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Quantitative Comparison of Alternative Designs for a Joint C4I Capability Certification Management (JC3M) System

A Student Project

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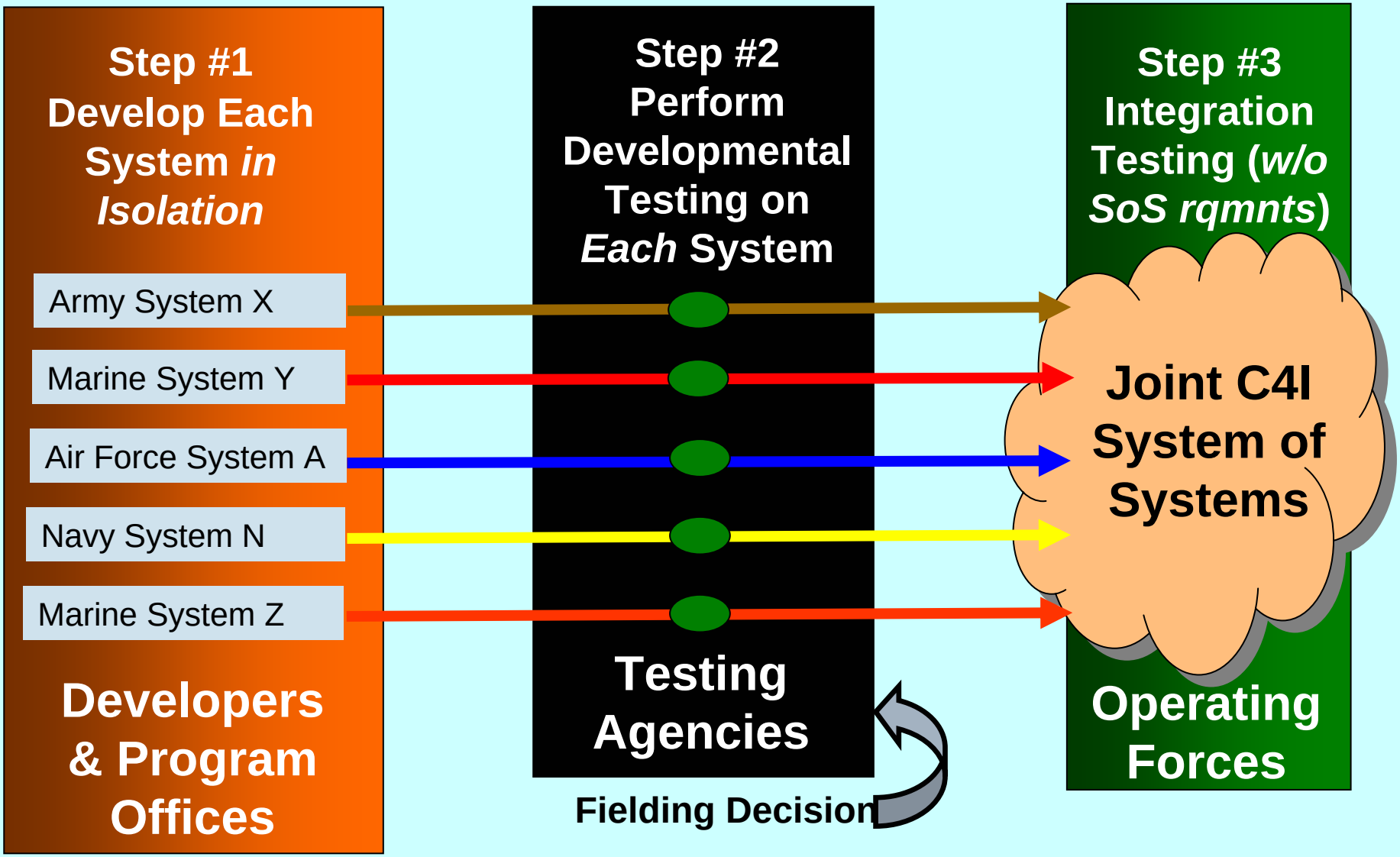
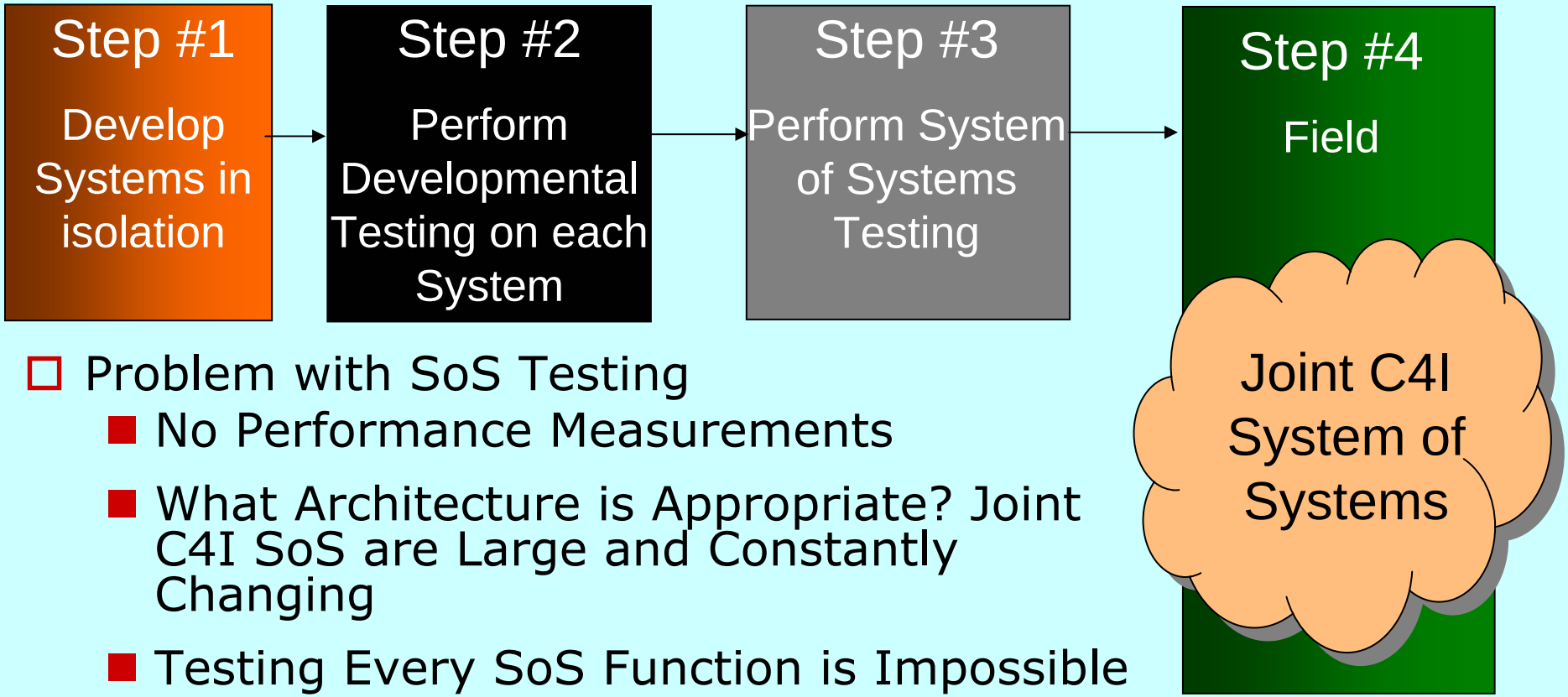
Outline

- Introduction & motivation
- A tailored SE process
- Problem refinement
- Design Alternatives
- Modeling & Simulation
- Life Cycle Cost Estimates
- Analysis of Alternatives
- Conclusions and further study

Motivation: Acquisition system & SoS integration needs

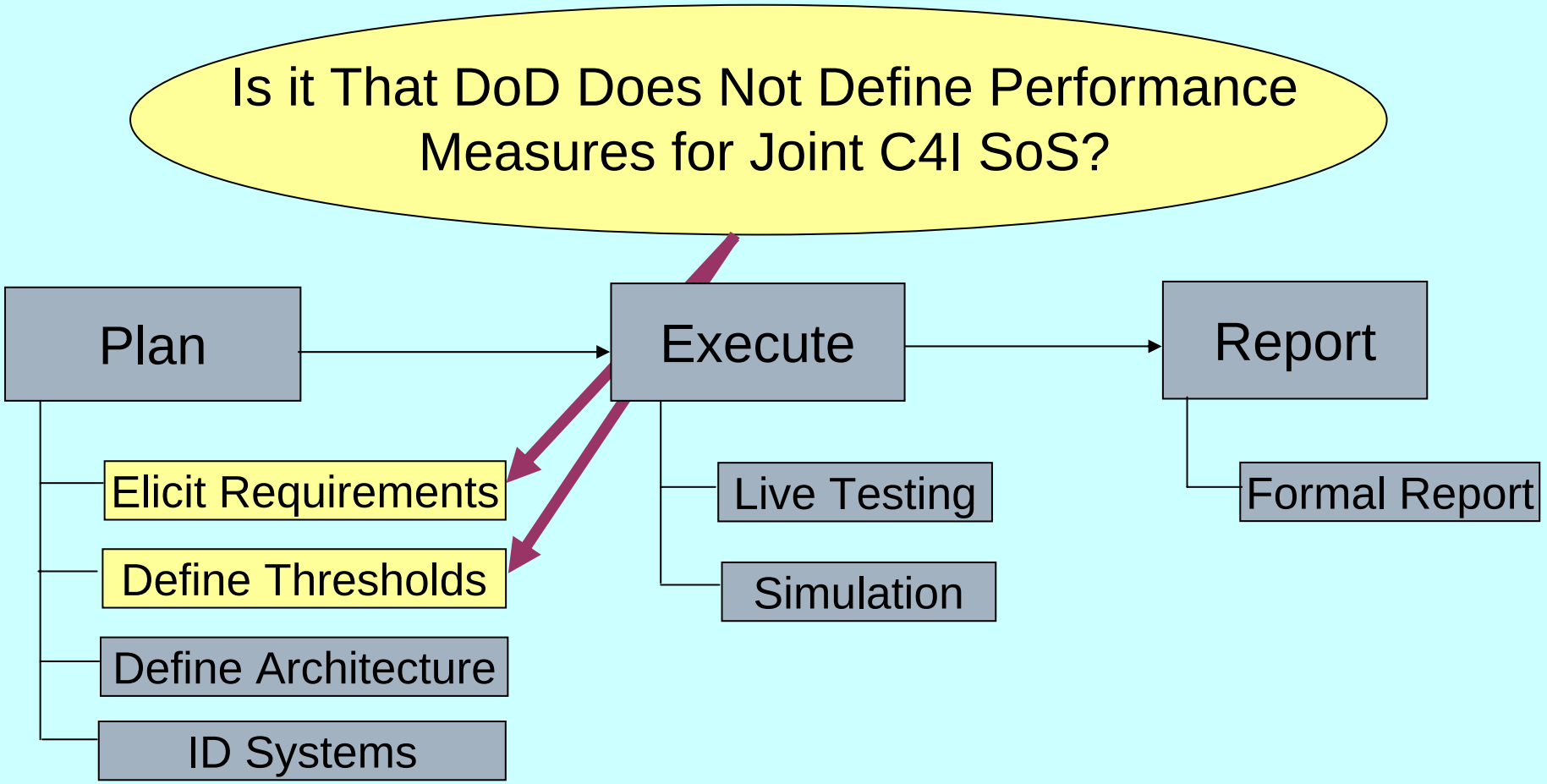


Current SoS Testing and Fielding



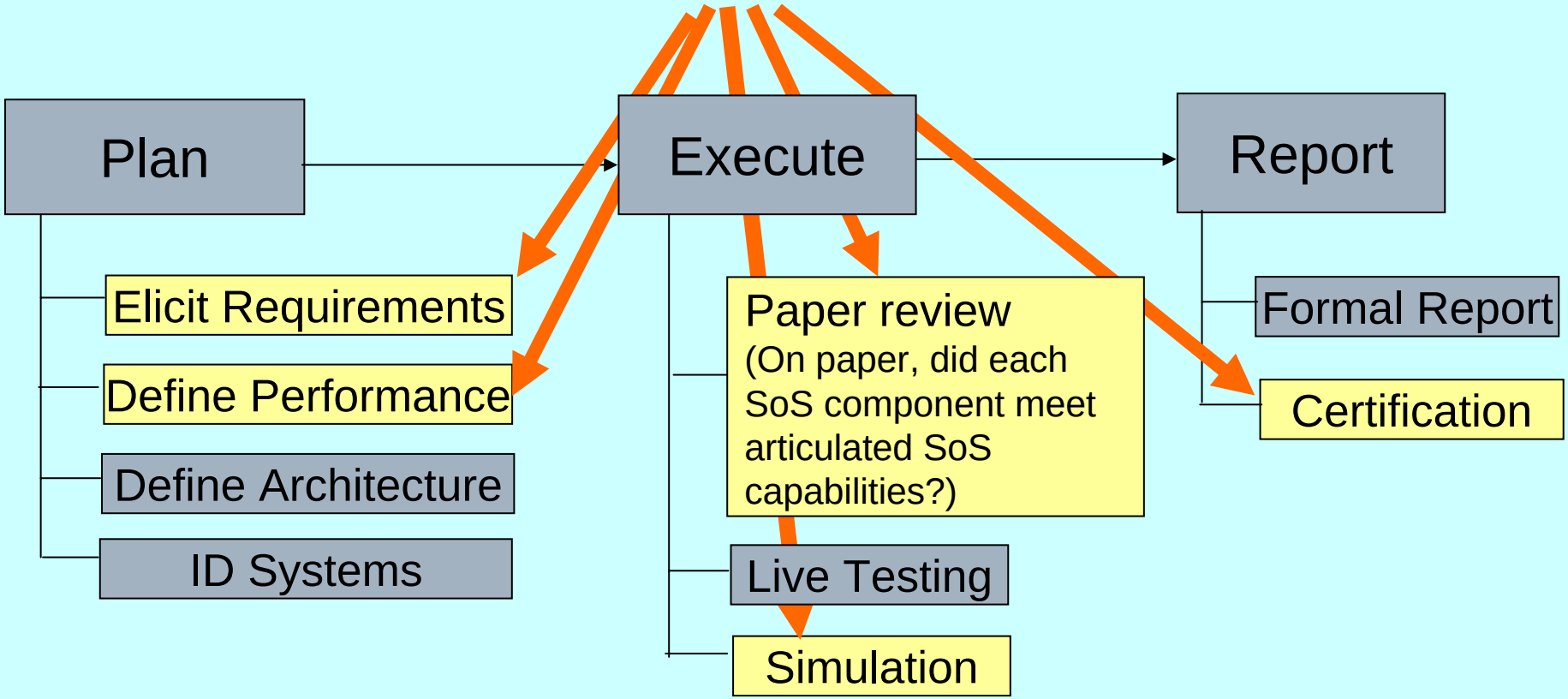
- Problem with SoS Testing
  - No Performance Measurements
  - What Architecture is Appropriate? Joint C4I SoS are Large and Constantly Changing
  - Testing Every SoS Function is Impossible
  - Hard to Determine What Failure is Since Quality of Service Requirements Change

What is the Real Problem?

