SMU School of Engineering

SMU Software Intensive Systems Research Overview

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Departments in SMU School of Engineering

- ***Engineering Management, Information and Systems (EMIS)***
  - ***Systems Engineering Program (SEP)***
- ***Computer Science and Engineering (CSE)***
- Mechanical Engineering (ME)
- Electrical Engineering (EE)
- Environmental and Civil Engineering (ENCE)

SEP ACADEMIC PROGRAM

Courses

- Developed in Response to Industry & Government Needs
- Developed by SEP DT

- Core-5
- Electives-
  - Current: 16
  - In-Development: 9

Faculty

Experienced in Defense Systems Development

- Resident
- Adjunct
  - Lockheed Martin
  - Bell Helicopter
  - Raytheon
  - L3 Com
  - MITRE Corp
  - Siemens
  - Abbott Laboratories
  - Freescale Semiconductor

SEP

Programs

Customer Driven

- Non-Degree Studies in SE
- SE Certificate Series
- MS SE
- PhD SE

Delivery

- On-Campus
- Internet
- Off-Campus Exec. Format

Students

Employed full-time by A&D Sector
- U.S. Citizen
- DoD Security Clearance

- Admissions – 1000+
- Graduates MS SE – 555

SEP RESEARCH PROGRAM

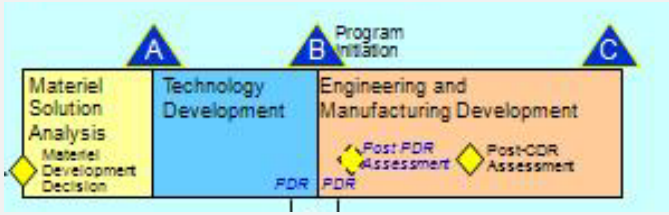
Research Projects

Defense Systems

- Modeling and Analysis of Defense Systems Development
- Technology Linkage, Selection and Transition to US Warfighter
- Systems Requirements Engineering and Integrated Verification &Validation
- Defense Systems Design and Development

Research Focus

Defense Systems



Funded Research

- US Navy SPAWAR
- DoD DAU
- Lockheed Martin

SEP

Research Areas

PhD SE Students

Selected

- Complex System Design "Management Flight Simulator" Development
- Methodology for Optimizing Verification, Test and Evaluation Complex System Development
- Methodology for Measuring SoS Development Performance
- Methodology for Analysis of Technology Alternatives

Students

PhD SE and AS

- 30 Students
  - 2 Full-Time
  - 28 Part-Time
    - Lockheed Martin
    - U.S. Navy SPAWAR
    - Boeing
    - Raytheon
- 20 Applicants in Queue

SMU SEP ORIGIN AND DEVELOPMENT

1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009

SMU School of Engineering

- Admit Students & Approve Degree Plans
- Deliver SE Courses
- Direct and Administer SEP
- Deliver SE Courses
- Advise PhD students

ad hoc Systems Engineering Council

- Idea
- SEP Concept Development
- SEP Proposal
- SMU
  TTU
  UTA
  UTD
- SMU Proposal

SEP Development Team

- Develop SE Courses
- Promote SEP
- Identify & Select Adjunct Faculty

Industry and Government Volunteers

- Promote SEP
- Identify & Capture Needs
- Develop SE Courses
- Develop Proposals
- Identify & Select Adjunct Faculty

