

Quantifying Uncertainty for Early Lifecycle Cost Estimation (QUELCE)

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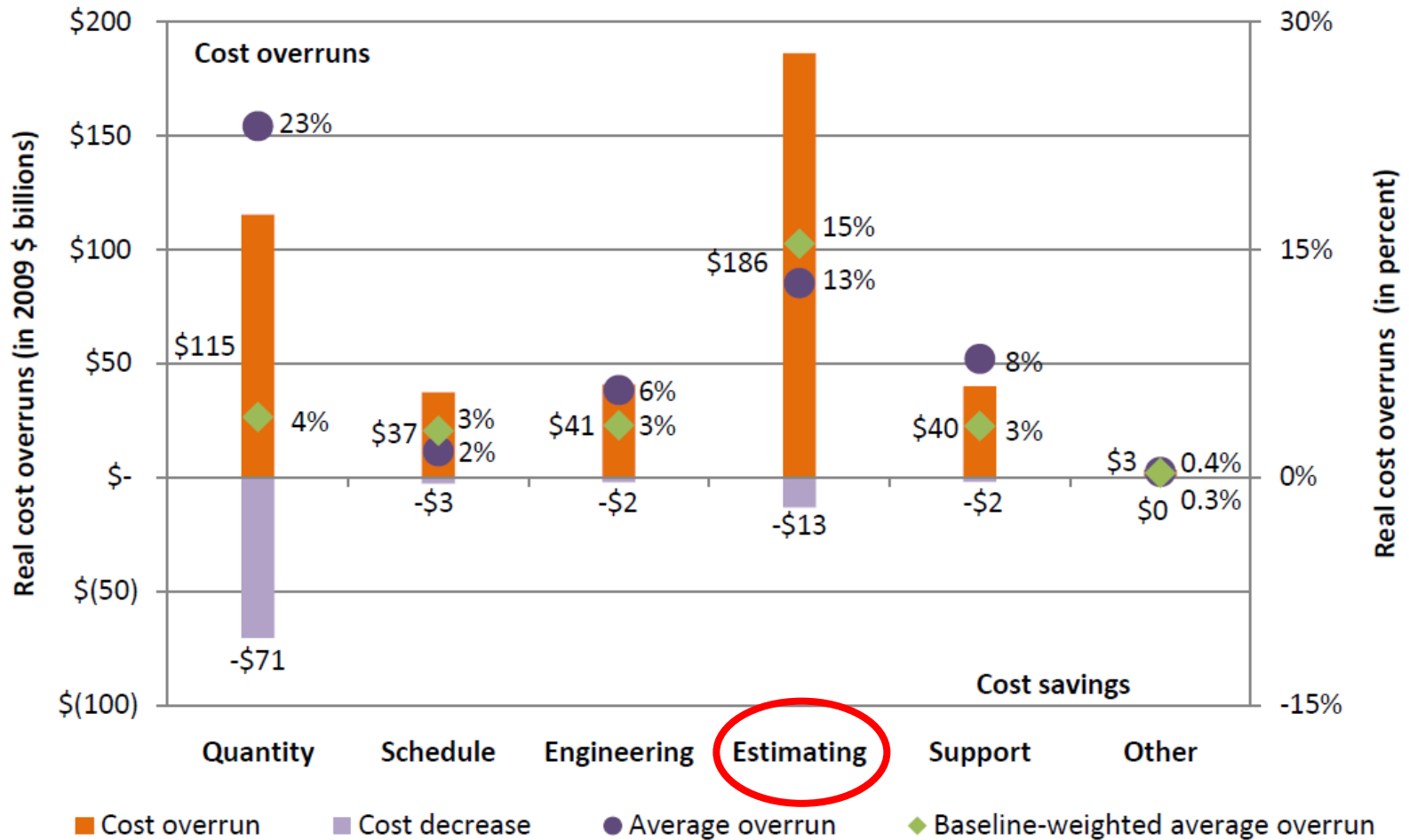
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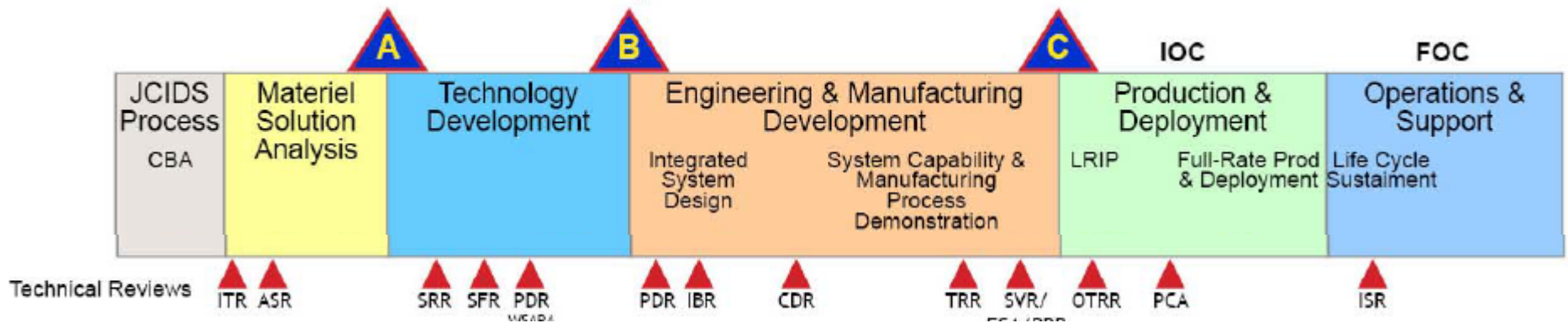
Problem: DoD Program Cost Overruns



