Availability Modeling for Complex System

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Overview & Outline

- Background & Introduction
- Modeling Approach
- Example
- Steps
- Conclusion

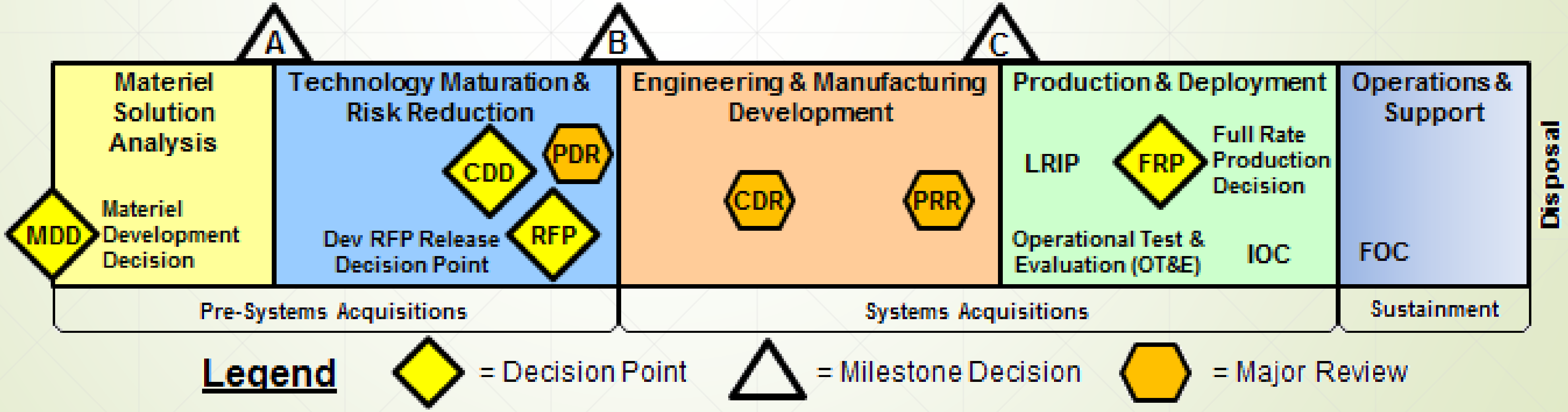
Why Model?

Background & Introduction

- Complex System - "a system with numerous components and interconnections, interactions, or interdependencies that are difficult to describe, understand, predict, manage, design, and/or change." - *Complex System Classification, INCOSE 14th Annual International Symposium, 2004*
- Availability – A measure of "the percentage of time that a system or group of systems within a unit are operationally capable of performing an assigned mission." *DoD RAM-C Manual*
- Measure of Operational Suitability
- Measure of Operational Effectiveness

Need

- Complex System comprehension
- Early System Development
- Networked Systems
- Sustainment KPP (Key Performance Parameter)



Modeling Approach

- Bayesian Networks
  - Current Use
  - Based on Node Probability Tables
- Model Based Systems Engineering
  - Data Sharing
  - Distributed Models

Availability Equations

$$Inherent\ Availability = A_i = \frac{MTBF}{MTBF + MTTR}$$

$$Operational\ Availability = A_o = \frac{MTBM}{MTBM + (MTTR + MLDT)}$$

- MTBF = Mean Time Between Failure
- MTBM = Mean Time Between Maintenance
- MTTR = Mean Time To Repair
- MLDT = Mean Logistics Delay Time

Reasons for Using Bayesian Networks

Pros	Cons
New evidence can be incorporated	Difficult incorporating expert opinion into Conditional Probability Tables
Simple representation of uncertainty	Spatial and temporal dynamics
Missing observations can be taken into account	Continuous data representation
Straightforward representation of causal relationships between system variables	No feedback loops in model
Use a variety of input data	Determining BN structure with experts
Structural and parameter learning	
Variables can be visually displayed	