SMU | BOBBY B. LYLE SCHOOL OF ENGINEERING
EMIS - SYSTEMS ENGINEERING PROGRAM

SEP DEVELOPMENT

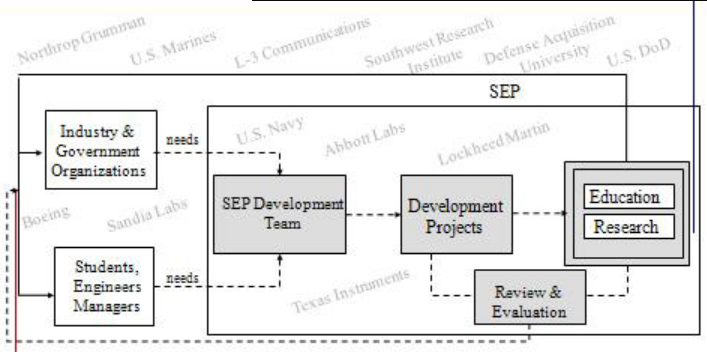
SEP Development Team Membership

Current DT

Organization	Location
Abbott Laboratories	Irving, TX
Abbott Laboratories	Chicago, IL
Aerospace Quality Research and Development	Dallas, TX
Agilecast	Irving, TX
BAE Systems - Electronic Warfare	Merrimack, NH
Bell Helicopter	Hurst, TX
Boeing Aerospace Support Division	Ft. Walton, FL
California Edison	Rosemead, CA
CBI	Dallas, TX
Diversified Technology, Inc	Ridgeland, MS
Eaton Aerospace	Fort,Worth, TX
Eaton Aerospace	Jackson, MI
Elbit Systems	Ft Worth, TX
Freescale Semiconductor	Ausin, TX
Hewlett Packard	Plano, TX
iWave Software, LLC	Frisco, TX
JaCo Systems	Dallas, TX
L-3 Communications Integrated Systems	Greenville, TX
L-3, Communications Link	Arlington, TX
Lockheed Martin Aeronautics Company	Ft Worth, TX
Lockheed Martin Missiles & Fire Control	Grand Prairie, TX
MAGNACOM, Inc.	Huntsville, TX
Mitre Corp.	Mclean, VA
NASA Johnson Space Center	Houston, TX
NASA Marshall	Huntsville, AL
Raytheon Space & Airborne System	Plano, TX
Raytheon - Network Centric Systems	McKinney, TX
Raytheon Integrated Defense Systems	Andover, MA
Raytheon Intelligence & Information Systems	Garland, TX
Raytheon Space and Airborne Systems	Dallas,TX
Sandia National Labs	Albuquerque, NM
Siemens Automation	Richardson, TX
Siemens Government Services	Richardson, TX
Spirit Aero	Whichita, KS
Statistical Design Institute	McKinney, TX
Strategic Thought Group	Fort Worth, TX
Systems Design, LLC	Acton, Ma
Texas Instruments	Dallas, TX
Translog International	Bristow, VA
U.S. Army Info Systems Engineering Com	Ft. Huachuca, VA
U.S. Navy Naval Air Systems Command	China Lake, CA
U.S. Navy SPAWAR Systems Center	Charleston, SC
U.S. Navy SPAWAR System Center	San Diego, CA
US Navy JTRS	San Diego, CA
Vought Aircraft Industries	Irving, TX