Source: December 2009 SAR; analysis by CSIS Defense-Industrial Initiatives Group
Cost and Time Overruns for Major Defense Acquisition Programs, 2010

Technical Challenge: Early Lifecycle Cost Estimation

Weapon Systems Acquisition Reform Act of 2009 -
Public Law 111-23 **Requires Pre-Milestone A Cost
Estimates with Confidence Level**



Challenges:

- 1) Mismatch between available information and inputs to existing Cost Estimation Relationships (CERs),
- 2) Lack of transparency into assumptions and constraints using analogies



Adding Transparency to Cost Estimates

Constraints

- Cost, Schedule
- Resource limits
- Other

Directives

- policy, publication...

QUELCE uses Scenario Planning Workshop techniques to discover unrecorded assumptions and constraints

Scoping

- Deliverables
- Requirements
- Complexity
- Lifecycle

Estimating

Estimate

- Size, defects, costs, duration, staffing
- Documented inputs, assumptions
- Estimating method
- Comparable projects
- Sensitivity analysis

Resources

- Skilled people
- Tools, methods
- Organization



New 2015 Cost Challenge: Incorporating Capability Tradeoffs

DoD recommends the Use of Multi-Attribute Decision Model (MADM)

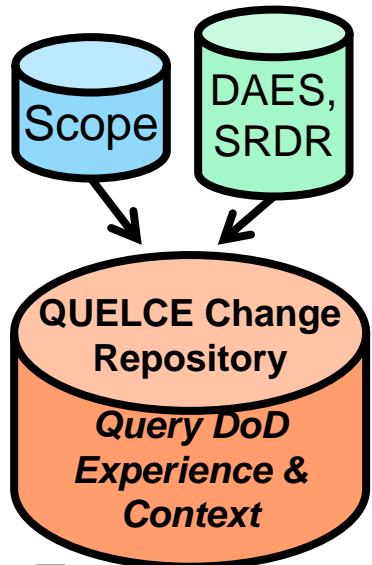
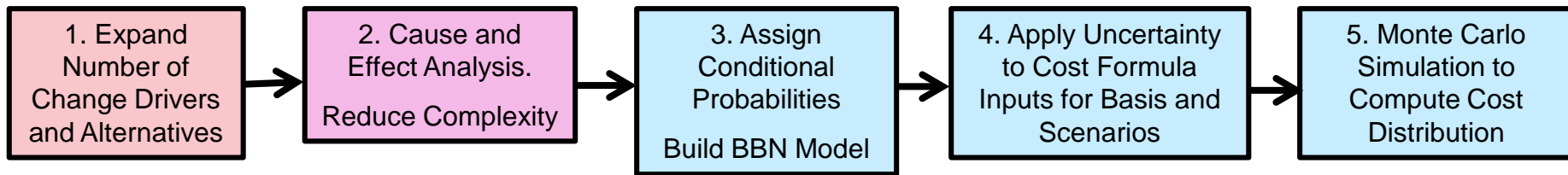
“...use the knowledge of capability trade-offs to determine where a small trade in capability (e.g., top speed of an aircraft) could be adjusted for large cost savings.”

