Raytheon
Customer Success Is Our Mission

MISSION:
A WORLD OF INNOVATION

Estimating ROI for Large Scale Six Sigma and Test Automation Projects

C F Boncek
Engineering Fellow
July 22 2014

Classification

U	UNCLASSIFIED
	THIS PRESENTATION HAS BEEN REVIEWED AND APPROVED FOR GENERAL AUDIENCES eTPCR IDS-5779

The case study described herein is for educational purposes and was developed solely to illustrate the principals described.

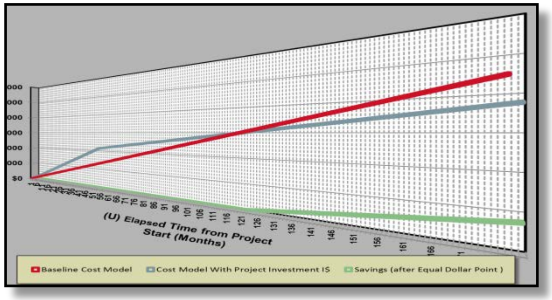
Any similarity to any existing project whether fielded or planned is unintentional and purely coincidental.

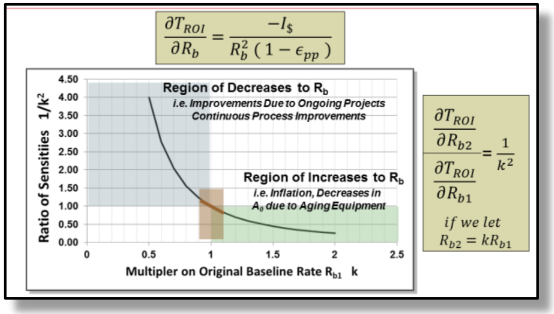
The presentation contains graph material and mathematical language. Viewer discretion is advised.

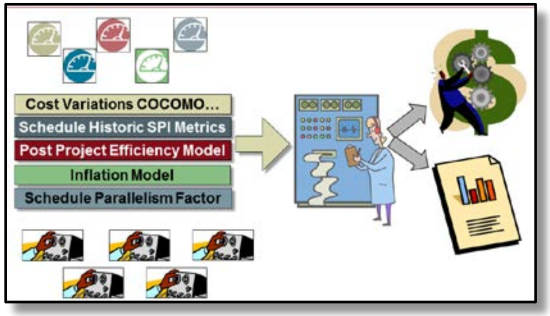
Raytheon

Presentation Topics and Flow

- Motivation for the Project
- Starting Point: The Basic Linear Model
  - Definitions of Terms and Basic Equations
- The Monte Carlo Model
  - The ‘Knobs’: Random Variables and Random Parameters
  - Sensitivity Analysis for Each Parameter
    - Impact of Uncertainties and Randomness
    - Impact of Variations in Project CPI and SPI
- Example Case Study and Results
  - 10,000 Run Simulation of Scenario
  - Interpretation of Results
- The Success Triad: Test Automation Considerations





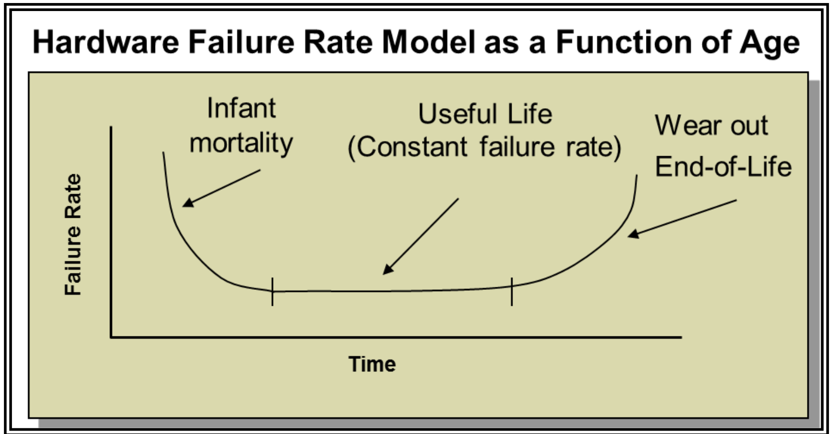


Talk Outline: From Motivation to a Predicted ROI

Project Motivation: Hardware Age Risks

Using "Bath-Tub" Failure Model

Raytheon



Raytheon Principles of Systems Engineering PoSE
Module 8: Specialty Engineering (SEPOSE108-110930)

Radar Hardware Cooling	**39 years**
Radar Antenna-Pattern Hardware	**38 years**
Signal Routing Hardware	**38 years**
Digital Control Drawer A10	**38 years**
Doppler Extension Hardware	**35 years**

Failure of any of these will stop production

Age	Year Built	Unit
39	1973	Radar Cooling
38	1975	Frequency Conversion / Signal Routing
38	1975	Signal Modulator/Routing Network
38	1975	A10 Control Unit
35	1978	Doppler Extension Unit 784083
33	1980	RF Control Assembly 785141
33	1980	IF Control Assembly 785158
23	1990	Adapter, Interfaces A & B
23	1990	Switch Unit, Interfaces A & B
23	1990	Adapter, Interface Real Time Data
23	1990	Switch Unit, Interface E Real – Time Data
23	1990	Adapter, Interface Pattern Control
23	1990	Switch Unit, Interface Pattern
20	1993	Doppler Control Unit
20	1993	Signal Gen and IF Control Unit
20	1993	Intracom Drive Control Unit
20	1993	Interrupt Distribution Unit
20	1993	Range Attenuator Drive Unit
18	1995	Launch Display/Switch Unit
18	1995	Launch Interface Unit
18	1995	Program Monitor Unit
18	1995	Front End Dog House Upgrade
15	1998	Interface A, B & F
15	1998	Operational Control Pulse Unit
11	2002	Intracom Buffer Unit
10	2003	DTU [illegible] Switch Unit
8	2005	Mono-pulse Injection Unit
8	2005	Interface Equipment
6	2007	Radar Triggers Switch Box
5	2008	Electronic Synthesizers Interface
2	2011	RF Conditioning Units
1	2012	Range Delay Timing Unit

Facility Hardware Age List

See appendix for complete lists and additional details

High

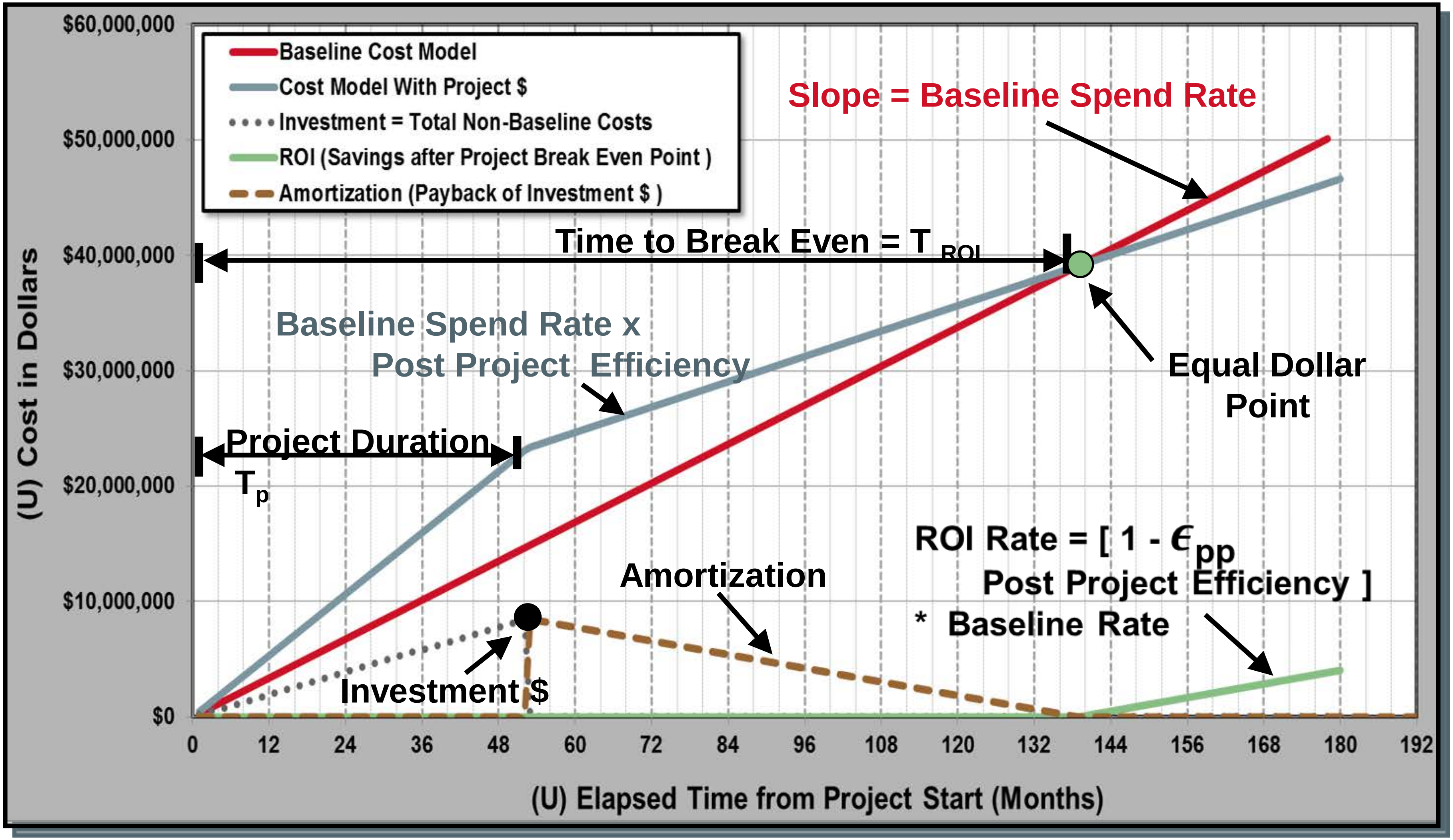
Risk of Stopping Production Due To Equipment Failure

Low

Part Obsolescence Growing % of Baseline $; Impacts SW too !

