Verification and Validation Summit 9

"Fast-Time & Real-Time Simulation for NextGen"

Presented to: V&V Summit 9

By: Mike Paglione, FAA ANG-C41

Date: September 17, 2014

Question

Based on your own experiences, what are the major factors that challenged your software development projects ?

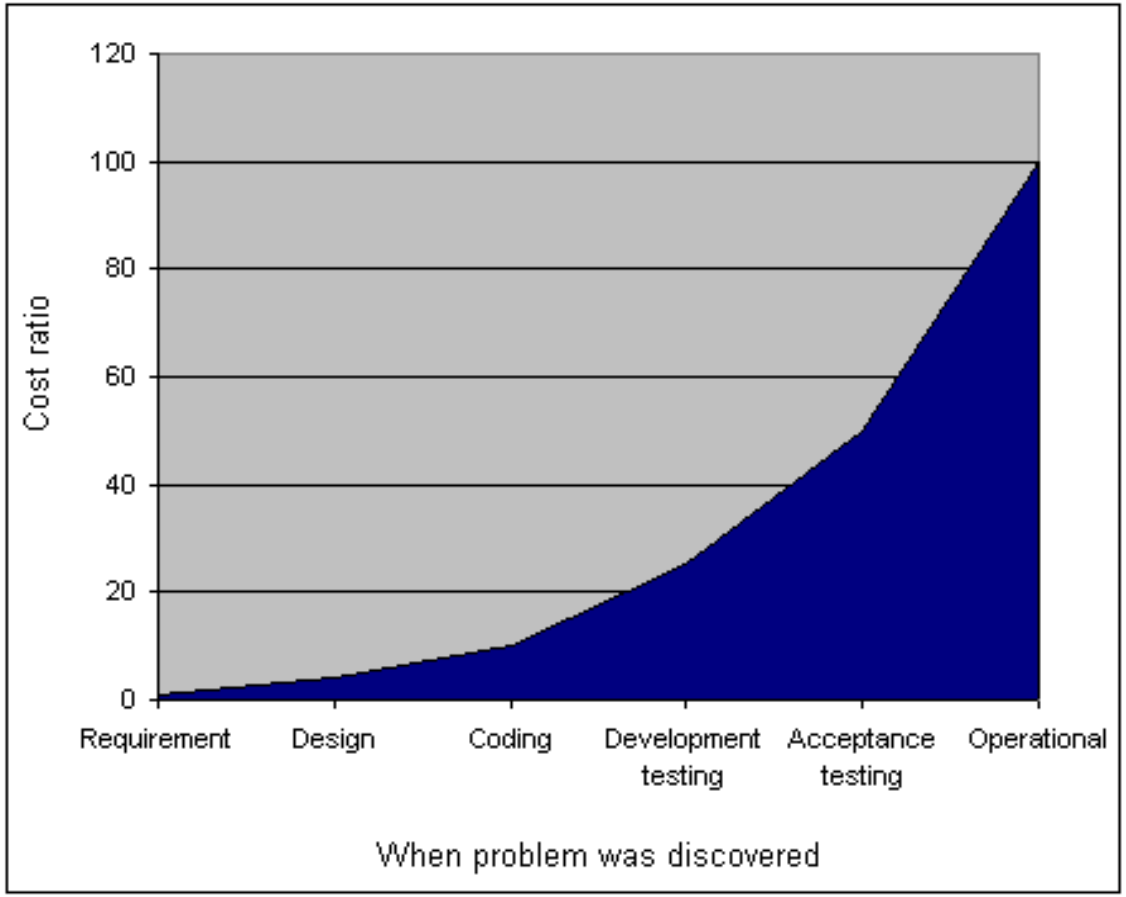
Standish Group Asked about 400 IT Executive Managers*

Project Challenged Factors	% of Responses
1. Lack of User Input	12.8%
2. Incomplete Requirements & Specifications	12.3%
3. Changing Requirements & Specifications	11.8%
4. Lack of Executive Support	7.5%
5. Technology Incompetence	7.0%
6. Lack of Resources	6.4%
7. Unrealistic Expectations	5.9%
8. Unclear Objectives	5.3%
9. Unrealistic Time Frames	4.3%
10. New Technology	3.7%
…Other	23.0%