Bayesian Network Availability Modeling Process

Step 1
- Availability Decompositio n

Step 2
- Parameter Initial Estimation

Step 3
- Build Node Probability Tables

Step 4
- Integrate Bayesian Network

Step 5
- Validate Results

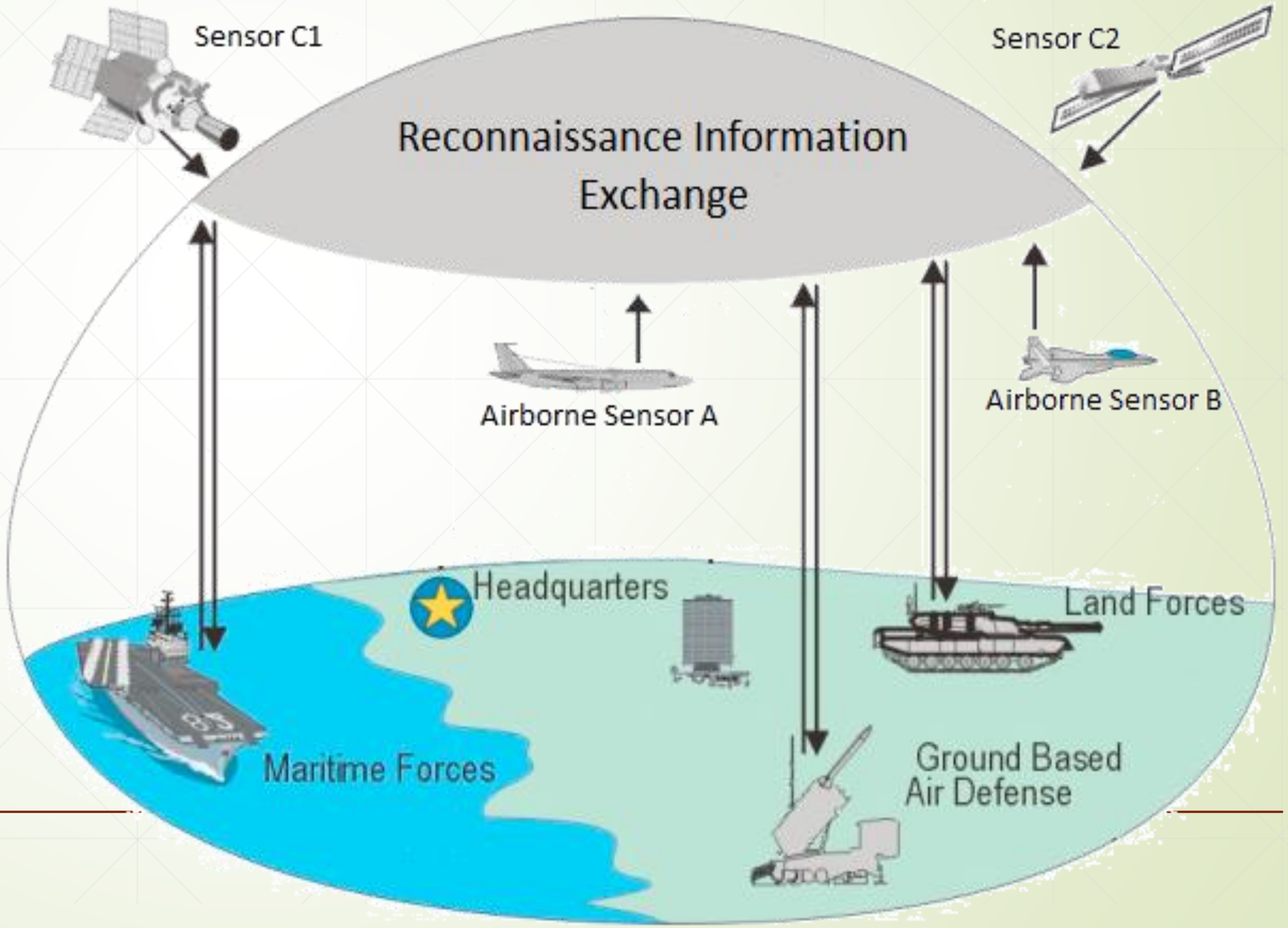
Step 6
- Incorporate into Complex System

Step 1: Availability Decomposition

- Can Availability be modeled?
- Breakdown Availability into variables with known models:
  - MTBF
  - MTTR
  - MLDT
- Determine variable relevancy to the problem
- Determine if variable is controllable

Example Complex System Availability Analysis

Goal: Meet 95% Reliability to meet Availability KPP



Step 2: Parameter Initial Estimation

- Example: MTBF
  - Qualitative
    - Expert Opinion
    - Surveys
  - Quantitative
    - Field data
    - System analysis
- Determine distribution
  - Normal
  - Weibull
  - Exponential