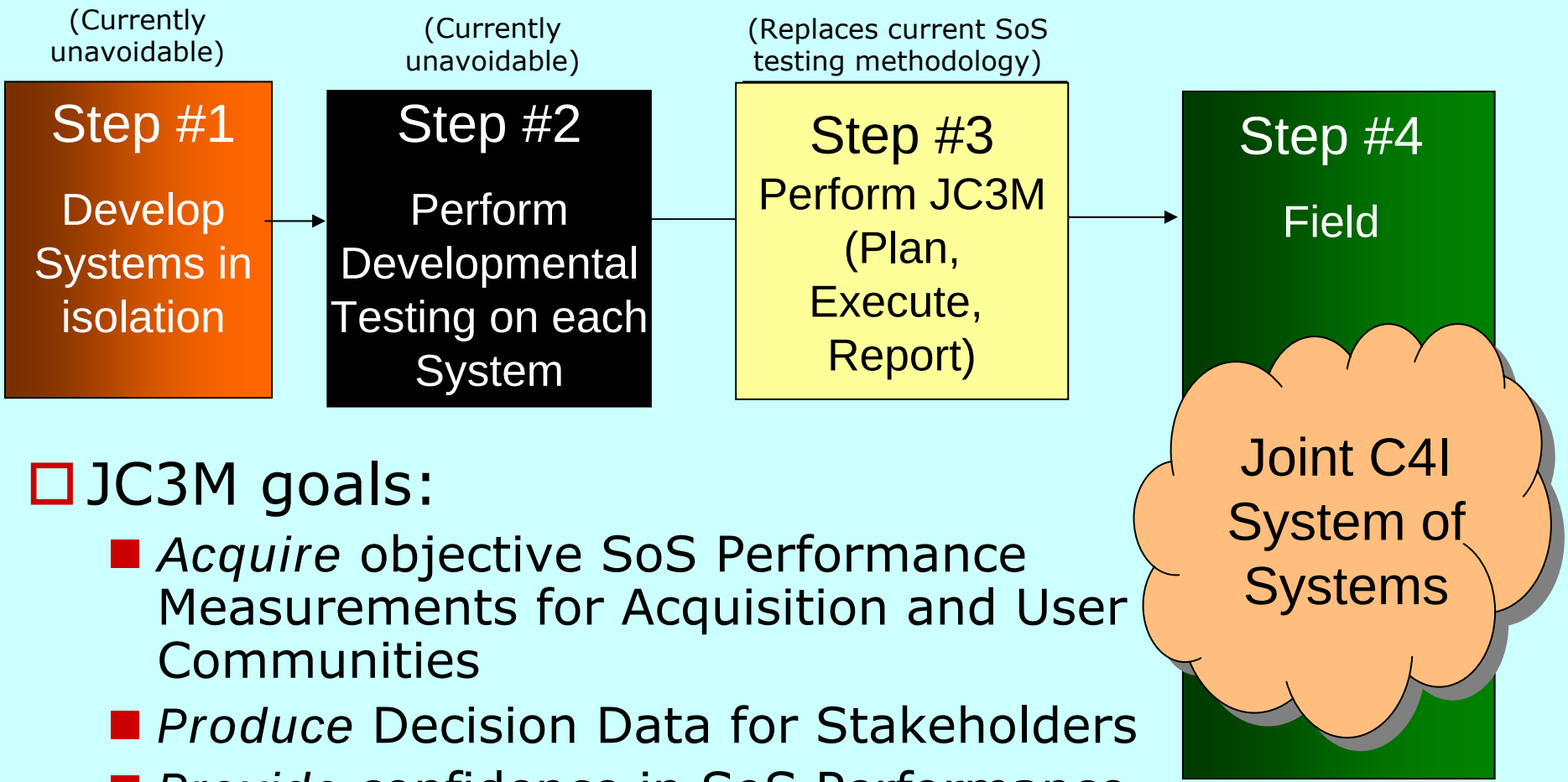


What's the Solution?

Develop a System that articulates SoS capabilities, determines whether each SoS component system supports these capabilities, and reports the results

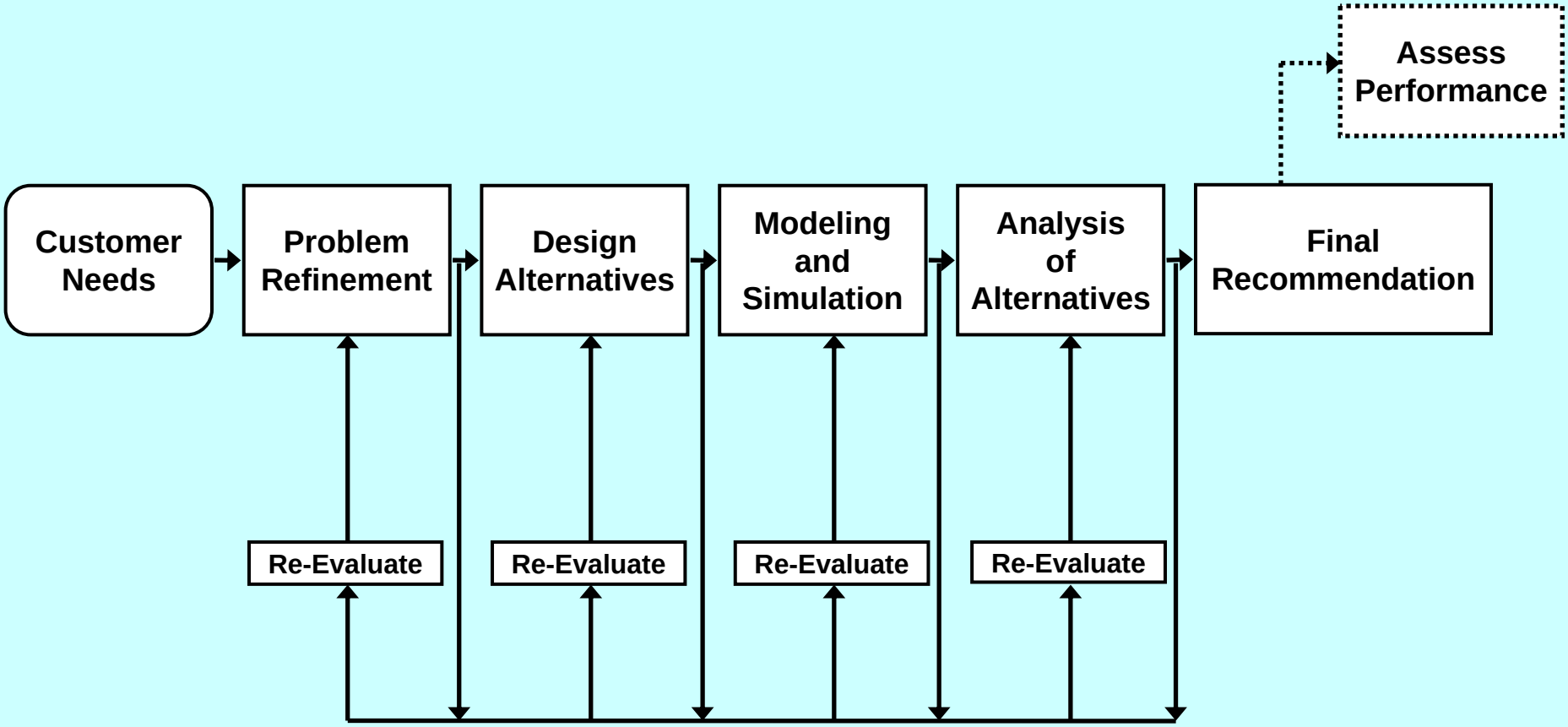


JC3M in Testing and Fielding



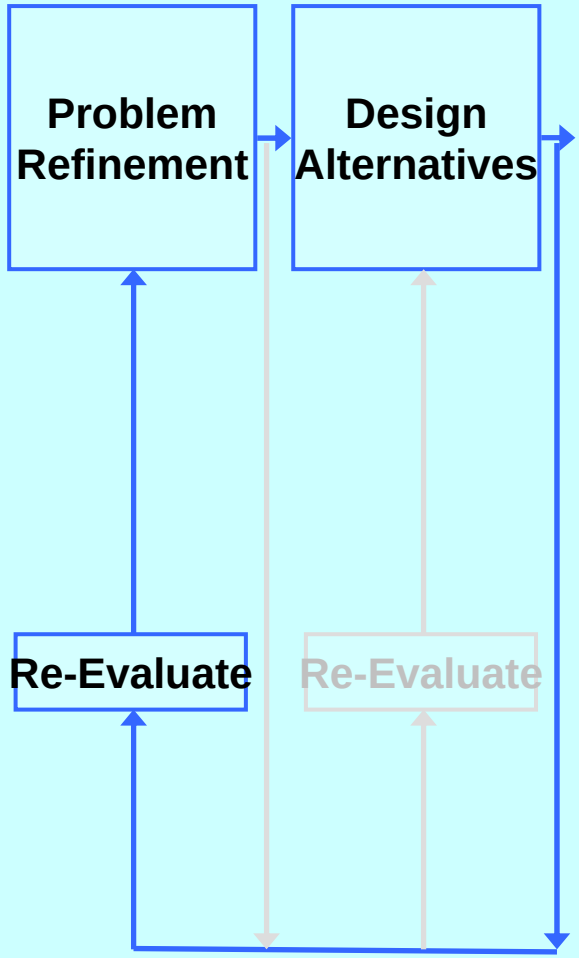
- JC3M goals:
  - *Acquire* objective SoS Performance Measurements for Acquisition and User Communities
  - *Produce* Decision Data for Stakeholders
  - *Provide* confidence in SoS Performance for Users

Systems Engineering Process

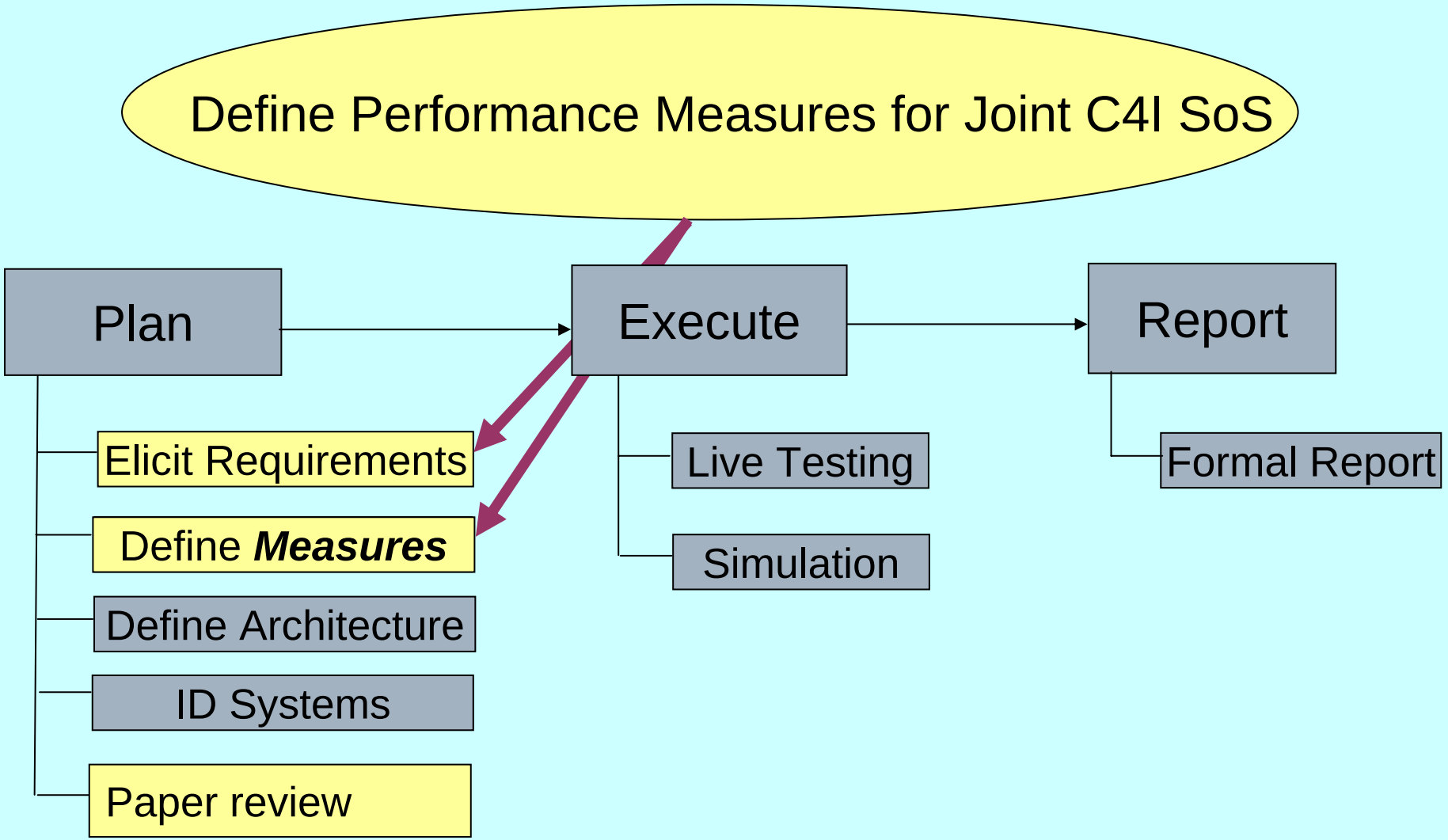


Revised Problem Statement

- Original problem focus:
  - Define Threshold Values
- Research revealed the true problem …
- Refined problem focus:
  - Define Measures to be Evaluated

