Cost and Risk Considerations for Test and Evaluation of Unmanned and Autonomous Systems of Systems

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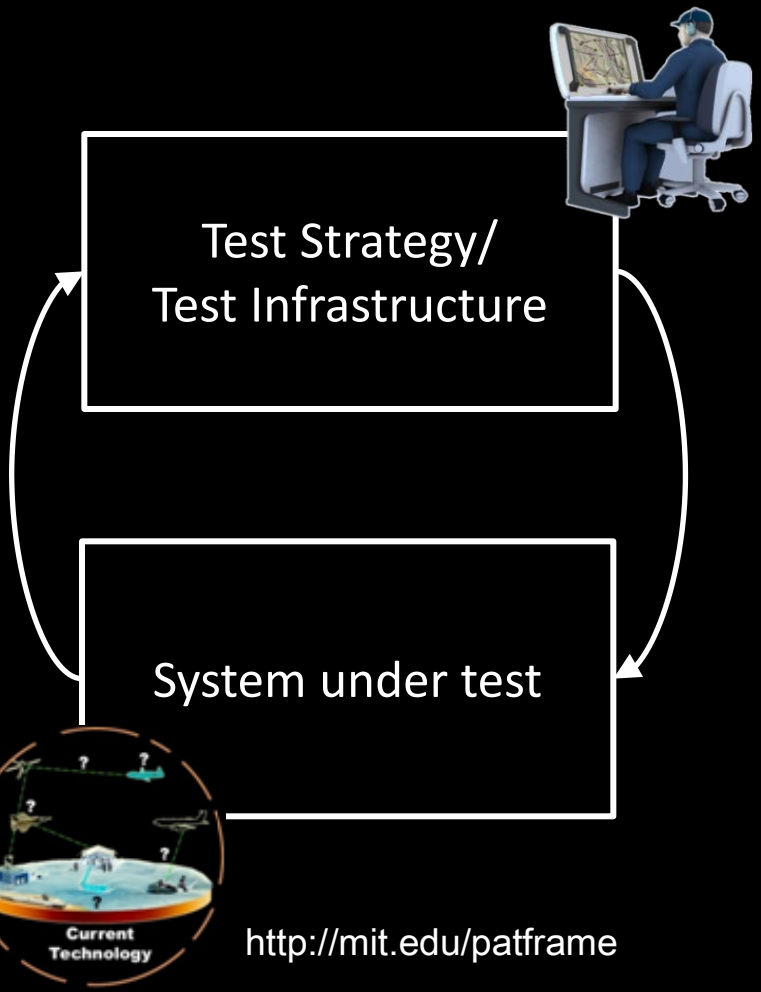
The Challenge

What is a UAS? Why UAS? Why UASoS?

The evolutionary nature of Unmanned and Autonomous Systems of Systems (UASoS) acquisition needs to be matched by evolutionary test capabilities yet to be developed.

Singer, P. W., *Wired For War: The Robotics Revolution and Conflict in the 21st Century* (Penguin, 2009)

The Prescriptive and Adaptive Testing Framework (PATFrame)

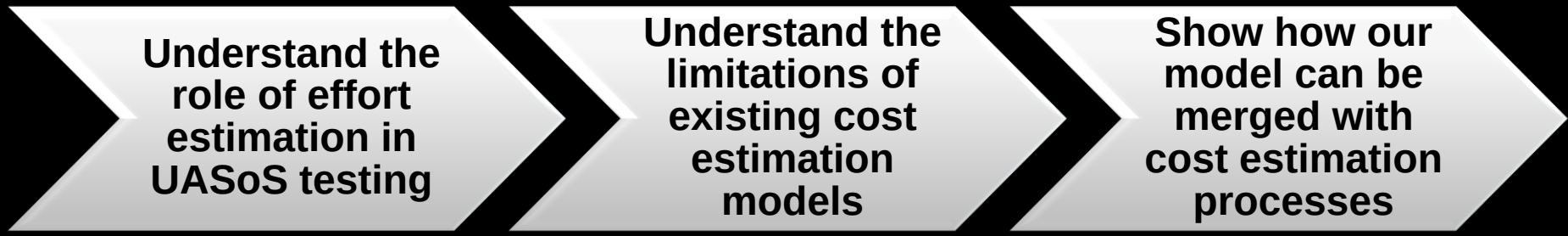


http://mit.edu/patframe

Why focus on testing?