Raytheon

Conceptual Framework: Linear Model part I



The Basic ROI Prediction Equations Before Modeling Uncertainties

Monte Carlo Analysis *Case Study* Parameters

$ 3.0 M Facility's Baseline

$ 8.5 M Project Investment: Hardware, Non-Baseline SW Dev & Support

4.4 Year Project Duration[1] = *52.5 months*

3% Yearly Inflation Model Applied to Baseline Budget[2]

30% Schedule Parallelism Improvement[1]

0.85 < CPI < 1.15 Required Performance Entire Project

0.85 < SPI < 1.15

$ 23.3 M Expenditure at Complete: Baseline Rate plus Investment Dollars

[1] *includes 30% Schedule Reduction by Parallel Activity, Early IV&V*

[2] *inflation could be set to zero to model flat budgets*

Input Data for Monte Carlo Input Parameters

Raytheon

Definition of $I_\$$ Investment Dollars

- Investment includes all HW, SW, Other Labor and Capital not covered in the Baseline Budget or by the Core Team

- Estimates for Investment Are Based on C5,EPIC and Other Approved Tools Such as COCOMO[2] and CRA[2] etc.
  - Requirements Development
  - HW Development[1]
  - SW Development[1]
  - Integration[1]
  - Verification[1]
  - Validation[1]

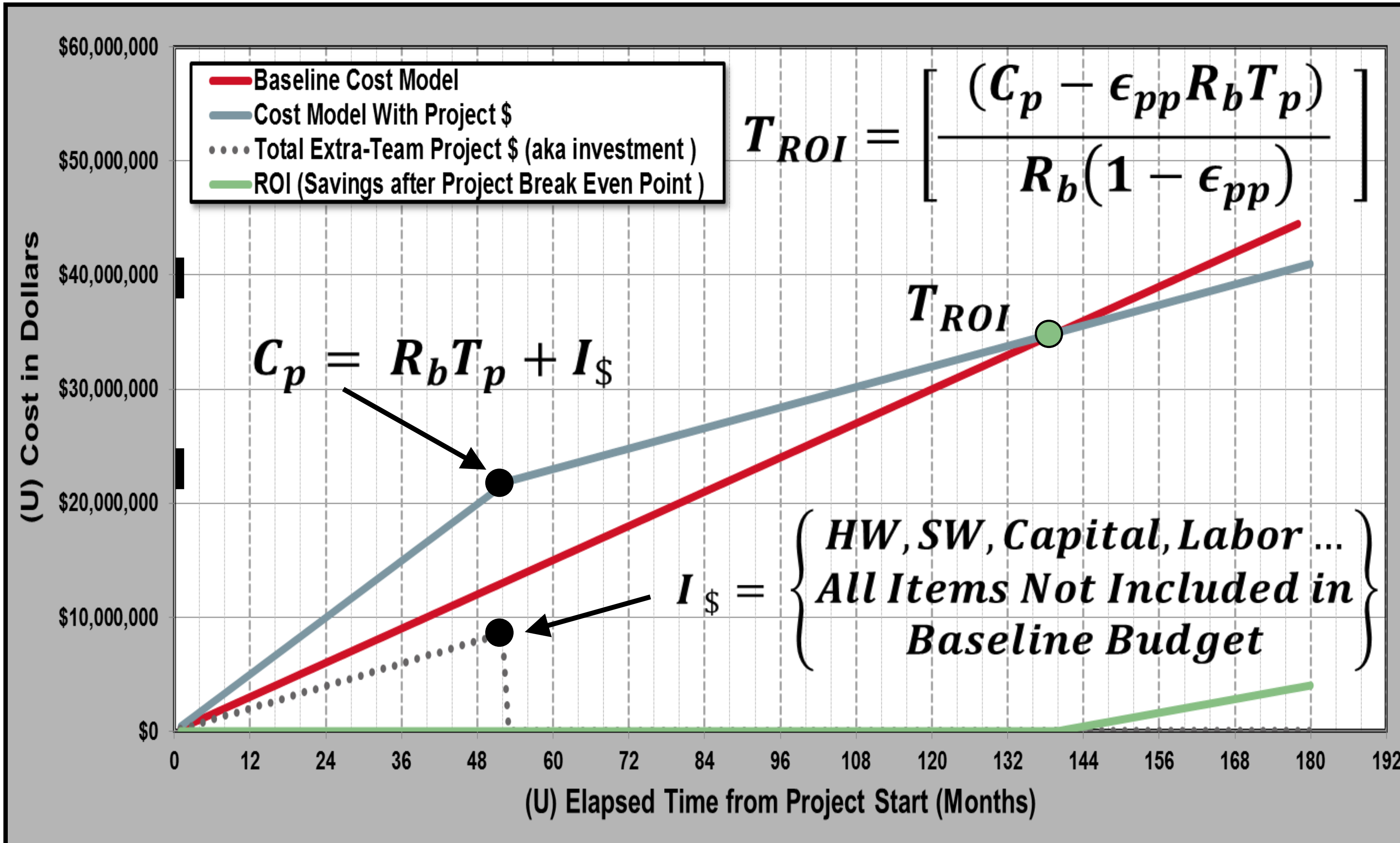
PROJECT BUDGET		Non Team $
Requirements Dev Budget	dollars	15000
HW Dev Budget	dollars	3781000
SW Dev Budget	dollars	4588500
IVV Budget	dollars	125000
Capital	dollars	99
Total Project Components		***8509599***

[1] *portion not done under Baseline funding of $3.0 M / year*

[2] ***CO**nstructive **CO**st **MO**del & Cost Risk Analysis Tools*

In this example the Investment is: $8.51M HW, SW and IV&V

Conceptual Framework: Linear Model part II



The Basic ROI Prediction Equations Before Modeling Uncertainties

Raytheon

The Basic ROI Equation and Sensitivities

$$T_{ROI} = T_p + \frac{I_\$}{R_b(1-\epsilon)}$$

Basic Equation

Sensitivity to Project Duration

$$\frac{\partial T_{ROI}}{\partial T_p} = 1$$

Sensitivity to Post Project Efficiency

$$\frac{\partial T_{ROI}}{\partial \epsilon} = \frac{I_\$}{R_b(1-\epsilon_{pp})^2}$$