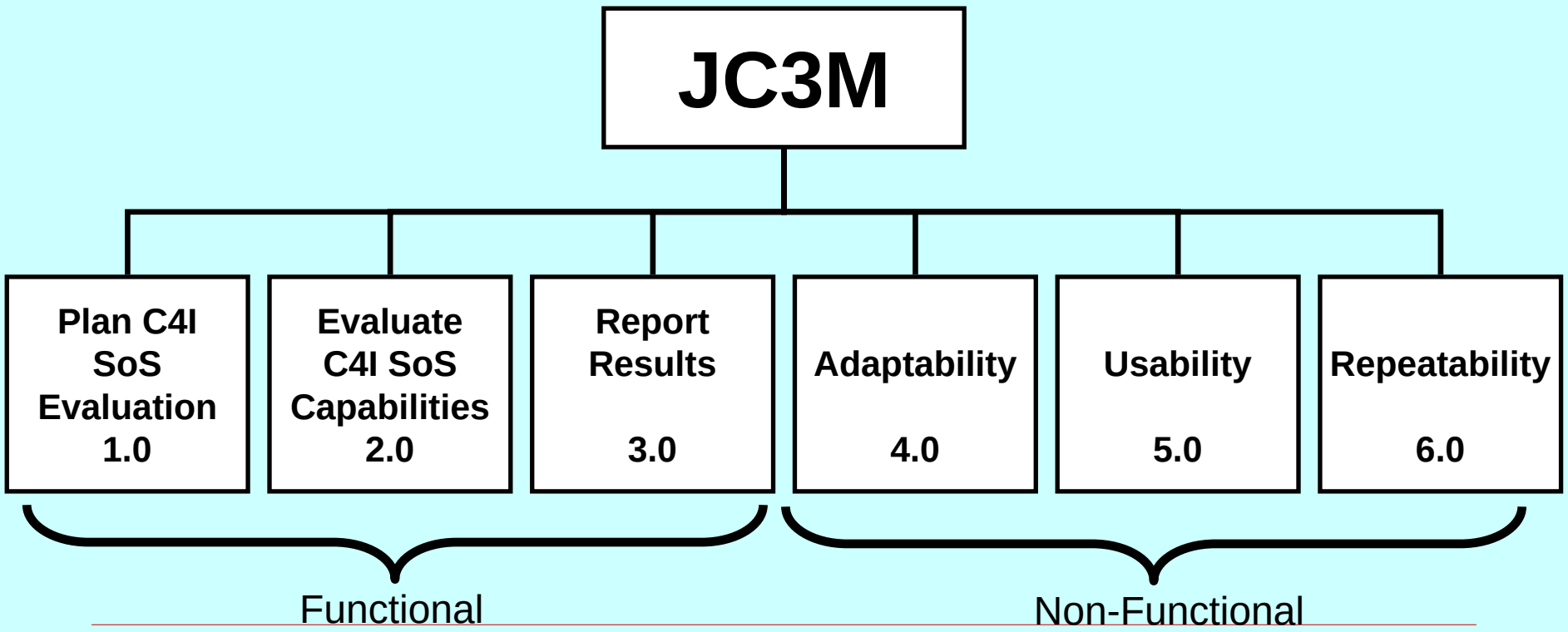


Revised Problem



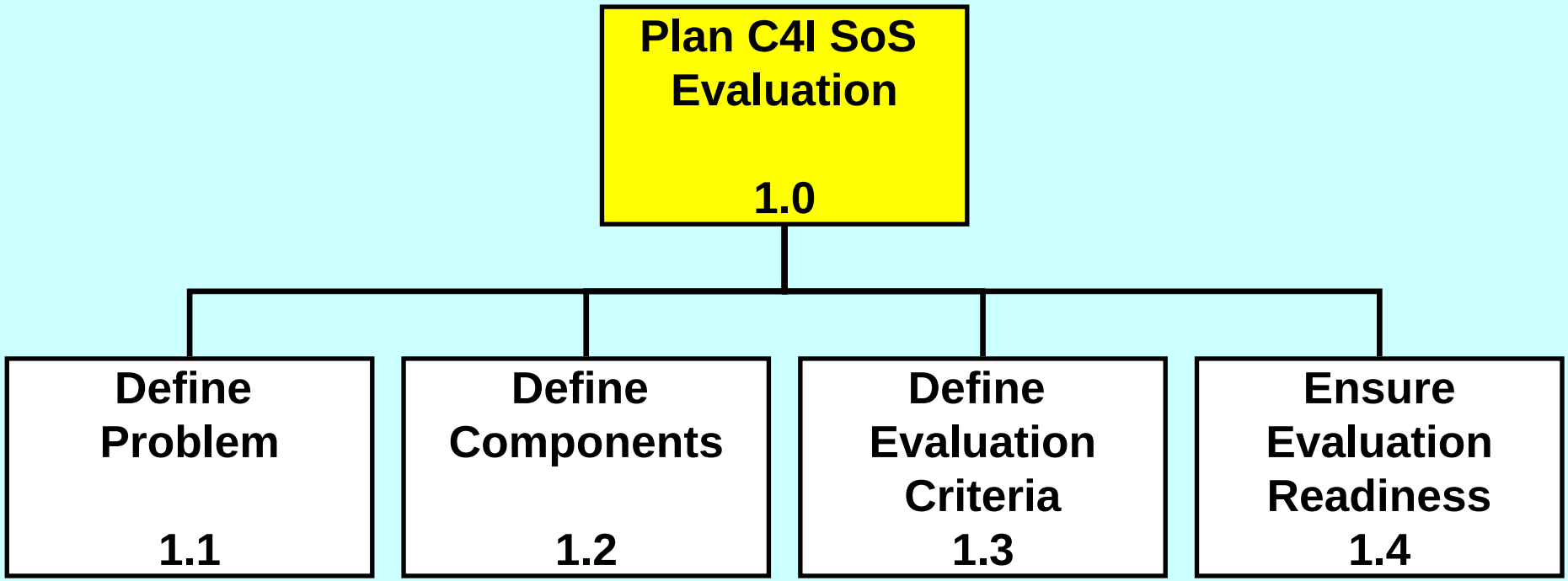
JC3M Value Hierarchy

- Developed from Refined Problem Statement
- Based on Stakeholder Analysis

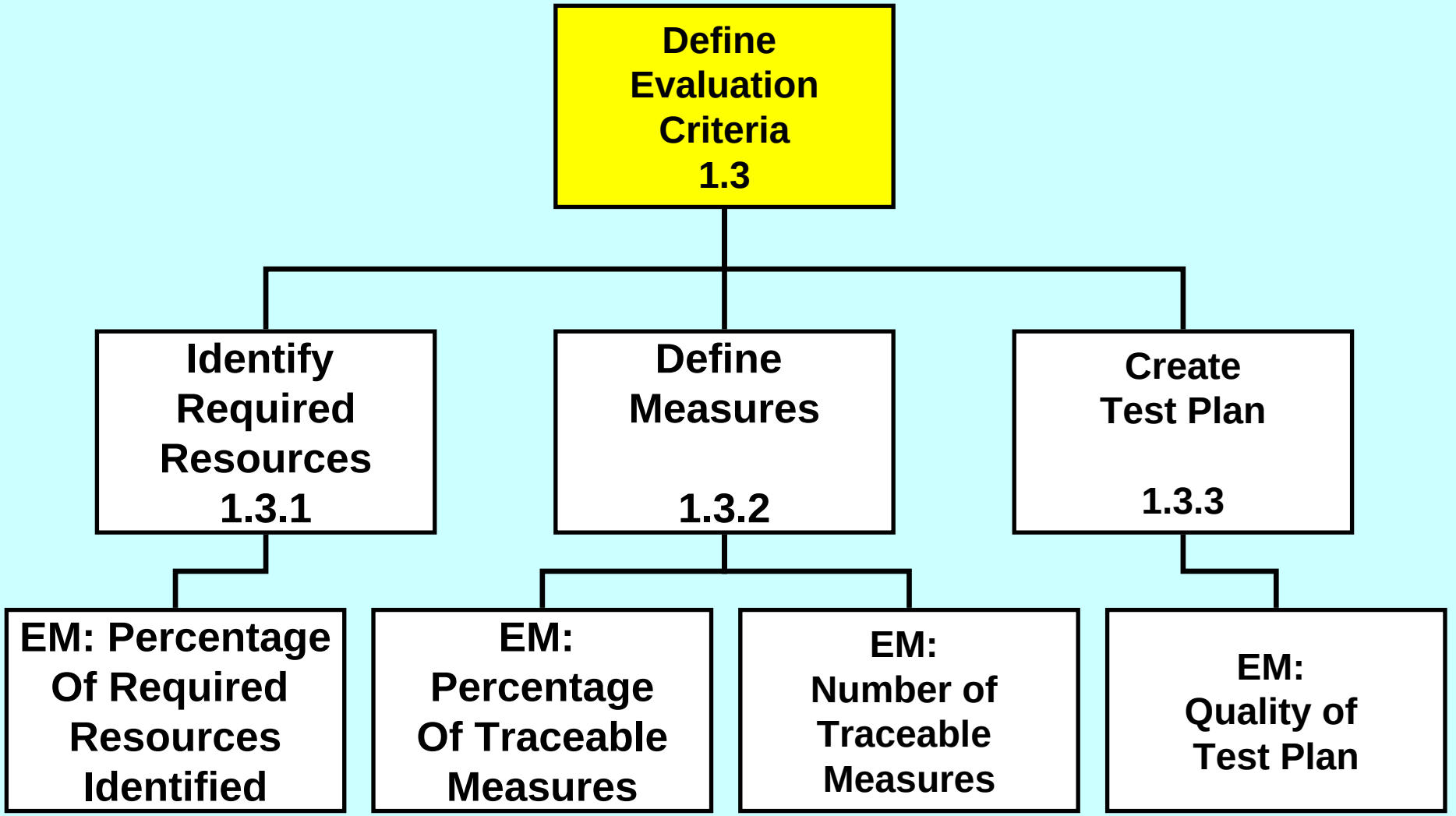


Plan C4I SoS Evaluation

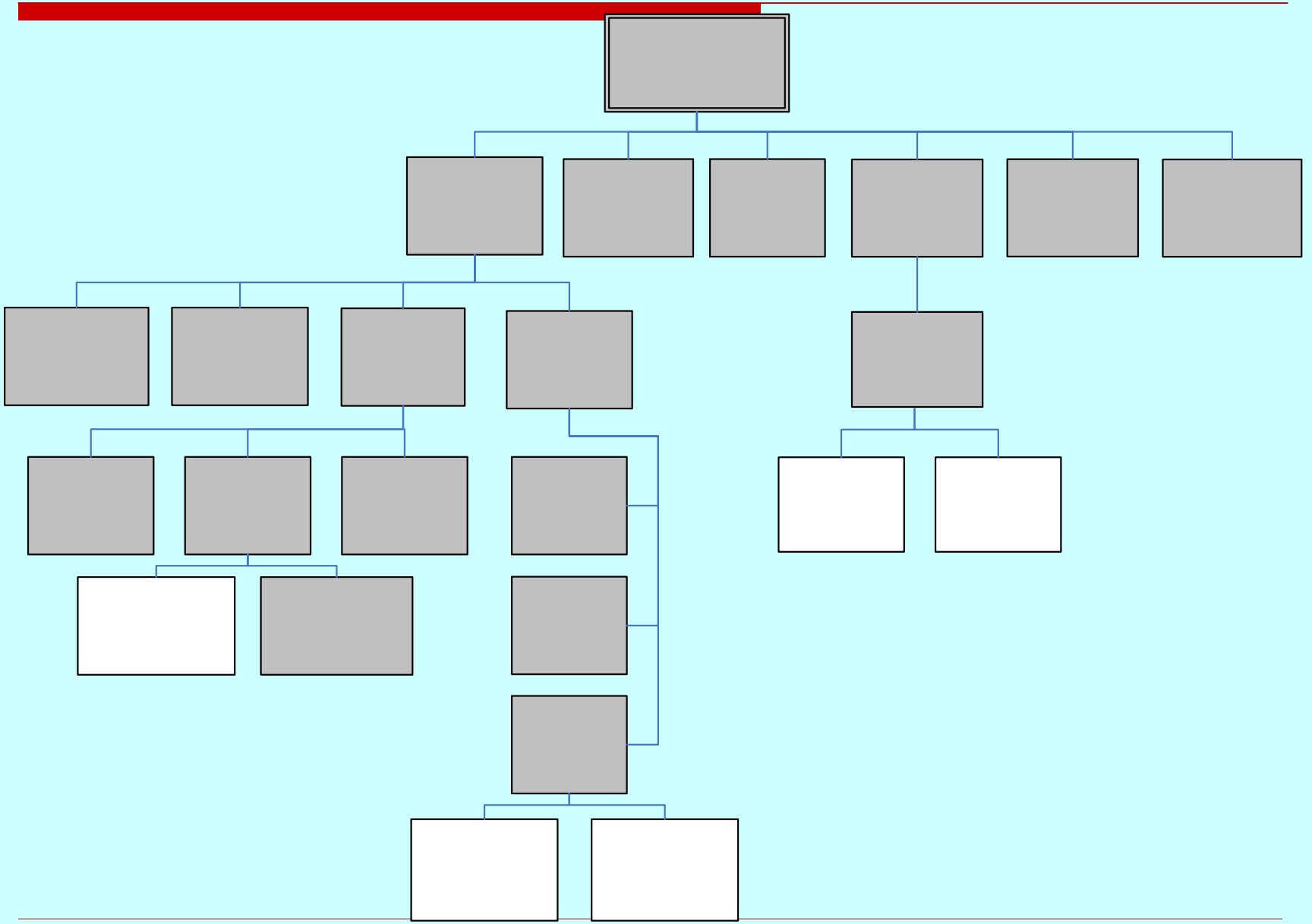
JC3M Functional Decomposition



Define Evaluation Criteria 1.3



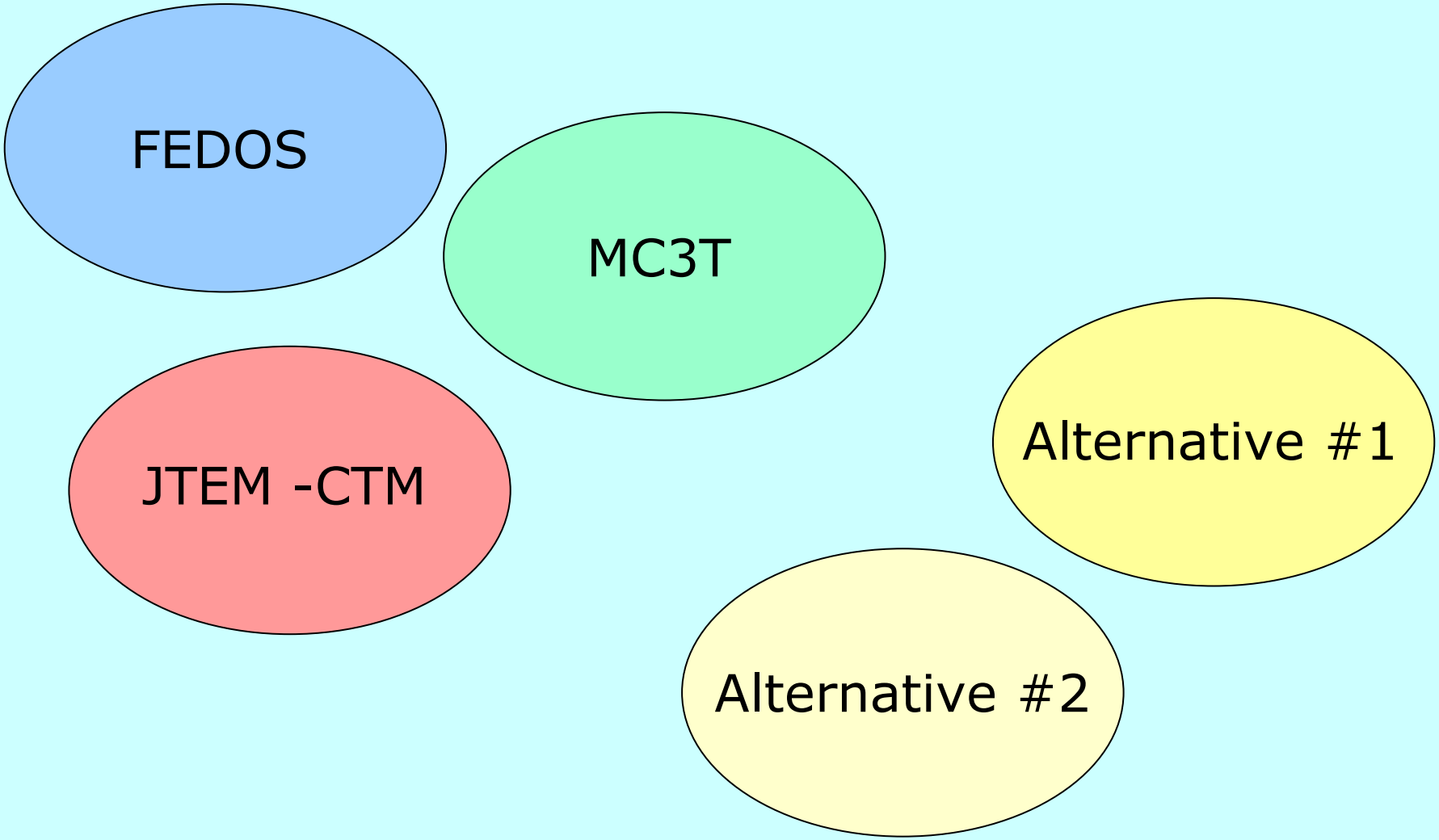
JC3M Value Hierarchy



Evaluation Measures

	Percentage of Traceable Measures	**Days to Plan Evaluation**	**Quality of Planning Outputs**	**Elasticity of Labor**	**Elasticity of Duration**
JC3M Function	Define Measures 1.3.2	Planning Results 1.4.3	Planning Results 1.4.3	Input System Flexibility 4.1	Input System Flexibility 4.1
Definition	Alternative generated measures, traceable to stakeholder requirements, divided by the number of measures generated by the alternative. Ratio level data, from 0 – 100%	Elapsed time (in days) of planning for C4I SoS evaluation Ratio level data $\geq$ 0 hours	Quantify the overall quality of the planning documents produced. Ordinal – Low, Medium, High	Divide percent change in labor hours to conduct planning phase of JC3M by the percent change in systems under test. (Quantifies ability to scale.) Ratio level data from $0 - \infty$	Divide percent change in duration to conduct planning phase of JC3M by the percent change in systems under test. (Quantifies ability to scale.) Ratio level data from $0 - \infty$