Step 3: Build Node Probability Tables

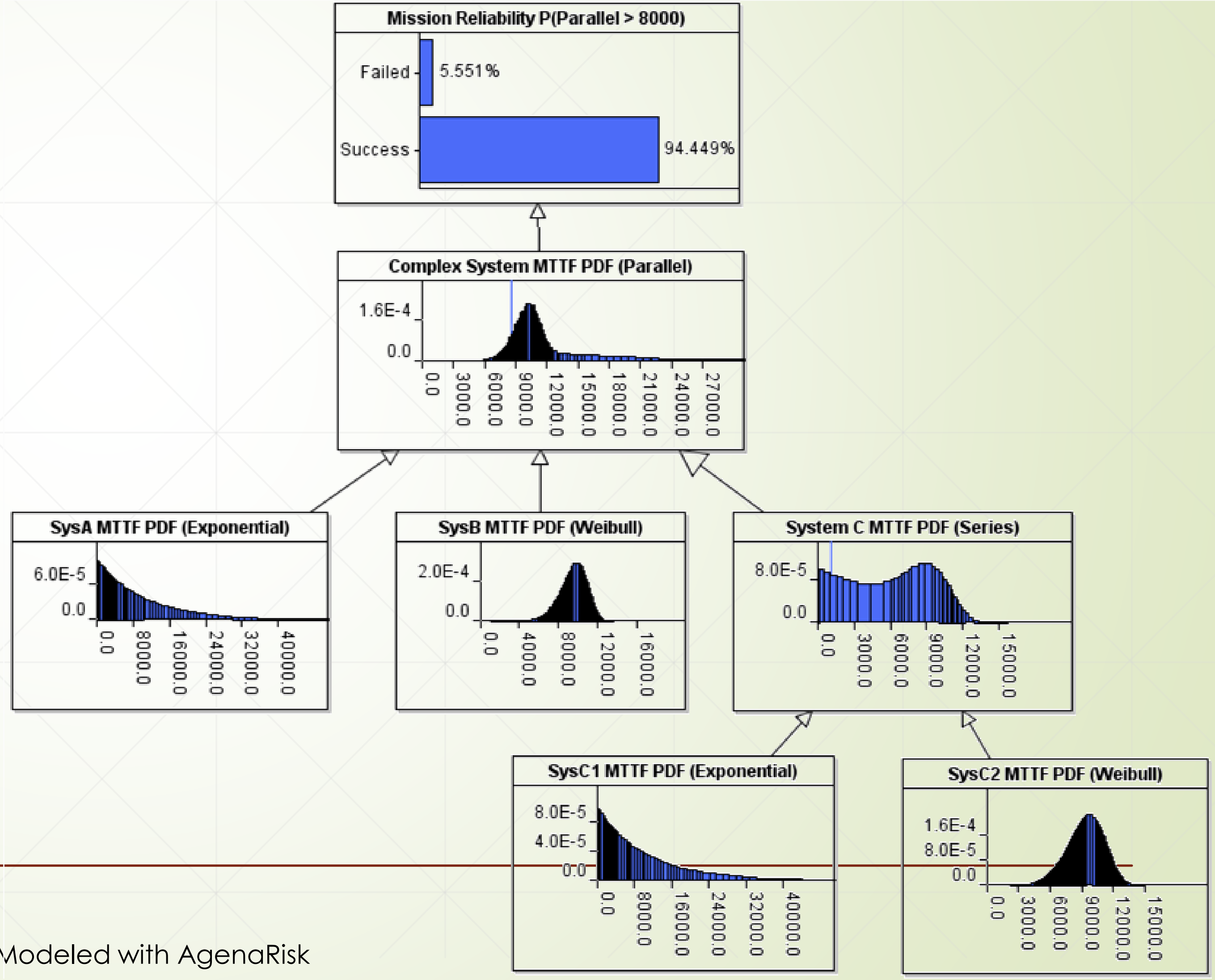
Node Conditional Probability		**Mission Success**	
		True	False
System A Functional	True	0.6	0.5
	False	0.4	0.5

Node Conditional Probability		**Mission Success**	
		True	False
System B Functional	True	0.8	0.1
	False	0.2	0.9