Sensitivity to Baseline Rate

$$\frac{\partial T_{ROI}}{\partial R_b} = \frac{-I_\$}{R_b^2(1-\epsilon_{pp})}$$

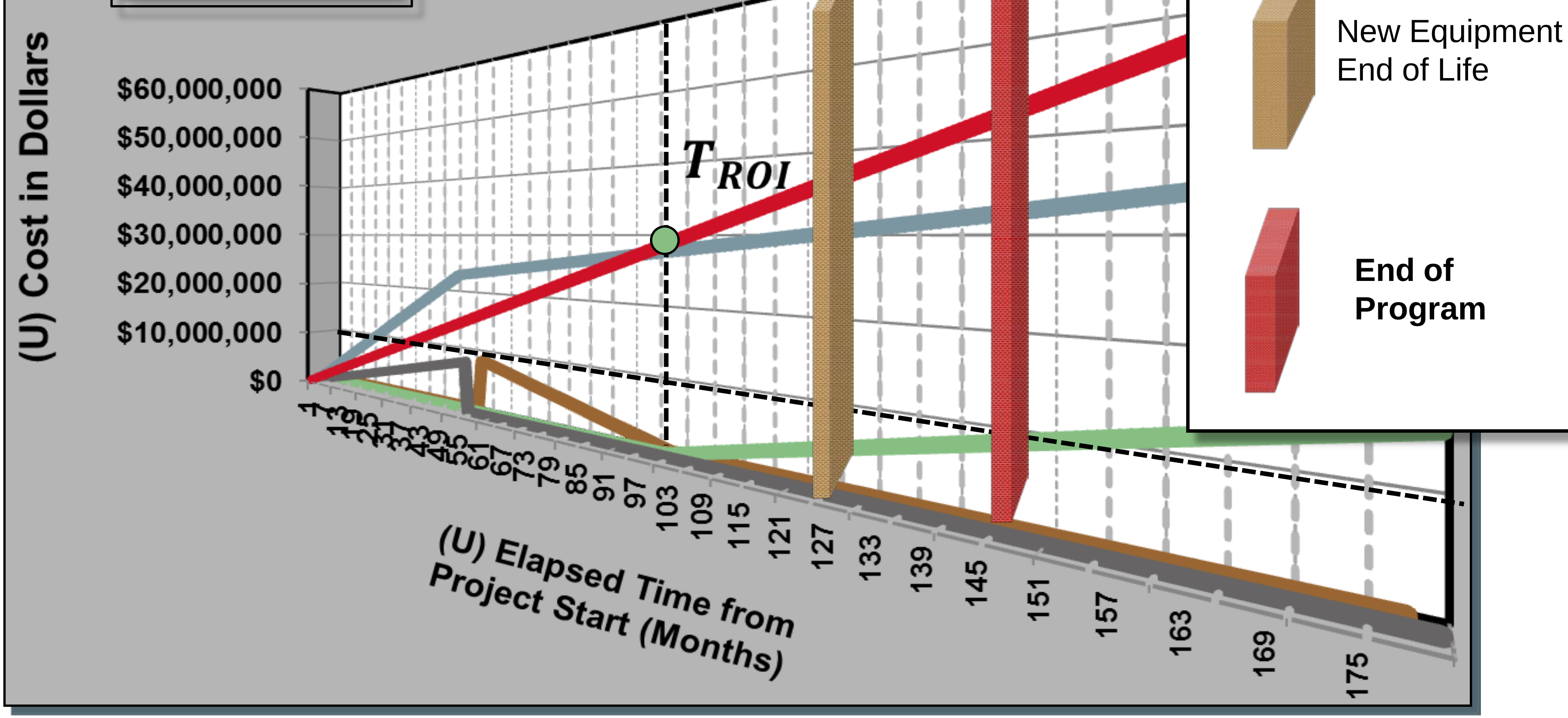
Sensitivity to Investment $

$$\frac{\partial T_{ROI}}{\partial I_\$} = \frac{1}{R_b(1-\epsilon_{pp})}$$

Sensitivities of the Basic Equation to the Four Parameters

Sensitivity of T_{ROI} to Project Duration T_p

$$\frac{\partial T_{ROI}}{\partial T_p} = 1$$

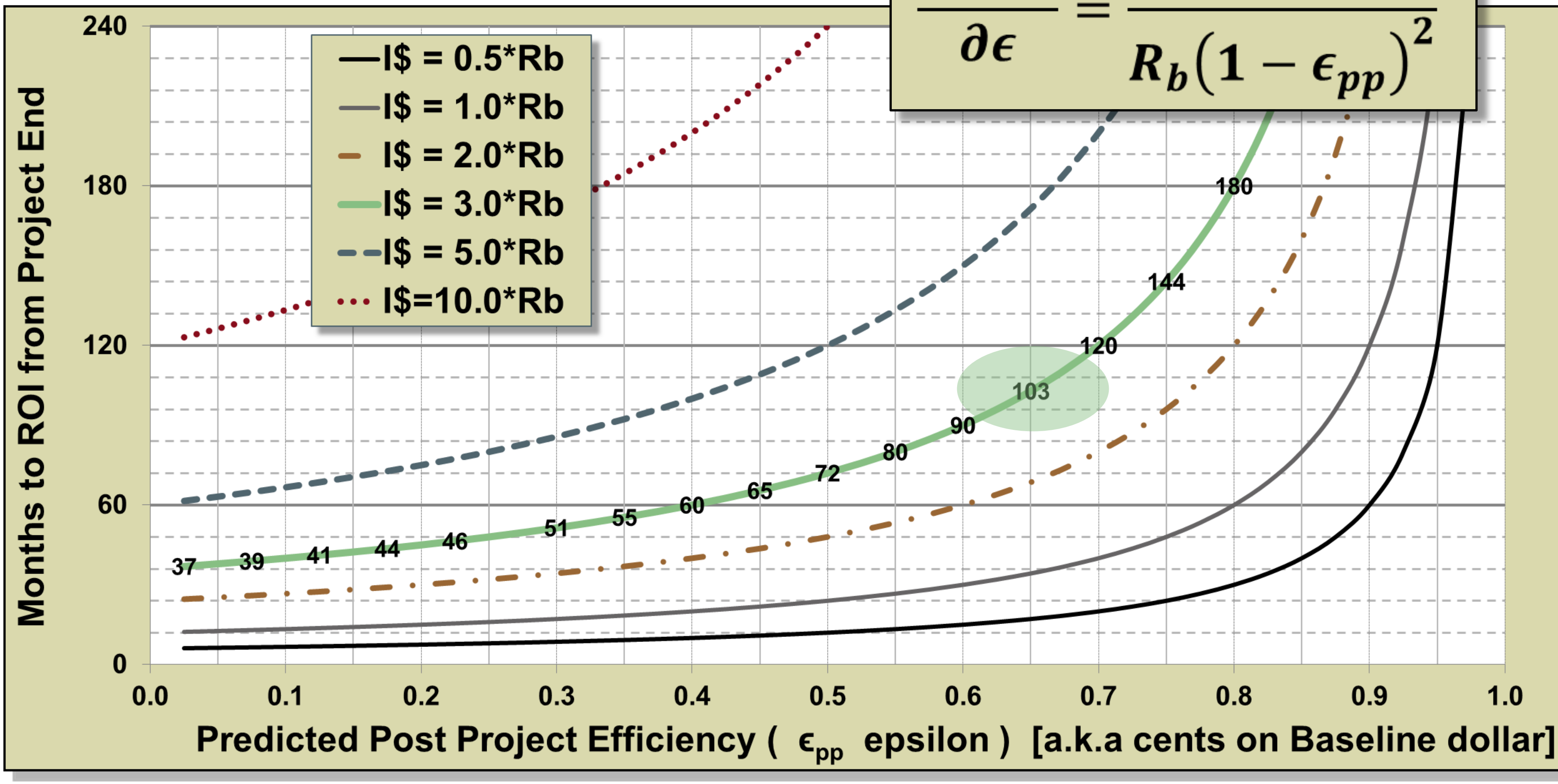


Commit Early, Start-on-Time, Finish Early for the Biggest ROI

Sensitivity to T_{ROI} to Predicted Post Project Efficiency ϵ

Raytheon

$$\frac{\partial T_{ROI}}{\partial \epsilon} = \frac{I_{\$}}{R_b\left(1-\epsilon_{pp}\right)^2}$$



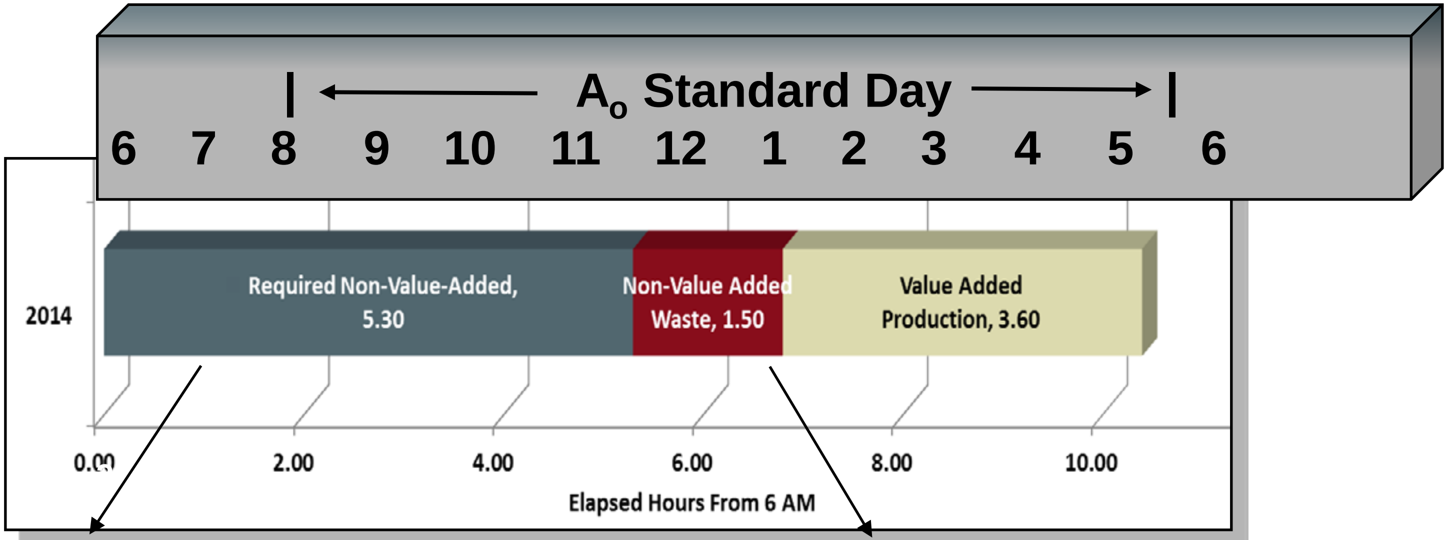
Impact of Post Project Efficiency on Investments of Various Sizes

Estimating Final Efficiency ϵ_{pp}

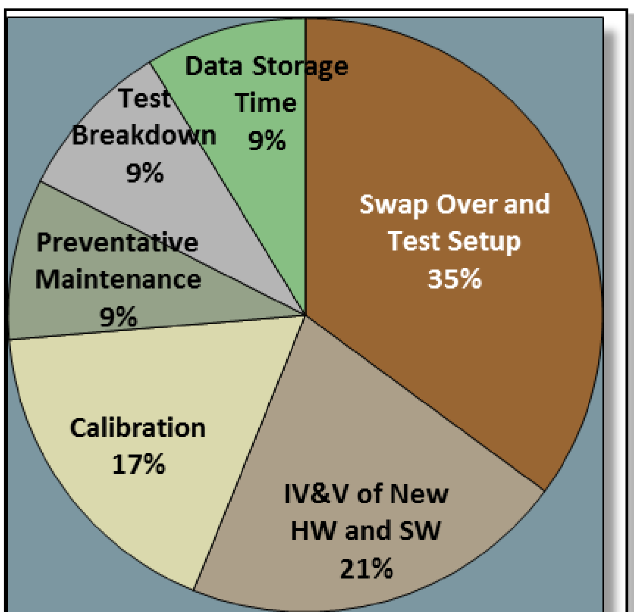
OK, Now we have the equations but how can we scientifically estimate the final expected efficiency to convince the boss ?

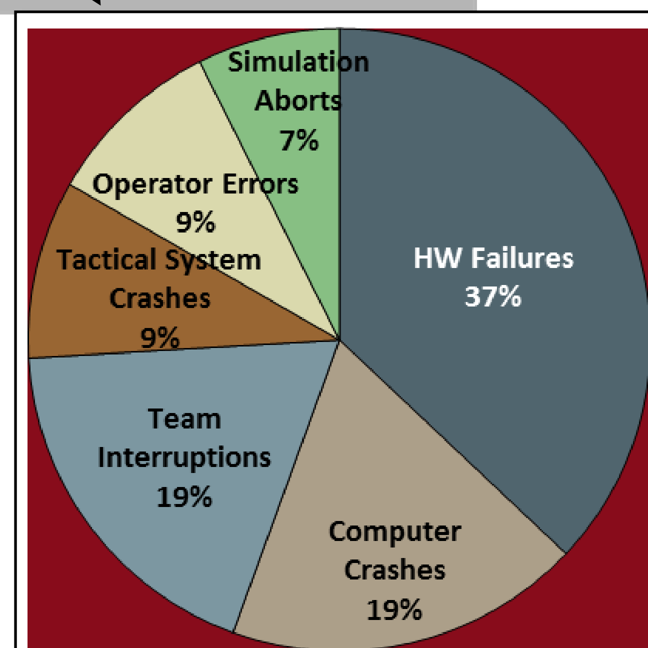
This Section Summarizes The Approach to Predicting ϵ_{pp}