- Need for T&E processes to recognize levels of effectiveness
- Need to focus on the interactions between components and emergent behaviors
- Need to move away from boundaries between DT and OT
- Need ability to make effective contingency plans as requirements change

Three main objectives



The need for effort estimation of UASoS testing

- There comes a point when effort invested does not reduce risk at a justifiable rate
- Emergent properties especially when UASoS fielded for the first time drive up costs
- Current projects are based on similar past projects and extrapolations that do not account for other risks
- Produce strategic options and guidance to improve confidence and ability to prioritize
- Avoid unreliable estimates and unfavorable system performance
- Finding problems before delivery is much cheaper and less time consuming

Data Sources

Literature Review	• Existing DoD procedures on testing • Cost modeling techniques • Risks and costs of UASoS
Interviews	• Program managers, researchers, subject matter experts, DoD personnel • Risks identification and Resource estimation
Surveys	• Gather cost driver data from subject matter experts
Case Studies	• Quantitative inputs to cost model • Validation of cost model
PATFrame Workshops	• Use these as an opportunity for interviews and feedback

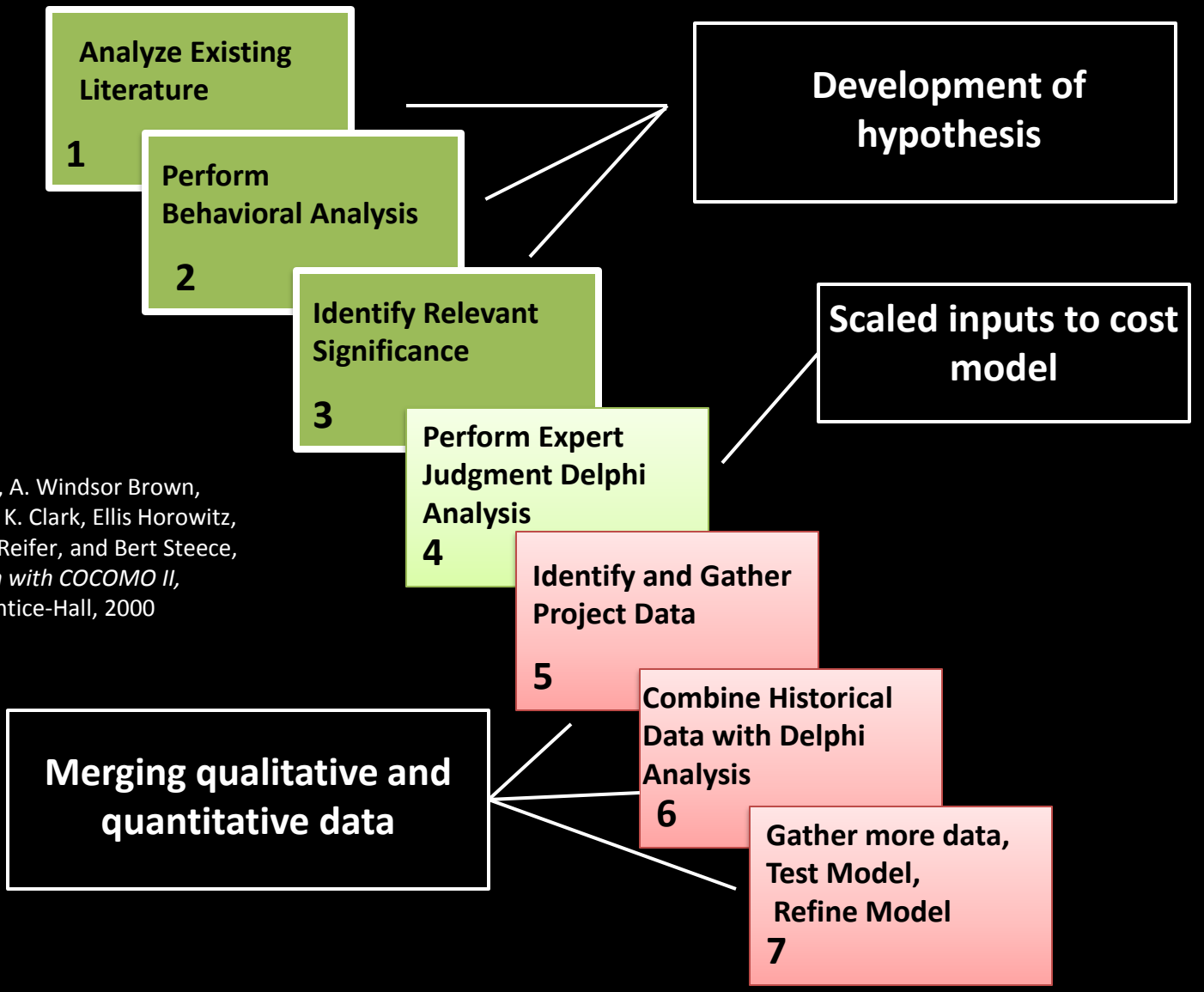
Existing Cost Modeling Approaches (1)