Cost Capability Analysis, by Frank Delsing, Defense AT&L:
September–October 2015, p12

***QUELCE more richly supports this challenge using
scenario analysis within the Bayesian Belief
Network (BBN) probabilistic model***



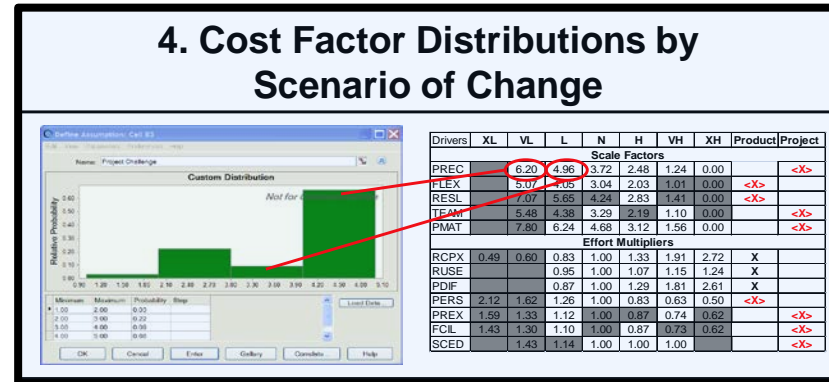
The QUELCE Solution



2. Dependency Structure Matrix

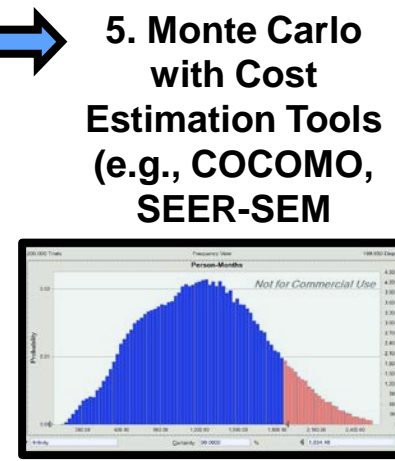
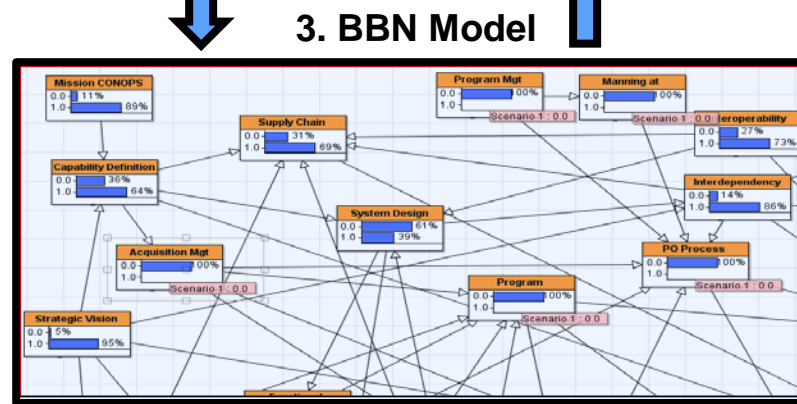
Change Drivers - Cause & Effects Matrix