Notional Time Block Categories and Metrics



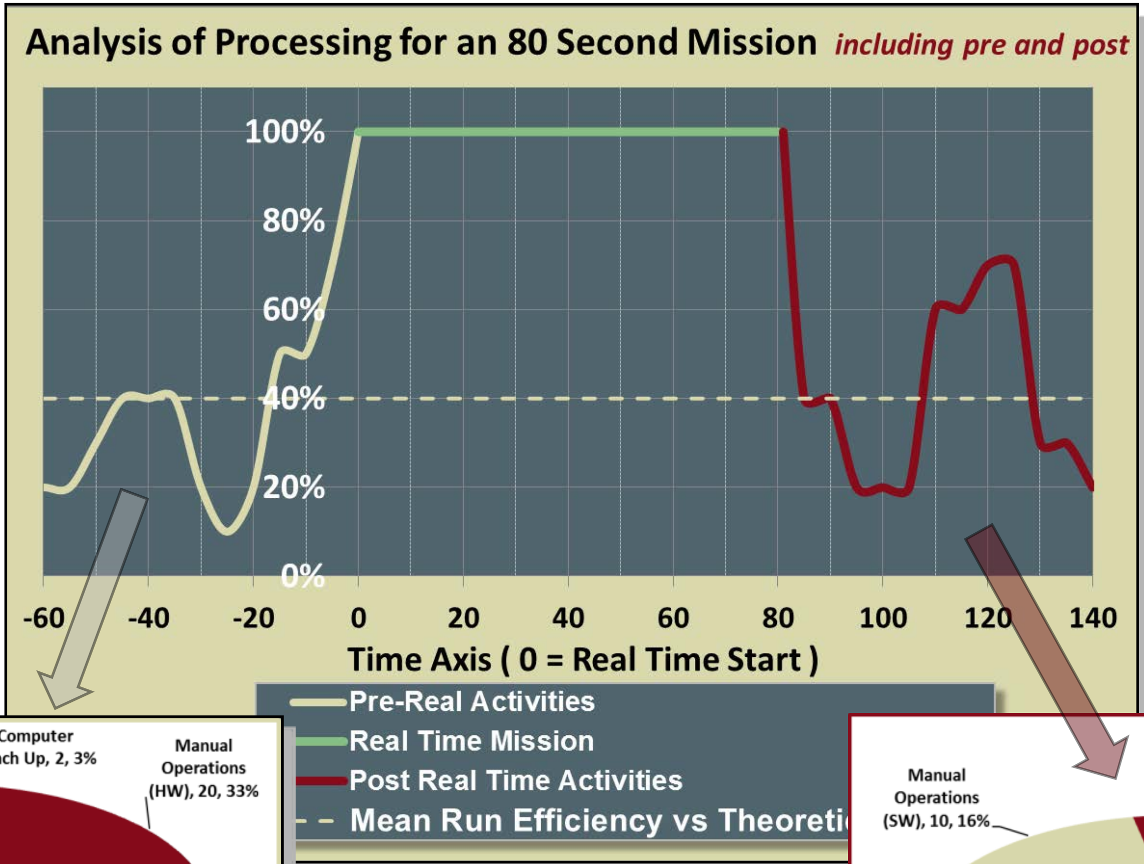
9/80 day 45 minute lunch adjusted





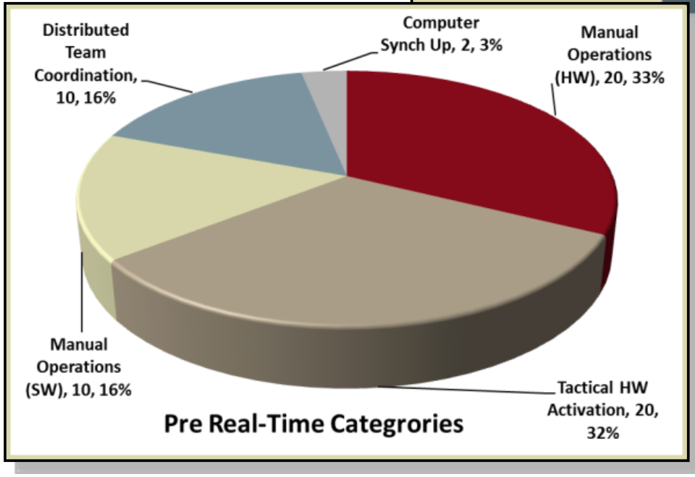
Raytheon

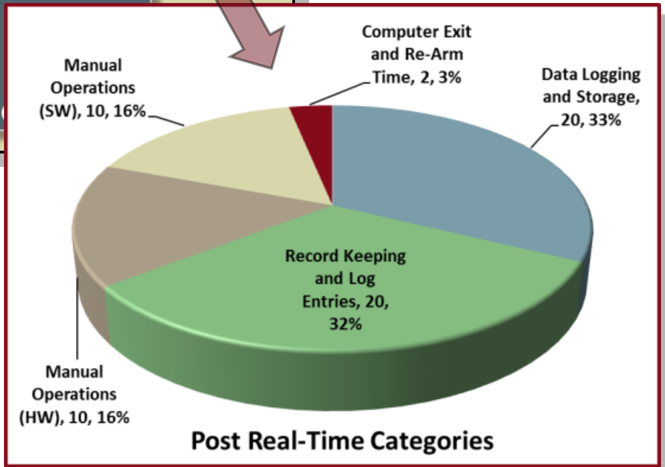
‘Real Time’ Machining Categories



Example
40% of
Theoretical
Maximum of
45 80s runs/hour

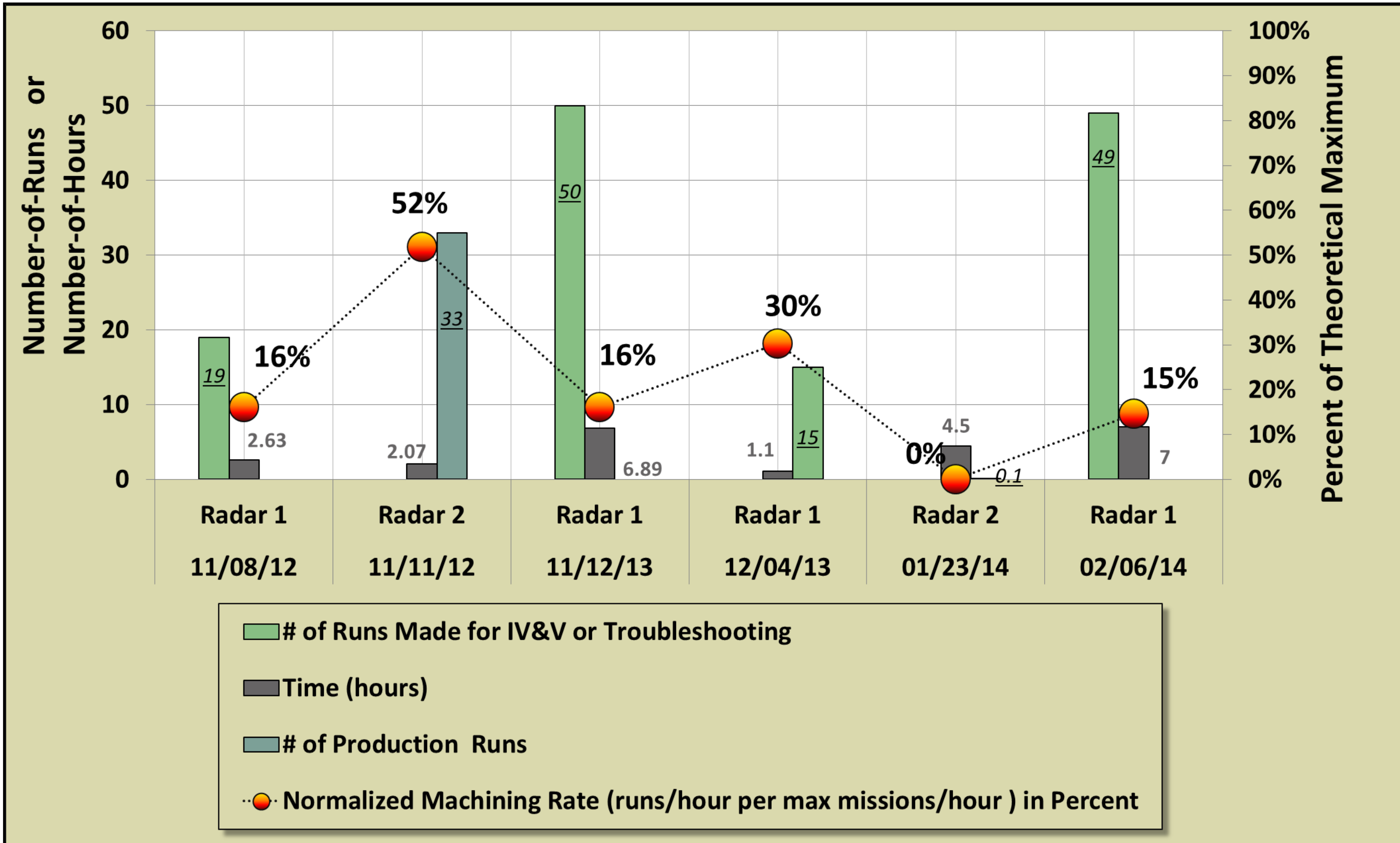
$$\frac{80 \text{ sec}}{200 \text{ sec}}$$



