Some Critical Success Factors for Industrial/Academic Collaboration in Empirical Software Engineering

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EASE Project Workshop

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Outline

- Relevant (U.S.) CeBASE experiences
  - NASA High Dependability Computing Program
  - Army Future Combat Systems
- Some critical success factors
  - Incremental results
  - Sustained upper management commitment
  - CRACK participants
  - No missing links in adoption chain
  - Fully collaborative activities
  - Careful definition of data, metadata
  - Careful handling of intellectual property
- Conclusions

Relevant CeBASE Experiences
-U.S. context; may be different in Japan

- Government-sponsored collaborations
  - NASA High Dependability Computing Program
  - Army Future Combat Systems
  - NASA Software Engineering Lab
  - FAA Air Traffic Control Systems

- Direct industry collaborations
  - USC, UMD, FC-MD affiliate programs

Applied Research
NASA High Dependability Computing Program

Project Goal: Increase the NASA's ability to engineer highly dependable software systems via the development of new techniques, processes, and technologies.

Research Goal: Develop high dependability technologies and assess their effectiveness under varying conditions and transfer them into practice at NASA

Partners: CMU (PI), UMD, USC, MIT, U. Washington, 2002-2006

UMD/USC Level of Effort: $5 million over 5 years

Activities:

- Empirical investigation of NASA and NASA-contractor dependability problems
- Development of new technologies and engineering principles to address general forms of the problems
- Evaluation and iterative improvement of our results using realistic testbeds
- Model-based technology transfer which will provide the technology users with results of the effectiveness of the technology under varying conditions

HDCP Testbed Objectives

- Buy down risks of using new HDCP technologies
  - Pre-qualify new technologies in mission context
- Enable cost-effective HDCP technology integration
  - Dependability objectives vary by mission
  - Testbeds provide mission-relevant cost-effectiveness data
- Accelerate pace of HDCP technology maturity, relevance
  - Via early and accurate feedback
- Accelerate pace of technology transition
  - Usually around 18 years for software engineering technology

Accelerating Technology Maturity via Hierarchical Testbeds

- Level 1: Researcher-specific testbeds
  - Scenarios oriented around researcher's technology
- Level 2: Common, distributable, mission-representative testbeds
  - Integrating Level 1 testbeds into common framework
  - Full complement of supporting capabilities
- Level 3: On-site, off-line mission testbeds
  - Test technology on actual NASA computers and software
  - Ability to use Level 2 supporting capabilities
- Level 4: On-site, live mission platforms and software
  - Carefully prepared; real proof of the pudding

SCRover Response to HDCP Testbed Criteria - I

- Representative of NASA, NASA-related missions
  - First external application of JPL MDS technology
  - Campus public safety robot
    - Using state-based autonomous control
  - Extensive review, support by JPL MDS personnel
- Full complement of supporting capabilities (current state)
  - Specs and code (UML, C++ baseline, xADL extension)
  - Mission scenario generations (MDS GEL-based)
  - Instrumentation (xADL/Mae assertion checks)
  - Tracers (seeded defects based on SCRover development)
  - Data analysis tools (xADL/Mae)
  - Experimental guidelines (FC-MD guidelines)