Effects	Mission / CONOPS	Change in Strategic Vision Capability Definition	Advocacy Change	Lossing Technical Gaps (CBA)	Building Technical Capability & Capacity (CBA)	Systems Design Interdependency	Functional Measures	Scope Definition	Functional Solution Change (measure)	Funding Schedule	Acquisition Management	Program Mgt - Contractor Relations	Project Social / Dev Env	Prog Mgt Structure
Mission / CONOPS	1													
Change in Strategic Vision	3	1												
Capability Definition	3	3	1											
Advocacy Change			1											
Lossing Technical Gaps (CBA)			2	1	3	1	1	2						
Building Technical Capability & Capacity (CBA)			2	2	2	1	1	1	2					
Systems Design			1	2	2	2	2	2						
Functional Measures						2	2	2						
Scope Definition									1					
Functional Solution Change (measure)									1	1				
Funding Schedule										1	1			
Acquisition Management											1	1		
Program Mgt - Contractor Relations												1	1	
Project Social / Dev Env													1	1
Prog Mgt Structure														1

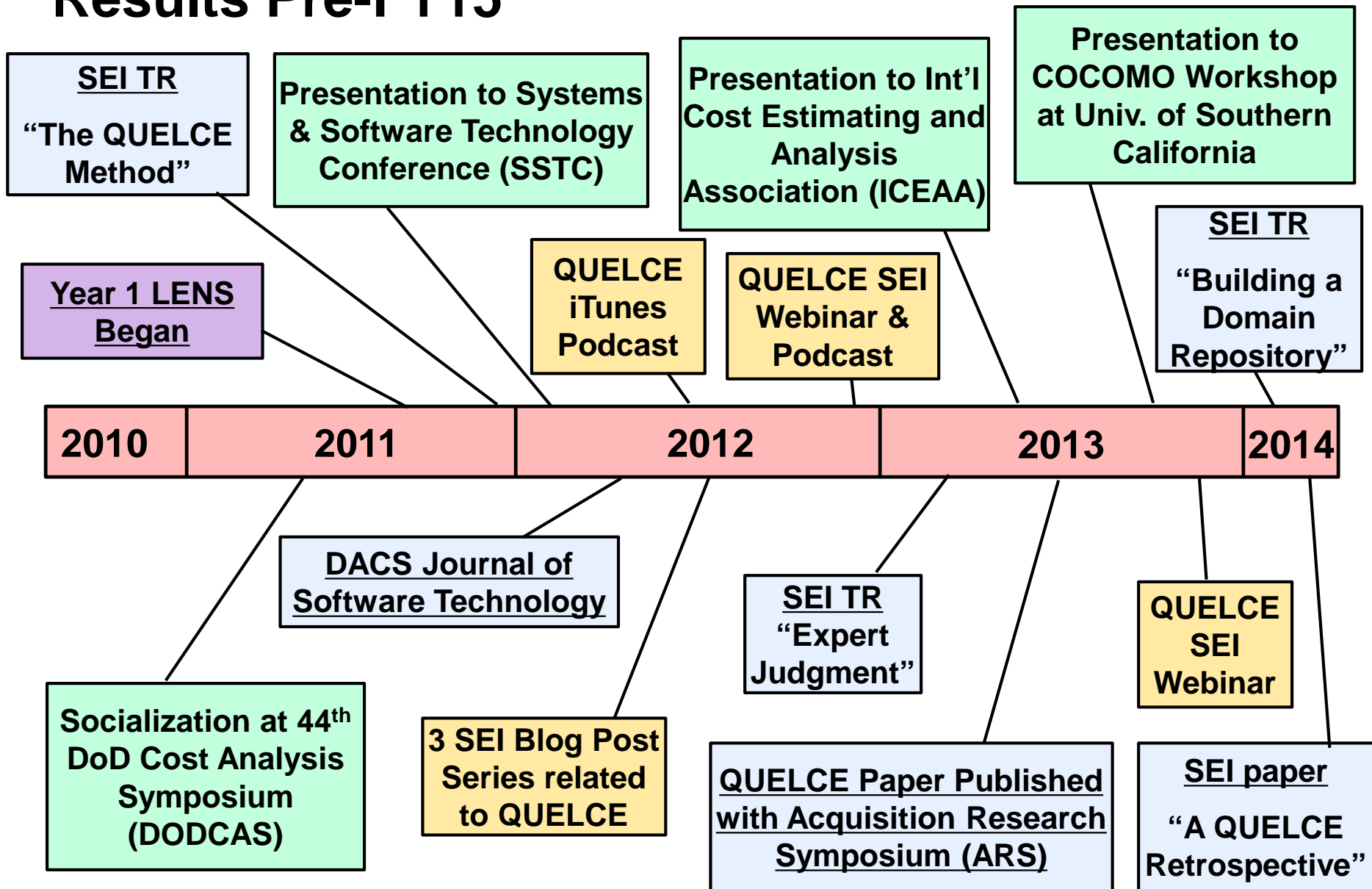


1. Driver State Matrix

Change Driver	Current State	Alternative States
Scope Definition	State: None added	Alternative States: None added, None added (reduced), None added (reduced)
Mission / CONOPS	State: Defined	Alternative States: None added, None added
Capability Definition	State: None	Alternative States: None added, None added
Funding Schedule	State: Established	Alternative States: None added, None added
Advocacy Change	State: State service program	Alternative States: None added, None added
Change Technical Goal (CBA)	State: Selected Trade	Alternative States: None added, None added



Results Pre-FY15



FY15 Results and Accomplishments

Identification of New Change Drivers

- Confirmed expert reproducibility (coding change drivers in artifacts)
- Expanded taxonomy with sustainment/modernization change drivers

DoD and Defense Contractor Use

Machine learning to automatically recognize change drivers

- Created Coding Tool to create training data sets
- Implementing Natural Language Processing and Machine Learning Recognition of “Change Drivers”

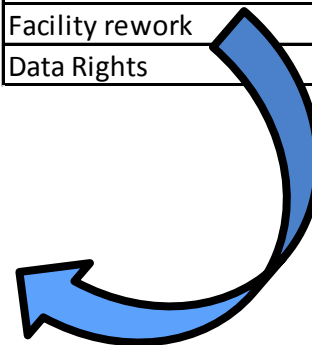
Group expert judgment experiments

- Will be quantifying benefit of calibrated group judgment over individual judgment
- Will inform modeling of judgment uncertainty and affects deployment

Identification of New Change Drivers

A	Acquisition Environment