Cost Estimation Method	Focus	Limitations
COSYSMO Constructive Systems Engineering Cost Model (Valerdi, 2008)	Estimate system engineering effort	Only applicable at the single system level
COSOSIMO –Constructive Systems-of Systems Integration Cost Model (Lane, 2009)	Estimate the system engineering effort for development of SoS, …integration of the SoS components into the SoS framework	Does not account for flexibility and emergent behaviors of complex SoS testing
"Bridge the gap between software test processes and business value" (Li et al, 2009)	Value based testing to better align investments with project objectives and business value	1. More applicable to business critical projects rather than safety critical domains 2. Is tailored to software testing

Existing Cost Modeling Approaches (2)

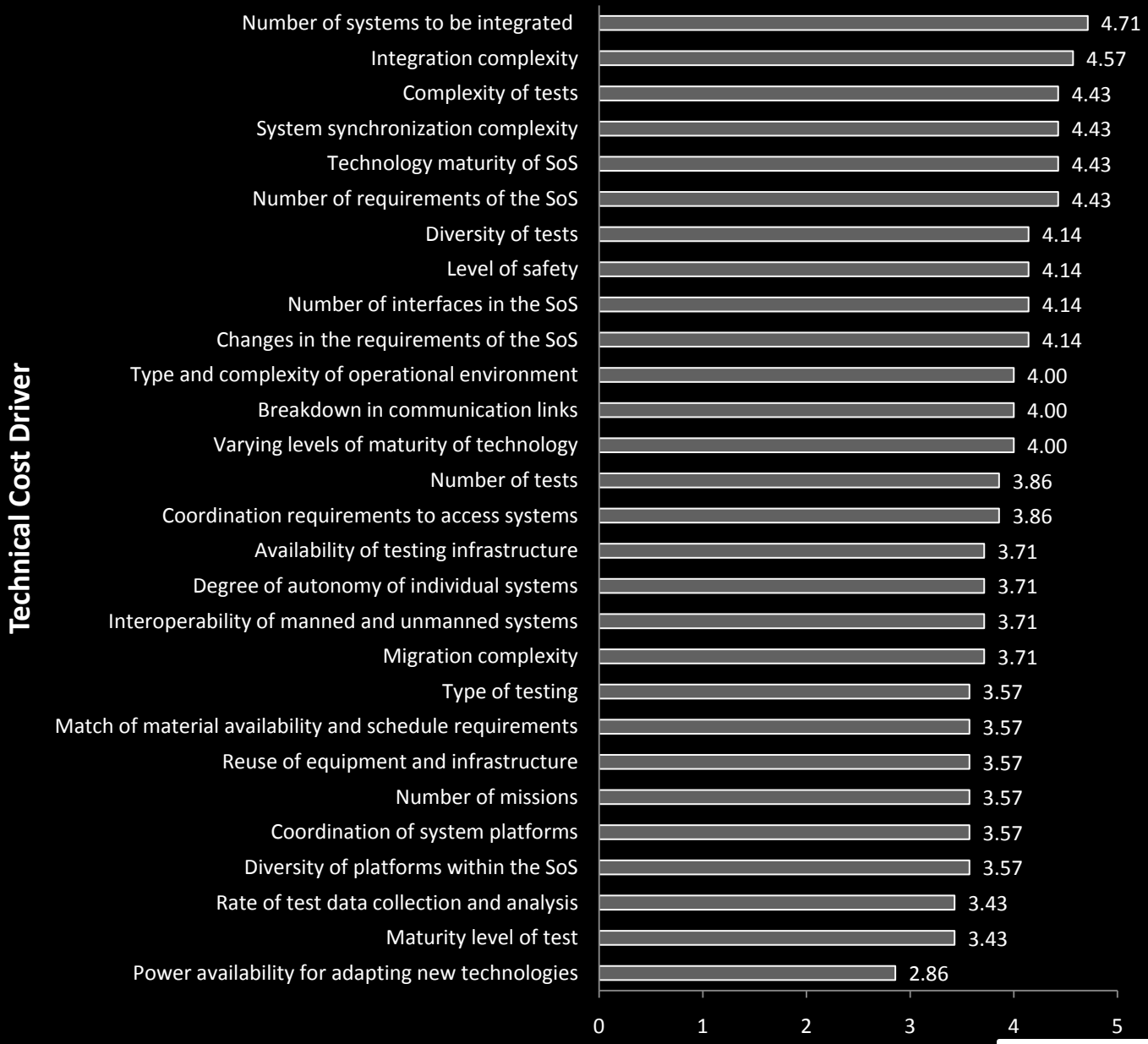
Cost Estimation Method	Focus	Limitations
"Managing your way through the integration and test black hole" (George)	Integration effort = (number of predicted defects * average time to find and fix a defect) + (number of test cases * the average time to run a test case)	1. Assumes only issue with integration testing is defects which are easy to find 2. Assumes fixing one defect does not create another
"Sizing systems test for estimating test execution effort" (Aranha and Borba, 2007)	Estimate the size of a software test which is required to determine the test execution effort	1. Assumes test size = number of steps to complete test and complexity = relationship between tester and product 2. Does not account for other cost drivers in UASoS testing