SEP Development Process

Development Model
Industry-Government-Student Partnership

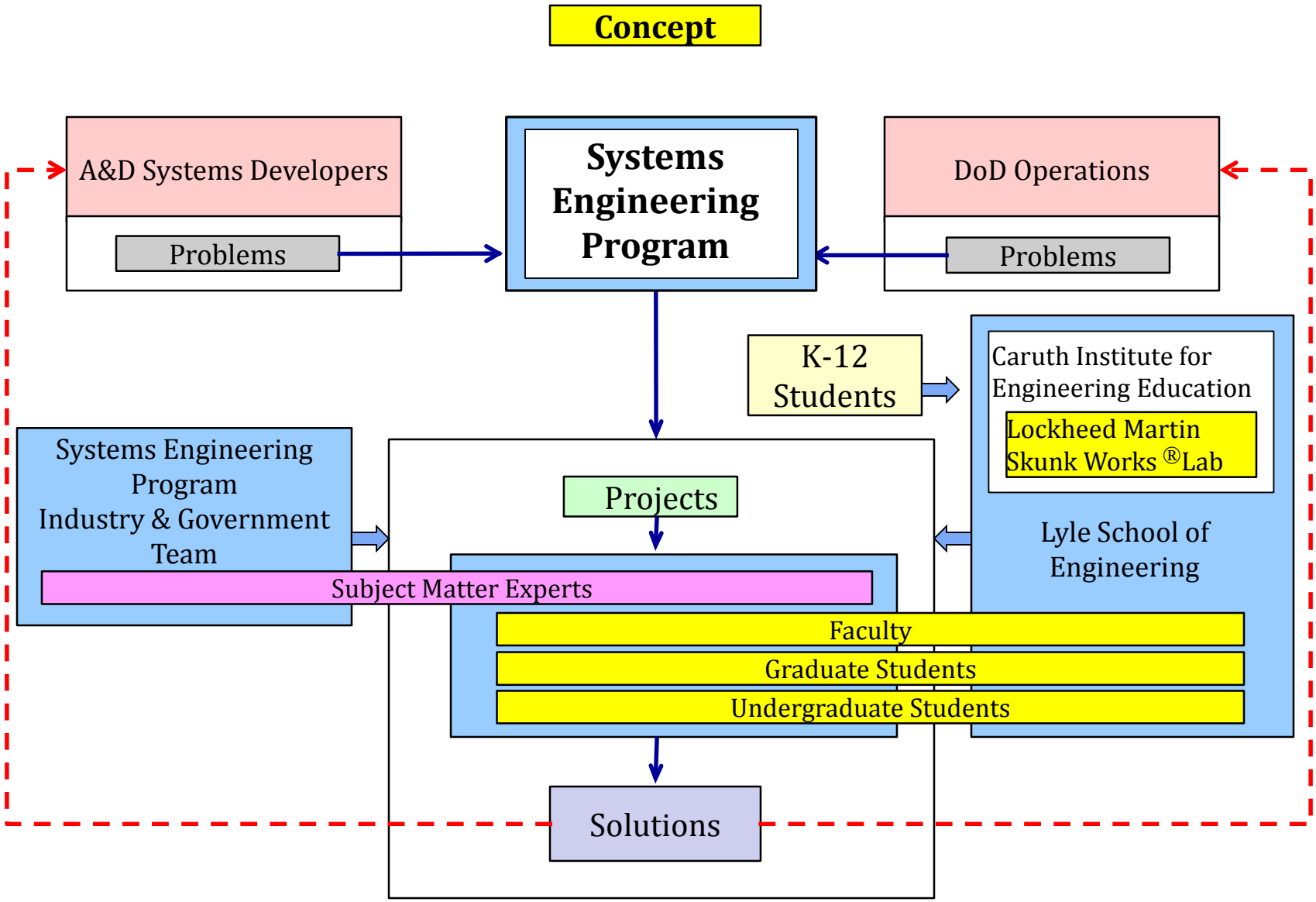


SEP Development Projects

Customer-Driven

- PhD SE Start Up
- MS SE Rev4
- New SE Courses
- Defense Systems Developer Needs-Driven Curriculum Review w/INCOSE North Texas Chapter
- Systems Design and Integration Track

FRAMEWORK FOR RESPONSE TO DEFENSE CONTRACTORS AND DOD OPERATIONS PROBLEMS



SEP SUMMARY

The SMU Systems Engineering Program was conceived (1991) and has been developed and administered in response to Dallas/Ft Worth region aerospace and defense systems developers, with focus on:

- U.S. AT&L/defense contractor workforce improvement by offering SE courses developed, delivered by defense industry subject matter experts

- Research conducted by SMU faculty, PhD students and SEP DT volunteers in response to defense systems developers priority needs in selected areas

Utilize SMU faculty* (resident and adjunct), DT members* and PhD SE students* with extensive experience (multiple company) on diverse U.S. defense development programs

Aircraft Programs

•F-35	• F-16	• A-12 +ATA	• B-2	• C-17	• S-3
•F-22 + ATF	• F-8	• A-10	• B-1	• C-130	• V-22
•F/A-18	• A/FX	• A-7	• B-52		

Advanced Classified Programs – Sensor Programs – Missile Programs

* Most hold active DoD security clearance

PROPOSED SERC RESEARCH PROJECT

DEFENSE SYSTEMS REQUIREMENTS ENGINEERING AND V&V

Phase 1 – Develop Top-Tier Guide for Engineering Requirements for Defense Systems and Integrated Validation & Verification of Requirements

Background

Defense Systems development program success begin with "right" requirements – LC-balanced, compatible, consistent, prioritized – depends on development cycle integrated V&V

Approach

- Utilize D/FW region defense contractor working groups using the SMU SEP DT to document current practice and capture prioritized needs
- Conduct literature and DoD/Industry survey of relevant guidance and methodologies

Objectives

- Purpose/Objectives
  - To provide a unified guide for defense systems developers
  - Reduce costs by integrated Modeling, Analysis and Simulation to more effectively utilize data and reduce testing
  - Improve AT&L Workforce through capture of experience and practice from retiring component of workforce
- Benefits
  - To reduce testing for systems requirements V&V
  - To reduce costs