Rationale and Relevance	Identifies objectivity of performance measures. Performance measures traceable to doctrinal references will be perceived as objective, increasing the value of the evaluation.	Predicts SoS evaluations that can be conducted in a year. Alternatives that permit multiple SoS evaluations generate data to support fielding decisions sooner.	Identifies predicted utility of alternative. Quality of the planning products drives the overall value of the alternative.	Predicts changes in cost of SoS evaluation based on size. Can be used to determine most effective alternative based on SoS size.	Predicts changes in duration of SoS evaluation based on size. Can be used to determine most effective alternative based on SoS size.

Alternatives

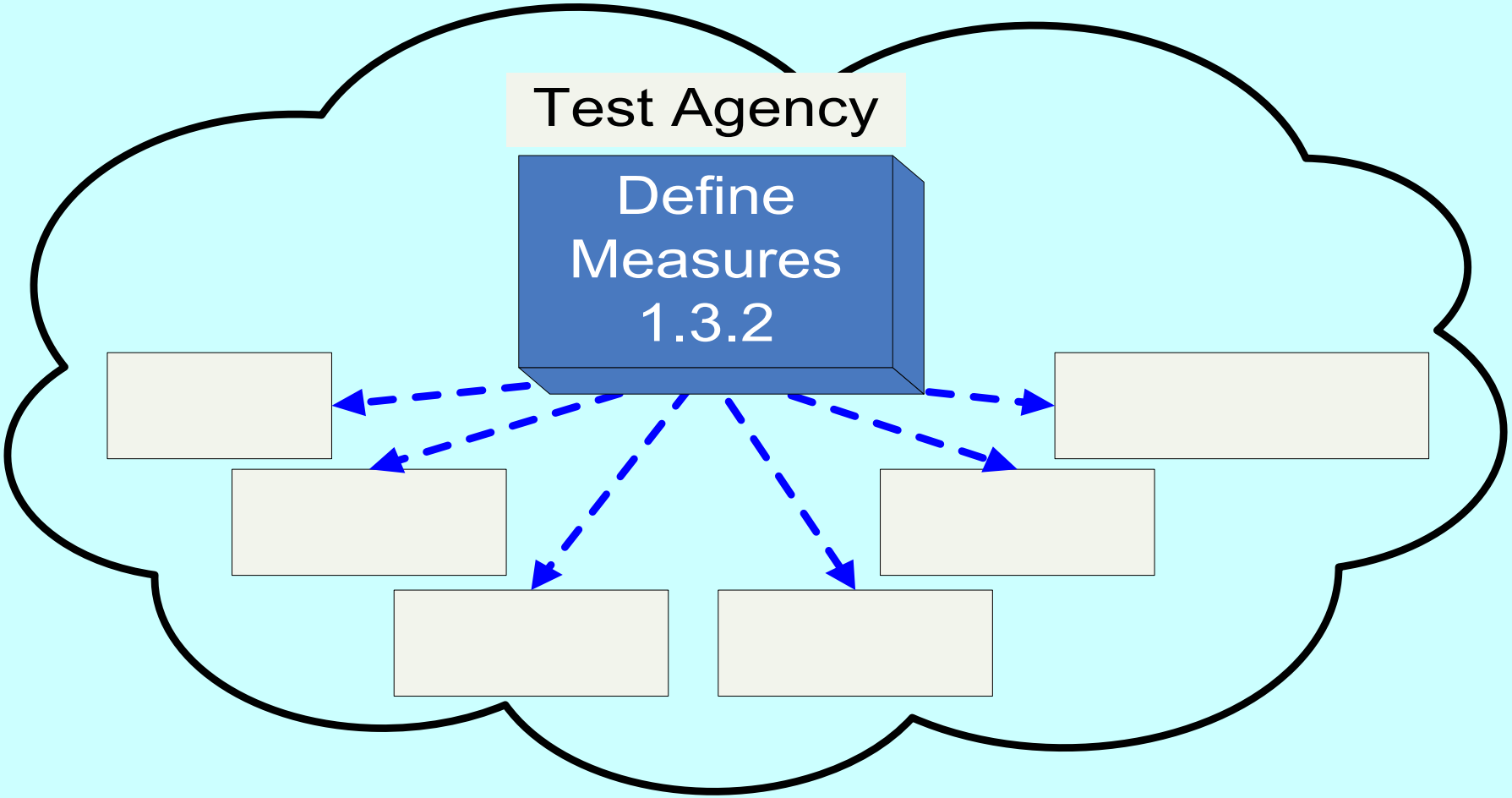


Morphological Box Process

Define the Problem	ID Systems Under Test	Define Criteria	Ensure Readiness
Have SMEs Do It	What PM Requests	Ask Users	PM Review
Acquisition Manager Defines	DoDAF Document Review	What PM Asks For	SAR Review
Acquisition Manager Defines	Engineering Document Review	Test Everything	Test Manager Review
Get from CDD	Ask JITC	Stakeholder Review	

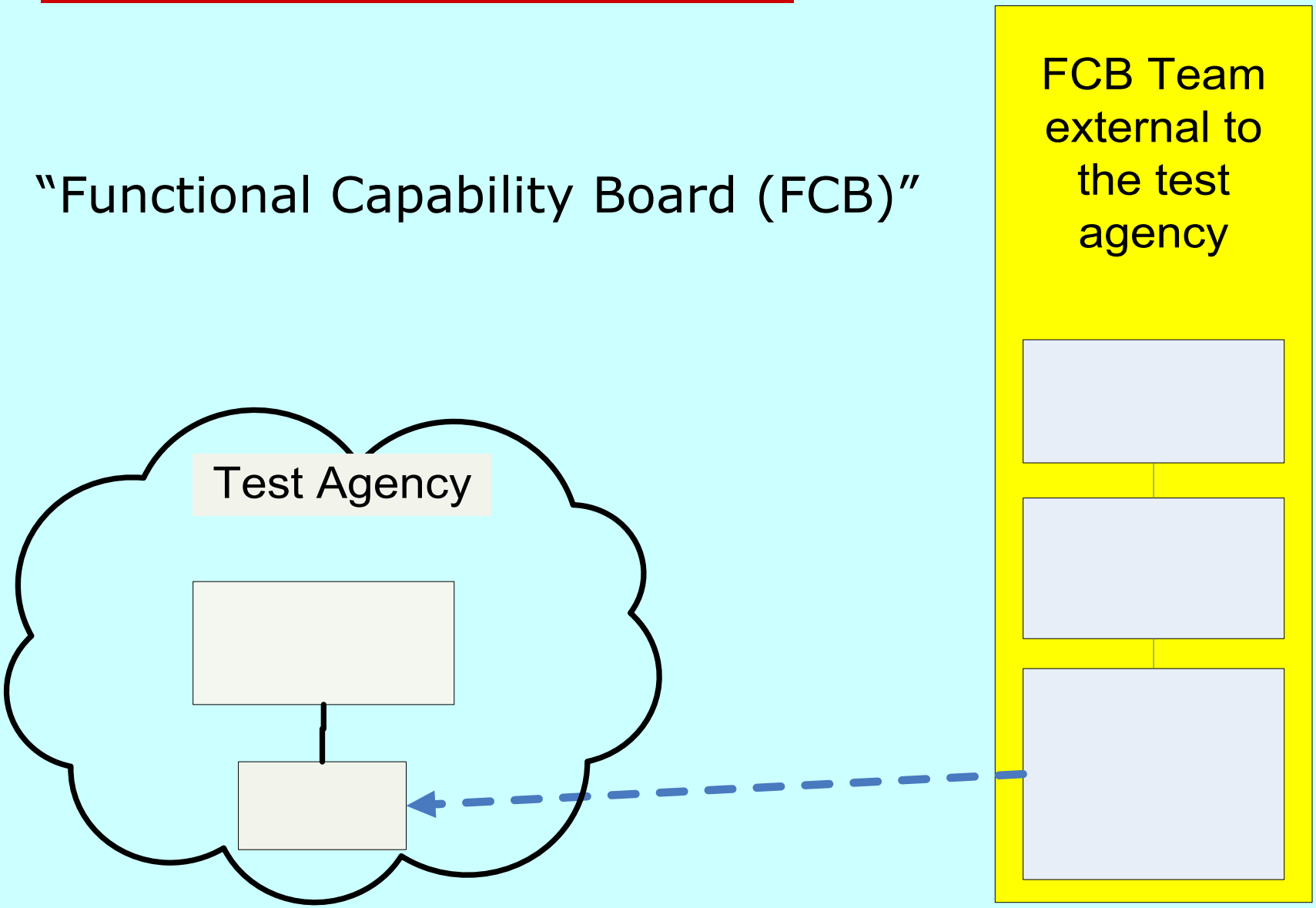
Alternative #1

"System Capabilities Review (SCR)"

