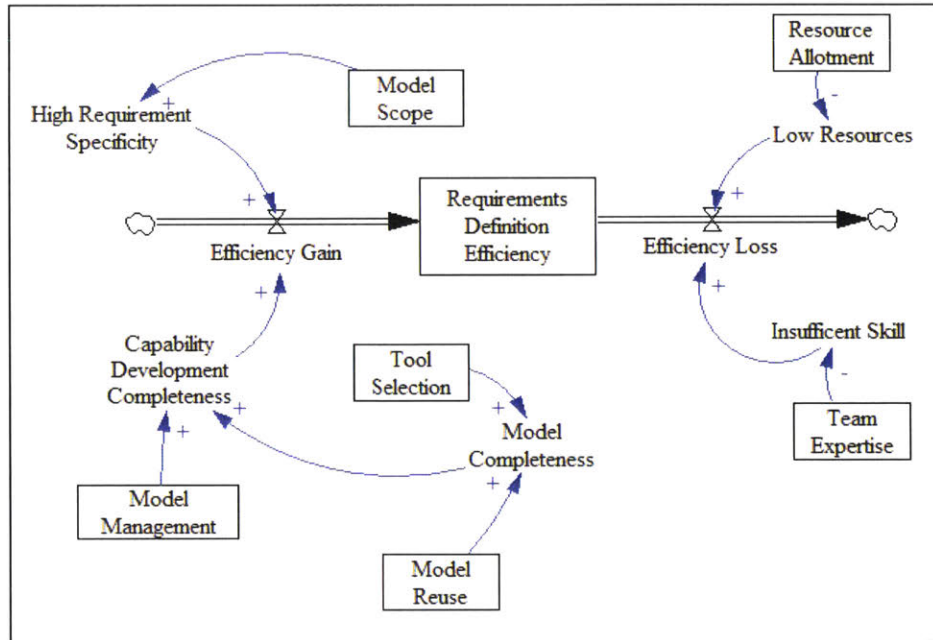


Figure 19: Requirements Definition Modeling System Impacts

One of the key components of requirements definition is the requirement specificity. This is an extremely difficult quality to achieve, as the acquisition office must forecast the exact needs of the system as a thought process before much experimentation can be done. On the other hand, too much specificity can lead to over constraint and excessive capability and cost. Non-linear costs can arise when two requirements are constrained against each other in a way not specifically desired or needed by the end customer.

This difficulty can be offset by incorporating models that can allow a contractor to perform tradeoffs (such as speed versus weight). Providing that the overall success criteria of the model is clearly established or given a chance to iterate with feedback from the acquisition office, this allows companies the flexibility to design their proposal in innovative ways not envisioned by the acquisition office. To enable this relationship, however, the scope of the models and environment that the contractors can use as trade-space must be clearly defined (and as large as possible).

Augmenting requirement specificity is the factor of model completeness. Essentially, model completeness measures how much of the real environment is captured by the model, allowing for real capability definition and accurate modeling results. Model completeness is primarily governed by careful tool selection, resources and the amount of quantitative assessment required for the contract. Tool selection also accounts for the modeling framework that is being implemented (for instance, XML verses SysML). Based on the desired modeling area, the tool(s) used can provide much clearer analysis (especially for cost, schedule and other non-physics based models).

Finally, model management proves critical to ensuring that the full capabilities of the desired system (and relevant models) are captured. As the contract progresses, new program capabilities will be requested, or forgotten requirements restored. It will be critical to refresh the models and update the

contractors with pertinent changes. This area also offers unique capability to acquisition officers as a program matures to understand exactly what the implications of changing requirements would be between stages (Engineering transition to production, for instance).