Sponsors and Collaborators

- Sponsors
  - Dallas/Ft Worth region defense contractors
- Funding
  - $ TBD for 2 years – Phase 1
- Collaborators
  - SMU : Jerrell Stracener
  - Texas A&M University : Abhijit Deshmukh
  - Texas Tech University : David A. Wyrick

Note: Currently an unfunded SMU SEP Research Project

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Research in Software Intensive Systems

Dr. Jeff Tian, Dr. LiGuo Huang, Dr. Delores Etter

- **Software Verification & Validation, Risk Management and Dependability Improvement**
  - *Risk identification and management through systematic defect classification and analysis*
  - *Usage-based statistical testing to focus on high-usage/high-leverage operations and components*
  - *Integrated data analysis and reliability modeling*
  - *Evolvable risk reduction experience bases*
- **Applications:** Commercial, telecommunications, aerospace, web-based, e/web-service, and embedded systems
- **Focus:** Systematic, risk-based dependability improvement

Research in Software Intensive Systems

Dr. Jeff Tian, Dr. LiGuo Huang, Dr. Delores Etter

- **Complete Life-cycle Cost/Schedule/Quality Engineering**
  - *Integrated process and product measurements*
  - *Predictive cost/schedule/quality modeling and economic analysis*
  - *Value-based software quality engineering through stakeholder collaboration*
  - *Stakeholder-oriented hybrid process modeling & simulation*
  - *Automatic requirement traceability modeling for ease of developing, measuring and testing system-level non-functional requirement attributes.*
- **Quality Aspects/Attributes:** availability, reliability, safety, security, performance, usability, scalability, maintainability, etc.
- **Focus:** stakeholder Win-Win cost/schedule/quality engineering throughout the entire life-cycle

Research in Security Engineering

Dr. Suku Nair, Dr. Jeff Tian, Dr. LiGuo Huang

Coverage

- *End-to-end security*
- *Devices, networks, and systems security*
- *Physical security (Access control)*
- *Policies and logistics*
- *Financial implications*

Focus

- *Systems vs. Ad hoc Perspective*
- *Process vs. Product Perspective*
- *Business vs. Deployment Perspective*

NSA Center of Excellence

CSE and SMU have been designated as a ***National Center of Academic Excellence in Information Assurance Education*** by NSA and the Department of Homeland Security. March 2006

HIGH ASSURANCE COMPUTING AND NETWORKING LAB

Create an Authoritative Forum for the convergence of the needs and solutions of Government, Industry, and Researchers dedicated to addressing security issues

SMU/Skunk Works Partnership

Dr. Delores Etter

Partnership – first time that Lockheed Martin Skunk Works® has partnered with an engineering program

Goal – Integrate the Skunk Works design philosophy into the engineering program to make our students more creative/innovative

Characteristics of Skunk Works projects include:

-rapid design/development,

-maximum use of commercial systems,

-small focused team

SMU Participation in Net-centric Software Engineering Consortium and NSF I/UCRC

- Net-centric Software Engineering Consortium
  - *Working with industrial/university partners since 2005*
  - *Focusing on system reliability, security, and safety of Net-centric software and systems*
  - *Emphasizing risk identification and management in system development life cycle*
- NSF I/UCRC of Net-Centric Software and Systems
  - *Established in March 2009 (SMU/UTD/UNT)*
  - *an academia-industry collaborative approach of research and development in net-centric systems*
  - *Industrial members: Lockheed-Martin Aero, Raytheon, Boeing, Cisco, EDS/HP, Texas Instruments, T-Systems, Fujitsu, Codekko, GlobeRanger, Hall Financial Group*

Software Data Quality and Estimation Research In Support of Future Defense Cost Analysis (1)

- **Agency:** DoD SERC
- **SMU Researcher:** LiGuo Huang
- **Collaborator:** USC Center for Systems and Software Engineering
- **Objective:** Research and develop next generation of data definitions and estimation methods for complex software-intensive systems

Software Data Quality and Estimation Research In Support of Future Defense Cost Analysis (2)

Coverage:

- *Improve current cost estimation metrics, models and methods for software-intensive systems (SISs) to reflect emerging changes in DOD SIS cost and process drivers.*
- *Collect and analyze data to test hypothesis about SIS cost estimation metrics, models and methods (i.e., software sizing, reuse and productivity).*
- *Explore alternative SIS cost estimation methods via data mining of SIS size, effort, and process data.*
- *Develop chapters on DoD SIS software sizing, reuse and productivity for a Software Cost Estimation Metrics Manual.*
- *Support the establishment of policy, related guidance, and recommended implementation approaches for data collection and analysis across all DoD acquisition programs which leverage existing and emerging data standards.*
- *Develop and evolve an integrated SIS data repository and related tools which enable program assessment, cost analysis, SIS development risk assessment, and progress measurement.*

Software Data Quality and Estimation Research In Support of Future Defense Cost Analysis (3)

SMU Focus:

- *Perform data mining of DoD project and cost data repositories to determine relationships between shortfalls in SIS architecture & risk resolution and SIS rework effort.*
- *Develop DoD-oriented case-based or analogy-based cost estimation models.*
- *Expand data mining of DoD project and cost data repositories to determine commonalities and variabilities within and across different categories of DoD software projects.*
- *Perform data mining of the new attributes of DoD project and cost data to determine commonalities and variabilities within and across different categories of DoD software projects.*

Automatic Inference of Risk Reduction Knowledge Base(1)

- **Objective:** Research and develop an automatic approach to constructing risk reduction knowledge base for complex software intensive systems
- **Collaborators:** NASA JPL V&V
- **Motivation Example:** The mishap of Mars Climate Orbiter (MCO) launched in late December, 1998.

What happened?

The MCO entered the Martian atmosphere at approximately 57km, not at its estimated 110km.

Unit mismatch among interoperating software subsystems/components. Ground navigation software used English units, not the required Metric units.. All other calculations were in metric.

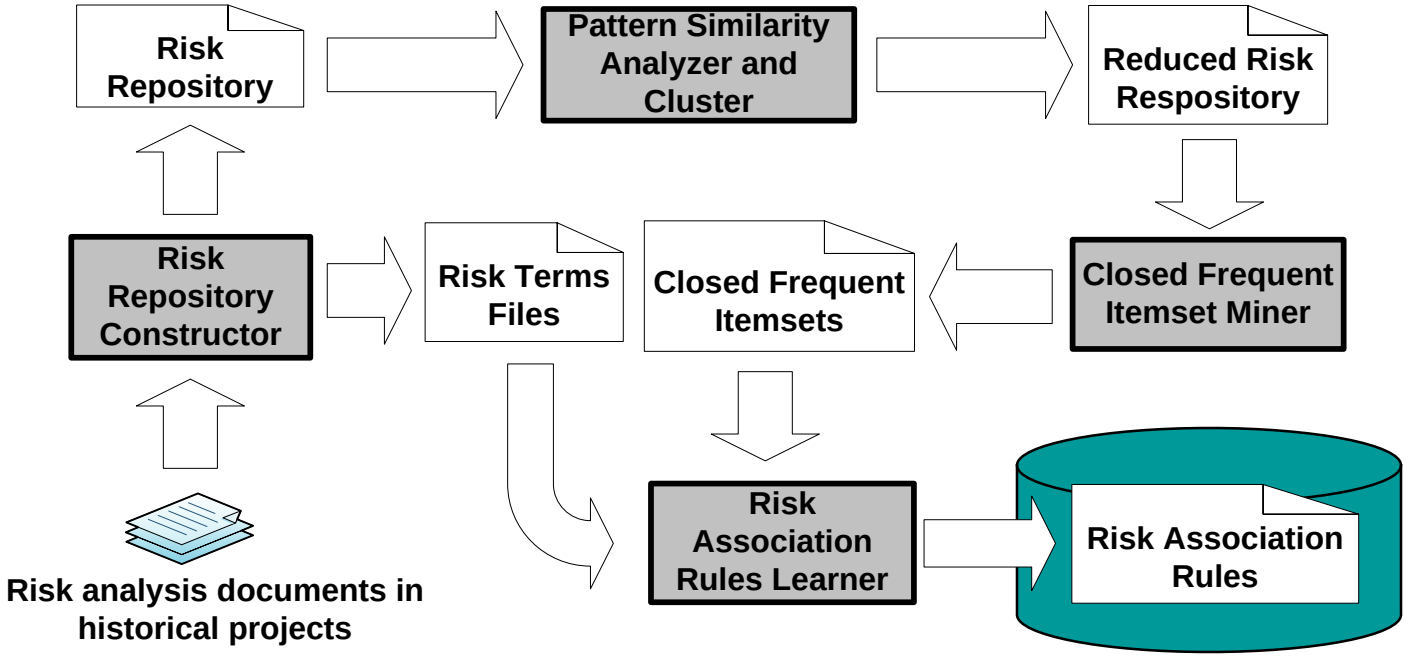
The discrepancy sent the spacecraft closer to the planet than its calculated trajectory indicated. Increased atmospheric stress destroyed the spacecraft.

