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Cost Estimation as an Intensive Human Interactive Systems Engineering Problem

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Abstract

Cost Estimation as an Intensive Human Interactive System Design Problem

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Abstract —This paper will compare and contrast the difference between Intensive and Non-Intensive Human Interactive Systems. Further, this paper will investigate the role of Governance, Culture, Process and Tools (GCPT) in each of the 2 systems, Intensive and Non-intensive. Finally, this paper will apply the GCPT Framework to the system of Organizational Cost Estimation and provide examples of results that Raytheon has seen in its effort to improve the accuracy, affordability and accountability of the current bidding/estimation process.

Agenda

1. Introduction – Definitions
2. Types of Human Failures
3. “Capability” vs “System” vs “Device”
4. Non-Intensive Human Interactive Systems
5. Intensive Human Interactive Systems
6. The GCPT Framework for Intensive Human Interactive Systems
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9. Process
10. Tools
11. GCPT Maturity Index
12. A Generalized Cost Estimation Flowchart
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14. An Example of GCPT for In-Process Metrics Collection
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Introduction

- Systems Design:
  - *Systems Design is an interdisciplinary field of development that focuses on how to design and manage complex capability based systems over their life cycles.*
- Cost Estimate:
  - *A cost estimate is the approximation of the cost of a program, project, or operation. The cost estimate is the product of the cost estimating process.*
- Intensive Human Interactive System:
  - *An Intensive Human Interactive System is any organized activity through which complex human interaction, participation and judgment and possibly motivation plays a key role in the outcome of the activity.*

Types of Systemic Failures in Human Interactive Systems

- Soft Human Failure (SHF):
  - A Soft Human Failure (SHF) occurs in systems which minimize human interaction and involvement to "simple" tasks.
- Hard Human Failure (HHF):
  - A Hard Human Failure (HHF) occurs when a human needs to complete much more intensive and difficult activity in conjunction with the other parts of the system.
- Complex Human Failure (CHF):
  - CHFs are an entirely different class of failures than SHFs and HHFs. CHFs are more closely associated with human capabilities, motivations, desires, preferences, and beliefs.

"CAPABILITY" vs "SYSTEM" vs "DEVICE"

- Many systems designers are trained to believe that the device that they deliver to customers is the "system" and when properly created, that "system" delivers "capability" required by the customer.
  - **However, this is almost never true**.
  - **Without the proper human interaction, the device cannot alone deliver the capability required.**
- Fundamentally, there are four elements which compose most Human Interaction Systems: tools, processes, cultural elements, and governance.
- Within the context of this paper we will refine the definition of an **Intensive Human Interactive System**:
  - *An intensive human interactive system is defined as that suite of governance models, cultural elements, processes, and tools which together enable a complex capability.*

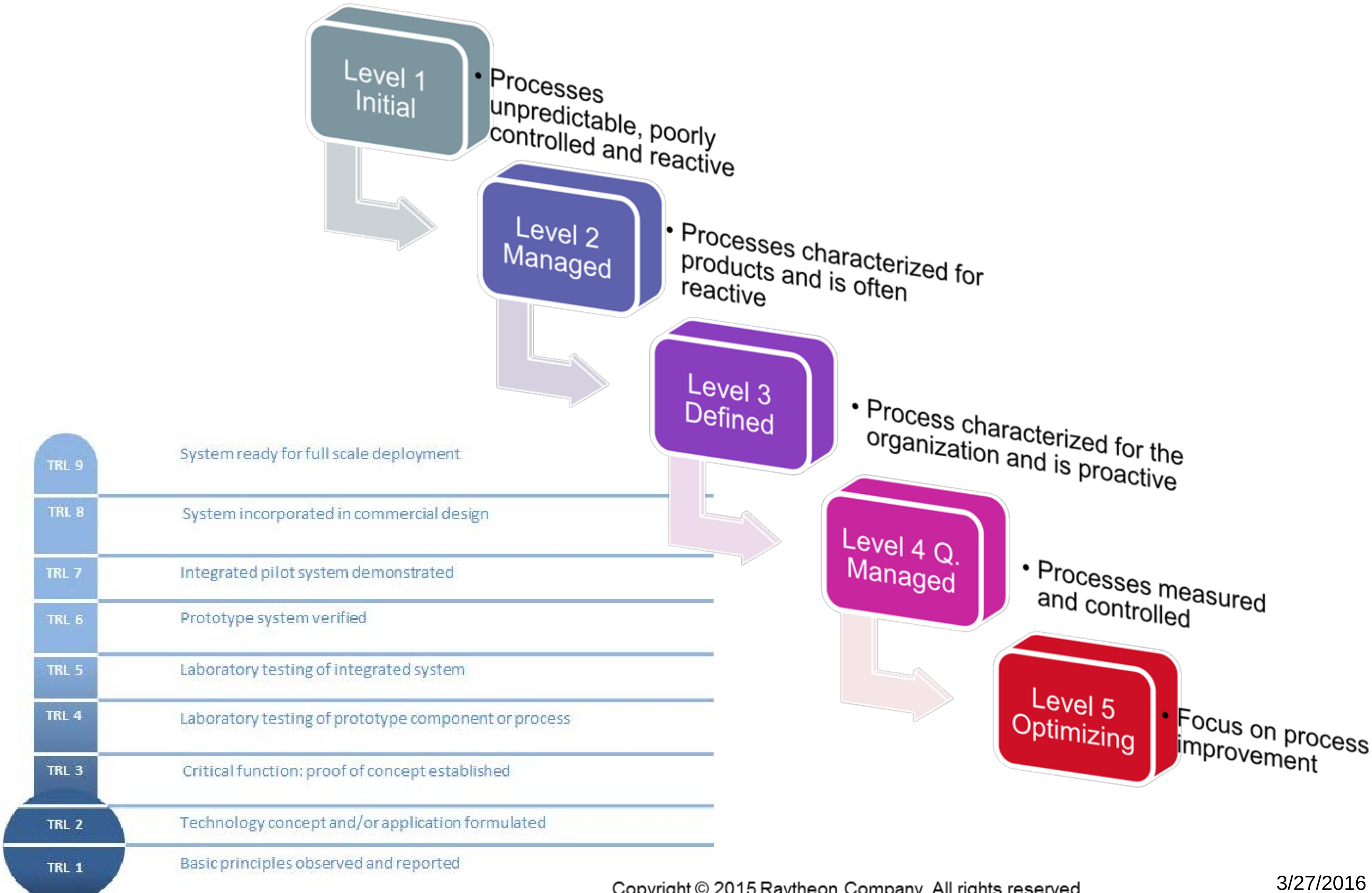
Difference Between Intensive and Non-intensive Human Interactive Systems

- Non-intensive Human Interactive Systems are comprised of capabilities in which either the user already contains a high degree of motivation to use or is so trivial to accomplish as to make motivation not an issue.
  - The system designer is not worried about whether or not the user *wants* to use the product or whether there is a complex interaction of various individuals of varying motivation.
  - As long as the product is usable (given the appropriate training materials to mitigate SHFs and HHFs), the system designer's job is done.
- Intensive Human Interactive Systems will certainly have SHF modes and/or HHF modes that will need to be mitigated, however, additionally users may not may not be motivated leading to CHF modes.
  - Tools alone are insufficient in overcoming CHF modes.

The GCPT Framework for Intensive Human Interactive Systems

- The GCPT (Governance, Culture, Processes, and Tools) Framework describes the four elements required for any Human Interactive System to achieve its desired capability
  - Governance describes the model/method one will use to measure that the system is delivering the expected results during deployment.
  - Culture, reflects the need to have people trained to exercise the other system elements in such a way that the system can achieve success.
  - Process, simply reflects the need for well-defined processes that the overall system executes to repeatedly achieve success.
  - Tools, describes those devices and machines which are built to automate processes.

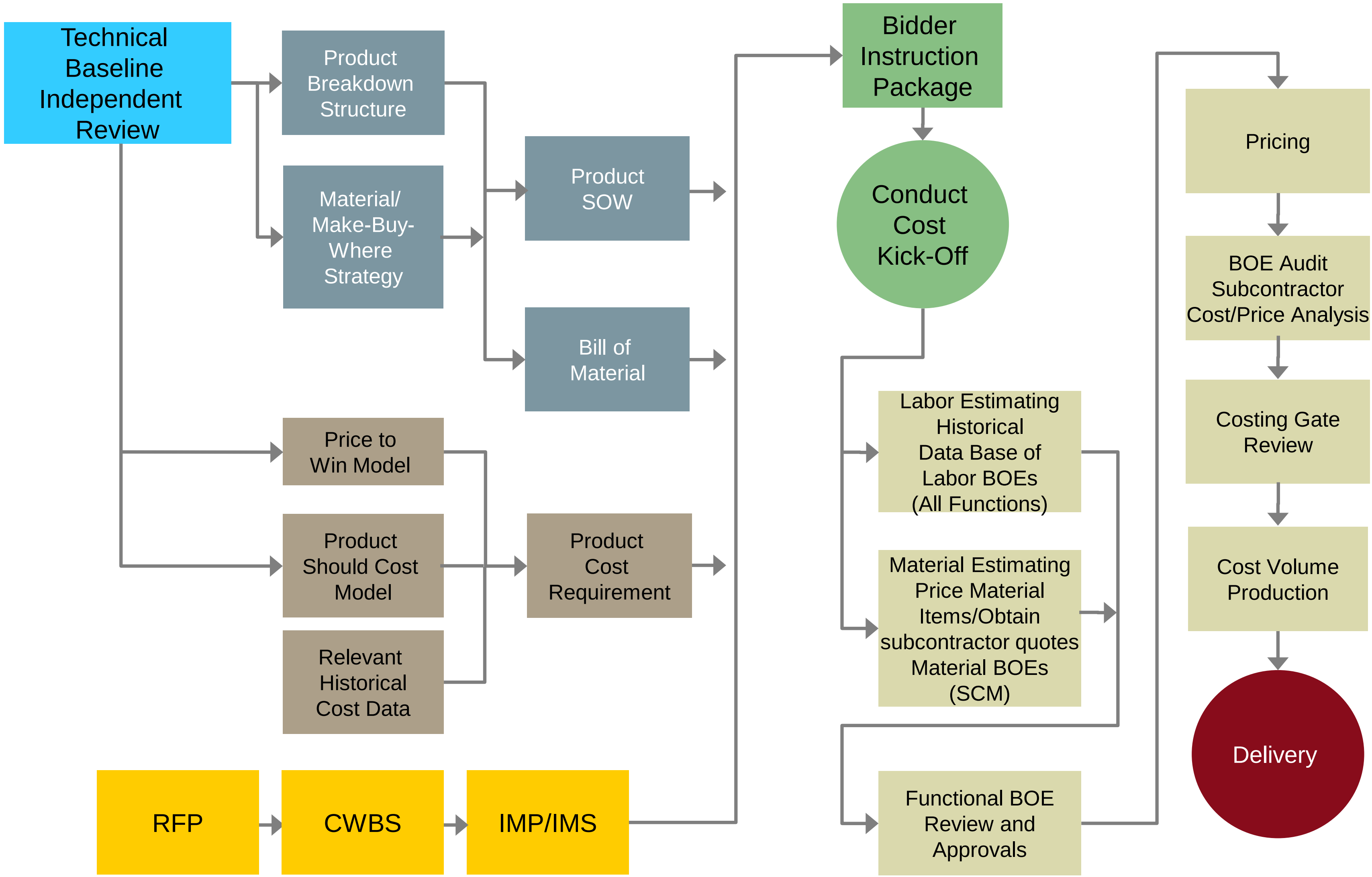
Path to Improvement



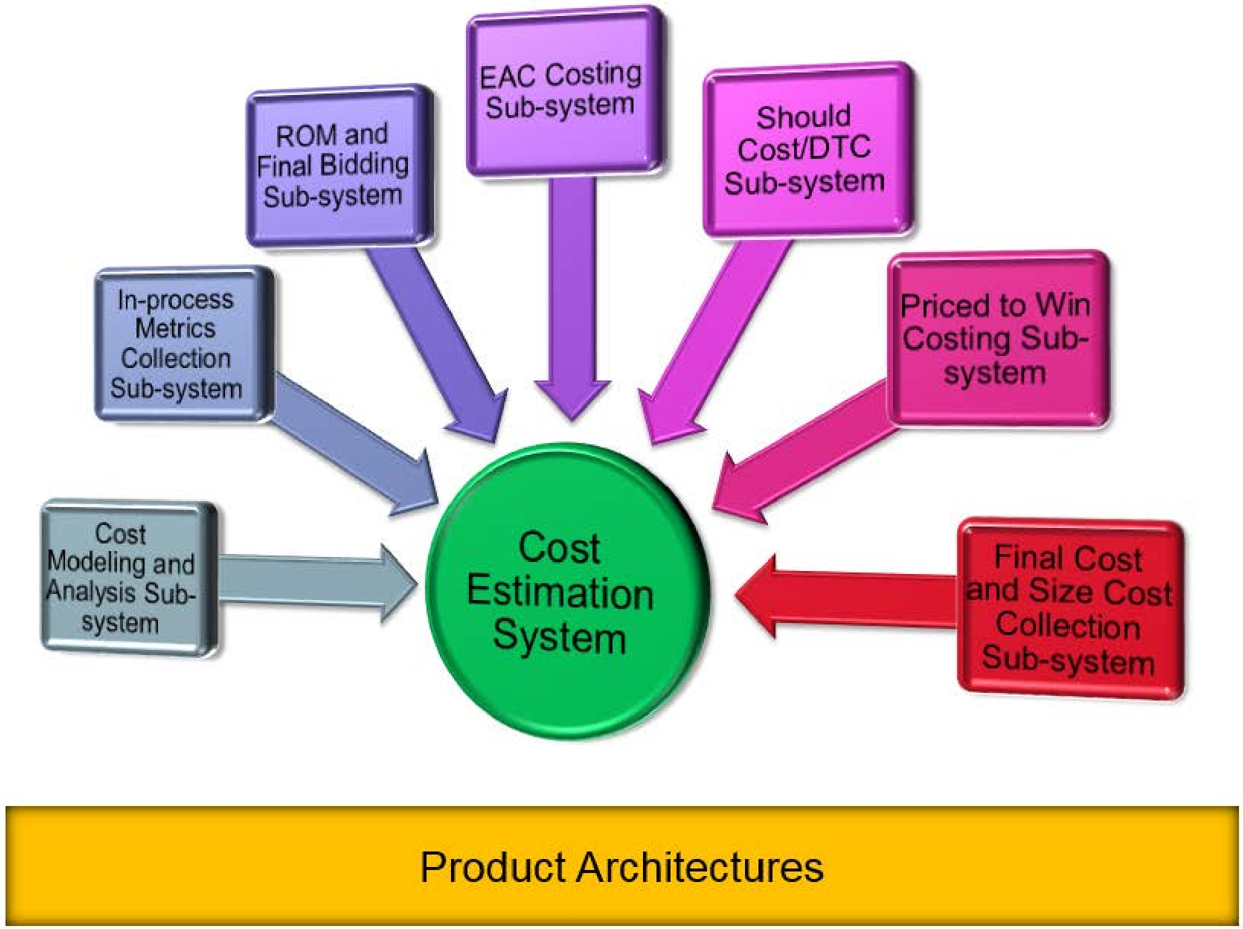
GCPT Maturity Index

Research Type	Research Description	TRL	TRL Description	Description when TRL reached	Focus of effort to reach TRL	Governance	Culture	Process	ProtoTools (Eng Dev'd)	Tools (IT Dev'd)
6.1	Basic Research	1	Basic principles observed and reported	Problem and Potential Solution Identified	Preliminary identification of problem; potential solutions identified	Problem identified; potential solutions identified; potential ROI identified				
		2	Technology concepts or applications (or both) formulated	System Trades Conducted, Point Design Selected	System trades; indentification of point solution	Problem and potential solutions well-defined and documented; System trade study complete; System point solution formally identified				
6.2	Applied Research	3	Analytical and experimental critical function or characteristic proof of concept (or both)	System Design, CONOPs, Failure Modes Documented	System conops; System decomposition; system and product rqmts development	System elements defined; product rqmts defined; system performance rqmts defined	Cultural change rqmts defined; cultural elements identified; change toolkit templates completed	Process rqmts defined; Process changes / developments identified	Tool rqmts defined; Tool changes / developments identified	Tool rqmts defined; Tool changes / developments identified
		4	Component or breadboard validation in a laboratory environment	Critical Elements Designed and Checked Out	Preliminary design of products	Critical elements poc demo	Discussions and preliminary buyin with stakeholders	Process conops, flow, key steps defined; Successful preliminary review	Preliminary tool prototype or mock-up; Tool-process preliminary integration flow	Preliminary tool prototype or mock-up; Tool-process preliminary integration flow
6.3a	Advanced Technology Development	5	Component or breadboard validation in the relevant environment	Critical Elements Tested in Simulated Env	Final design of products; preliminary system performance analysis	Critical elements advanced poc demo	Discussions and detailed buyin with stakeholders	Process conops, flow, steps defined; successful design review	Tool design complete; tool tested by developers; successful review	Tool design complete; tool tested by developers; successful review
6.3b	Demonstration and Validation (DemVal) Activities	6	Demonstration of system or subsystem model or prototype in the relevant environment	All GCPT Tested in Simulated Env	System performance demonstration; deep stakeholder engagement	Components shown to meet performance rqmts; System meets expected perrormance	Stakeholder engagement plan in place; POC with pilot stakeholders successful	Stakeholder review and approval of process; process meets performance rqmts	Stakeholder review and approval of tool; tool meets performance rqmts	Stakeholder review and approval of tool; tool meets performance rqmts
6.4	Engineering and Manufacturing Development	7	Demonstration of a system prototype in an operational environment	All GCPT *Engineering Models* Piloted Successfully	Preliminary (Test) Deployment to small number of pilot areas; system performance documented; deployment via experts / design team	System shown to meet performance rqmts; deployment plan/metrics defined	Proto training proven effective; stakeholder engagement effective; Lessons learned incorporation plan	Process successfully piloted; preliminary process performance metrics reported	Tool successfully piloted; may include significant use of experts	Tool successfully piloted; may include significant use of experts
		8	Actual system completed and "flight qualified" through testing and demonstration activities	All GCPT *Final System Elements* Piloted Successfully	Deployment to small number of areas; deployment via experts / design team; Focused training for operational deployment	System shown to meet performance rqmts	Final training proven effective; stakeholder engagement effective; lessons learned incorporation in place	Process fully integrated into IPDS; Process released into management system; Process rqmts compliance demonstrated thru user deployment	Tool released, under configuration control, referenced appropriately within mangement system; Tool usability demonstrated via users	Tool released, under configuration control, referenced appropriately within mangement system; Tool usability demonstrated via users
		9	Actual system "flight proven" through successful mission operations	All GCPT in LRIP	Limited deployment according to written deployment plan; deployment via operational team	System performance metrics recorded and monitored as part of standard metrics set	Final training proven effective; stakeholder engagement effective; lessons learned incorporation in place	Process fully integrated into IPDS; Process released into management system; Process rqmts compliance demonstrated thru user deployment	Tool released, under configuration control, referenced appropriately within mangement system; Tool usability demonstrated via users	Tool released, under configuration control, referenced appropriately within mangement system; Tool usability demonstrated via users
6.6	Operational Systems (Maintenance)	"10"	System Deployed, Operational, and Effective	All GCPT in Production / Sustainment	Ongoing pervasive deployment and maintenance	Ongoing deployment; Ongoing performance measurement	Minor Training Package Updates as necessary	Minor updates as necessary	Minor updates and bug fixes as necessary	Minor updates and bug fixes as necessary

Costing Activities Flow Chart



Key Sub-System Components Supporting the Cost Estimation System Flowchart



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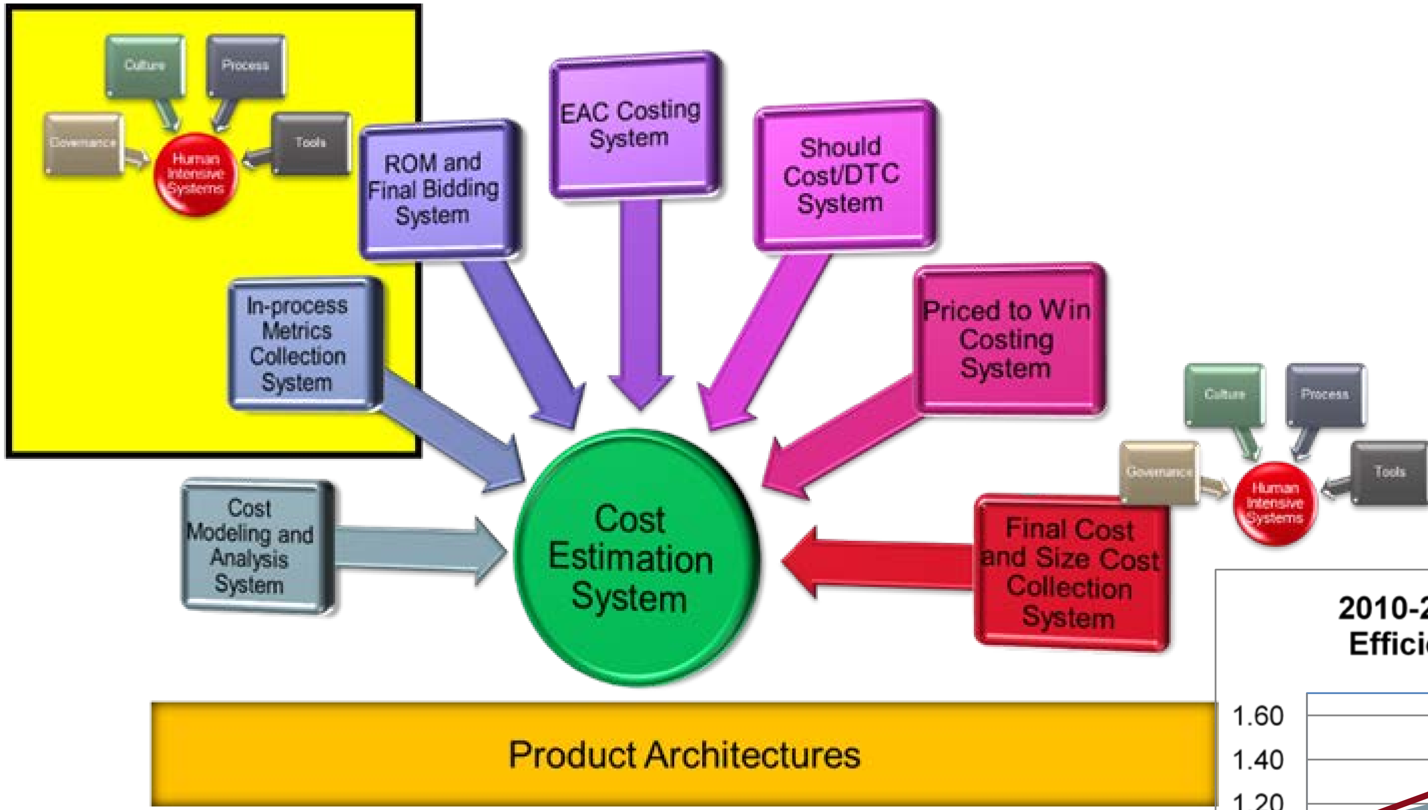
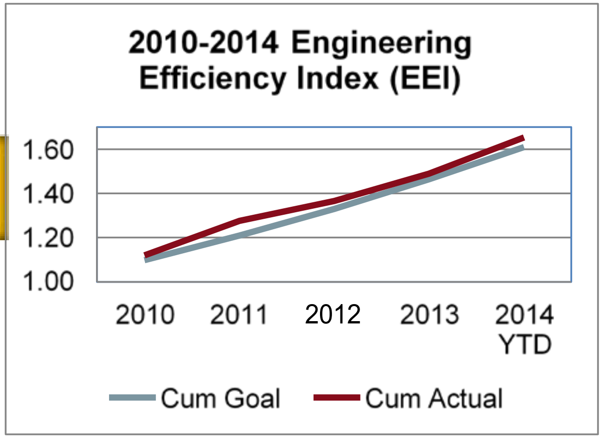
An Example of GPCT for In-Process Metrics Collection





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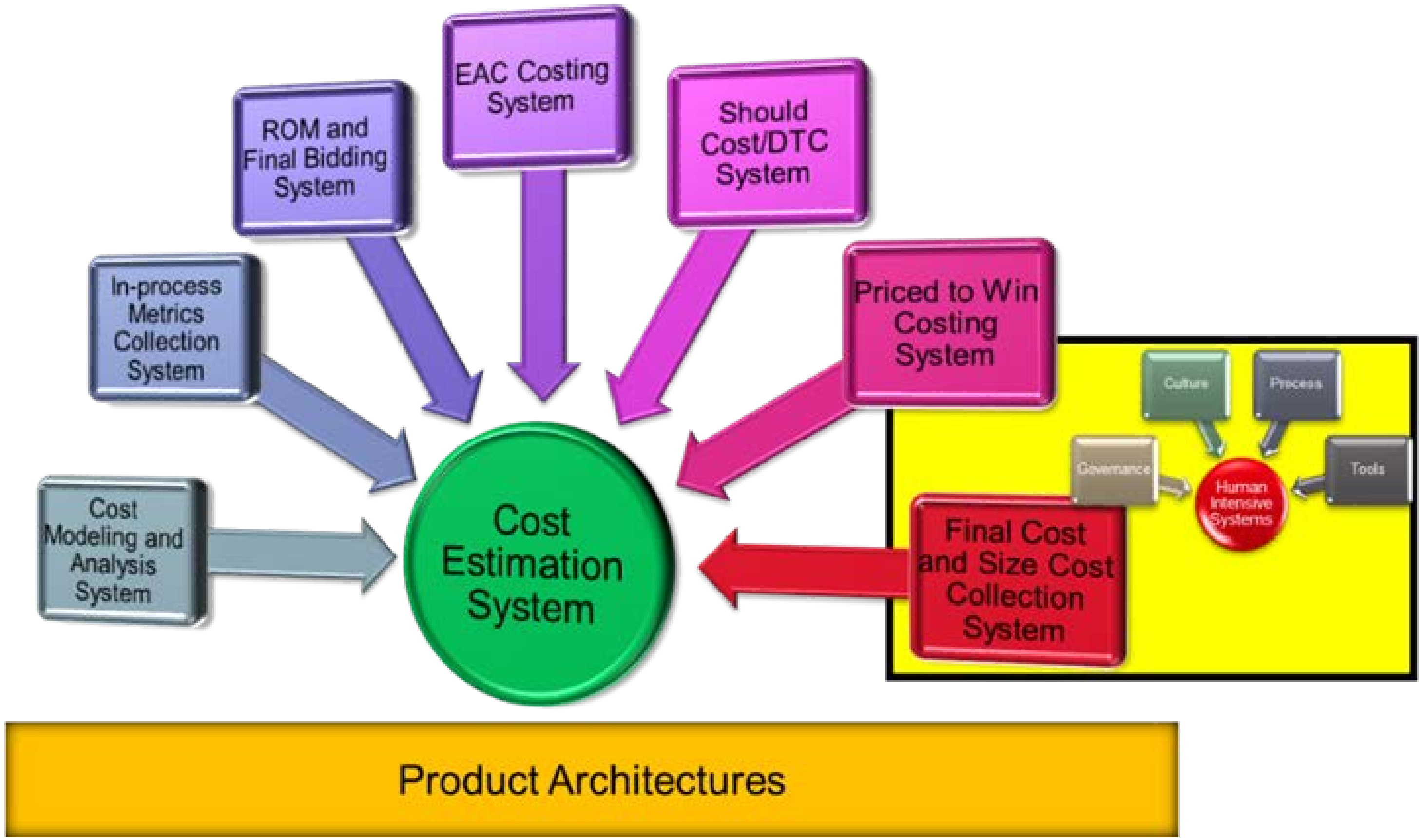

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HWEC Completed Products Status Scorecard Instructions

Summary

- With Intensive Human Interaction Systems simply providing a better tool or better instructions to an existing tool is not sufficient to overcome most failure modes
- Adding the organizational construct of Governance, Culture, Process and Tools (the GCPT framework) provides the necessary elements to insure success for a new or upgraded capability that involves an Intensive Human Interaction System
- Most of the investment is spent on Tools and yet the success or failure of the implementation of the Tool within the organization often has less to do with the Tool and more to do with the Governance or Culture (training, socialization etc) or Process surrounding the use of the Tool.
- The application of the GCPT Framework is nearly universal as it relates to nearly any Intensive Human Interactive System.

Biography

Dr. Robert Wright *received B.S., M.S., and Ph.D. degrees in Physics from the University of California at Los Angeles in 1988, 1990, and 1994. He has been with Raytheon Space and Airborne Systems in El Segundo, California since 2003. His current role there is as the Director of Engineering Operations, where he oversees the internal operation of the engineering organization, including development of strategy, execution of improvement initiatives, and oversight of the operating budgets. He has previously managed software and hardware development groups, overseen IRAD portfolios, and began his career as a semiconductor research scientist at The Aerospace Corporation*

Mr. David Scott *received his B.S. and M.S. degrees in Industrial Engineering from the University of Arkansas at Fayetteville in 2003 and 2005. David has been with Raytheon Space and Airborne Systems in Dallas and McKinney, Texas since 2005. His current role is a Senior Engineering Excellence Project Lead. His efforts focus on creating lasting change for improvement initiatives to achieve the Engineering organization strategy. He has previously served as an Integrated Product Team Leader for a suite of Multi-Spectral Targeting Systems, served as a Six Sigma Expert, managed the McKinney Texas Logistics Operations organization, and started with Raytheon in Logistics Distribution Management.*

Mr. David Bloom *graduated from the University of California at Davis in 1983, Mr. Bloom has worked for the Naval Weapons Center, Lockheed Martin, Lawrence Livermore National Labs and since 2008, for Raytheon Space and Airborne Systems (SAS). Mr. Bloom is currently the Cost Estimation Subject Matter Expert (SME) for the Hardware Engineering Center (HWEC) of SAS. He has developed parametric models for all SAS Electronics Products and helped transform the culture of the organization in the use of parametric bidding methodologies. Mr. Bloom has patents and software copyrights along with a number of publications ranging from electromagnetic boundary value problems to cost estimation. In 2006, he won the International R&D 100 Award for innovating a cost effective Gigapixel Camera for persistent surveillance applications.*

Mr. Danny Polidi *received a B.S. and M.S. degree in Electrical Engineering from the California Polytechnic State University, San Luis Obispo, CA in 1990 and 1991. Upon graduation, started working at Space Systems/Loral on high frequency, microwave designs for space applications. Later, at Radian Technology, he became the Product Manager of the Digitally Tuned Oscillator Product Line where he was responsible for designing new circuits, writing code, and production. At NANOmetrics, Danny managed all Electronic Engineering activities. From 2004 – present he has worked at Raytheon as a Section Manger, Team Lead, Cost Account Manager and has been certified as a Program Manager.*

W***anda Grant*** *graduated from Pratt Institute with a B.S. Degree in Electrical Engineering in 1979. In 1982, Wanda received a M.S. in Electrical Engineering. Wanda is currently the Center Operations Manager and Chief Process Engineer for Raytheon Space and Airborne Systems (SAS) Hardware Engineering Center (HWEC).*