The Boehm Seven Step Modeling Methodology



Barry Boehm, Chris Abts, A. Windsor Brown, Sunita Chulani, Bradford K. Clark, Ellis Horowitz, Ray Madachy, Donald J. Reifer, and Bert Steece, *Software cost estimation with COCOMO II, Englewood Cliffs,* NJ:Prentice-Hall, 2000

Ranking of Technical Cost Drivers | n=10



Number of systems

Integration complexity

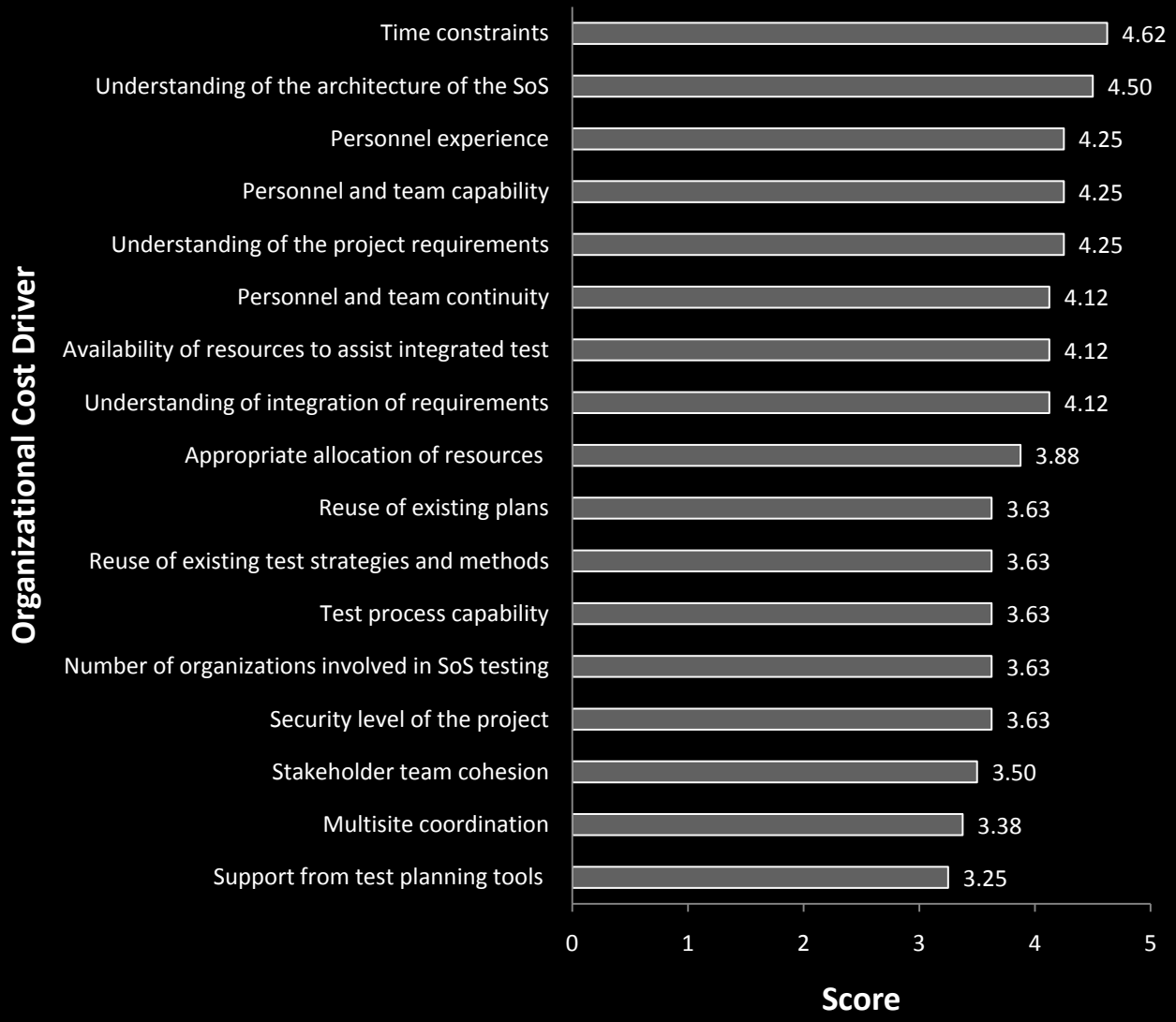
Complexity of test

Data collection rates

Maturity level of test

Power availability

Ranking of Organizational Cost Drivers | n=10



Time constraints

Architecture understanding

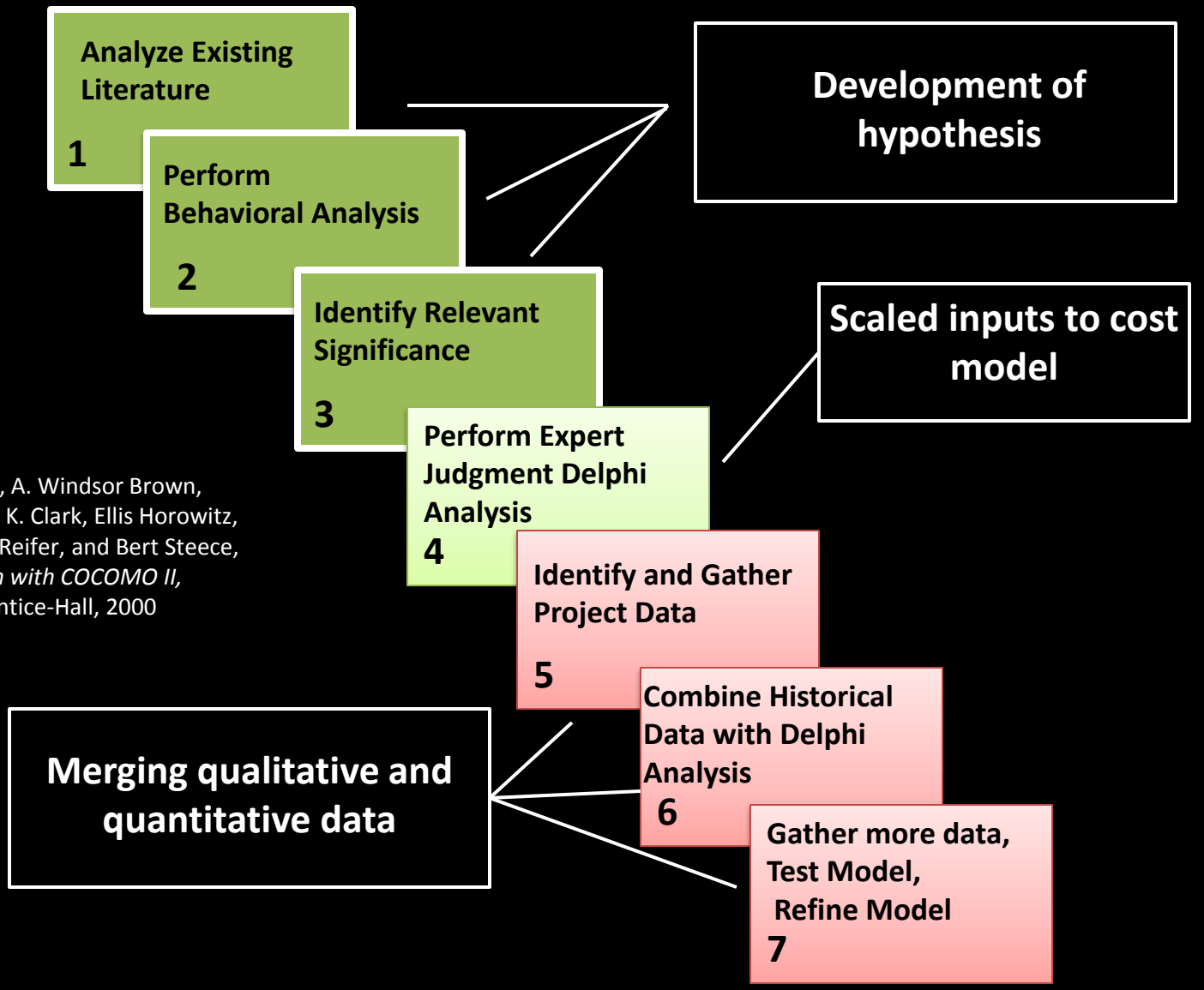
Personnel experience

Stakeholder team cohesion

Multisite coordination

Test planning tool support

The Boehm Seven Step Modeling Methodology



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Impact

- **Test and Evaluation Planners**
  - provide tradeoff analyses between costs and risk mitigation