*www.standishgroup.com

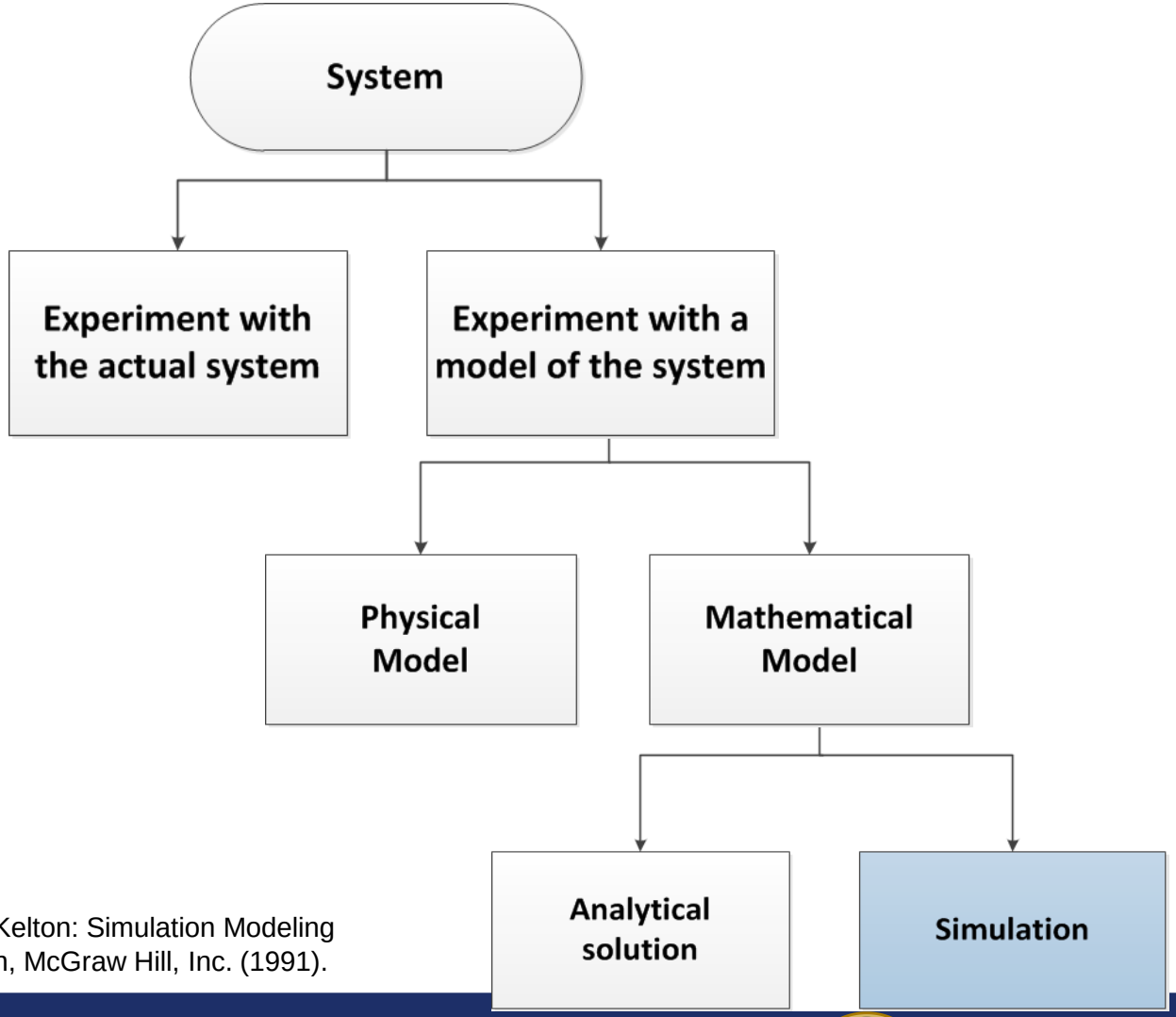
Relative Cost to Fix an Error

Pay Now or Really Pay Later…



Barry Boehm, *Software Engineering Economics*, 1981.