Defect Seeding

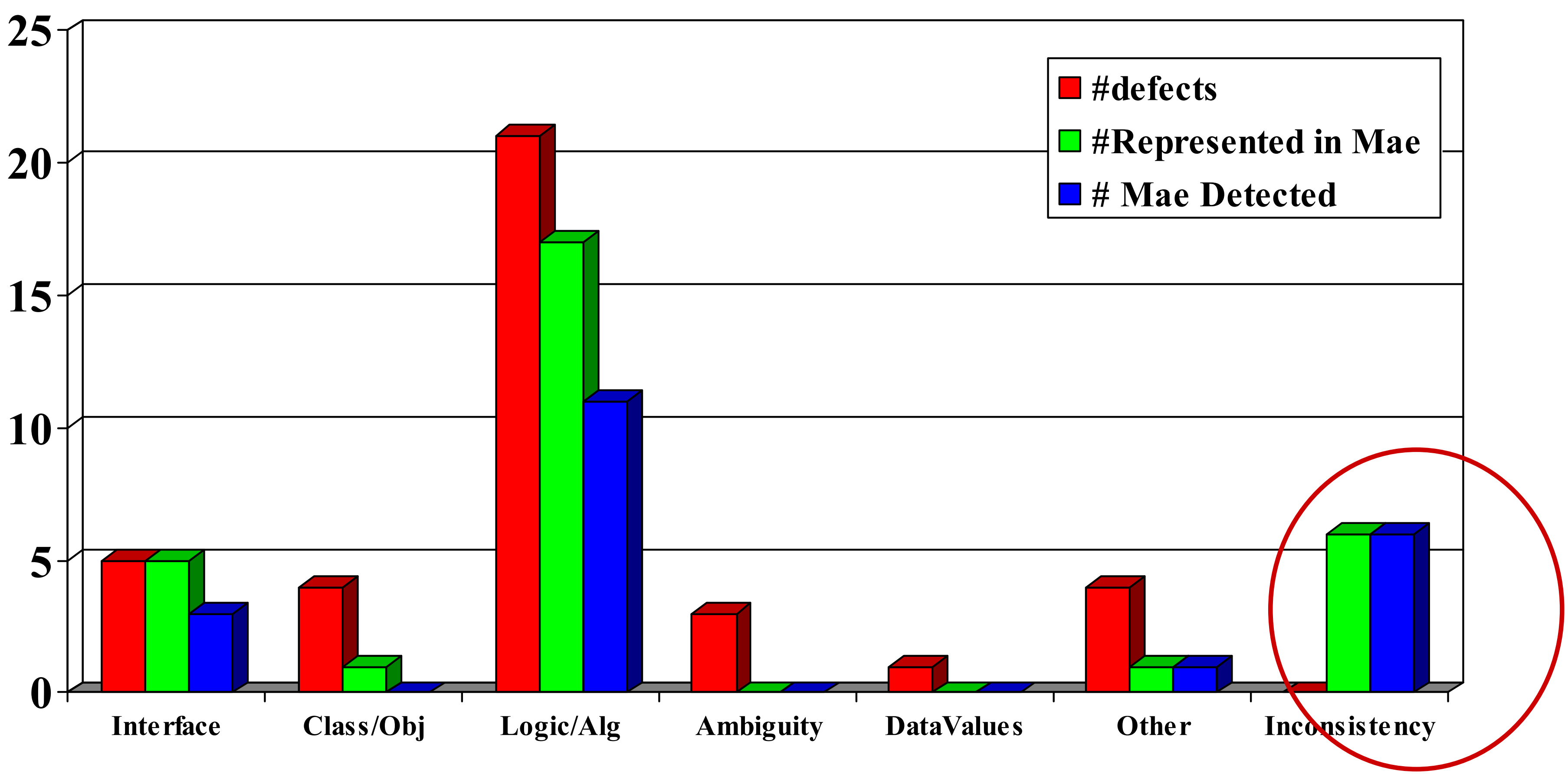
- Suppose HDCP technology finds 3 defects
  - Is this 100% of 3 defects, or 3% of 100 defects?
- Defect seeding
  - Seed testbed software with 10 defects
  - Suppose HDCP technology finds 6 of 10 seeded defects (60%)
  - Can estimate that it found 3 of 5 unseeded defects (60%)
- Assumptions
  - Seeded defects representative of existing defects
    - SCRover: obtained from project inspections, testing
    - Can also use representative NASA defect distributions
  - Test profile representative of operational profile
    - SCRover: use representative NASA mission scenarios

Example Intervention: xADL/Mae

- Refined SCRover UML specs into xADL*
  - Analyzed consistency, behavior with Mae tools
  - Instrumented code with xADL assertions
- SCRover testbed a good match for ADL interventions
  - Straightforward UML-xADL elaboration
  - Basic testbed infrastructure in place; usable for run-time assertion checking
  - Modest level of effort: 160 person-hours over 2 months
- xADL/Mae able to find 15 of 38 known defects, 6 unknown defects
  - Defect seeding analysis, defect distributions help determine what HDC techniques to apply next
- Successful comparative test of CMU Acme ADL
  - xADL and Acme found complementary defects
  - Led to NASA/USC/CMU effort to integrate, apply ADLs

* xADL: XML-based Architecture Description Language

Mae Defect Detection Yield by Type



Applied Research: Army Future Combat Systems (FCS)

- Complex system of systems (CSOS): $4 billion for Increment 1
- CeBASE funded by FCS and OSD Software Intensive Systems
  - Third year: $1.2 million per year
- Members of SW Steering Committee and Program Office software support team
- Ensure software issues are addressed throughout the program
- Provide proactive expert consultation to the Program Office and integration contractor (Boeing)
- Collaborate with Boeing to apply risk-driven spiral model to software and system acquisition
- Capture and analyze empirical experience data to support downstream program decisions and future CSOS acquisitions