Automatic Inference of Risk Reduction Knowledge Base(2)

- **Root Cause/Underlying Issues:**
  - *Verification & Validation:*
    - *Development and V&V did not rely on the Software Interface Specification (SIS) to ensure the software was compatible.*
    - *The mishap investigation board found no evidence of complete, end-to-end testing for the trajectory tracking software..*
- **Current NASA JPL V&V Problems:**
  - *A lot of risk reduction experience from historical missions*
  - *Unstructured information scattered in historical documents*

Automatic Inference of Risk Reduction Knowledge Base(3)

Approach Overview:



Unstructured historical mission/project risk reduction experience !

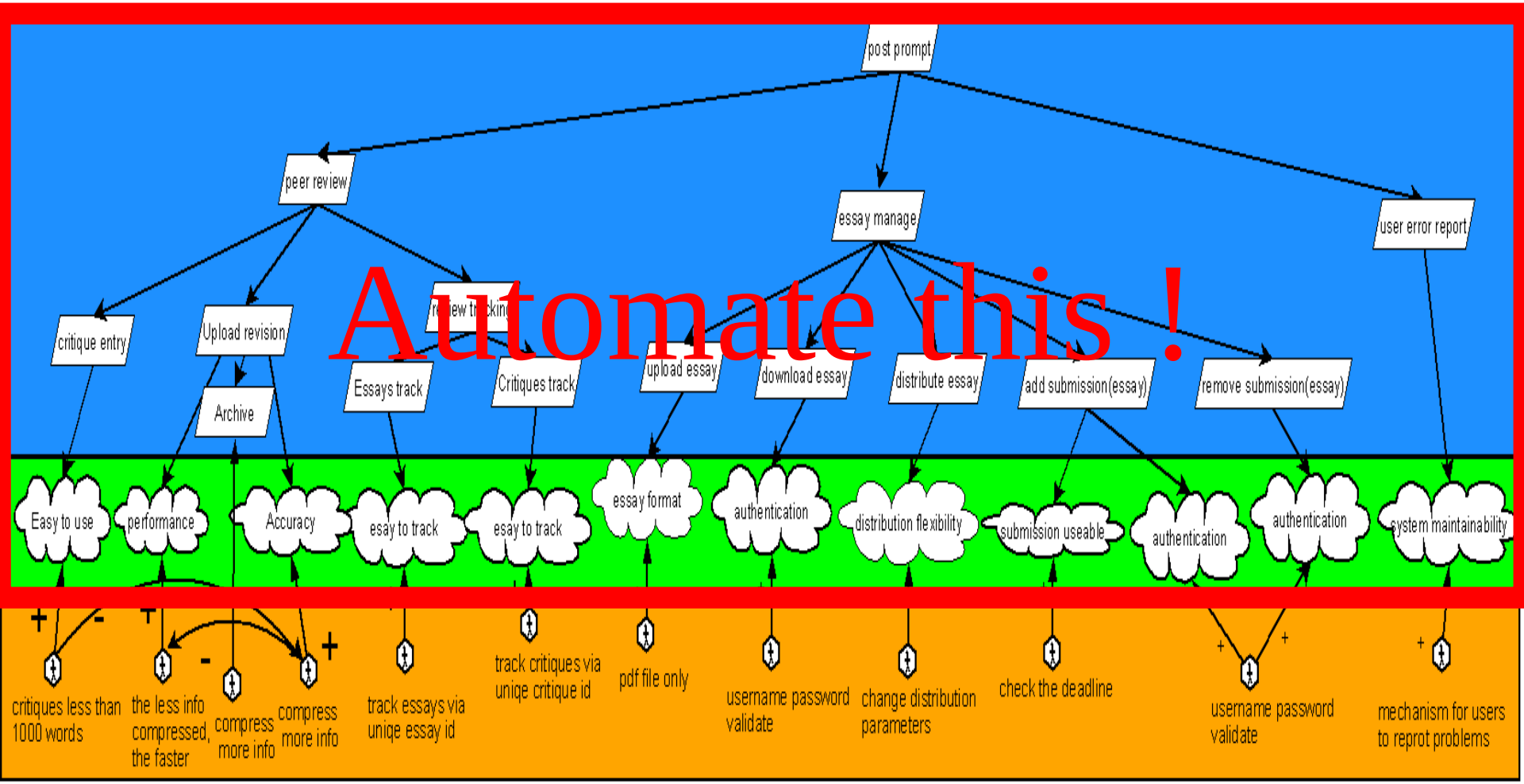
Organized historical mission/project risk reduction rules !