Ways to Study a System

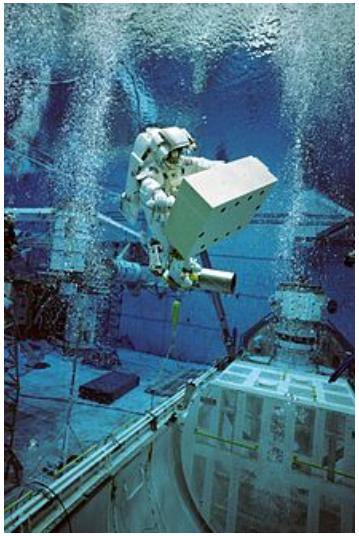


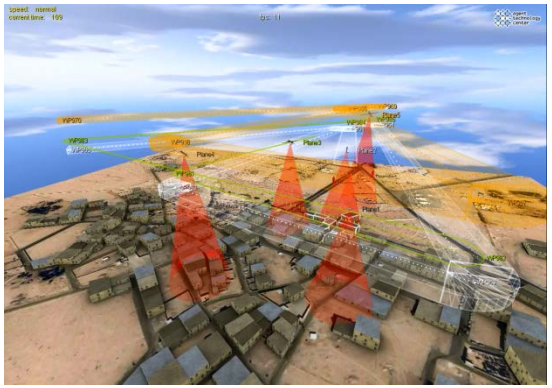
•Law, A. M., and W. D. Kelton: Simulation Modeling and Analysis, 2nd Edition, McGraw Hill, Inc. (1991).

Simulation

A Key Tool for Evaluation

Imitate the operations of various kinds of real-world facilities or processes, i.e. systems, making assumptions on how they work via a model*

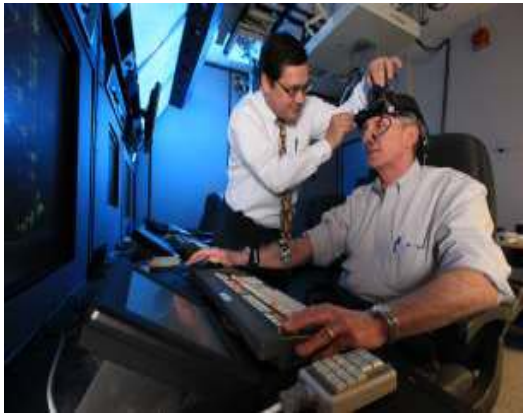




*Law, A. M., and W. D. Kelton: Simulation Modeling and Analysis, 2nd Edition, McGraw Hill, Inc. (1991).

Real-time Human-in-the-Loop (HITL) Simulation

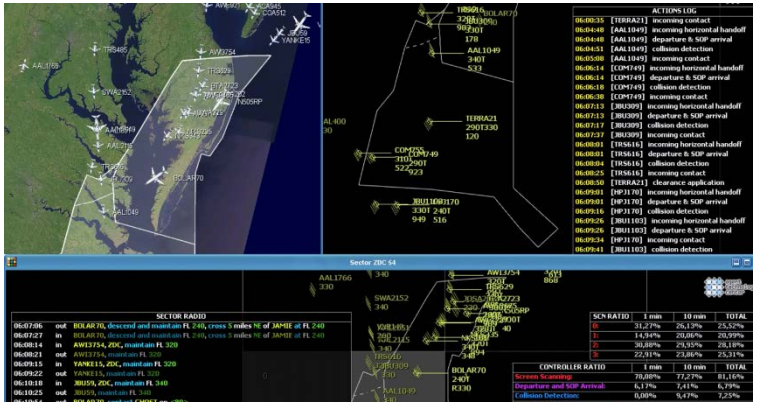
"…a human operator (e.g. air traffic controller) interacts with and reacts to simulated conditions in near real-time"*



**Harvey, A., Mullan C., Schwartz A., Magyarits S.: *Appendix 2: Best Practices in the Development of Simulation Scenarios for Validation Activities in Fast and Real-Time Simulation*, FAA and EUROCONTROL, (2003).