A.1	Acquisition Category (ACAT) Status
A.2	Governance, Policies, and Standards
A.3	External Interdependencies / Coordination
A.4	External Stakeholders
A.5	External Events
A.6	Other: Acquisition Environment
B	Acquisition Management
B.1	Acquisition Strategy
B.2	Contracting
B.3	Management Structure
B.4	Program Scope
B.5	Budget
B.6	Schedule
B.7	Staffing
B.8	Facilities, Support Technology, and Equipment
B.9	Program Information Management
B.10	Program-Contractor Performance
B.11	Other: Acquisition Management
C	Engineering Solution / Work Products
C.1	Conceptual Design / Requirements
C.2	System Architecture and Design
C.3	Production and Construction
C.4	Certification and Accreditation
C.5	Deployment, Operations, and Support
C.6	Technology Maturity / Readiness
C.7	Estimated Complexity / Difficulty
C.8	Supply Chain Products
C.9	Other: Engineering Solution / Work Products

Sample of Additional Sustainment/Modernization Change Drivers
Knowledge Transfer During Handoff from Contractor to DoD Organic
Relationships among the variety of sustainment stakeholders
Information assurance/cybersecurity surprises require redesign of HW/SW
Redesign needed to evolving requirements
Administrative and organizational aspects of the evolving security situation
Engineering Information Assurance and Cybersecurity Design
Contracting difficulties
Color of money during sustainment/modernization
Adaptive Maintenance
Perfective Maintenance
Corrective Maintenance
Staff recruitment and retention
Disparate commercial tools
Facility rework
Data Rights



Approximately 20 additional drivers for sustainment projects

Reproducibility experiments yielded reasonable Kappa agreement scores 0.6 – 0.75



DoD and Defense Contractor Use

DoD Space and Missile Command program

1. Identified 47 applicable change drivers, majority of which were not documented in a previous cost estimate supplied to CAPE
2. Dramatic learning curve in expert judgment calibration across 6 key experts
3. Positive verbal and written feedback from program

Commercial Defense Contractor program

1. Primarily valued the expert judgment calibration training and improvement
2. Praised value of the change driver and scenario discussion and SEI dependency structure matrix (DSM) tool
3. Using QUELCE for a major program bid (Oct-Dec) with initial feedback:

“...qualitatively seen a difference in our product owners' understanding and thought process associated with estimation...”