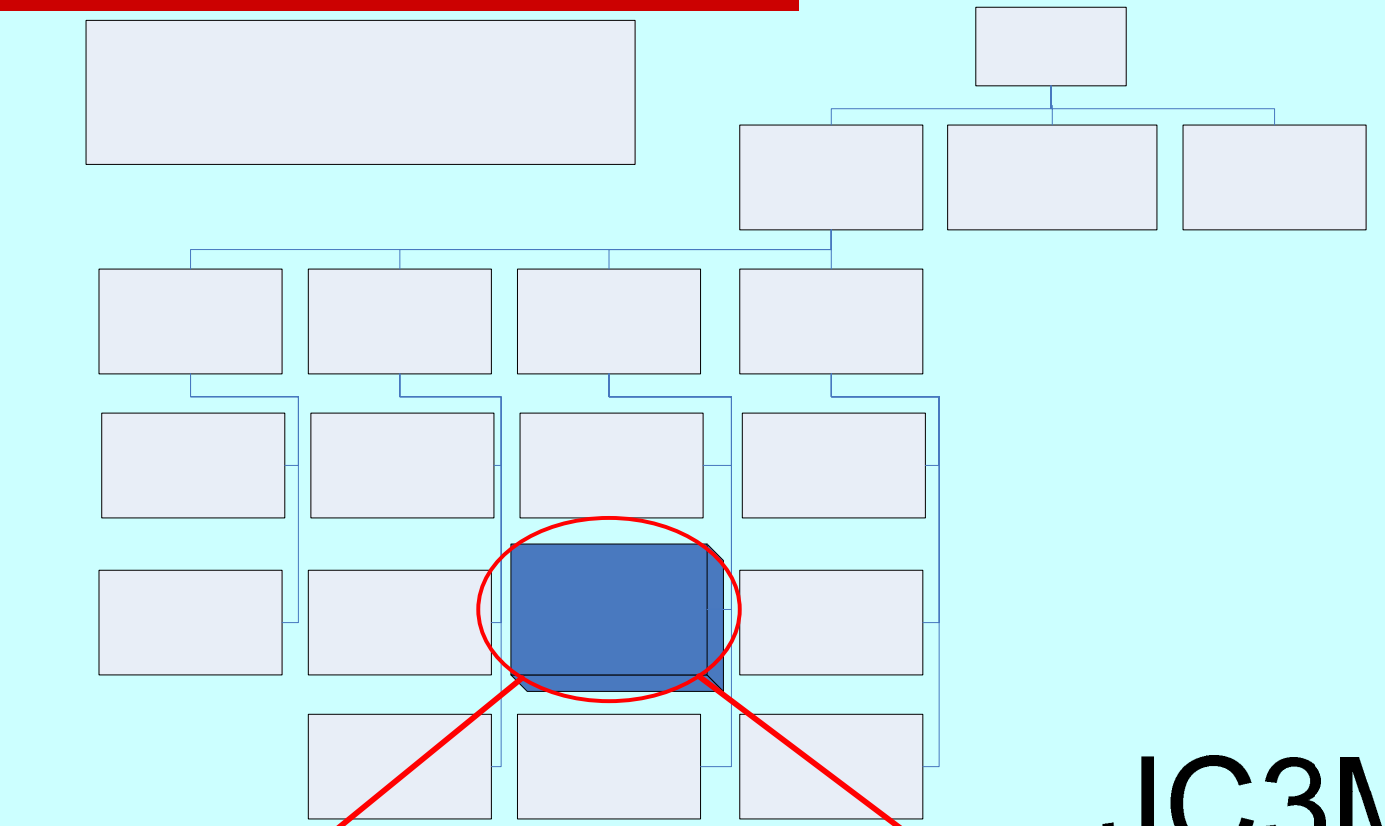


Alternative #2

"Functional Capability Board (FCB)"



Differences



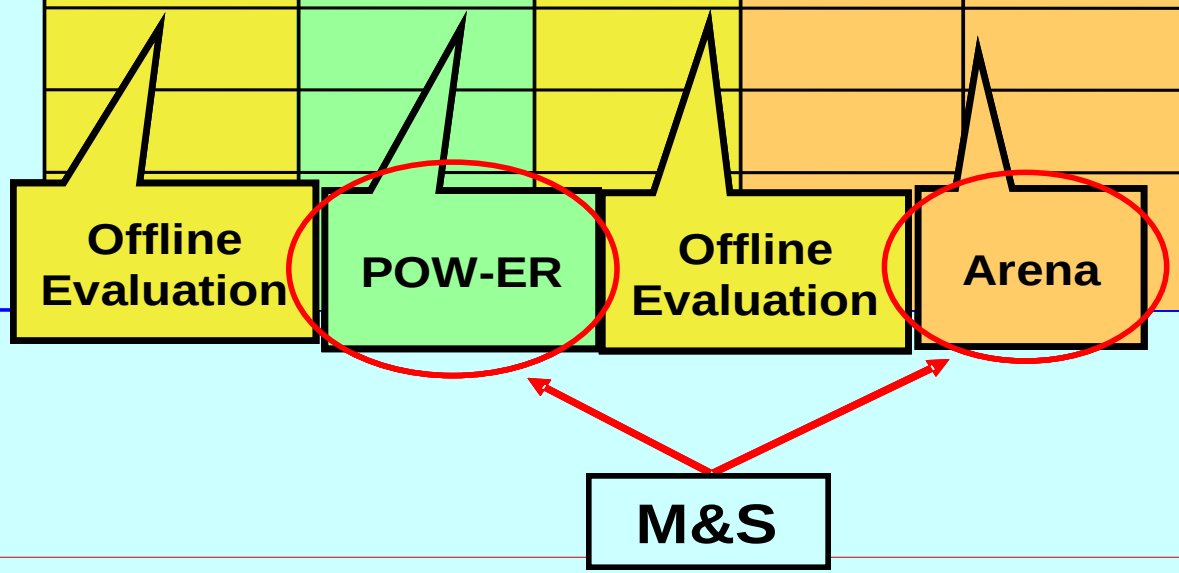
JC3M Fu

Alternatives Summary

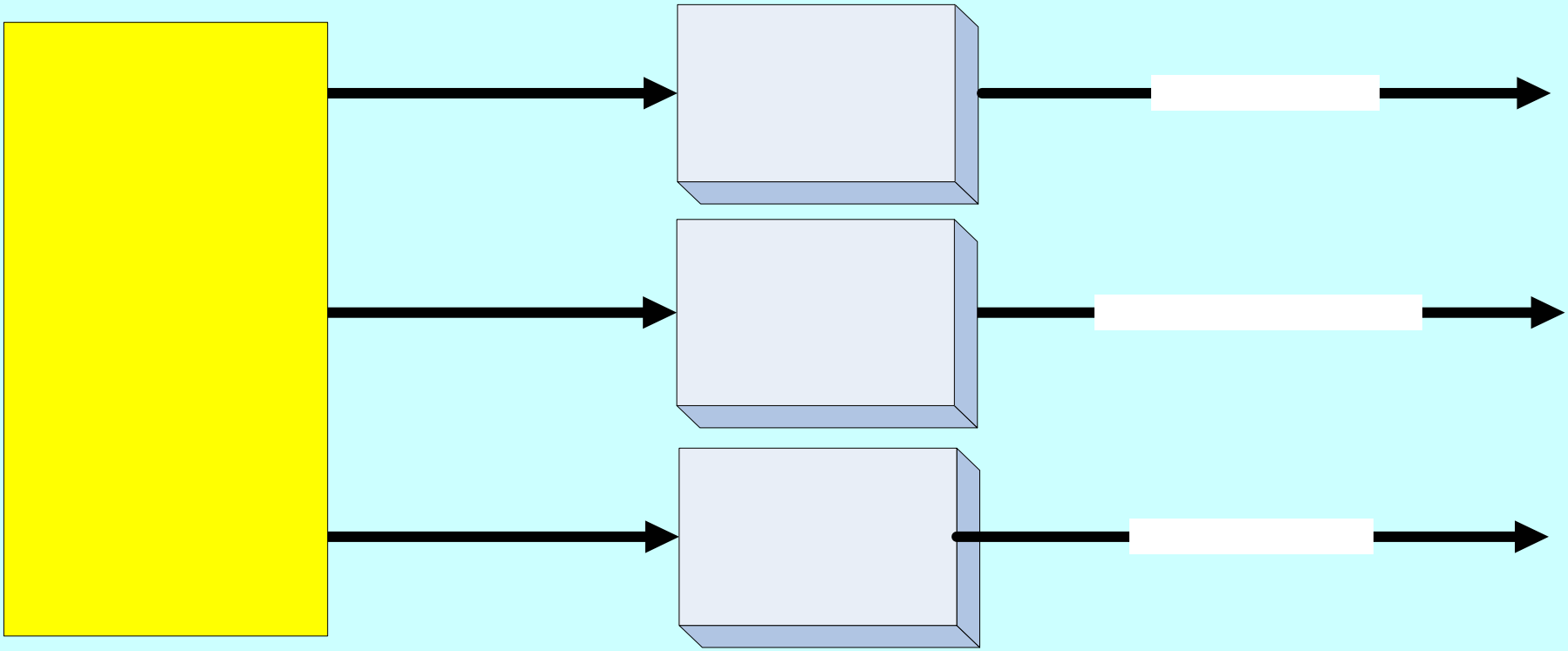
	Personnel	Use	Scope	Measures
FEDOS	Internal	Past	Service **test**	**Stakeholder agreement**
MC3T	Internal + External	Proof of concept	Service system **certification**	Doctrine developers & stakeholders
JTEM CTM	Internal	Model	Joint **Mission Effectiveness** Assessment	Doctrine, System documentation
SCR	Internal	Proposed	**Joint** capability assessment	Doctrine, System documentation
FCB	Internal + External	Proposed	**Joint** capability assessment	**C4I SME panel**

Fill in the blanks!

	Percentage of Traceable Measures	Days to Plan Evaluation	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration
Alternatives	**EM #1: 1.3.2**	**EM #2: 1.4.3**	**EM #3: 1.4.3**	**EM #4: 4.1**	**EM #5: 4.1**
FEDOS					
MC3T					
JTEM - CTM					
FCB					
SCR					



M&S Overview



Input

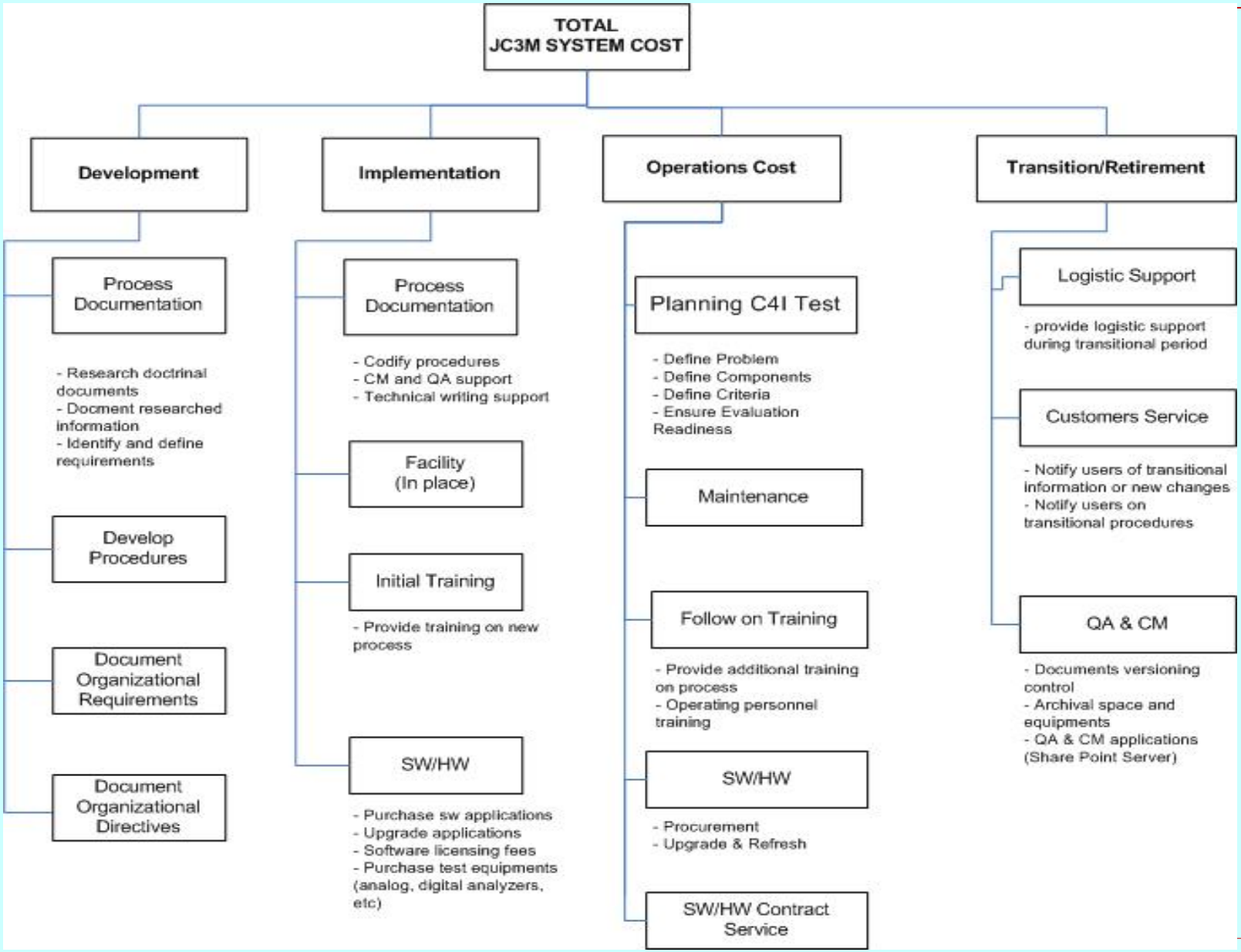
M&S Results

	Percentage of Traceable Measures	Days to Plan Evaluation	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration
Alternatives	**1.3.2**	**1.4.3**	**1.4.3**	**4.1**	**4.1**
FEDOS		140 days		0.87	0.86
MC3T		121 days		0.78	0.78
JTEM CTM		73 days		1.04	0.83
FCB		158 days		0.97	0.97
SCR		127 days		0.71	0.71