#### 9.4.3.2 Acquisition Strategy:

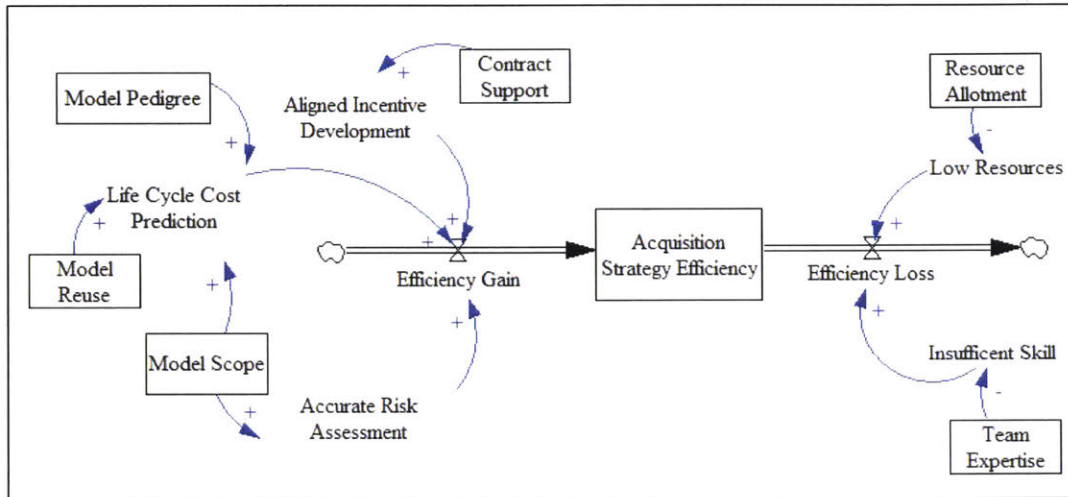


Figure 20: Acquisition Strategy Modeling System Impacts

A key advantage of model-based acquisition is the way in which performance and financial incentives can be aligned throughout the modeling and selection process (see Figure 20 **Error! Reference source not found.**). Without model-based acquisition, it' is extremely difficult to get contractors to innovate beyond what the requirements dictate. With model-based acquisition, it becomes much easier to encourage and accommodate that innovation, as well as demonstrate (by the incentive angle slope) what areas are most desired for improvement. Of course, contract support must include this incentive structure in order to work, requiring additional work. This additional contract rework time can provide huge dividends of either cost savings or performance enhancements.

One of the largest future cost savings that could emerge from this process is an accurate model of the total life cycle cost of the product(s) being developed – from engineering conception to service and support to end-of-life. This includes both cost and risk modeling. Model pedigree becomes a major component of accurate prediction – comparing parts that have been previously modeled, tested and used. Comparison studies allow for sister products to leverage real-world data about how unique materials, complex designs and rough wear can affect the lifecycle cost. Model reuse also plays into this factor as well, giving evaluators a higher level look at the way systems use parts with significant pedigree.

Model scope affects both life cycle cost prediction and the risk assessment. As one imagines, the model scope will only predict life cycles in the areas dictated for the modeling. However, in order to even begin accurately modeling the entire lifecycle of a product, a significant amount of base modeling must be accomplished first. Risk assessment is less subject to a threshold of model scope, as initial efforts only

need to focus on particular areas. For instance, once a category (radiation) is identified as the largest risk, only a minimally viable physical model needed to support radiation modeling must be created to properly inform the designer of the entailed issues.

**9.4.3.3 RFP Phase:**

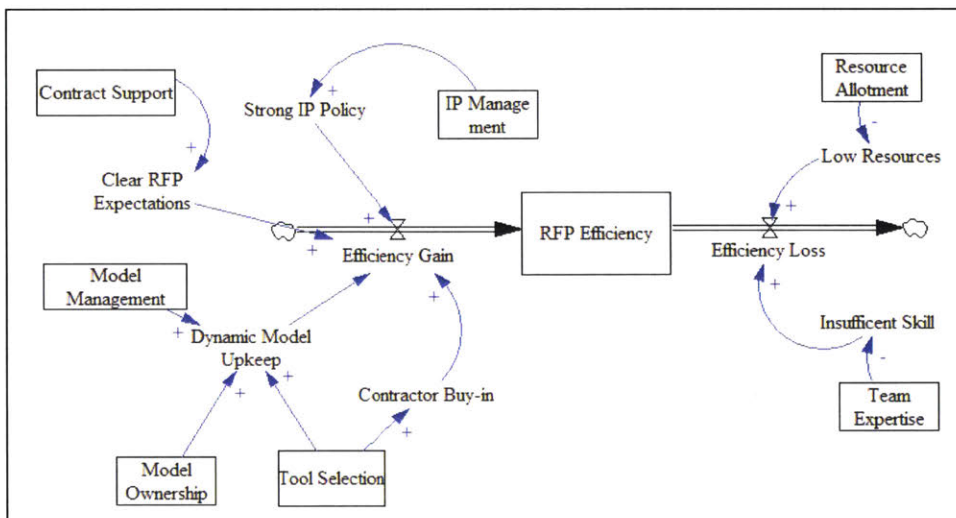


Figure 21: RFP Modeling System Impacts

The request for proposal phase is also affected by model-based acquisition for first and second order influences (see Figure 21). Should the resources be committed, the acquisition office will be maintaining a dynamic model to allow contractors to effectively design and showcase their final proposal. This dynamic model will undergo changes throughout the RFP process as bugs are found and additional incentives are added at the suggestion of contractors.