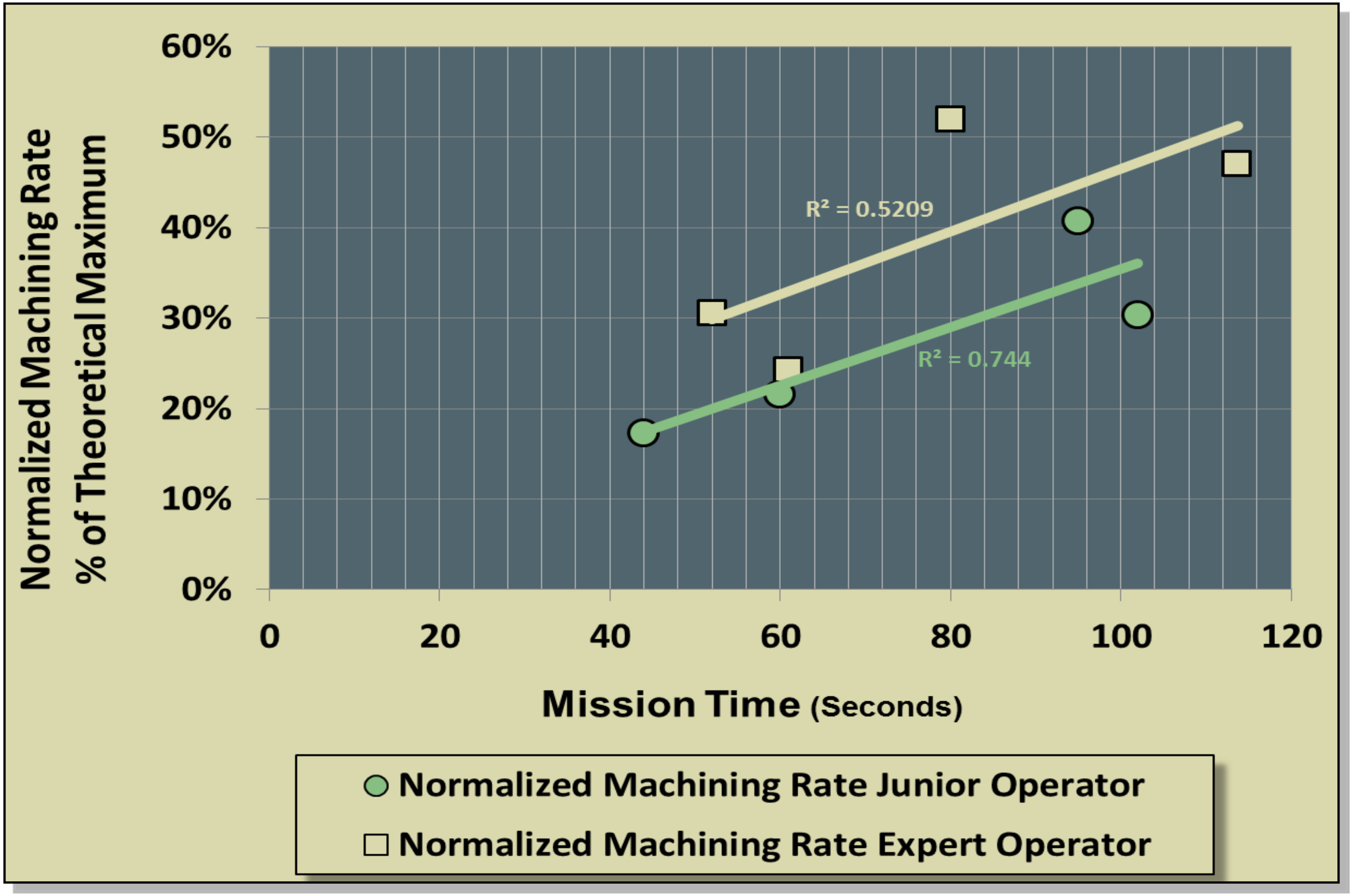


Oregon Productivity

Machining Rate for 2 Activities: IV&V vs. Production

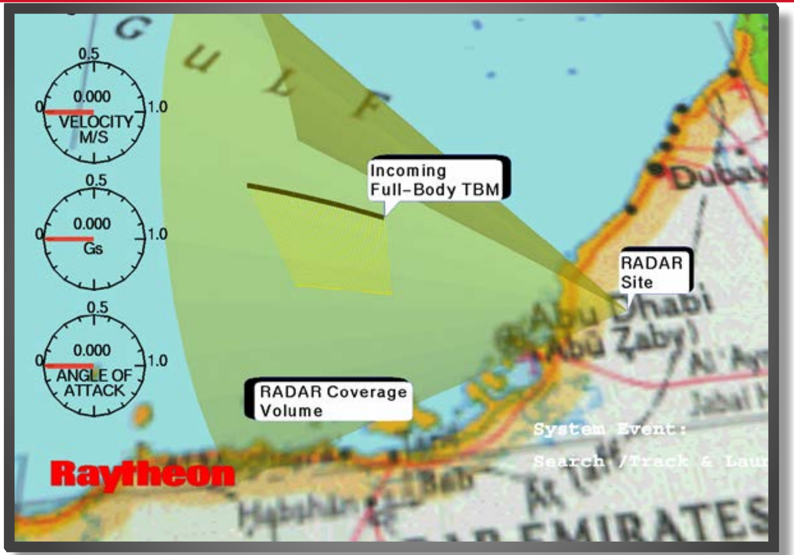


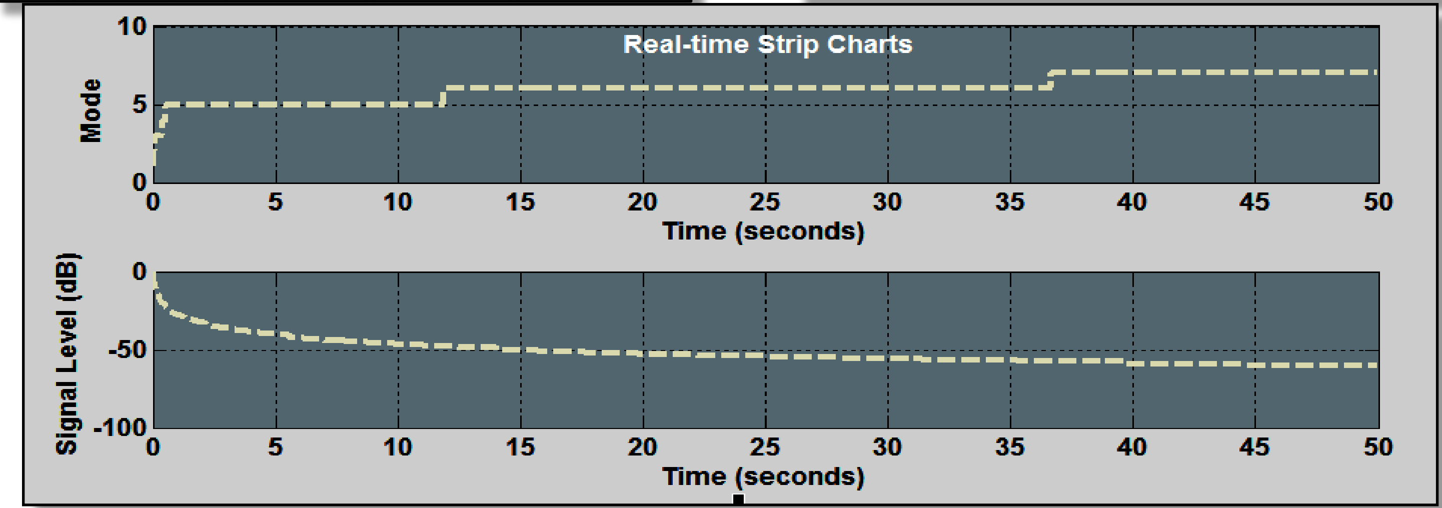
Correlating Machining Rate & Mission Time



Manual Operations and Other Human-Factors = Opportunity !

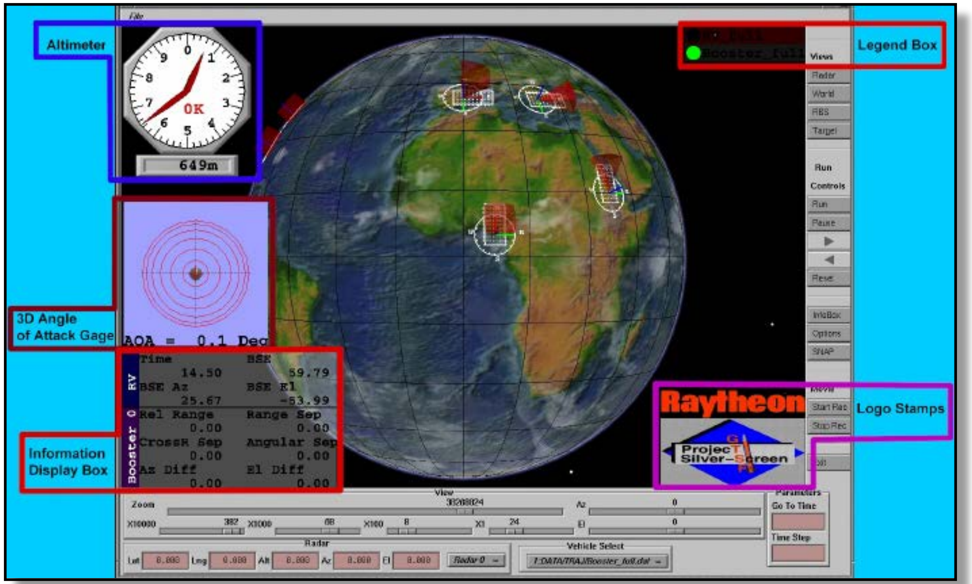
Next: Inventory of Real-Time Analysis Enablers

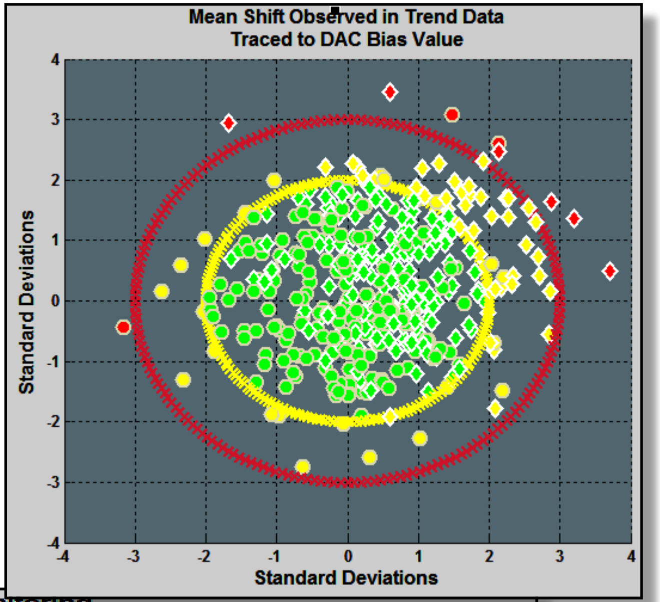


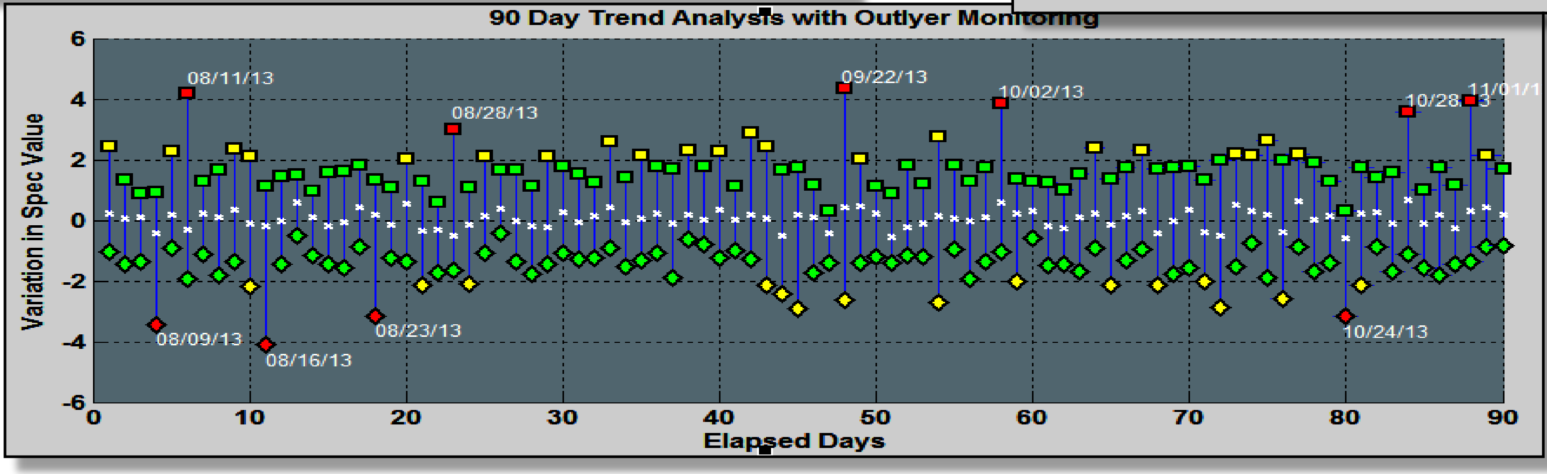


Real Time Analysis Tools Monitor Scenario Run-by-Run

Parametric Variations, Scenario and Trend Analysis



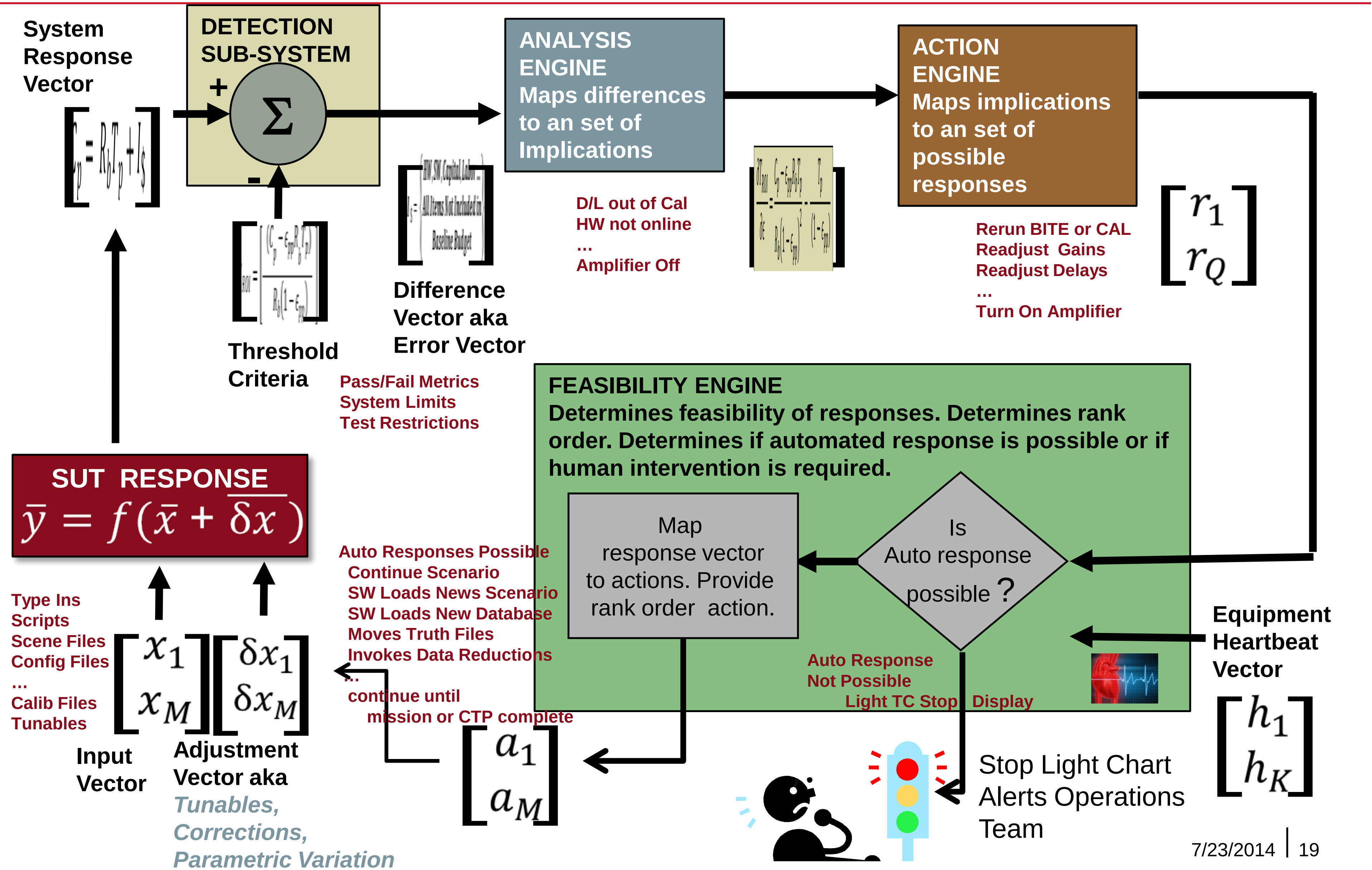




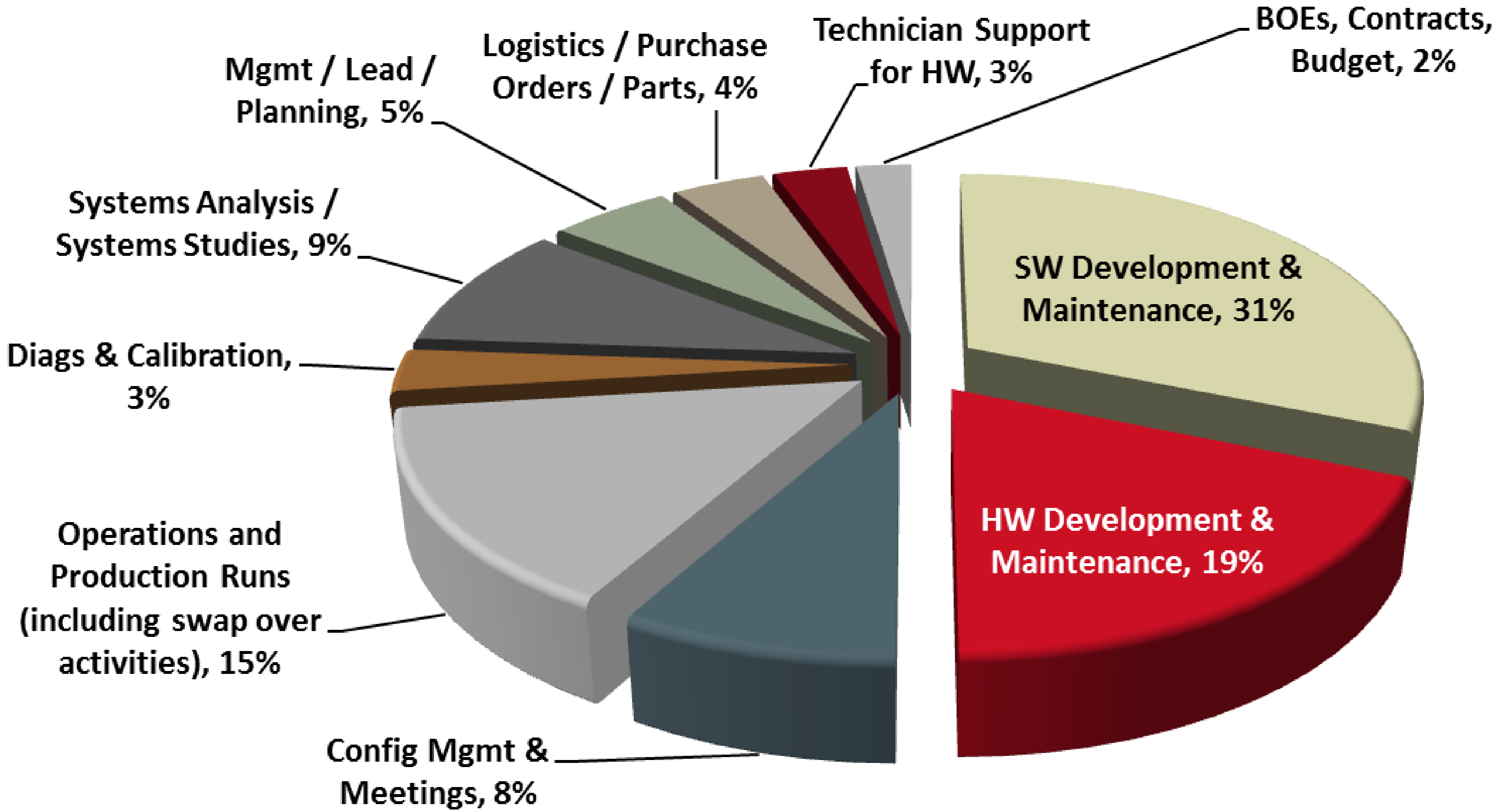
Identifies Anomalies and Historic Trends in SUT and Facility

Paradigm for Automated Test and Real-Time Analysis

Raytheon



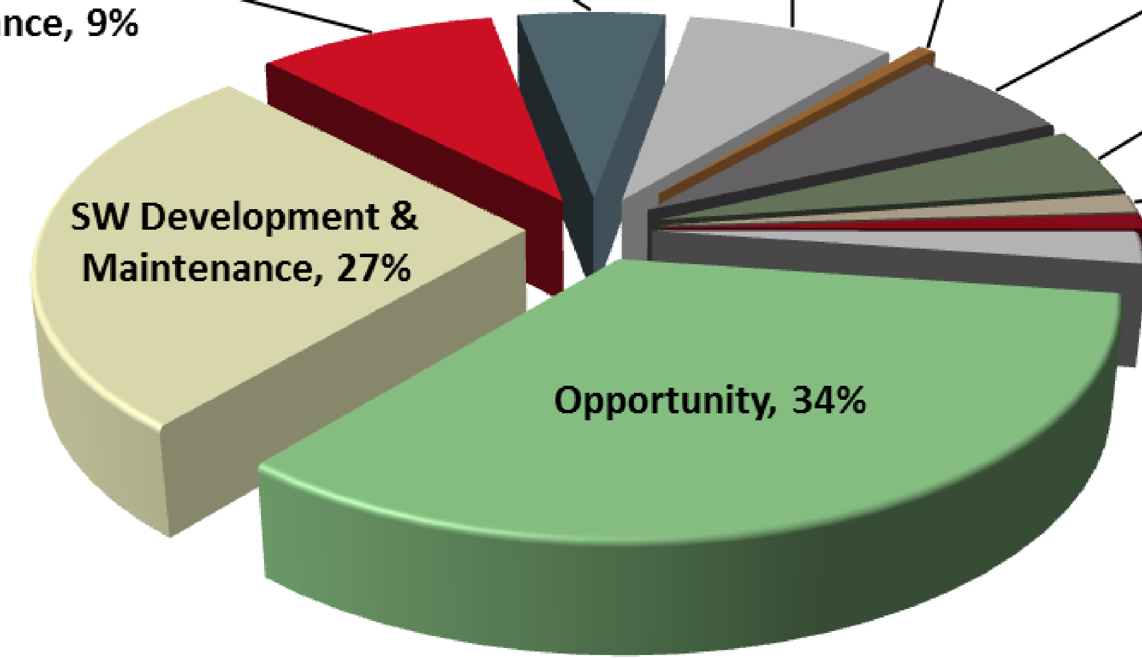
Case Study Baseline for R_b



Notional Yearly Expenditures for Case Study Based on Person Hours

Raytheon

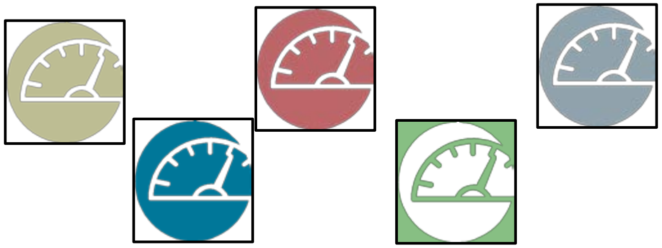
Estimated Final Average Expected Efficiency ϵ_{pp}



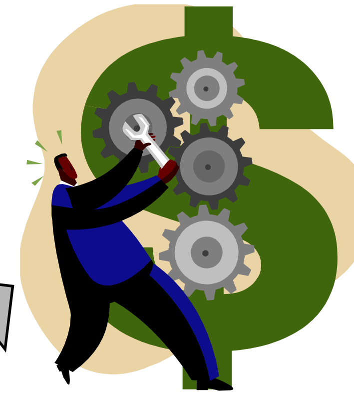
Project Impact on the Case Study Baseline: a 34% Opportunity

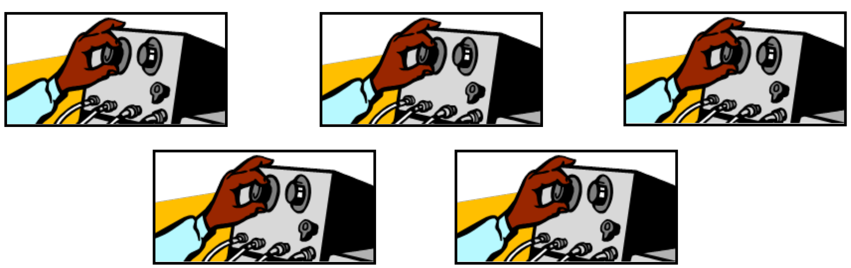
Raytheon

Monte Carlo Simulation and Parameters



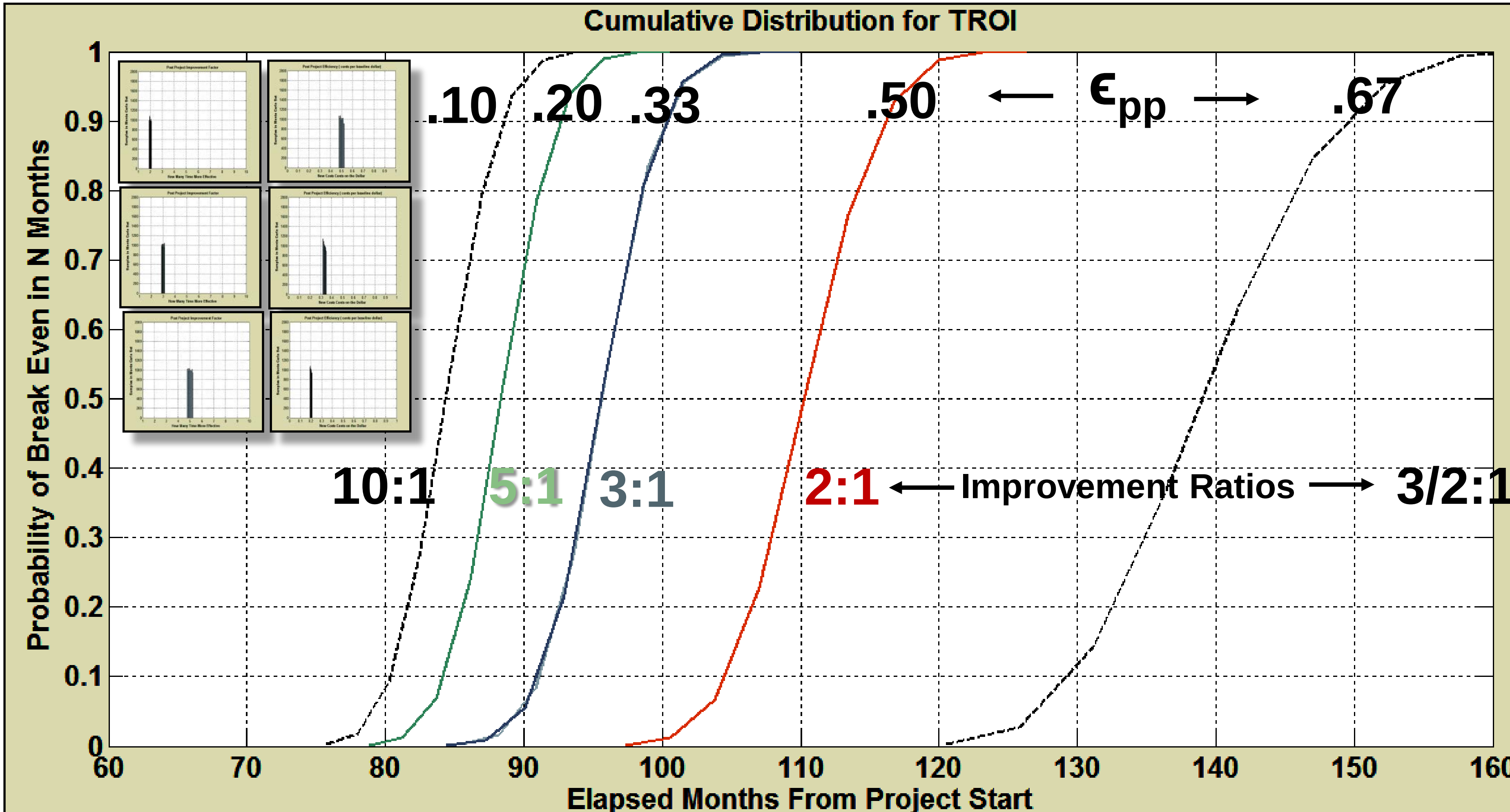
- Cost Variations CPI Model
- Schedule Historic SPI Metrics
- Post Project Efficiency Model
- Inflation and 'Go Do' Model
- Schedule Parallelism Factor





Monte Carlo Inputs a.k.a 'Control Knobs' and Outputs

Monte Carlo Analysis 10000 Runs *part II*



Probability Curves for T_{ROI} vs. Month for Several Efficiencies

Raytheon

Case Study Monte Carlo ROI Summary

Final Post Project Efficiency	Final Post Project Improvement	Break Even Year 90% Confidence	Break Even Quarter 90% Confidence	ROI Rate in $M/ year	Year For Five Year Opportunity $M	Total FiveYear Opportunity $M
0.667	1.50	2028	2nd	1.13	2033	5.6
0.500	2.00	2025	4th	1.69	2030	8.4
0.333	3.00	2023	3rd	2.25	2028	11.3
0.200	5.00	2023	4th	2.70	2028	13.5
0.100	10.00	2022	3rd	3.04	2027	15.2

ROI OPPORTUNITY CATEGORIES

New Business, Additional Programs, Increased Capacity

Additional Testing: Increased Probability of Finding Defects

Job Shadowing and Cross Training

Reduce Impact of Retiring SMEs and Aging Workforce

Develops Bench Strength and Strengths Programs

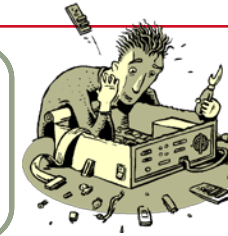
Monte Carlo ROI with Predicted Opportunity for Case Study

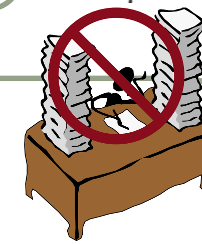
Raytheon

Synergy of Elements: More Capability per Dollar

1

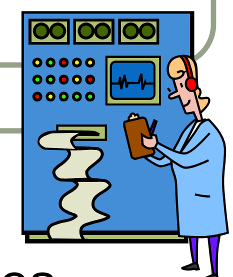
- Hardware Modernization and Upgrades Lead To
  - Reduced Maintenance and Obsolescence Costs





2

- Enable Automated Testing & Analysis Solutions
- Yield More Scenarios, Higher Machining Rate
- Create Time for Cross Training
  (Knowledge Loss is an Industry & Program Risk)



3

- Non-Tangible ROI
  - Increased Probability of Finding Latent Defects
  - Reduced Probability of Need for Failure Analysis Studies
  - Reduced Risks at All Levels: Program, DVT, Mission
  - Increased Customer Satisfaction

NoDoubt Performance ®
More Efficient Testing and Reduced Risk

General Principles and Rules-of-Thumb I

1

- Estimate Shortest Possible Time to ROI by Dividing Maximum[1] Project Investment by R_b: Calculate $I_\$/R_b$
- This is a Go / No Go Check.

2

- Measure current Intra-Set efficiency (*time between runs of the same type*)
- Slides 13, 14,15 and 16 provide some items for consideration.
- Estimate post project ***intra***-set efficiency .

3

- Measure current Inter-Set efficiency (*time between different scenarios*)
- Slides 13, 16 provide some items for consideration
- Estimate post project ***inter***-Set efficiency

[1] *Maximum the Sponsor is willing to invest in the project.*

General Principles & Rules-of-Thumb…
Continued on Next Slide

Raytheon

General Principles and Rules-of-Thumb II

4

- Estimate Readiness For Automated Test Solutions
- Refine Investment $I_\$$ (HW, SW, IVV, Capital) *See Slide 6, 28*

5

- Refine Final Average Post Project Efficiency *See Slides 19, 20*
- Final Average Efficiency is based on weighted efficiencies for each category against the baseline, prorated if T_{ROI} approaches new equipment lifetime.

6

- Compute Estimated T_{ROI} and Opportunity Rate *See Slide 5*
- Using the equation on slides 8, 9 and 5 or
- Based on a Monte Carlo Simulation which uses the equations on 5, 8,9 *See Slide 23, 24*

Estimated Time to ROI and ROI Opportunity;
Refine Models (see slide 28) and Repeat Steps 2 to 6 as Needed

Areas for Further Study

- Assessing Readiness for Test Automation Solutions
  - Defining Metrics for Test Automation Readiness and Adaptability
    - Connectivity: Network, Client-Server Architecture, Fiber, DDS,…
  - Key Performance Metrics
  - Survey of Real-time Analysis Capabilities
  - Success Rate for Automated Analysis Tools

- Modeling Final Average Baseline Rate
  - Developing a More Sophisticated Future Business Model
    - Probability Based Similar to ELF Categories (P_{win} > 50%, etc)

- Characterizing Non-Tangible ROI

Increasing Model Fidelity & Understanding of Contributing Factors

Summary and Conclusion (part I of II)

A method for estimating ROI has been presented.

The start of ROI (post amortization) is sensitive to the prediction (or estimate) of the final post-project efficiency.

Our methods for estimating the post project efficiency were described.

After reducing non-value-added-waste and minimizing required-but-non-value-add processes we address the question of production efficiency or “machining rate”.

For a real-time environment there is a theoretical upper bound to the productivity (machining rate).

Presentation Summary and Conclusions

Summary and Conclusion (part II of II)

The current performance was measured against this upper bound to determine the potential for improvement.

The ROI predictions from a Monte Carlo simulation of notional case study inputs were summarized to demonstrate how the principles and concepts will be applied to our project.

Automated analysis and data reduction is required for the success of test automation projects to prevent information overload on the analysis team and creating a data reduction bottleneck.

Presentation Summary and Conclusions

References

Glisson T.H. , *Introduction to Systems Analysis*,
McGraw Hill Book Company, New York, 1985, pages 19-22

Raytheon Software Council, *SWIFT Proposal Handbook*,
December 23, 2013, Document Number: SW-EN-015, Revision: A

Raytheon IDS SVTAD SysEPG, *SVTAD White Sheet Review*,
2014, slides 41-42,

Raytheon Process Asset Library (Internal Asset),
Computing_Return_on_Investment_ROI_on_Proposed_Process_Improvements_Guideline

http://ipdspal.app.ray.com/PALFiles/Integrated_Defense_Systems/00013586_001_Computing_Return_on_Investment_ROI_on_Proposed_Process_Improvements_Guideline.pdf

Contact Information

Chester Boncek
Engineering Fellow
Systems Integration Test Facility
Raytheon Company

+1 978.470.9076   (business)
chester_f_boncek@raytheon.com

350 Lowell Street
AMMZ342K
Andover, MA 01810   USA
www.raytheon.com

Raytheon

Get Off the Stage Chart

Thank You for your time.

Now for me…

Thank You and Post Talk Questions & Discussion

Additional Information

Additional Support Plots and Materials

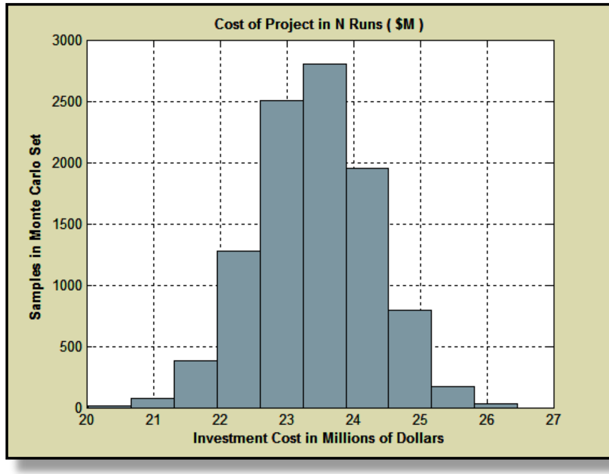
Monte Carlo Analysis 10000 Runs *part I*

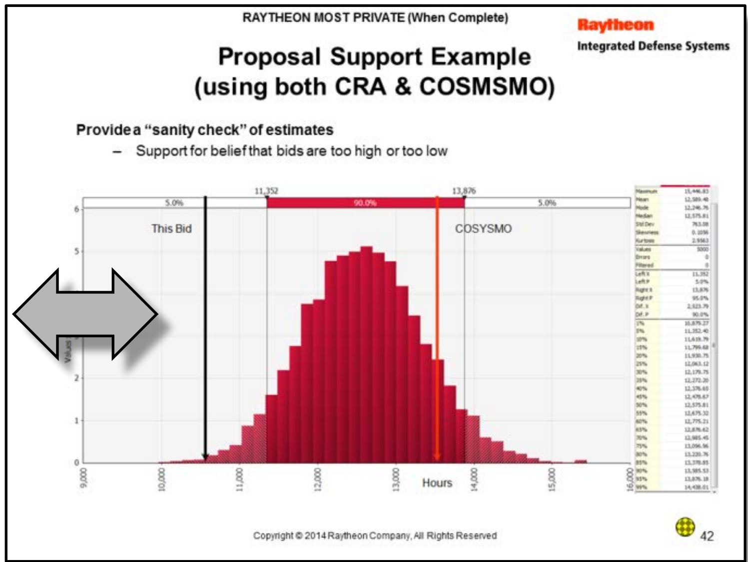
Cost Draws

μ = 23.3 M

σ = 5%

0.85 < CPI < 1.15





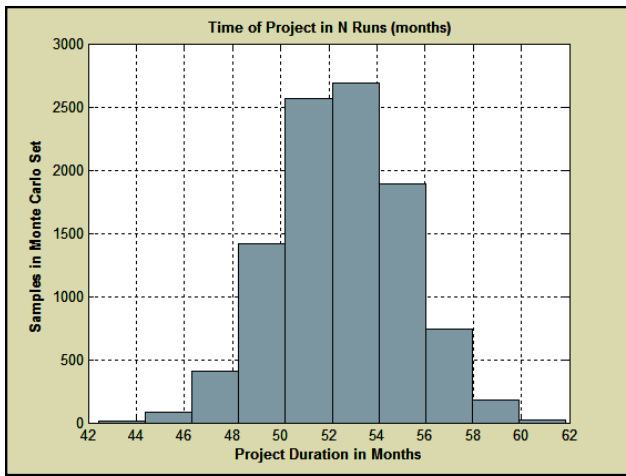
Reference [2] SVTAD White Sheet Template

Schedule Draws

μ = 52.5 M

σ = 5%

0.85< SPI < 1.15



Distributions Used for Cost and Schedule Variance Follow Standard IDS Methodology

Sensitivity Analysis Defined

Baseline Performance for a function for N parameters:

$$\Psi_0 = \Psi(p_1, p_2 \dots p_N)$$

Approximate changes to the function for changes in the parameters.

$$\Delta\psi \approx \sum_{n=1}^{N} (\partial\psi/\partial p_n)^* \Delta p_n \qquad \text{let } \Delta p_n = 0 \; i \neq n$$

then

$$\Delta\psi \approx (\partial\psi/\partial p_n)^* \Delta p_n$$

Reference [1]: Glisson T.H., *Introduction to Systems Analysis,* McGraw Hill Book Company, New York, 1985, pages 33-35

Now Let's Calculate the Sensitivity for the Four Terms in the ROI Equation

Raytheon

Definitions

Amortization: to pay a debt over a period of time usually in regular installments

Depreciation: allocate the cost of tangible assets over the useful life. Businesses depreciate long-term assets for both tax and accounting purposes

Raytheon

Abstract Approval Notice 16805

Abstract Reference #16805 has been APPROVED - IBM Lotus Notes

File Edit View Create Actions Tools Window Help

Open | Home | Chester F Boncek - Mail | Abstract Reference #16805 has been ...

Reply | Forward | New | Display | Report as Spam | Report as Suspicious | Deliver Sender's Mail to Junk... | More

Abstract Reference #16805 has been APPROVED

mholt to: chester_f_boncek

06/06/2014 03:54 PM

Hide Details

From: mholt@ndia.org

To: chester_f_boncek@raytheon.com

(Abstract Reference: Abstract Reference number: 16805; Abstract Title: Predicting Return-on-Investment (ROI) for Large Scale Six Sigma & Test Automation Projects)

Dear Sir/Madam,

Thank you for submitting your Abstract(Abstract Reference number: 16805) to the 29th Annual National Test & Evaluation Conference.

The review committee has approved your Abstract submission for presentation. Congratulations. We look forward to your participation in this exciting conference.

If you have general questions regarding the conference and the abstract approval process, please address them to Molly Holt at (703) 247-2572 or mholt@ndia.org. Please refer to your abstract reference number (Abstract Reference number: 16805) when you contact us regarding your submission.

Sincerely,
The Conference Planning Committee

TUESDAY JULY 22, 2014
BREAKOUT SESSION SCHEDULE *(CONTINUED)*

SESSIONS G-I			
LOCATION SESSION TITLE	**NATIONAL BALLROOM A SESSION G:** T&E Test Methods and Tools *(Continued)*	**NATIONAL BALLROOM B SESSION H:** T&E in a Financially Constrained Environment	**NATIONAL BALLROOM C SESSION I:** Alternate T&E Solutions
SESSION CHAIRS	Mr. Dick Dickson, Program Manager, Jacobs Technology	Dr. Mark Kiemel, President, Air Academy Associates	Dr. Lowell Tonnessen, Institute for Defense Analyses
3:50PM	**"DEVELOPMENTAL EVALUATION FRAMEWORK THROUGHOUT THE ACQUISITION LIFECYCLE"** ▸ Dr. Suzanne Beers, Electrical Engineer, The MITRE Corporation	**"CAPITALIZING ON ALL TEST DATA: STATISTICAL METHODS FOR DOING MORE WITHOUT MORE"** ▸ Dr. Laura Freeman, Research Staff Member, Institute for Defense Analyses	**"SURVEYS IN TEST & EVALUATION"** ▸ Dr. Rebecca Grier, Research Staff Member, Institute for Defense Analyses
4:15PM	**"IMPLEMENTATION & EFFECTIVENESS OF DESIGN OF EXPERIMENT FOR SMALL DOD PROGRAMS"** ▸ Mr. Solomon Desalegn, Operational Test Project Officer, U.S. Marine Corps OT&E Agency	**"PREDICTING RETURN-ON-INVESTMENT FOR LARGE SCALE SIX SIGMA & TEST AUTOMATION PROJECTS"** ▸ Mr. Chet Boncek, Engineering Fellow, Raytheon	**"THE IMPACT OF DYNAMIC BALLISTIC TESTING ON TRADITIONAL VULNERABILITY MEASURES"** ▸ Dr. James Walbert, Adjunct Research Staff Member, Institute for Defense Analyses
4:40PM	**"THE U.S. ARMY JOINT TEST ELEMENT: 'BOTTOM UP' REQUESTED, 'TOP DOWN' PROVIDED, WARFIGHTER DRIVEN"** ▸ LTC Manuel Ugarte, USA, Deputy Director, Quick Reaction Tests & Senior Operations Research Analyst, U.S. Army Test & Evaluation Center	**"THE CHIEF DEVELOPMENTAL TESTER & INDUSTRY TEST LEAD: PARTNERING FOR SUCCESS"** ▸ Mr. Joe Manas, Engineering Fellow, Raytheon	**"TEST & EVALUATION: WHERE SCIENCE MEETS SUCCESS"** ▸ Ms. Terri Kocher, Operations Research Analyst and Technical Director, Joint Research and Development, Inc.
5:05PM	**SESSIONS G-I CONCLUDE** *Conference Adjourned for the Day*		

07-22-2014 04:15 PM

NATIONAL BALLROOM B
SESSION H: T&E in a Financially Constrained Environment

Session Chair:
Dr. Mark Kiemel, President,
Air Academy Associates