Machine Learning: Highlight Annotation Tool (Tool updates occurring in October)

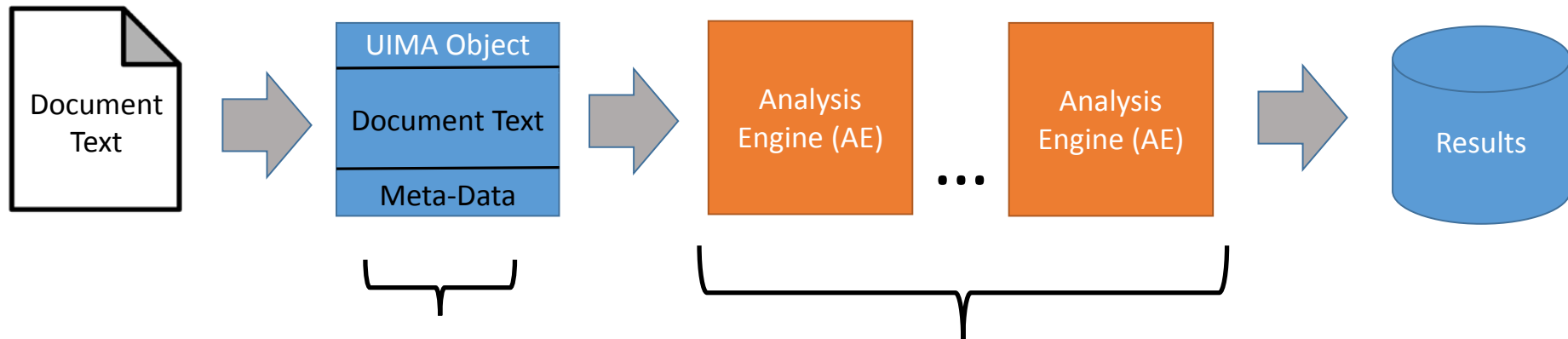


Replacing commercial proof of concept tool with customized, free tool for future use by SEI and clients to code artifacts against a taxonomy

Will expand community contributions to the QUELCE repository producing a “living” profile of change driver frequency by program type/context