  - provide support in day to day testing procedures
  - helps with more efficient use of time and resources
- **Program Managers**
  - better allocation of resources (time and money) based on cost estimates
  - better coordination of multiple programs
- **DoD Policy Makers**
  - give evidence of budgeting requirements for testing projects
  - ensure adequate testing of UASoS to be used

Summary

1. **There is need for optimized testing strategies for UASoS**
   - UASoS are in more demand in the DoD
   - The advances in the technology need to be matched by advances in testing capabilities

2. **Provide program managers, test conductors, and policy makers**
   - An integrated decision support system for testing UASoS
   - A means to predict how much effort is required to conduct a test of UASoS while minimizing risk
   - A basis to perform cost and risk tradeoffs and prescribe how tests can adapt depending on resource or schedule constraints

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Summary

- Test and Evaluation Need
  - Accelerate test planning for UASoS by supporting automation of current human-intensive (thus potentially error-prone) SoS test planning process
  - Optimize the joint mission oriented UAS T&E strategy by addressing and balancing multiple criteria
  - Predict, detect, and adapt to undesirable emergent behavior in UASoS T&E

- Science and Technology Challenge
  - Perform R&D of a multi-dimensional framework for knowledge representation across UASoS
    - R&D an ontology for key UAS SoS elements, relationships, and constraints
    - R&D critical UAS SoS design idioms and rich architectural models
    - R&D parametric UAS SoS project cost/effort models
  - Perform R&D to develop analyses and simulations across SoS models
  - Develop a Decision Support System (DSS) prototype that includes the multi-dimensional framework for analysis and simulation