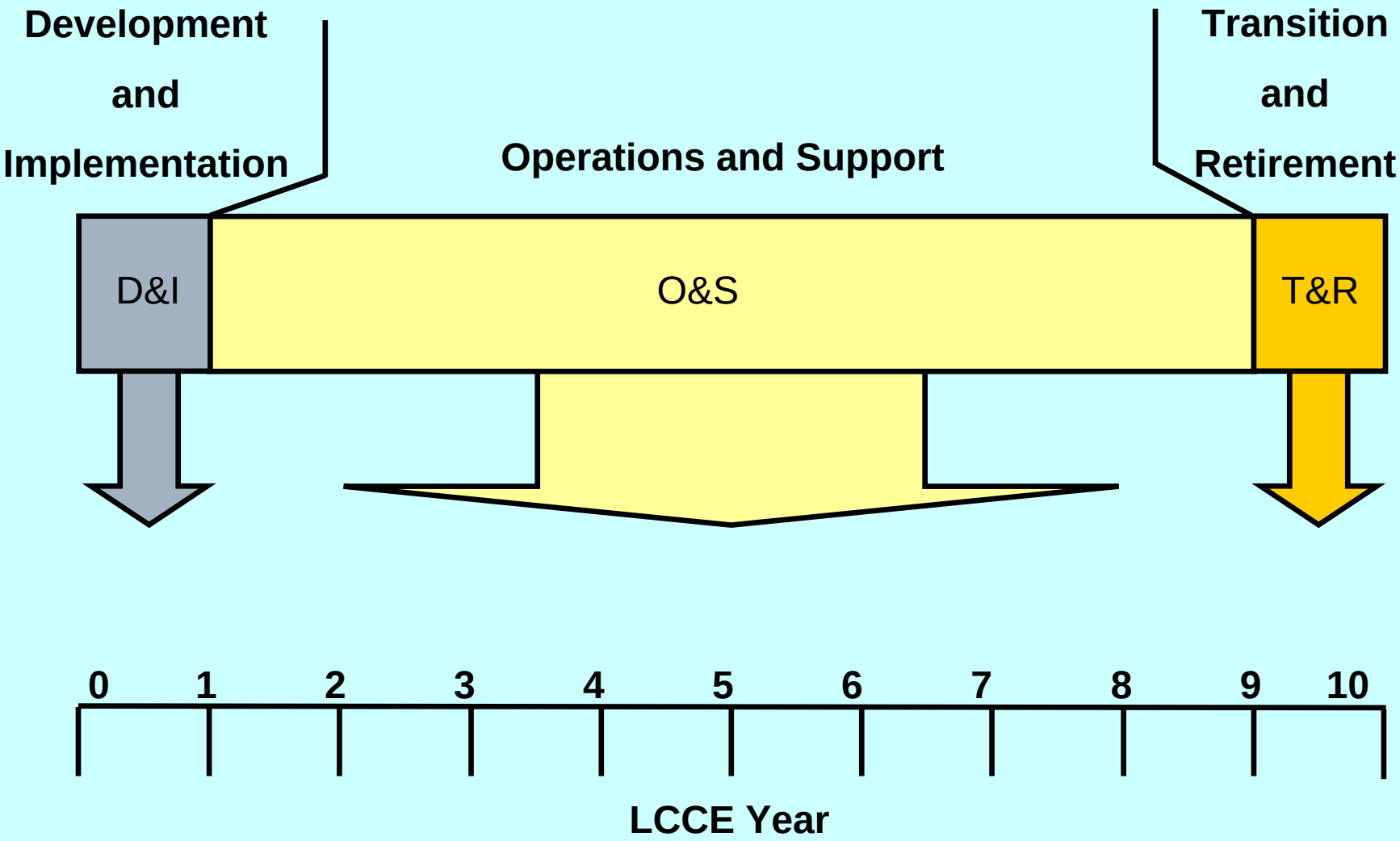
Complete EM

	Percentage Traceable Measures %	Days to Plan Evaluation Days	Planning Output Quality Likert Scale 1-4	Labor Elasticity Unitless	Duration Elasticity Unitless
Ideal Value	**100%**	**Less is better**	**4 is Ideal**	**Less is better**	**Less is better**
FEDOS	0	140	3.17	0.87	0.87
MC3T	72	121	3.25	0.78	0.78
JTEM CTM	**92**	**73**	**3.42**	1.04	0.83
SCR	**92**	158	3.00	0.98	0.98
FCB	88	127	2.75	**0.72**	**0.72**

LCCE – Cost Breakdown Structure



Life Cycle Phases of JC3M



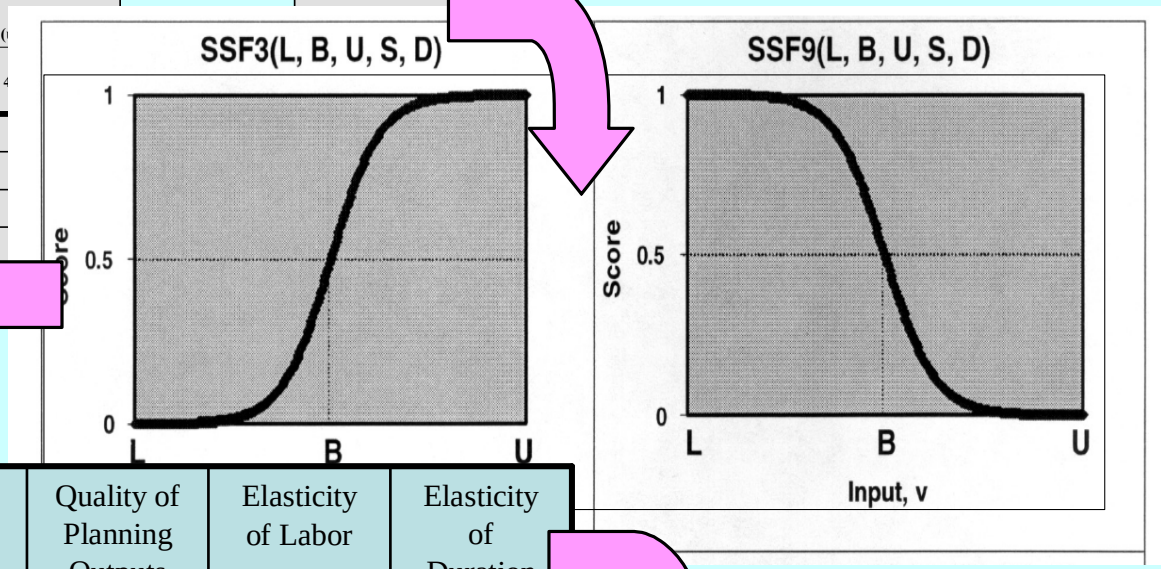
LCCE – Cost Summary

Alternatives	Life-Cycle Year					Total Cost ($)
	1	2	3	4…9	10	
FEDOS	1,052,527	419,497	419,497	419,497	52,200	**5,010,706**
MC3T	1,169,414	525,537	525,537	525,537	52,200	**5,975,913**
JTEM-CTM	1,030,000	2,470,000	1,169,414	558,535	52,200	**6,972,824**
FCB	2,323,117	650,223	650,223	650,223	52,200	**8,127,101**
SCR	2,121,421	624,451	624,451	624,451	52,200	**7,719,232**

Interpretation: The delta between the highest and lowest LCCE ≈ $3M, which is not a significant sum over a ten year span.

Value Modeling Overview

	Percentage of Traceable Measures (%)	Days to Plan Evaluation (Days)	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration
Ideal Value	100%	Less is better			
FEDOS	0	140			
MC3T	72	121			
JTEM CTM	92	73			
SCR	88	127			
FCB	92	158			



	Percentage of Traceable Measures	Days to Plan Evaluation	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration
EM Weights	**0.248**	**0.058**			

	Percentage of Traceable Measures	Days to Plan Evaluation	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration	Overall Utility (0 – 1)
FEDOS	0.00	0.04	0.39	0.06	0.14	0.63
MC3T	0.02	0.05	0.39	0.07	0.16	0.71
JTEM CTM	0.24	0.06	0.40	0.04	0.15	0.89
SCR	0.24	0.02	0.37	0.05	0.10	0.79
FCB	0.22	0.05	0.34	0.08	0.18	0.87

Translation of raw measurements into a normalized set of weighted values that can be added.

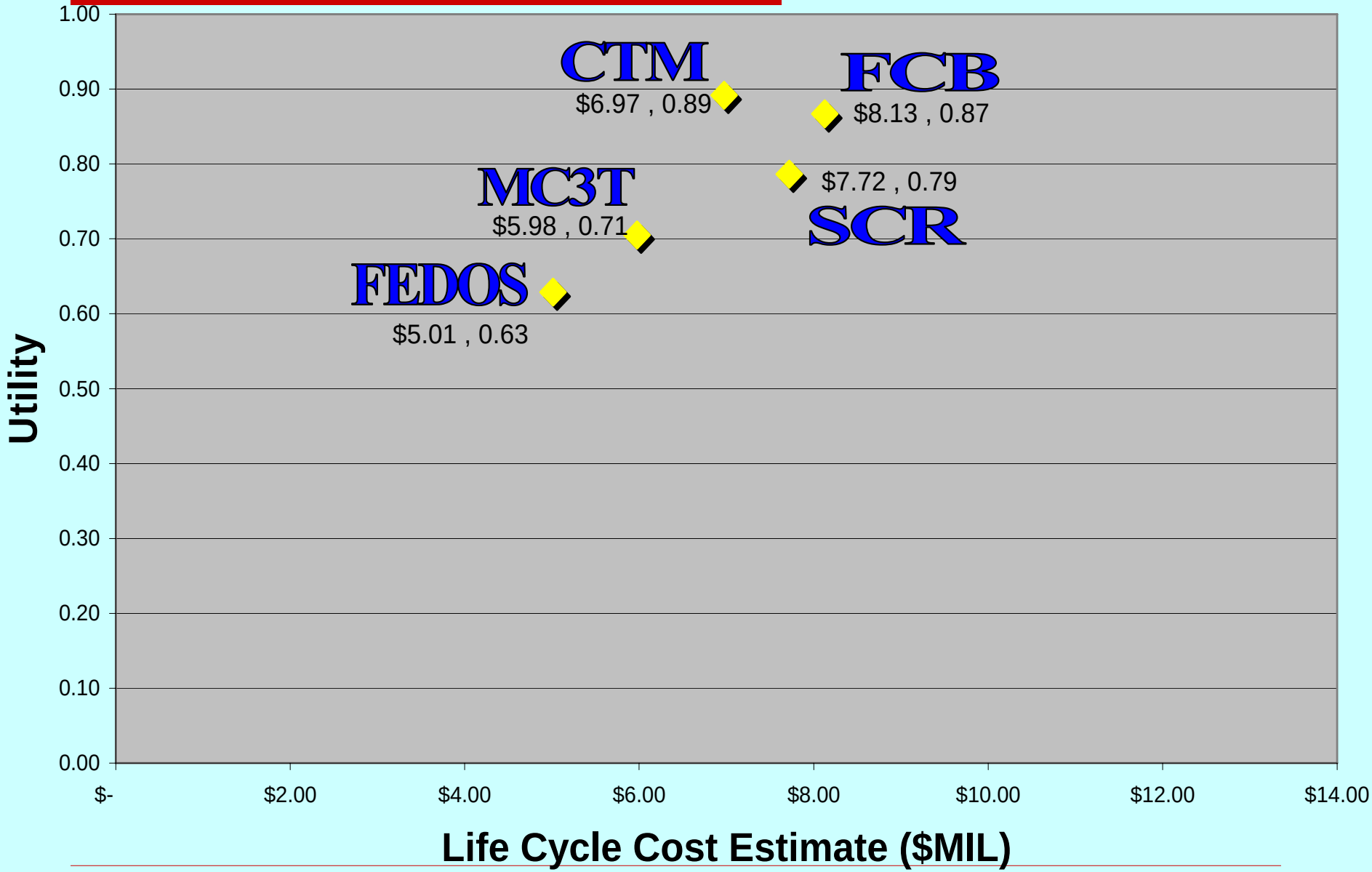
Quantitative Modeling Matrix

	Percentage Traceable Measures	Evaluation Planning Duration	Planning Output Quality	Labor Elasticity	Duration Elasticity	Overall Utility (0 – 1)
FEDOS	0.00	0.04	0.39	0.06	0.14	**0.63**
MC3T	0.02	0.05	0.39	0.07	0.17	**0.71**
JTEM CTM	**0.24**	**0.06**	**0.40**	0.04	0.15	**0.89**
SCR	**0.24**	0.02	0.37	0.05	0.10	**0.79**
FCB	0.22	0.05	0.34	**0.08**	**0.18**	**0.87**