Experts to query repository during QUELCE workshops to inform judgment

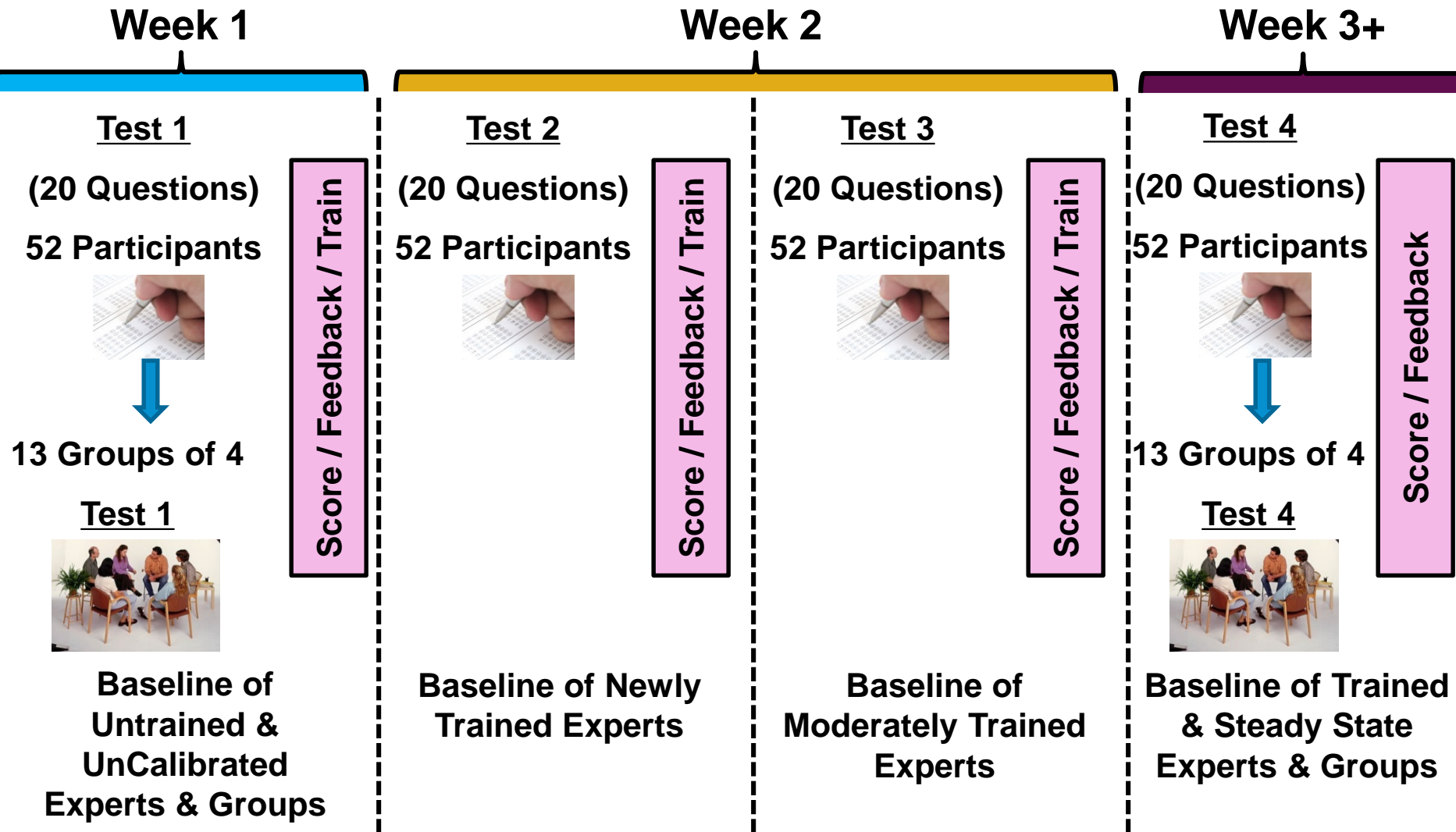
Machine Learning: Unstructured Information Management Architecture (UIMA) (Thru December)



Documents are represented in a generic UIMA format that can be consumed by existing tooling. Contains original text and metadata.

There can be one to many AEs.
Each AE processes the document text or meta data and enhances the meta data.
AEs are loosely coupled and can be added or removed without major code changes
Leverages CMU Watson techniques!

Group Expert Judgment Experiments (October – December)



Future Deployment Steps

Complete transition artifacts

- Process aids, checklists, online training, automation templates and custom tools

Establish a community of practice

- Integrate into DoD cost community at DoD and Service Level
- Integrate into DAU curriculum
- Host evolving QUELCE repository with community contributions

Engage with cost estimation tool vendors

- Arrange for seamless QUELCE automated front-end plug-and-play to existing tools

Deploy stand-alone on-line training and testing for calibration of expert judgment

Integrate QUELCE with Security Engineering Risk Analysis (SERA)

Summary

Novel Solution:

1. Scenario planning workshop techniques
2. Calibrated expert judgment
3. Sources of uncertainty in program execution
4. Modeled within a Bayesian Belief Network (BBN)
5. Connects to the input side of existing Cost Estimating Relationships (CERs) using Monte Carlo simulation

Impact:

1. Additional change drivers informed the next DoD program estimate
2. Change driver taxonomy and BBN supported Contractor scenarios
3. Validation highlighted direct primary benefits of calibrating expert judgment



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