Fast-time Computer Simulation

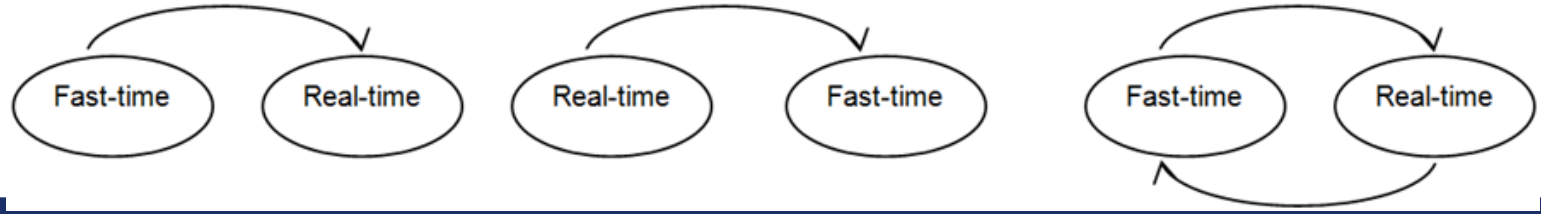
"… – no interactive humans, scenarios unfold using rule-based decisions that control interactions between actors within a computer model running in fast-time"*



*Harvey, A., Mullan C., Schwartz A., Magyarits S.: *Appendix 2: Best Practices in the Development of Simulation Scenarios for Validation Activities in Fast and Real-Time Simulation*, FAA and EUROCONTROL, (2003).

Simulation in Practice

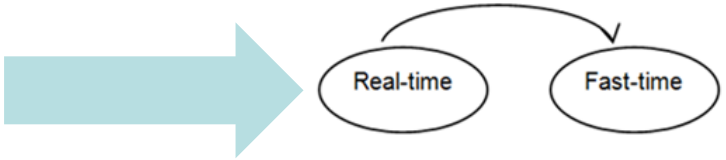
- **Traditionally one simulation method applied**
  - Fast-time simulation only
  - Human-in-the-Loop simulation only
- **Alternative perform both - leverage on strengths which mitigate weaknesses of other**
  - "All models are wrong, but some are useful" (George E.P. Box, 1987)
  - Suggested best practice: "coordination of fast-time and real-time validation techniques"*
- **Relationship of fast- and real-time analyses**



*Harvey, A., Mullan C., Schwartz A., Magyarits S.: *Appendix 2: Best Practices in the Development of Simulation Scenarios for Validation Activities in Fast and Real-Time Simulation*, FAA and EUROCONTROL, (2003).

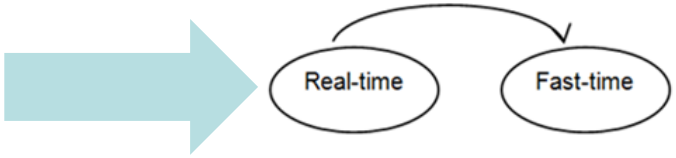
Example FAA Projects with both Real- & Fast-time Simulation Events

- **Conflict Resolution Advisories (CRA)**



- **Unmanned Aircraft System Airspace Integration Joint Test (UAS AI-JT)**

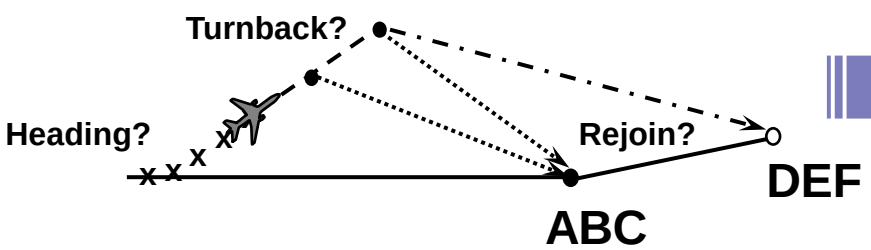
- **Staffed NextGen Towers (SNT)**



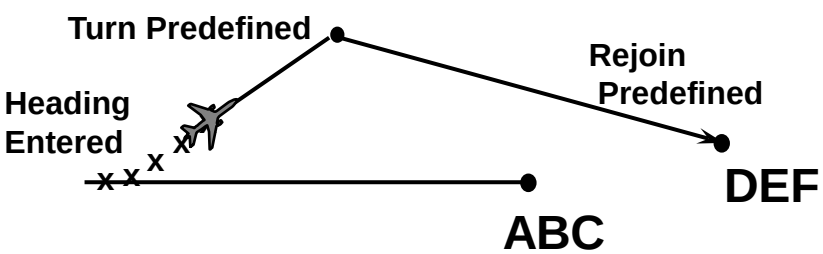
NextGen Project: Conflict Resolution Advisories (CRA)

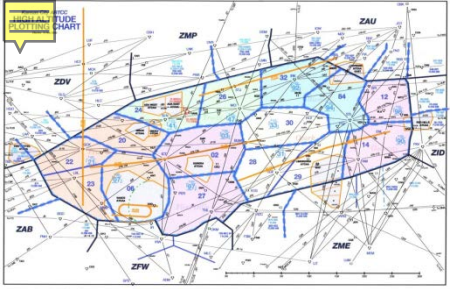
- Advanced decision support tool
- Proposes ranked resolution options for conflicts
- Supports use of “closed-loop” clearances
- Facilitates entry of amendments to automation
  - Improves trajectory and conflict prediction accuracy

Lack of Intent in Today’s System:



Closed System with CRA:



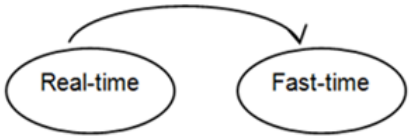


CRA Real-time HITL Simulation

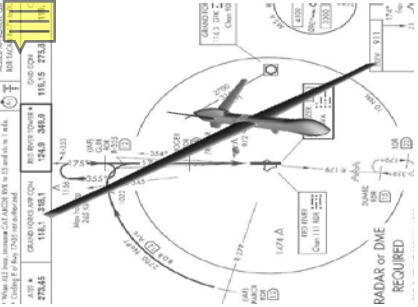
- **Experimental conditions**
  - Three sets of participants: 4-day sessions and 4 controllers per; total of 12 certified controllers and 6 front line managers (FLMs)
  - Contrasts with and without CRA menus
  - ZKC sectors 20 and 22 (2 teams of 2 with 2 FLM observers)
- **Results**
  - Validates that requirements via prototype functioned correctly
  - Most of the participants' subjective ratings favored CRA, and expressed that CRA was a useful concept
  - Illustrated some of benefits, e.g. showed that controllers solved potential conflicts more quickly and efficiently when CRA was available

CRA Fast-time Computer Simulation

- **Experimental conditions**
  - Factors studied: intent entry (% of full 2-part clearances entered), year (traffic density), en route center
  - Computer simulated 45,000 flights for over 240 hours
- **Results**
  - Improved Trajectory Modeling: 61 & 42% decrease avg. horizontal & vertical error, respectively
  - Improved Conflict Probe: 80% decrease in alerts

- 

HITL validates user requirements and FT simulation further validates benefits

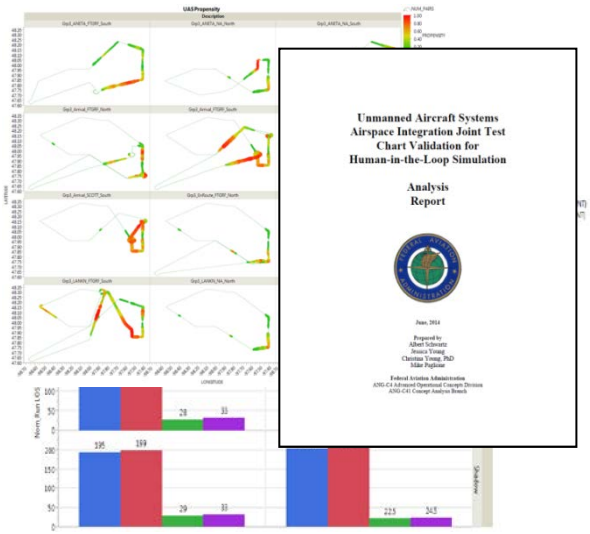


Unmanned Aircraft System (UAS) Procedure Development for DoD

- **DoD UAS AI-JT team researching the development of standard operating procedures for UAS**
- **Required to support the DoD's current training, support, and operational missions**
- **Long term need for increased access to the NAS, requiring operating procedures to mitigate the safety and efficiency risks**