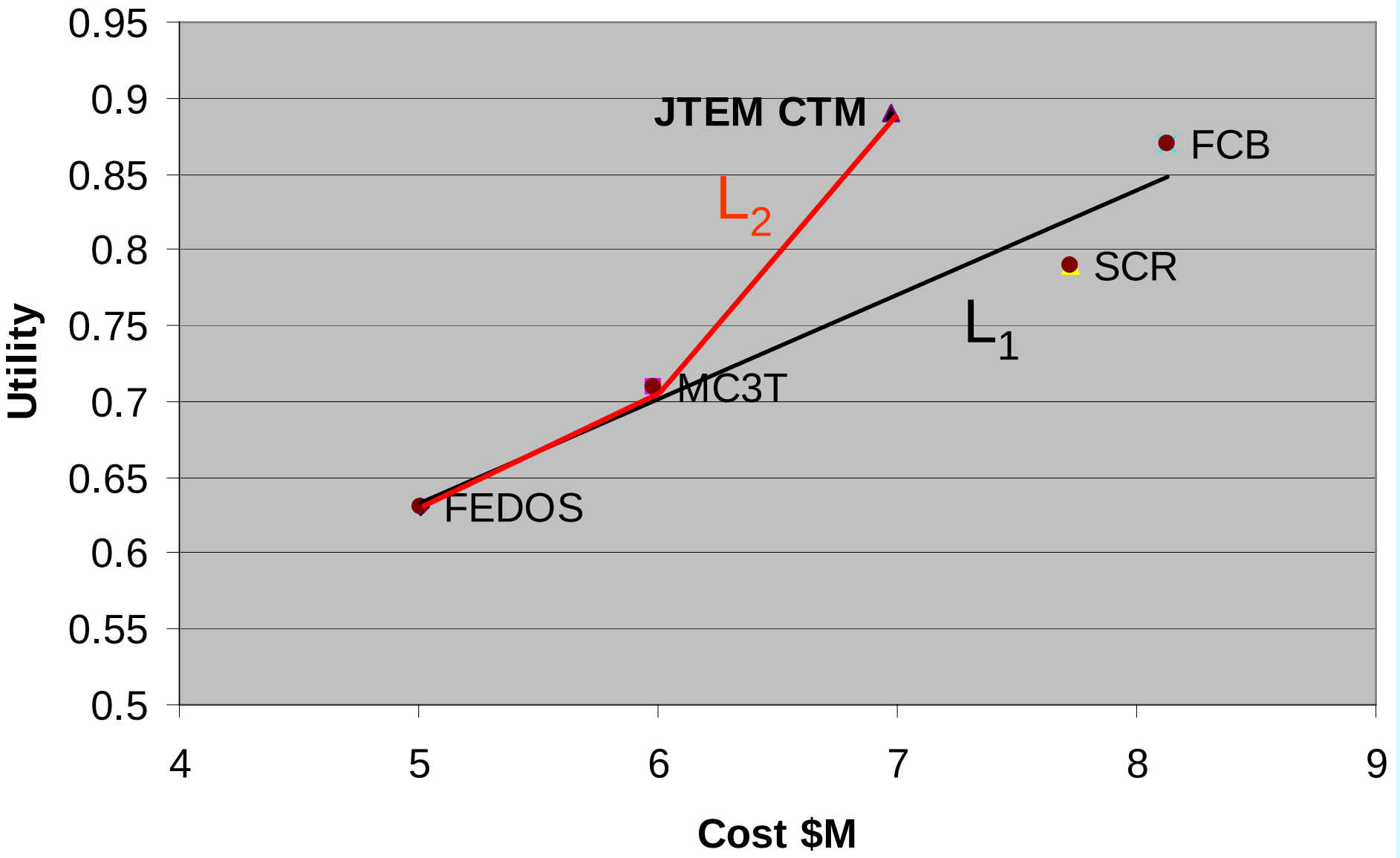
Utility & LCCE

	Percentage of Traceable Measures	Days to Plan Evaluation	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration	Overall Utility (0 – 1)	LCCE ($ M)
FEDOS	0.00	0.04	0.39	0.06	0.14	0.63	5.01
MC3T	0.02	0.05	0.39	0.07	0.17	0.71	5.98
JTEM CTM	0.24	0.06	0.40	0.04	0.15	0.89	6.97
SCR	0.24	0.02	0.37	0.05	0.10	0.79	7.72
FCB	0.22	0.05	0.34	0.08	0.18	0.87	8.13

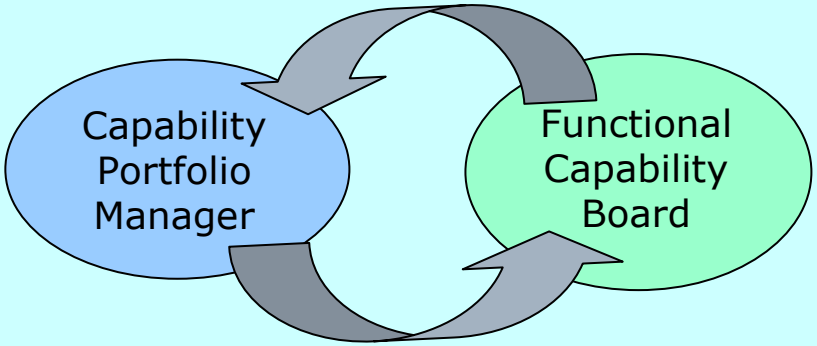
LCCE vs Utility

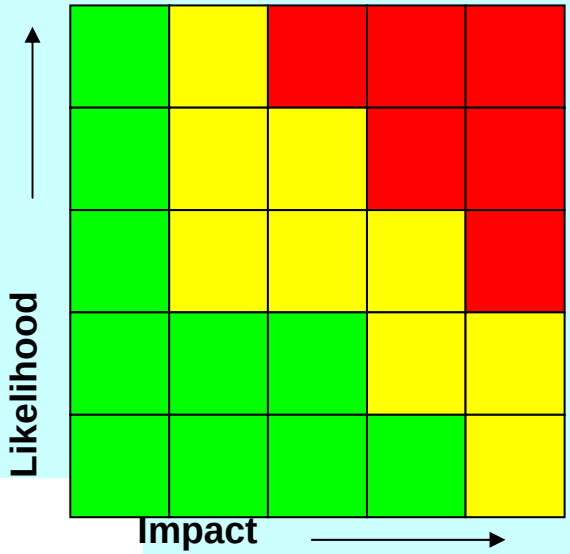


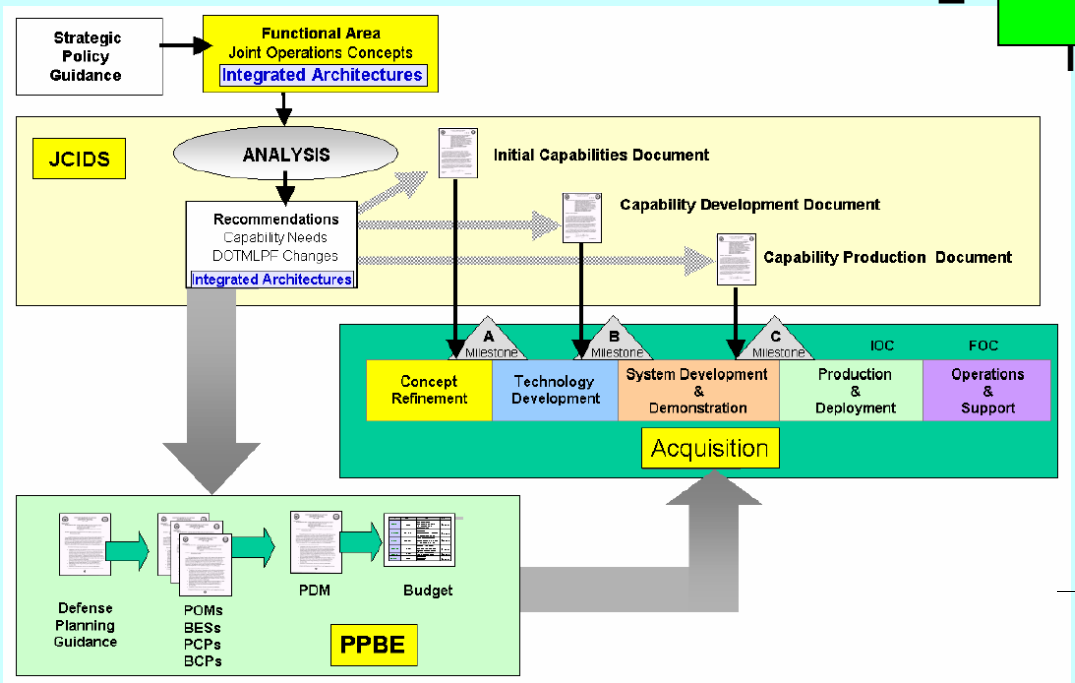
LCCE vs Utility



Way Ahead: 3 areas







Back-Up

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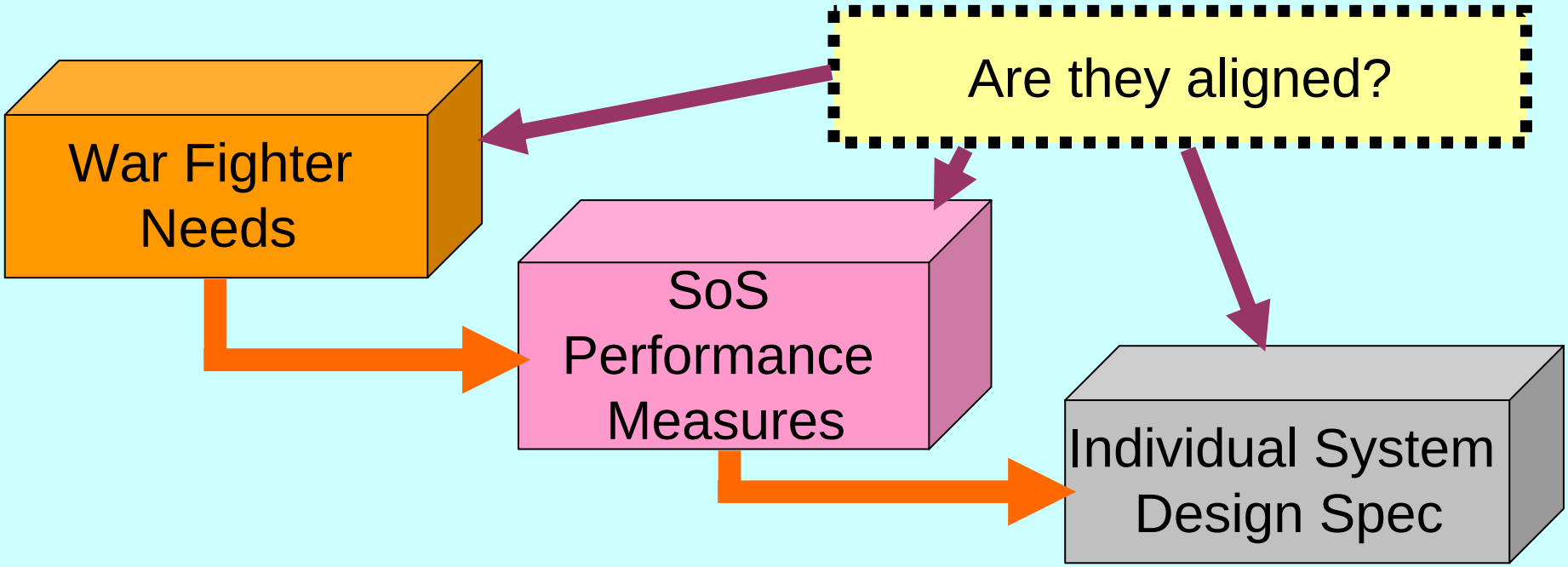
Refined Problem Statement

"There is no system that defines and compares System of System performance measures to war-fighter needs in an objective and measurable way."



Federation Of Systems (FEDOS)

Service Test Organization

System Requirements
System Test Plan
System Test Procedures

Elicit Requirements from Service Stakeholders for each event:

"AFATDS must display unit symbology"

System-Centric Testing

Did AFATDS report ammo status correctly?
Did EPLRS transmit firing data?

Service System "Owners"

Marine Air Ground Task Force C4I Capability Certification Test (MC3T)

Service Test Organization

SoS Capability Assmt Plan
SoS Performance Measures

Capabilities Package from Stakeholders for each event:

"AFATDS must send msg to TBMCS…"

Service Doctrine Developers System "Owners"

SoS Capability Assessment

Was Call For Fire:
Timely
Reliable
Accurate…

Joint Test & Evaluation Methodology Capability Test Methodology (JTEM CTM)

Joint Test Organization

Review Joint Doctrine, CONOPS, System Documentation for each event

Pgm Introduction Doc:
- **SoS, SUT, Environment, JOC, COI, MOP, MOE**
- **SoS Evaluation Strategy**

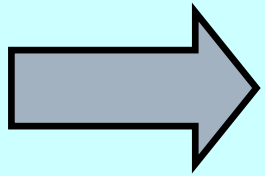
Test Plan

SoS Capability Assessment

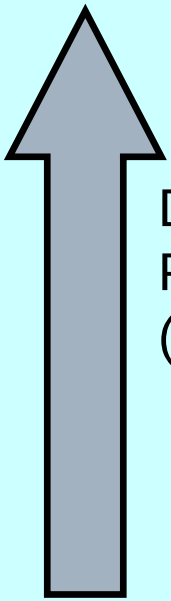
Was Call For Fire effective in a Joint Mission environment?
Is XXX an appropriate investment?

Functional Capabilities Board (FCB)

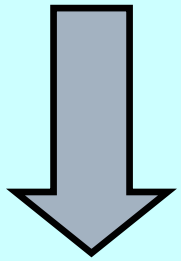
Joint Test Organization



SoS Performance Measures
SoS Test Plan
SoS Test Procedures



Define SoS Performance Measures (ongoing)



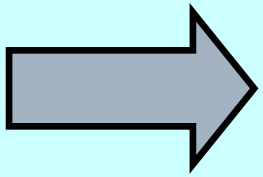
SoS Capability Evaluation

Was speed (accuracy, effectiveness, efficiency…) improved, unchanged, or degraded?

JCIDS C2 FCB, System Documentation

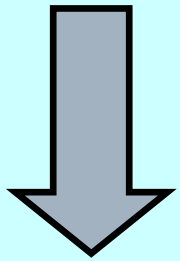
System Capabilities Review (SCR)

Joint Test Organization



SoS Performance Measures
SoS Test Plan
SoS Test Procedures

Review Joint Doctrine, CONOPS, System Documentation for each event



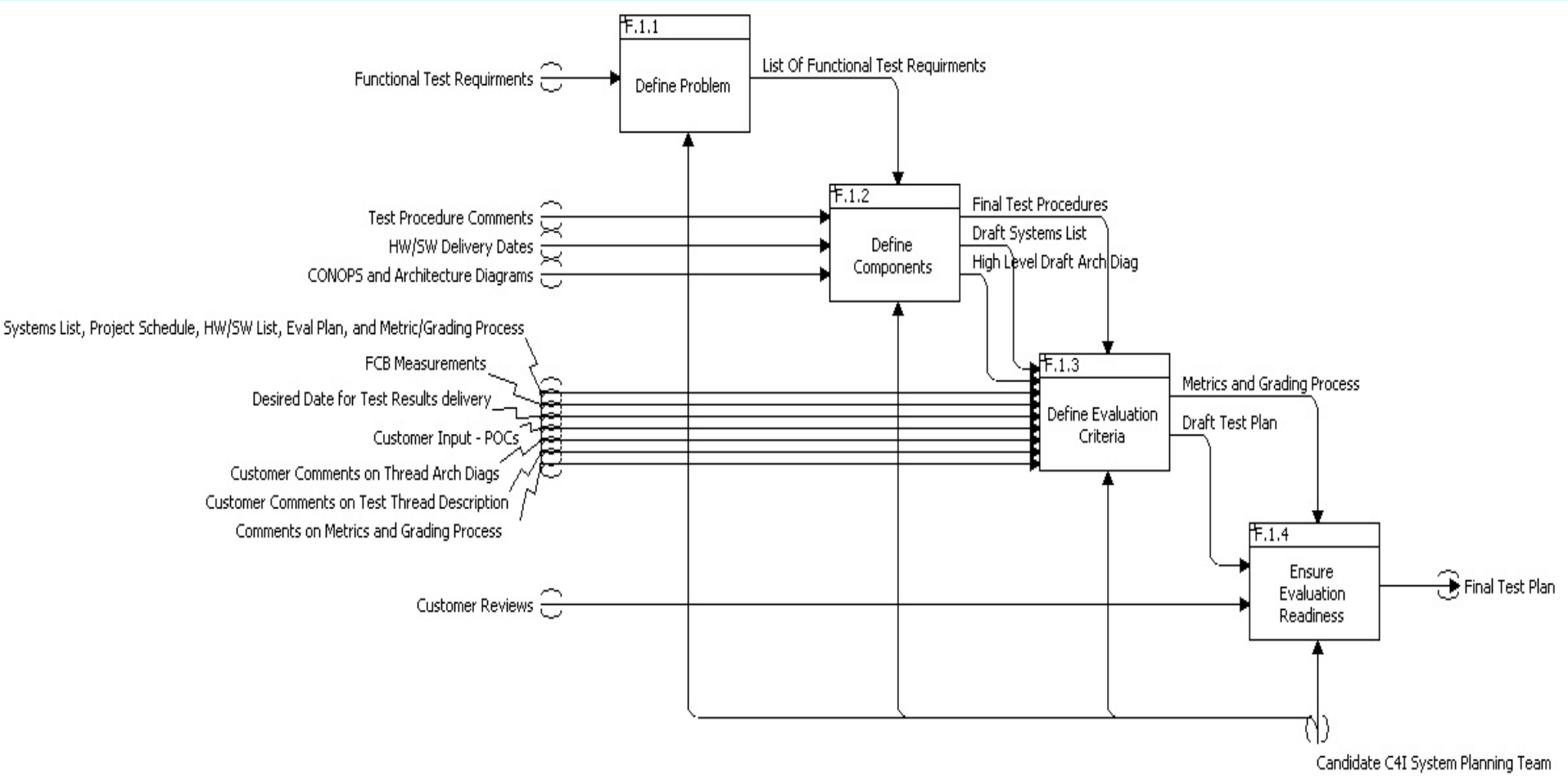
SoS Capability Evaluation

Was speed (accuracy, effectiveness, efficiency…) improved, unchanged, or degraded?

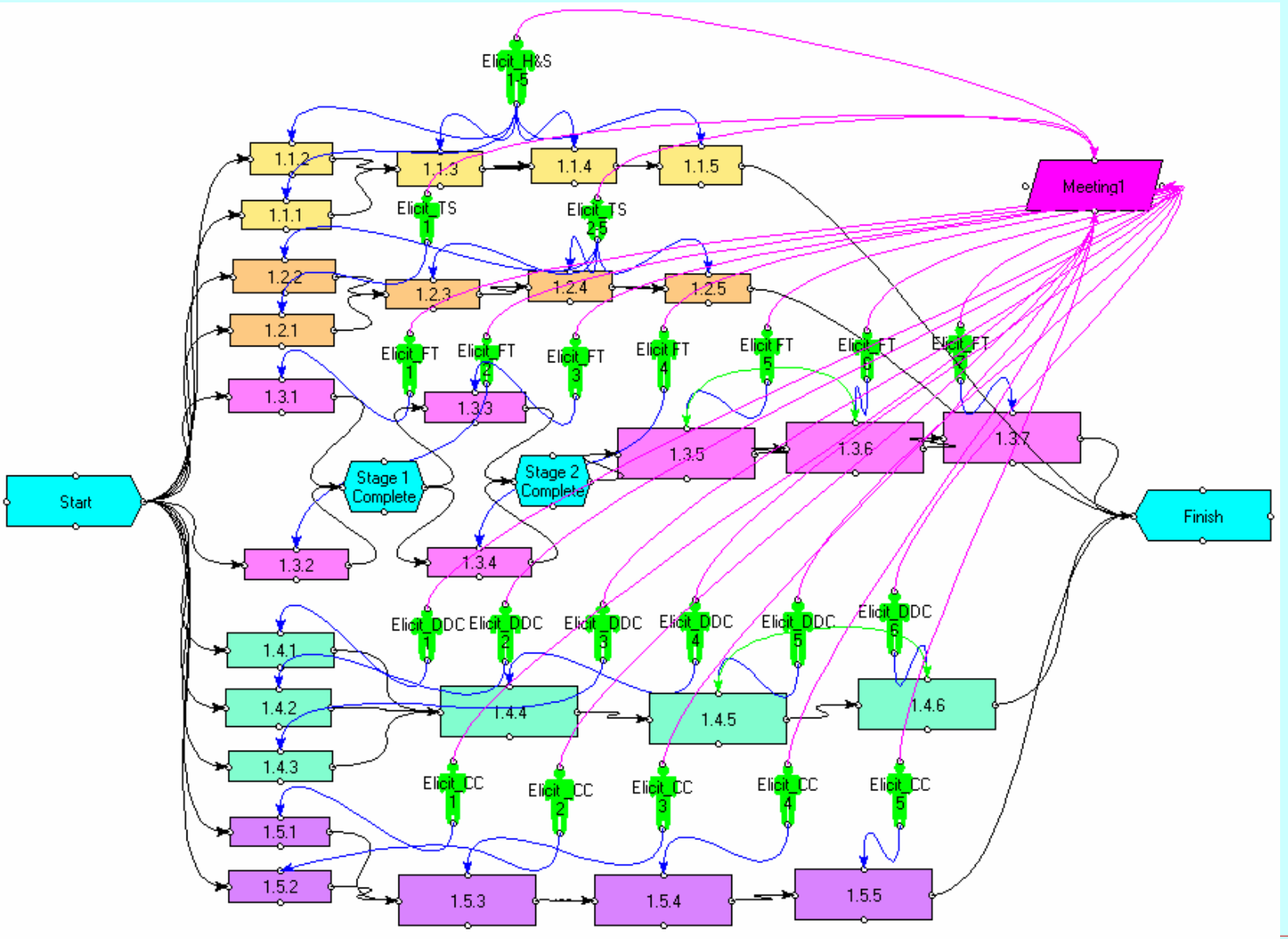
Blank Scoring Matrix

	Percentage of Traceable Measures	Days to Plan Evaluation	Quality of Planning Outputs	Elasticity of Labor	Elasticity of Duration
Alternatives	**1.3.2**	**1.4.3**	**1.4.3**	**4.1**	**4.1**
FEDOS					
MC3T					
JTEM CTM					
FCB					
SCR					

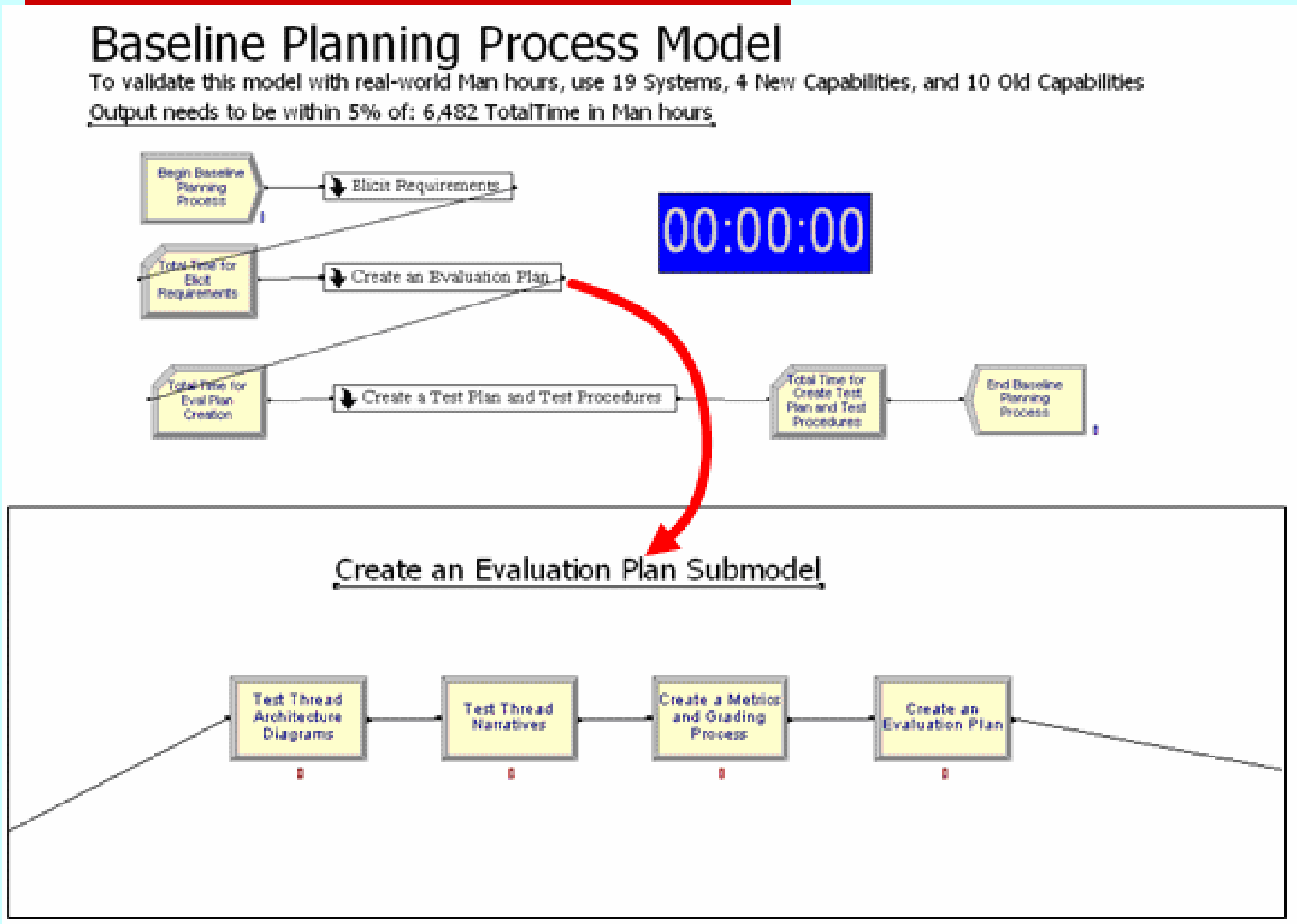
CORE


F.1.1
Define Problem
Functional Test Requirments
List Of Functional Test Requirments
F.1.2
Define Components
Test Procedure Comments
HW/SW Delivery Dates
CONOPS and Architecture Diagrams
Final Test Procedures
Draft Systems List
High Level Draft Arch Diag
F.1.3
Define Evaluation Criteria
Systems List, Project Schedule, HW/SW List, Eval Plan, and Metric/Grading Process
FCB Measurements
Desired Date for Test Results delivery
Customer Input - POCs
Customer Comments on Thread Arch Diags
Customer Comments on Test Thread Description
Comments on Metrics and Grading Process
Metrics and Grading Process
Draft Test Plan
F.1.4
Ensure Evaluation Readiness
Customer Reviews
Final Test Plan
Candidate C4I System Planning Team

POW-ER


Elicit_H&S 1-5
1.1.2
1.1.3
1.1.4
1.1.5
Meeting1
1.1.1
Elicit_TS 1
Elicit_TS 2-5
1.2.2
1.2.3
1.2.4
1.2.5
1.2.1
Elicit_FT 1
Elicit_FT 2
Elicit_FT 3
Elicit_FT 4
Elicit_FT 5
Elicit_FT 6
Elicit_FT 7
1.3.1
1.3.3
1.3.5
1.3.6
1.3.7
Start
Stage 1 Complete
Stage 2 Complete
Finish
1.3.2
1.3.4
Elicit_DDC 1
Elicit_DDC 2
Elicit_DDC 3
Elicit_DDC 4
Elicit_DDC 5
Elicit_DDC 6
1.4.1
1.4.2
1.4.4
1.4.5
1.4.6
1.4.3
Elicit_CC 1
Elicit_CC 2
Elicit_CC 3
Elicit_CC 4
Elicit_CC 5
1.5.1
1.5.2
1.5.3
1.5.4
1.5.5

Arena


Baseline Planning Process Model
To validate this model with real-world Man hours, use 19 Systems, 4 New Capabilities, and 10 Old Capabilities
Output needs to be within 5% of: 6,482 TotalTime in Man hours
Begin Baseline Planning Process
Elicit Requirements
00:00:00
Total Time for Elicit Requirements
Create an Evaluation Plan
Total Time for Eval Plan Creation
Create a Test Plan and Test Procedures
Total Time for Create Test Plan and Test Procedures
End Baseline Planning Process
Create an Evaluation Plan Submodel
Test Thread Architecture Diagrams
Test Thread Narratives
Create a Metrics and Grading Process
Create an Evaluation Plan

Conclusions

- JTEM CTM "wins"
  - Highest score, but . . .
  - . . . not by much
- JTEM CTM cost
  - High development: $3.5M vs $2.3M
  - Lowest O&S: $121,000/year