Requirements Traceability for Large Scale Software Intensive Systems (1)

- **Objective: Build a Hybrid Requirement Traceability (HRT) model to automatically trace system-level non-functional requirements to software functional requirements, design and code in order to quickly adapt to changes.**
- **Approach:**
  - *Apply text mining and Natural Language Processing techniques to classify and cluster FRs and NFRs from process artifacts (e.g., requirements documents)*
    - *Verify with original requirements – identify erroneous requirement classification*
  - *Trace the requirement changes to system architecture design and to code through the HRT model*
  - *Reverse engineer the HRT model from the code to verify and validate the requirements.*
- **Collaborator: NASA JPL**

Requirement Traceability (3)

– Example Requirement Interdependency Graph for Critical Resource Management System



Backup Charts

Requirement Traceability (2) – Research Overview

•STATUS QUO

- *System-level NFRs are difficult to trace, measure or test*
- *Traditional manual requirement traceability approaches requires intensive human efforts.*
- *Current research traces FR or NFR in separate models.*

But, automatically clustering FRs and NFRs in process artifacts can improve and semi-automate requirement traceability

•NEW INSIGHTS

- *Hybrid Requirement Traceability Model can reveal the FR and NFR conflicts*

o **Explicit associations between NFR s and FRs.**

o **Semi-automatic NFR traceability through text mining and NPL techniques.**

- **MAIN ACHIEVEMENT:**
- Demonstrated semi-automatic hybrid requirement traceability model
  - ✓ **improves effectiveness of NFR and FR traceability**
  - ✓ **improves measurability and testability of NFRs**
  - ✓ **improves adaptability to changes**
  - ✓ **reduces intensive manual efforts in NFR tracing**

- **HOW IT WORKS:**
- Apply text mining and Natural Language Processing techniques to classify and cluster FRs and NFRs from process artifacts
- Automatically build FR and NFR interdependency graphs
- Trace the requirement changes to system architecture design and to code through the HRT model
- Reverse engineer the HRT model from the code to verify and validate the requirements.

- **ASSUMPTIONS AND LIMITATIONS:**
- **Formatted requirement specifications (no specific templates are required)**
- **Complete requirement specification documents**

•QUANTITATIVE IMPACT

System-level NFRs can be automatically linked to related FRs

- **Task1: Verify FR/NFR clusters in real world large scale software applications**
- **Task 2: Explore automatic requirement conflict detection in large scale software applications**
- **Task 3: Explore the effectiveness of automatic requirement traceability recovery from code**

•END-OF-PHASE GOAL

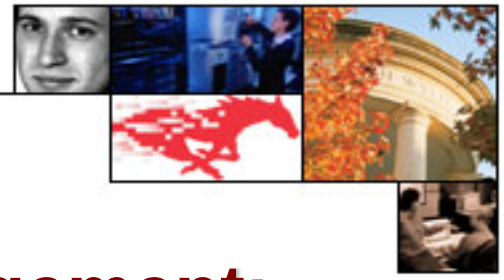
- *Improvements and automation of NFR traceability*

More effective and efficient NFR and FR management and traceability

Make it easier to trace, measure and test system level NFRs

Better adaptability to changes

•Semi-automatic Hybrid Requirement Traceability (HRT) Model integrates FR/NFR tracing