UAS Procedure Development Fast-time Computer Simulation

- **Analysis utilized to conduct iterative fast-time simulation and shared for subsequent HITL**
  - Detailed analysis of airspace and air traffic of test site
  - Set of scenarios defined (baseline, nominal, contingency, UAS type)
- **Helped DoD develop the initial UAS procedures**
- **Results of FT computer simulation**
  - Confirmed UAS could fly procedures
  - UAS separation analysis with background traffic
  - Specific recommendations for HITL
  - Results shared in multiple TIMs and documented in report



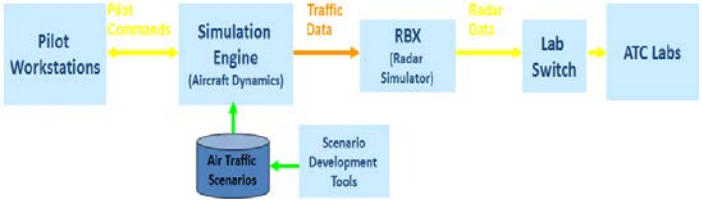
UAS Procedure Development HITL Real-time Simulation

- **Designed to study the efficacy of DoD procedures***
- **Includes 2 wks, 4 participant groupings, 30-45min runs/group**
- **High fidelity HITL experiment with multiple assets from WJHTC:**

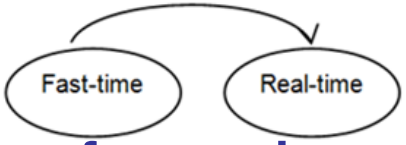
NIEC (RAPCON, ARTCC, UAS),

AFTIL (Tower),

and TGF Labs



- **Conducted in July 2014; analysis on-going and results pending**

- 

FT computer simulation supported development of procedures, lowered tech. risk of HITL; HITL continued this and conducted initial concept validation/demonstration

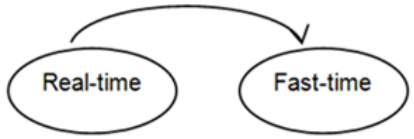
*This was not a formal FAA Test & Evaluation (T&E) or Validation & Verification (V&V) Exercise, rather a research effort surrounding an operational concept test/demonstration.

Staffed NextGen Tower (SNT) Concept Real-time HITL Simulation

- **Concept**
  - Paradigm shift from using the tower's out-the-window (OTW) view to using electronic surface surveillance as the primary means for providing tower control services
- **HITL Real-time Simulation**
  - Modelled Dallas/Fort Worth International Airport
  - 16 controllers, 8 wks, 96 trials, 45 minutes runtime each
  - Assuming south flow configuration running mixed runway operations on the eastern half of the airport
  - IFR SNT resulted 10% increase in departure rate and some improvement to departure taxi metrics

Staffed NextGen Tower (SNT) Fast-Time Simulation

- **Conducted Fast-Time Computer Simulation using AirTOp Tool**
  - Ran baseline and multiple scenarios varying runway occupancy times
  - Extrapolated user benefits leveraged from SNT HITL-1 results in IMC conditions over entire DFW airport for 24 hours period
  - Results showed minimal difference in both throughput and ground delay metrics when compared to current operations

- 

HITL demonstrated the concept, validated preliminary requirements and FT simulation expanded model with similar results

Recommendations

- **Fast- and real-time simulation methods complement each other to aid in the validation process**
- **Important to coordinate activities between fast- and real-time simulation activities***
  - "Communicate with fellow fast-time and real-time researchers"
  - "Clearly state and document your design assumptions"
  - "Clearly state the likely implications of your assumptions"
  - "Standardize scenarios for use in both fast- and real-time simulations when possible"

*Harvey, A., Mullan C., Schwartz A., Magyarits S.: *Appendix 2: Best Practices in the Development of Simulation Scenarios for Validation Activities in Fast and Real-Time Simulation*, FAA and EUROCONTROL, (2003).

Integration of Computer Model & Real-time Simulation Elements

Point of Contact

Mike Paglione
Concept Analysis Branch Manager (ANG-C41)

William J. Hughes Technical Center

Building 300, Floor 2nd, Column K-36

609-485-7926

mike.paglione@faa.gov