Example Node Probability Table

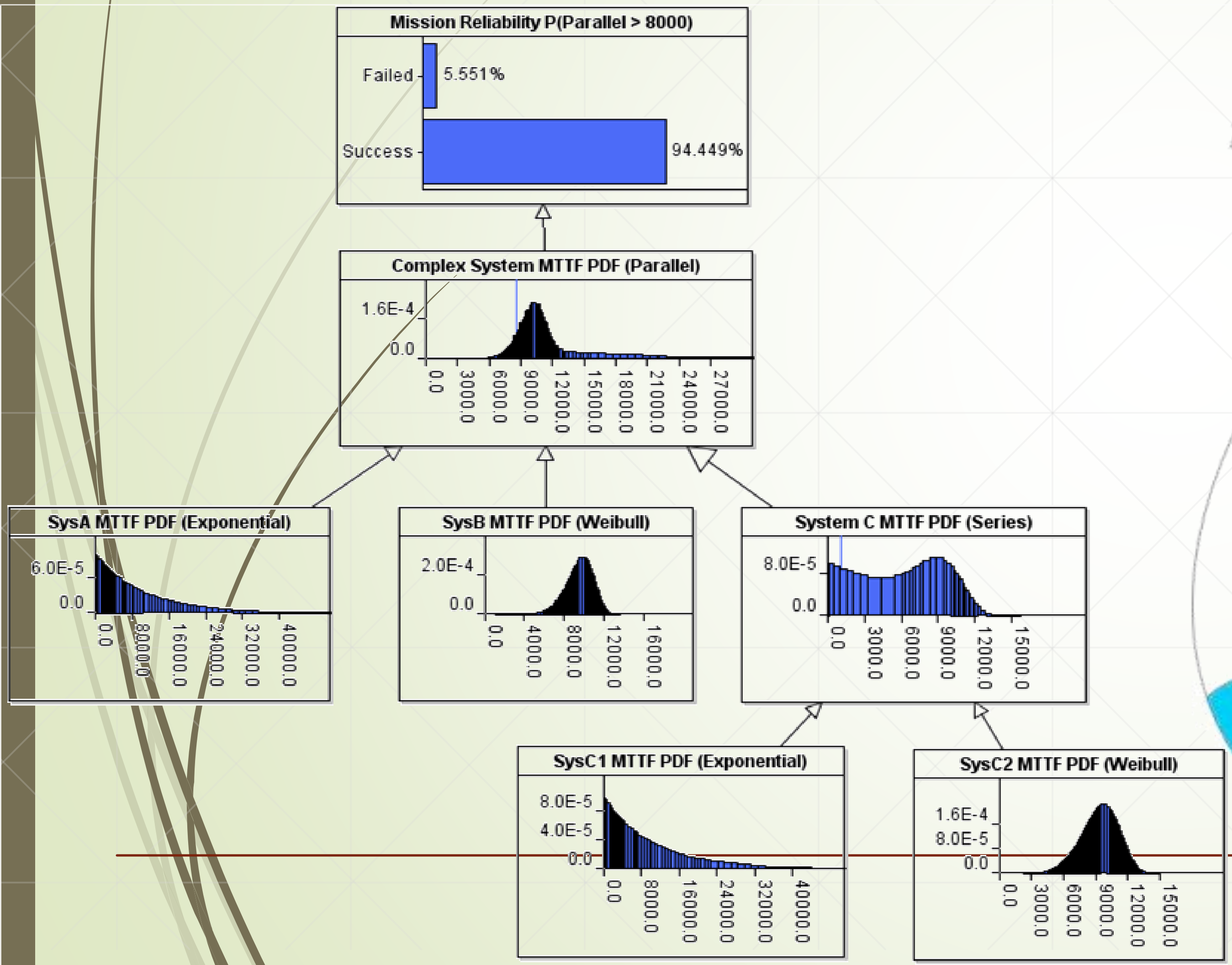
Step 4: Integrate Bayesian Network

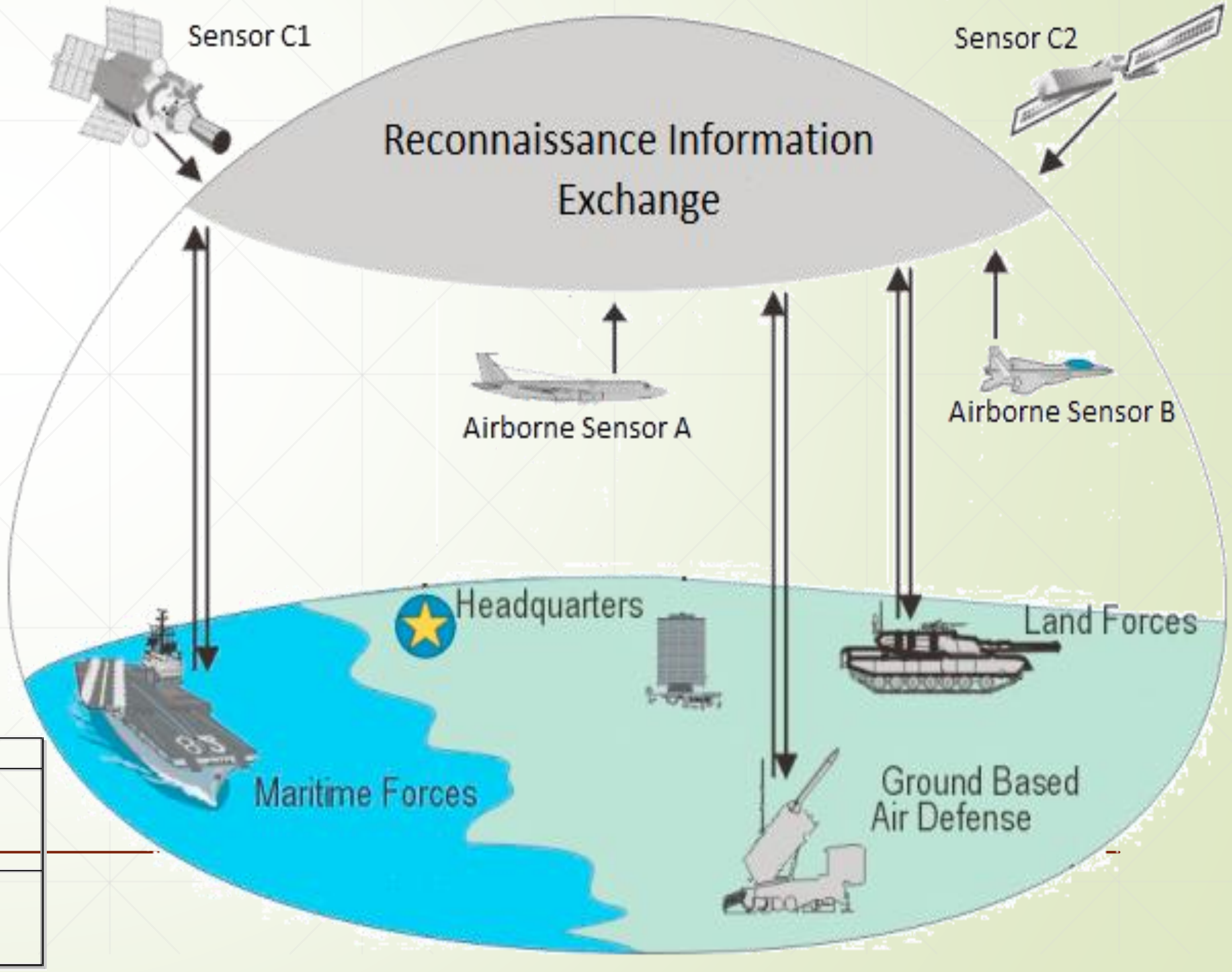
- 2 Exponential systems
  - System A: FR = 0.0001
  - System C1: FR = 0.0001
- 2 Weibull
  - System B: Shape(β)=8 Scale(η)=10,000
  - System C2: Shape(β)=6 Scale(η)=10,000
- Probability Density Function
- Probability of success at 8,000 hours
- Results:
  - 94.5% Reliability



Modeled with AgenaRisk

Example CS Availability Analysis





Step 5: Validate Results

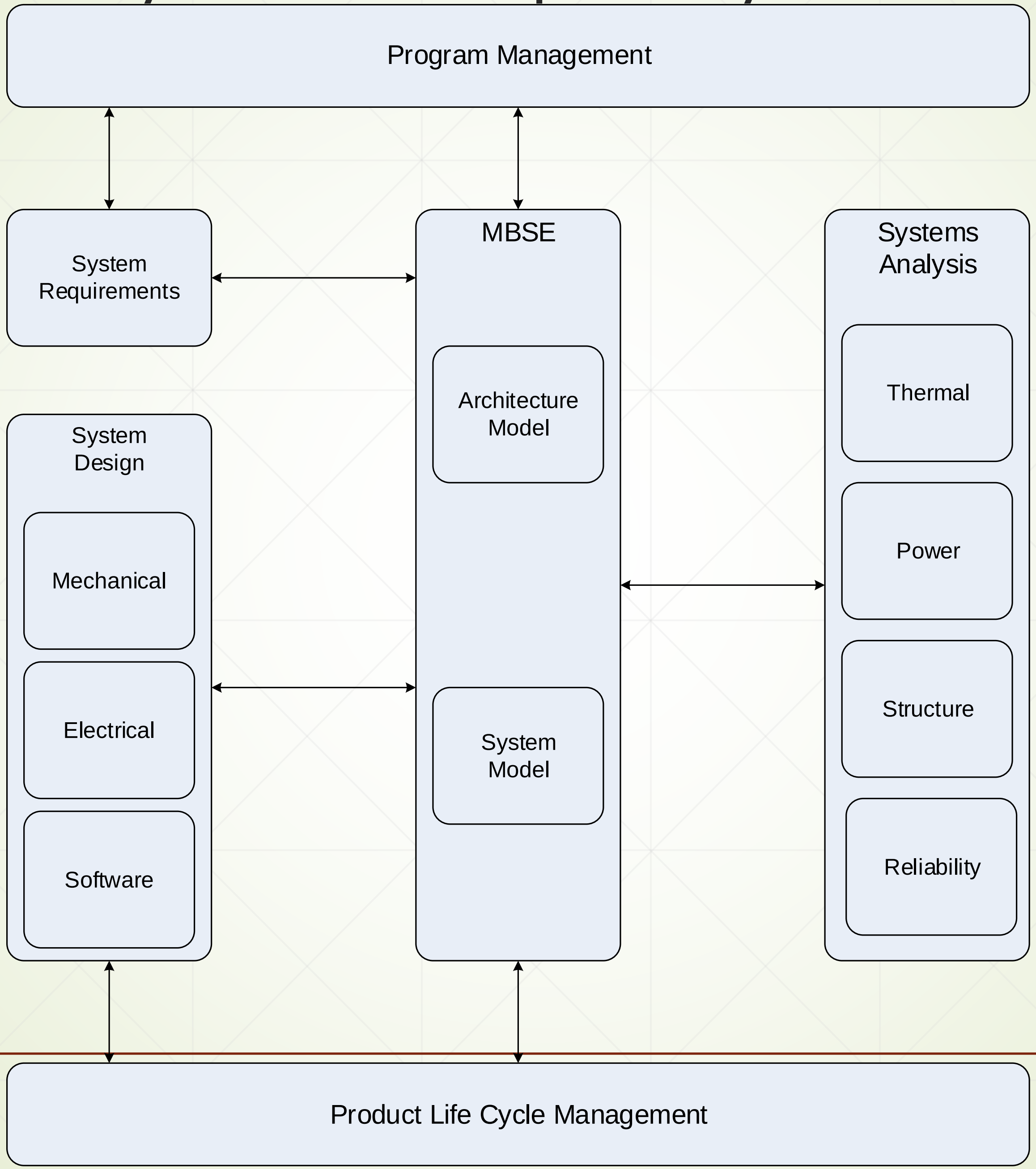
- Validation against expert opinion
- Validation against other source data
- Validation against published results
- Initial estimations can skew results