Understanding the model ownership is one of the most important pieces of this process. The model owner also dictates what the purpose of the model will be (i.e. digital twin, design to build, etc.). Model ownership becomes particularly complicated with multiple stakeholders (acquisition offices). In this case, it might be best to establish an independent outside contractor to maintain various pieces of the model to prevent a model that has two masters (and therefore has competing requirements). Model management builds on this concept, understanding the process by which artifacts and other changes get implemented into said models.

Tool selection can make the model upkeep easier or harder, depending on the familiarity with the current team’s understanding. More importantly, however, it also dictates how much of a buy-in the contractor has with a particular proposal method. As model-based acquisition progresses, it is extremely important to take into account the expertise and experience that the contractors bidding on the project have regarding particularly tools, otherwise the contractor will be forced to operate in an inefficient fashion with undesired software.

Strong IP policy will also make a crucial difference as to the acceptability of contractors and subcontractors to use models to bid. Clear, previously-approved IP management plans and common practices must be published and followed to maintain clear IP firewalls between companies.

Finally, model-based acquisition allows for clear expectations in an RFP, with a possibility for a pre-calculated preliminary score. This must be supported in the contract stage with clear incentives and quantitative expectations.

#### 9.4.3.4 Evaluation Phase:

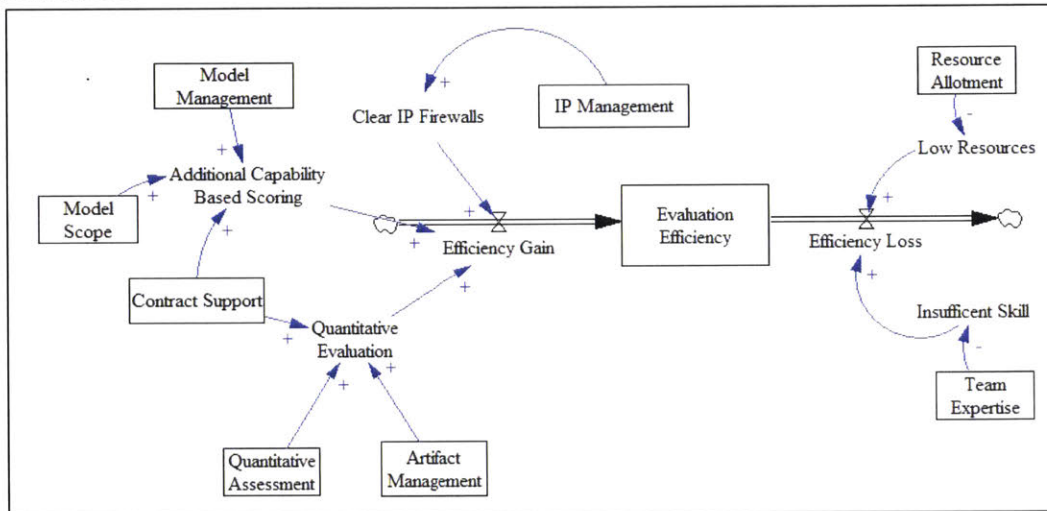


Figure 22: Evaluation Modeling System Impacts

The evaluation stage is the most contentious of all the stages, which can also lead to the greatest gain for acquisition offices by following model-based acquisition practices (see Figure 22 **Error! Reference source not found.**). First and foremost, all models must be quantitatively assessed and validated with clear criteria. While easily described, this is a difficult part of the process due to the variety of factors phased into a proposal. The more a clear-cut set of evaluation criteria can be published before submission, the lower the likelihood of a contested decision.

Building this quantitative assessment in the first place, developing an artifact management and recording process and having each piece supported by the contract can all make this difficult aspect a success. If preliminary scores or criteria are released to the contractors before submission, care must be taken to prevent competitors from “gaming the system.”

A quantitative assessment is the reward companies receive for exceeding the requirements originally presented. Based on the differing incentive structure provided by the contract support, different capabilities can be encouraged above others depending on the application (i.e. cost above additional speed). Management of the model (to incorporate additional capability only realized with model development) and scope (occasionally additional new modeling parameters to capture contractor ideas) allow for the realization of this additional capability.

Similar to the RFP stage, strong IP management plans must be in place to prevent the spread of valuable company data from even within the acquisition office. Companies must verify and trust this plan before they would be willing to submit technically sensitive data.

#### 9.4.3.5 Contract Award:

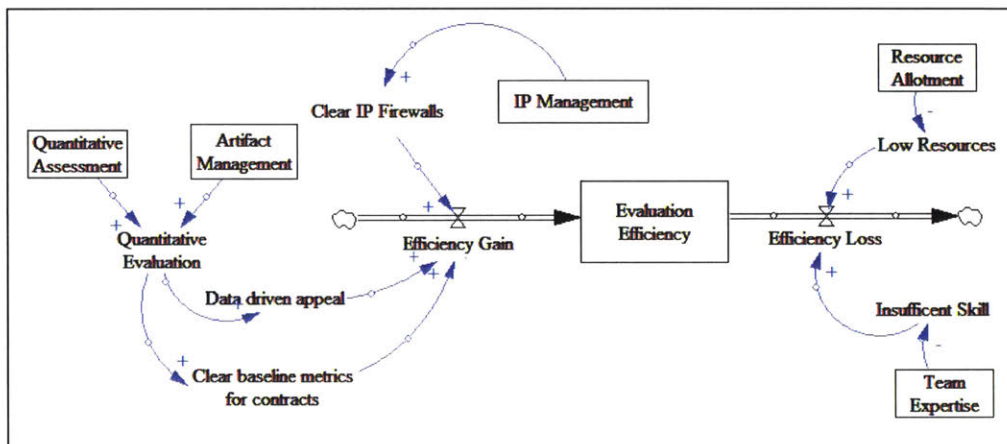


Figure 23: Award Modeling System Impacts

Finally, the contract award stage showcases other advantages of a model-driven approach (see Figure 23). Quantitative evaluations lead to fewer and better informed appeals, preventing months of valuable time from being lost. These evaluations also prevent or reduce the expense the acquisition office must commit to legal resources if an appeal is filed.

The same data provided in the RFP also allow for an incentive-driven contract framework for stages still yet coming (deployment or support). Incentives could be built that further reward accurate cost data in the future, building the pedigree of those models even further.

Aside from appeals and contract management, IP will have to be carefully monitored to ensure that winning subcontractors do not unfairly leverage competition that they might have seen. Even better, this process can facilitate interaction if a sub-contractor further down the line has an improvement on the performance of the product.

#### 9.4.3.6 Other Phases:

There are other phases of the 'Big A' acquisition program that can be examined through the system dynamics models to help determine coverage of the assessment metrics. Unfortunately, as you approach areas in contract execution, SSR, PDR, CDR, Manufacturing, Deployment and Service and Support, the returns are less clear for two reasons.

First, system dynamics models become increasingly complex, the building of which is well beyond the scope of this model. Second, each of the acquisition phases above captures some of the larger execution metrics, allowing achieving the validation goal of ensuring coverage of quantifiable metrics. To see further validation of this, please see the validation section of the thesis.

## **10. Next Steps and Follow-on Work**

The next steps of this thesis involve testing out the assessment process and outcomes on actual acquisition offices. Fortunately, this work has already created significant interest in existing acquisition offices across several branches. Using the methodology in this thesis, the author expects for the first assessment process to finish in the summer of 2017.

Further work can also be done to refine criteria and perform a deep-dive validation across multiple acquisition offices. More work can also be done to refine the administration of the process.

## 11. Glossary

<u>Term</u>	<u>Definition</u>
Acquisition	See 7.2.1
Agile	A software development process focused on fast, iterative sprints to produce high quality code
Artifact	A unexpected finding in a model that must be addressed
Blackbox	A software term that relates how software units are evaluated using interfaces only (instead of seeing source code)
Big 'A'	See 7.4.2
CMM	See 7.6.1
CMMI	See 7.6.2
Contextual Data	Data that links other data together in order to create a cohesive model
Contractor	The organization looking to fulfill the acquisition
Digital Twin	A model that enacts the same characteristics as the physical object it is representing
DoD	Department of Defense
Firewall	A software blockade to prevent cyber intrusion
Incentive	Resources provided to the contractor as a reward
IP	Intellectual Property – Ideas, concepts or code owned by either contractors or the government
Model	See 7.2.2
Requirement	A mandate that must be fulfilled to satisfy an acquisition
RFP	Request for Proposal
Simulation	See 7.2.3
Tribal Knowledge	Knowledge that is known to the people working on the system, but not documented anywhere
SME	Subject Matter Expert