Future Combat Systems Risk Example: Limited speed of CSOS Software Development

–Many CSOS scenarios require close coupling of complex software across several systems and subsystems

–Well-calibrated software estimation models agree that there are limits to development speed in such situations

–Estimated development schedule in months for closely coupled SW with size measured in equivalent KSLOC (thousands of source lines of code):

$$\text{Months} =\sim 5 * \sqrt[3]{\text{KSLOC}}$$

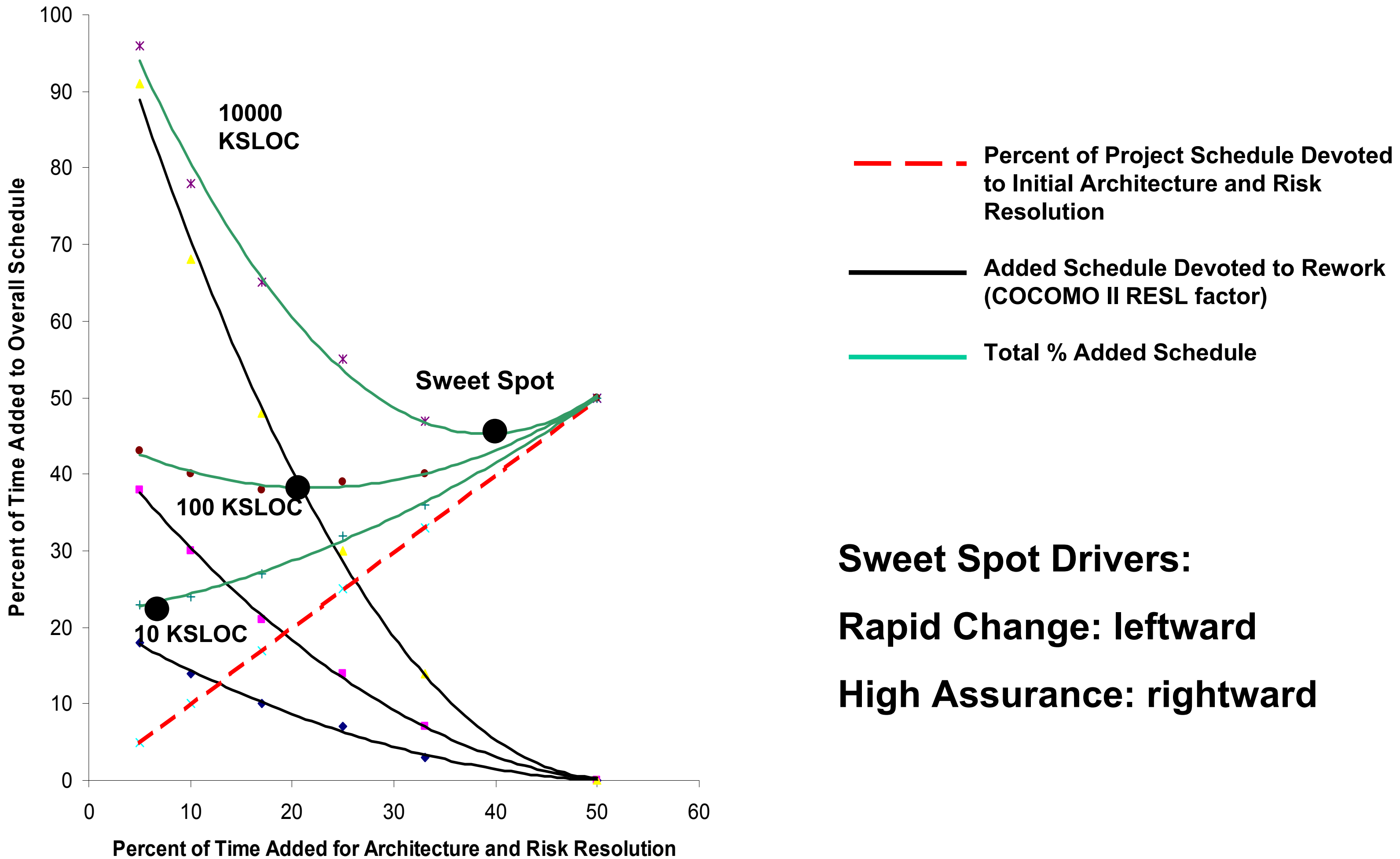
KSLOC	300	1000	3000	10,000
-Months	33	50	72	108

Strategy to meet end-of-decade target (over 10,000 KSLOC):

–Use SAIV process. Architect for parallel incremental development, rapid integration of smaller supplier components

How Much Architecting Is Enough?

-A COCOMO II Analysis



Sweet Spot Drivers:

Rapid Change: leftward

High Assurance: rightward

Future Combat Systems Risk Example:

COTS Upgrade Synchronization and Obsolescence

Risk: Many subcontractors means a proliferation of evolving COTS interfaces

Strategy: Emphasize COTS interoperability in source selection process. Establish COTS tracking system and refresh strategy.

Risk: Aggressively-bid subcontracts can lead to delivery of obsolete COTS

- New COTS released every 8-9 months (GSAW)
- COTS unsupported after 3 releases (GSAW)
- An actual delivery: 120 COTS; 46% unsupported

Strategy: Contract provisions ensuring delivery of refreshed COTS products.

CeBASE CSOS Experience Base:

Risks, Issues, Lessons Learned

- **Building lessons learned experience base to**
  - **learn from early phases of FCS**
  - **improve later phases of FCS**
  - **provide an experience base for other DoD projects**

- **Example Experience Bases**
  - **An <u>independent report of the top ten software risks</u> as identified by the Software Team**
  - **A <u>web-accessible software issue tracking system</u> that captures select program issues brought to the attention of the software steering committee**
  - **A <u>web-accessible lessons learned experience base</u> that analyzes and synthesizes the software problem areas and tracks their evolution and resolution over time**

CeBASE

USC CSE

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Upper Management Commitment

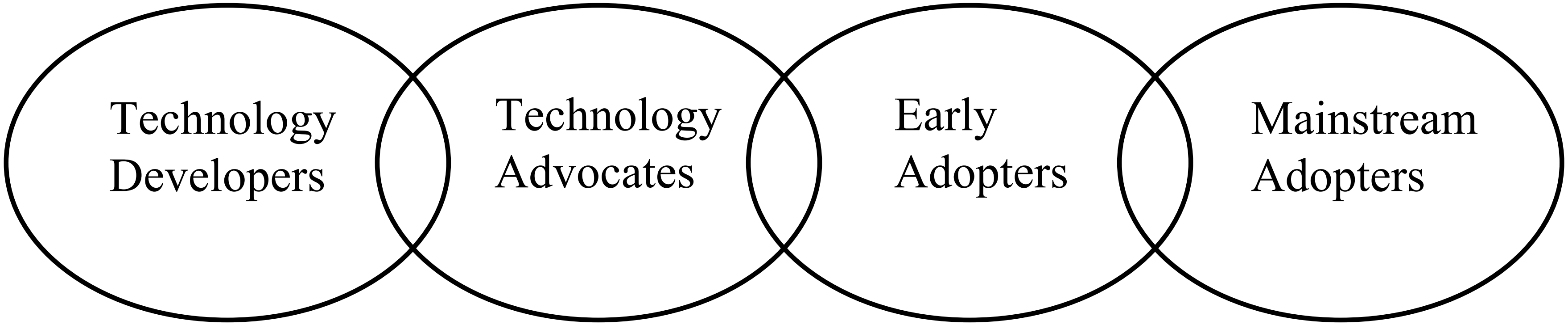
- Personal and organizational commitment
- Stable sources of funding, key personnel, data
- Participation in reviews
- Responsiveness to problem situations

CRACK Participants

- Collaborative
  - Otherwise no teamwork
- Representative
  - Otherwise poorly-matched projects
- Authorized
  - Otherwise authorization delays or misleading "commitments"
- Committed
  - Otherwise missing participation, contributions
- Knowledgeable
  - Otherwise delays, unacceptable products

To get value from the collaboration, don't send the people you won't miss. Do send your crack (expert) people.

No Missing Links in Adoption Chain



- **Avoid communication gaps**
  - **About technology, user domain knowledge**
- **Ensure rapid adaptation to change, problems**

Fully Collaborative Activities

- Some co-location; some electronic collaboration
- Coverage of all adoption-chain links
- Co-evaluation of processes, tools, methods, metrics
  - Common core with special industry extensions
- Group prioritization activities
  - Stakeholder win-win negotiations

Careful Definition of Data, Metadata

- Common core with special industry extensions
- Management-relevant data
  - But not used in performance reviews
- Low data collection overhead
  - E.g, log file interpretation

Intellectual Property

- Data protection
- Data summarization
- Tool rights
- Non-disclosure agreements
  - Don't overdo; don't underdo

Conclusions

- Some definite successes and failures
- Critical success factors explain most differences
  - Incremental results
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