Step 6: Incorporate Into Complex System Model

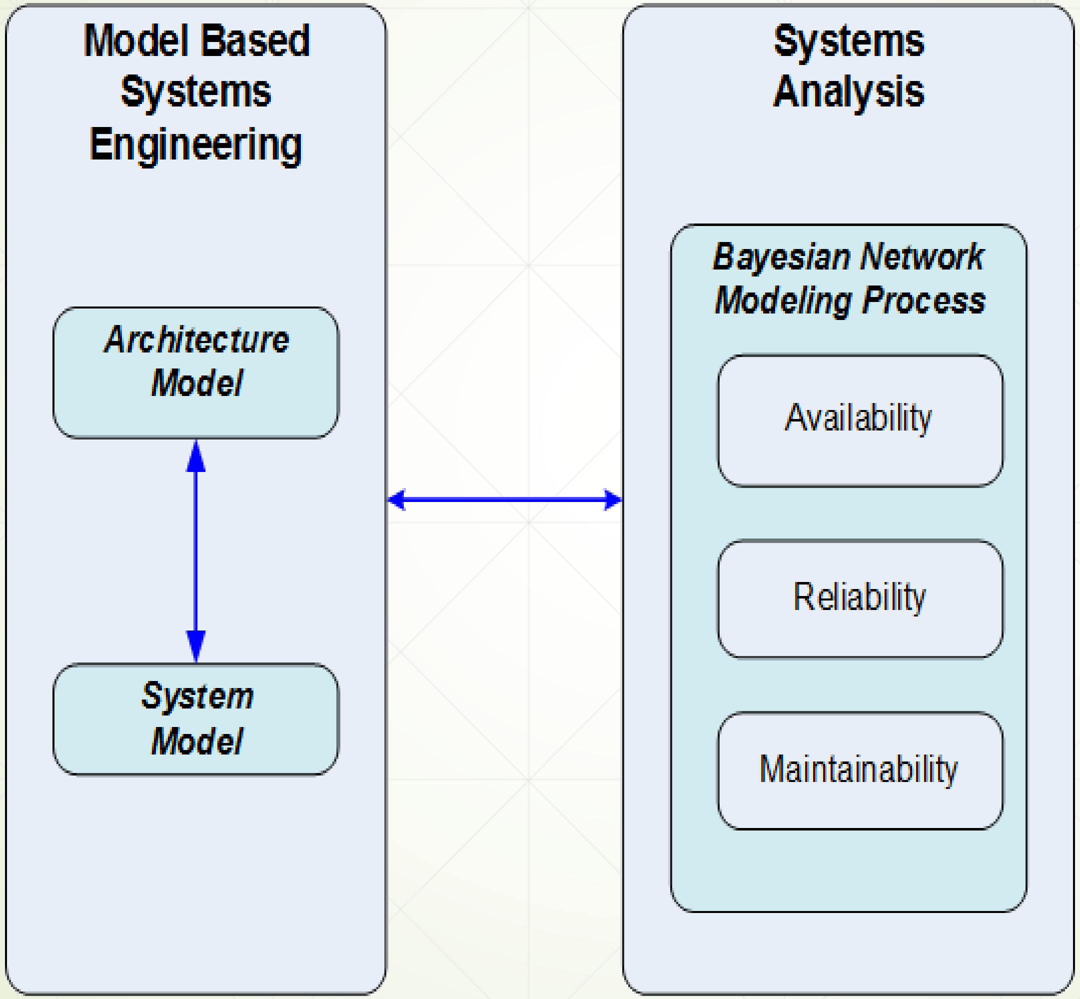
- Initial Estimation
- Use data from analysis: MTBF = 13,567 hours
- Assume MTTR = 8.5 hours
- Input known data into Availability Analysis
- Inherent Availability = 99.94%

$$Complex\ System\ Inherent\ Availability = A_i = \frac{MTBF_{CS}}{MTBF_{CS} + MTTR_{CS}}$$

Model Based Systems Tapestry

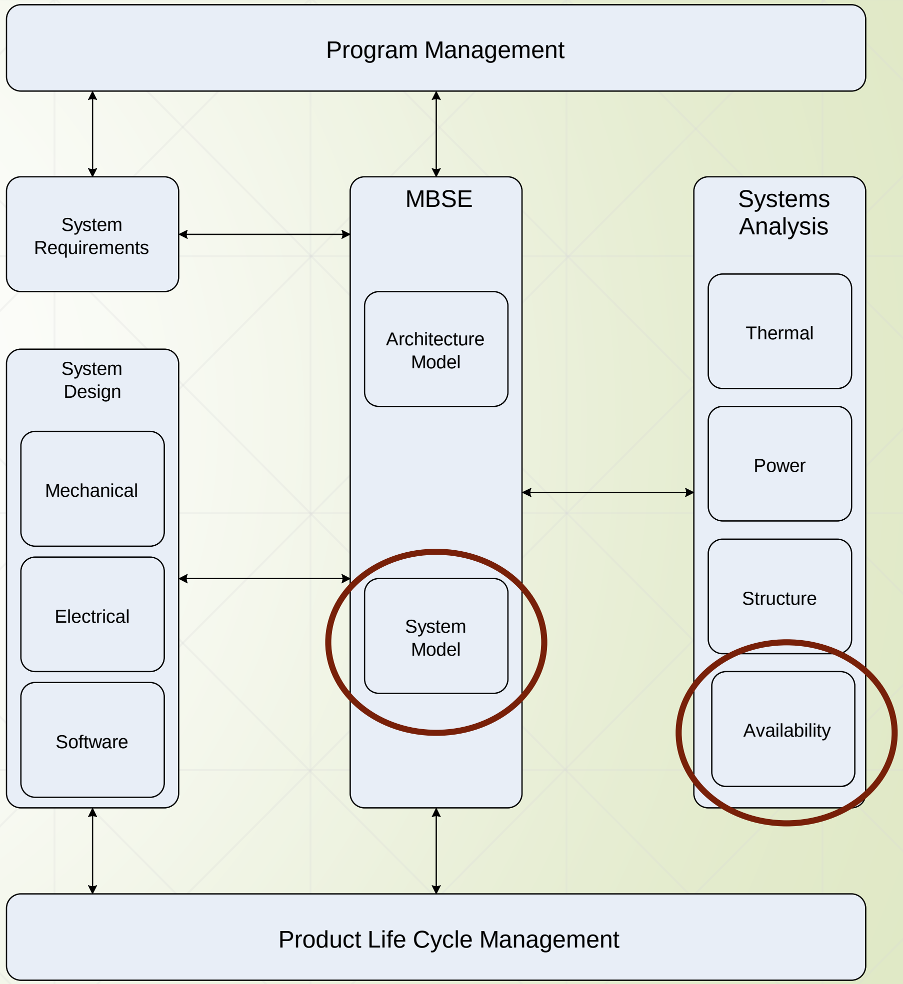


Detailed System Framework



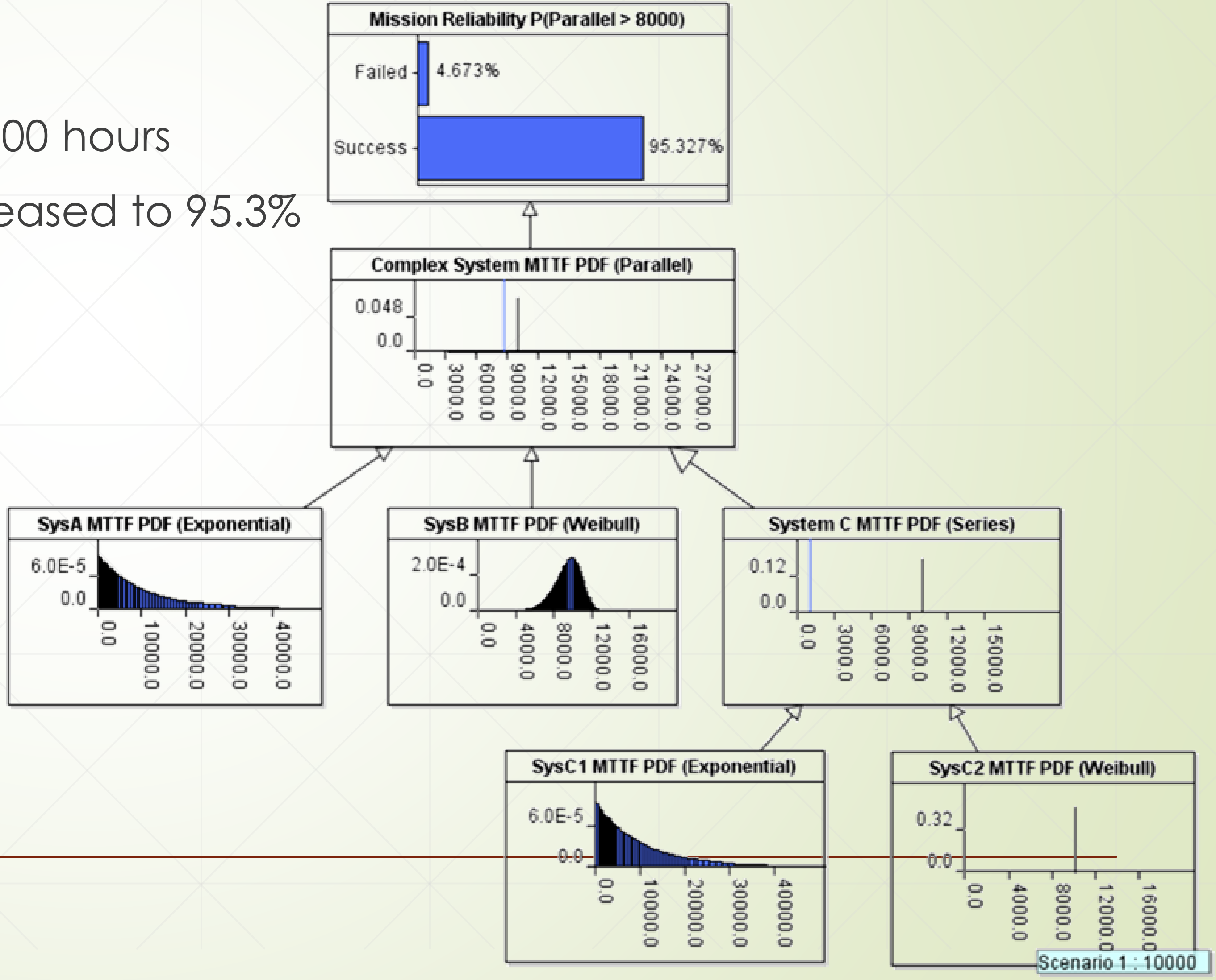
Model Based Systems Engineering Incorporation

- CS results valid?
- CS results meet performance requirements?
- Follow SE Process
- Design Synthesis
  - Meets functional requirements
- Design Loop
  - Optimization using systems engineering



Use Existing Data to Improve Analysis Accuracy

- C2 MTTF Observed: 10,000 hours
- Resulting Reliability Increased to 95.3%



Summary and Conclusions

- Integrated Systems Engineering model
- Optimization based on procurement or mission need
- Continuous improvement approach
- Ideal and efficient design selection

Next Steps and Future Work

- Integrate model into actual program
- Apply model to other requirements