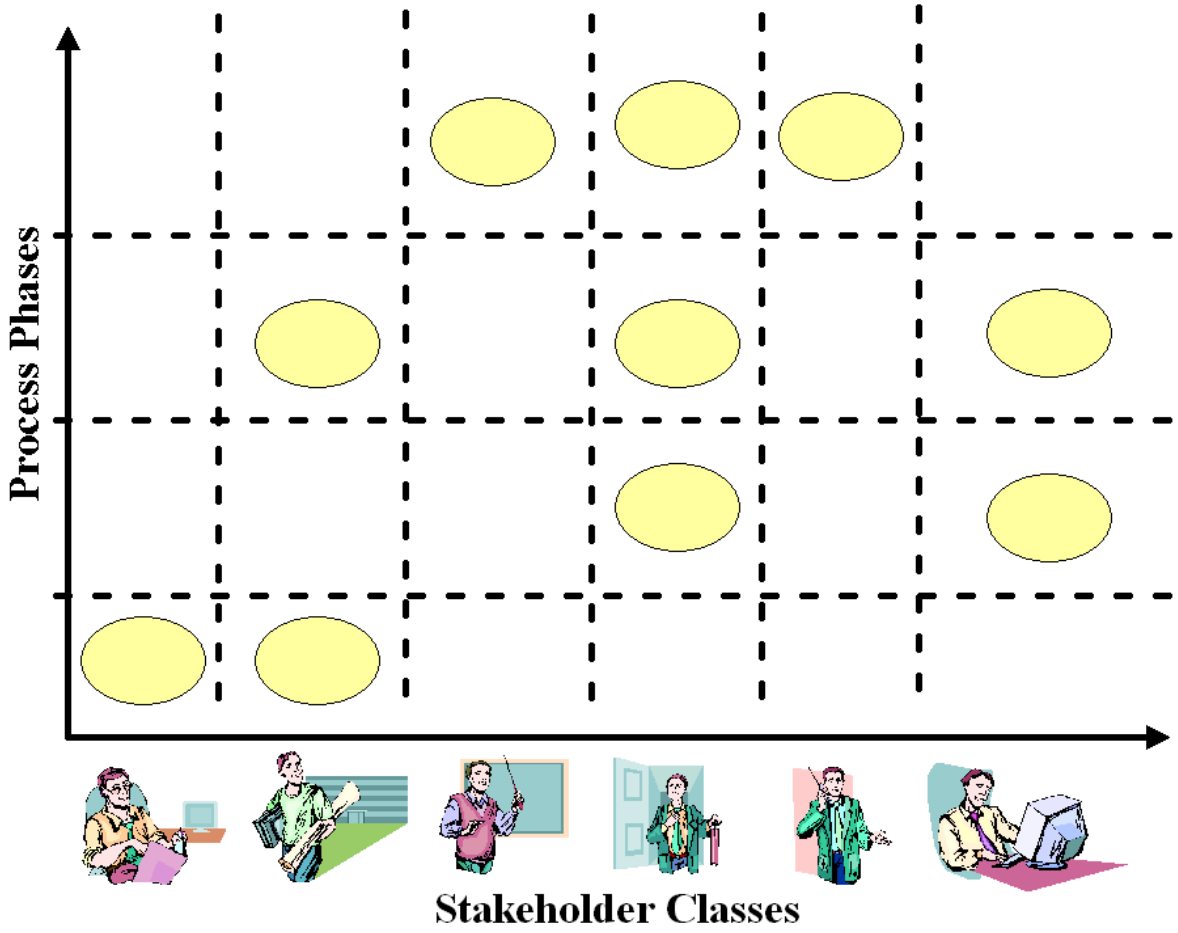


Hybrid Modeling and Simulation for Trustworthy Software Process Management: A Stakeholder-Oriented Approach

- **Objective:** Research and develop stakeholder-oriented approach to hybrid process modeling and simulation for large scale software intensive systems (in distributed development setting)
- **Collaborators:**
  - *USC Center for Systems and Software Engineering*
  - *Irish Software Engineering Research Centre*

Two Dimensions of Process Modeling & Simulation Concerns

- Stakeholder Classes
- Process Phases



Stakeholder-based Hybrid Process Simulations: