NORTHROP GRUMMAN

Systems Engineering and User Needs

Strategies and Tactics for the Evolving System Acquisition Environment

National Defense Industrial Association

13th Annual Systems Engineering Conference

October 27, 2010

Dr. W. David Reese, CSEP

Dr. Conrad B. Monson

Systems and Specialty Engineering

Northrop Grumman Electronic Systems

Agenda

NORTHROP GRUMMAN

- The Human Engineering (HE) element of Systems Engineering (SE)
- HE in the System Life Cycle
- Benefits of incorporating HE early
- Misperceptions of the value of HE
- Lessons learned from real programs
- HE in the multi-dimensional SE environment
- Summary

Human Engineering (HE) in Military Systems Acquisition*

NORTHROP GRUMMAN

- Involves engineering human interfaces to integrate personnel into the design and ensures user needs are considered throughout the system development process

- Often used synonymously with Human Factors Engineering
  - Understand the human factors or capabilities (i.e., cognitive, physical, sensory, and team dynamics)
  - Integrate capabilities into system design for optimal system performance
    - Characterize work to be performed
    - Create effective, efficient, and safe human hardware/software interfaces

- Encompasses Human Systems Integration (HSI)
  - Technical and management processes for integrating human considerations within and across all system elements
  - Focuses on key domains effecting humans including Human Factors, Manpower, Personnel, Training, Safety, Habitability, Survivability

* Adapted from Mil Standard 46855, Dept. of Defense Handbook *Human Engineering Program Process and Procedures*

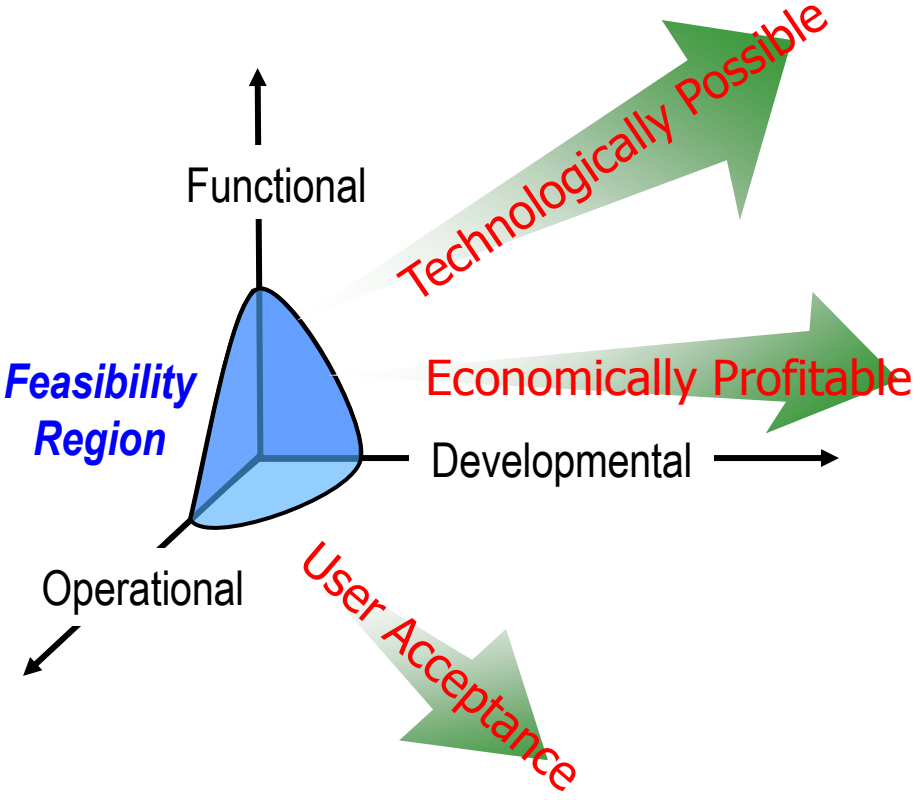
User Needs – The Indispensible Compass for Systems Engineers

NORTHROP GRUMMAN

- All Engineering efforts can ultimately be traced to user needs
  …*and users tend to be human*
- Engineers can often be narrowly focused
  - Optimized solutions for a particular engineering discipline
  - Only a limited focus interfaces that integrate engineering disciplines
  - Lose sight of the global or overall perspective
- System Engineering should optimize designs across engineering disciplines and multiple developmental dimensions
- Meeting user needs is key to driving correct design decisions
  - Human Engineering identifies those needs and helps develop designs to meet those needs

HE is Part of a Multi-dimensional Systems Engineering Approach

- Systems Engineers must address competing challenges across multiple engineering dimensions in seeking fully integrated designs
- HE effort to address user needs can often be shortchanged during the Developmental Phase because impacts are not seen until the Operational Phase



Benefits of incorporating HE early

NORTHROP GRUMMAN

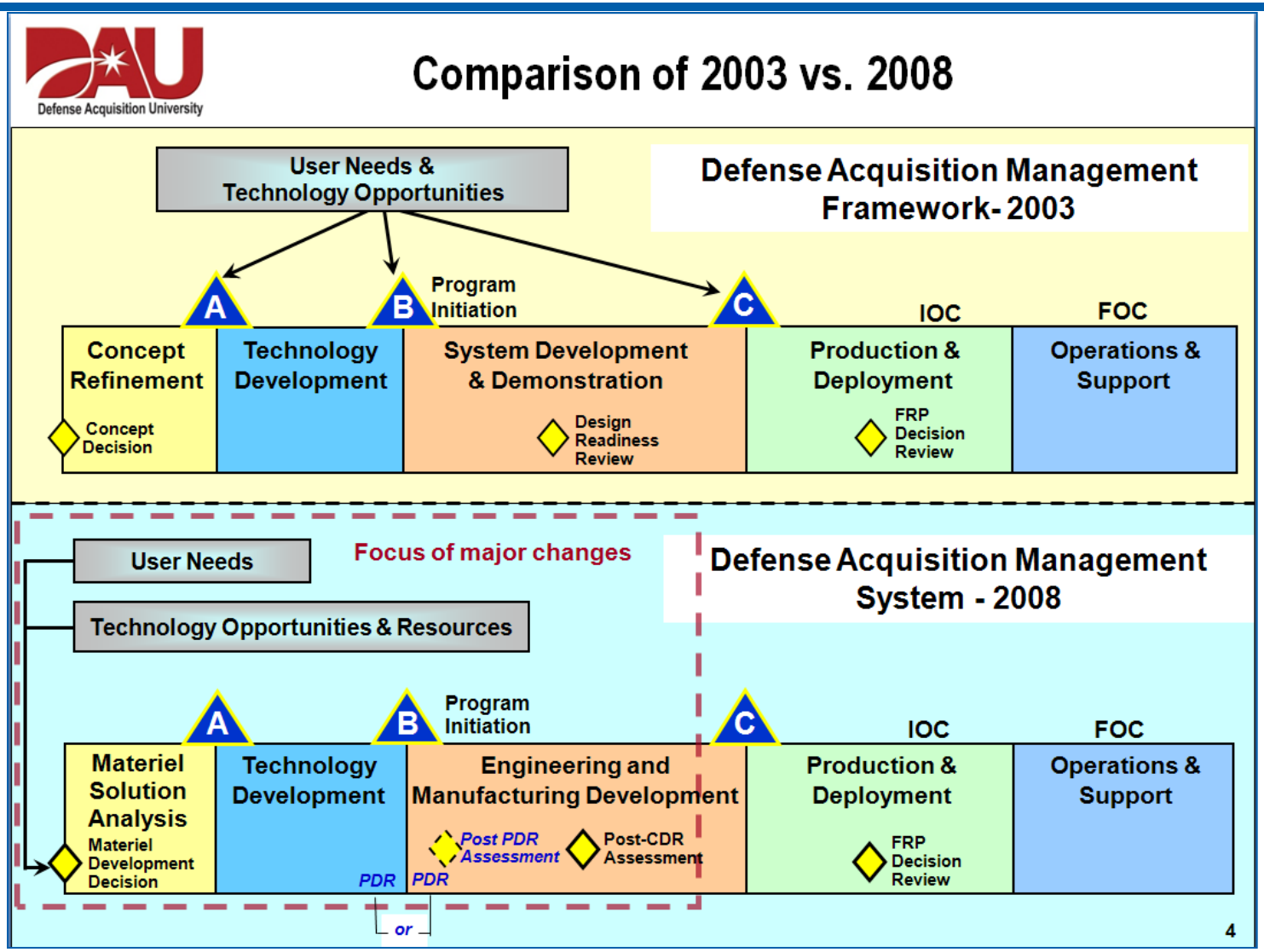
- Excluding user needs from early trades may “fatally “ flaw design decisions
- As system designs mature, changes to accommodate user needs become more costly
  - Significant re-work to address requirement failures and user dissatisfaction
- Although difficult to retro-fit systems after the fact, it may be necessary for legacy system extensions or reuse in new systems—especially if legacy system did not adequately address user needs in its design

Misperceptions About the Value of HE

NORTHROP GRUMMAN

- Customers, managers, business developers, and even end users will overlook the criticality of conducting HE early and in development
- Common misperceptions:
  - User needs cannot be understood until user performance data can be collected
  - Users can adapt to designs
  - More training will overcome deficient designs
  - Hardware and software engineers can adequately address user needs without support from HE specialists
- Primary HE challenge: Stakeholder buy-in to commit finite project resources to HFE
  - Stakeholders should have accurate estimates of LCC associated with meeting user needs
  - Stakeholders need to understand risks associated with delaying HE efforts

DoD Acquisition Focus on Up Front User Needs



*Source: Bradford Brown, *DoD Instruction 5000.02 Operation of the Defense Acquisition System Statutory and Regulatory Changes*, 8 December 2008, Defense Acquisition University

HSI Mandate from DoD

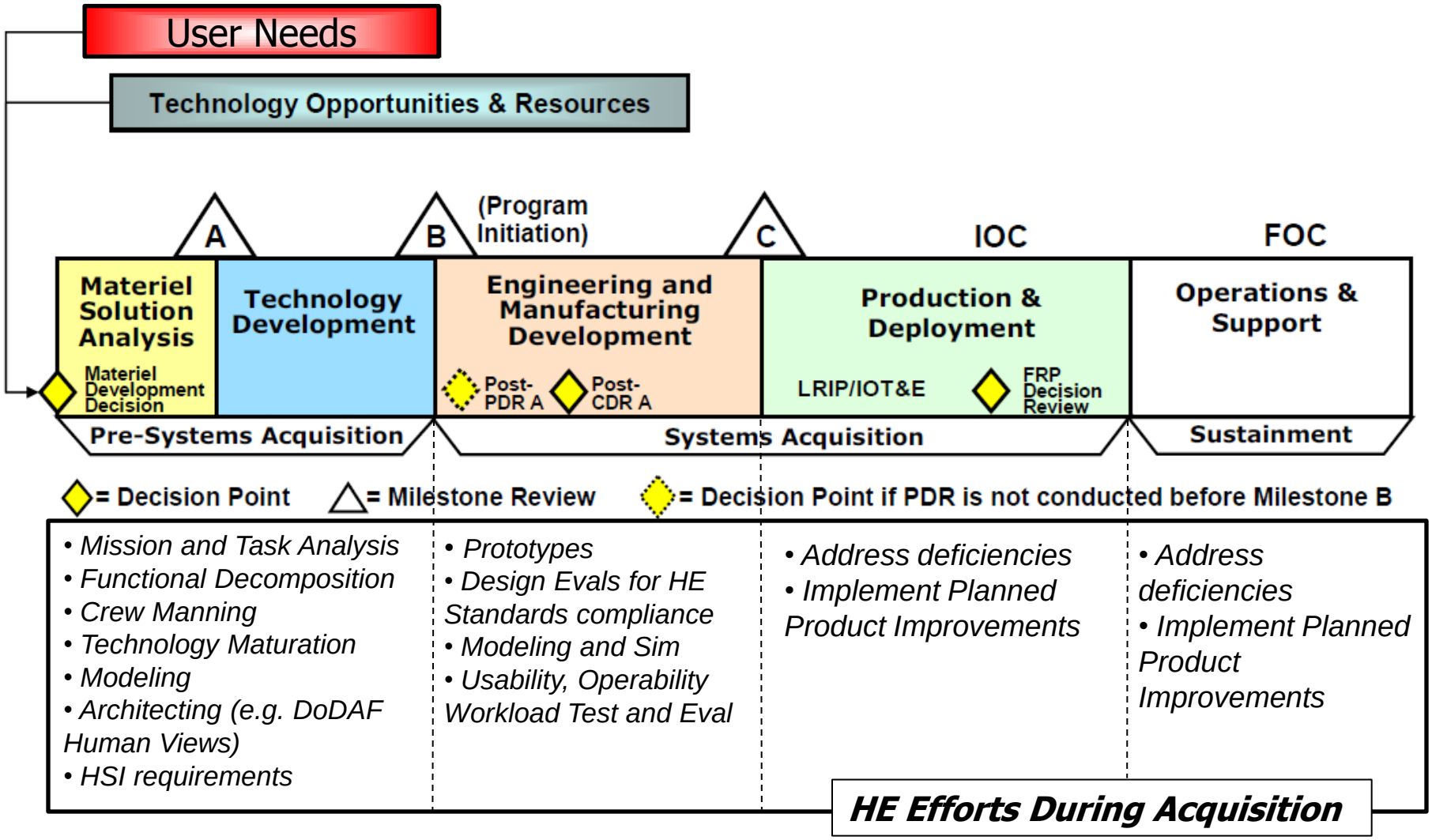
Department of Defense

INSTRUCTION NUMBER 5000.02 December 8, 2008

USD(AT&L) SUBJECT: Operation of the Defense Acquisition System

'The PM shall have a plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system" (from Enclosure 8)

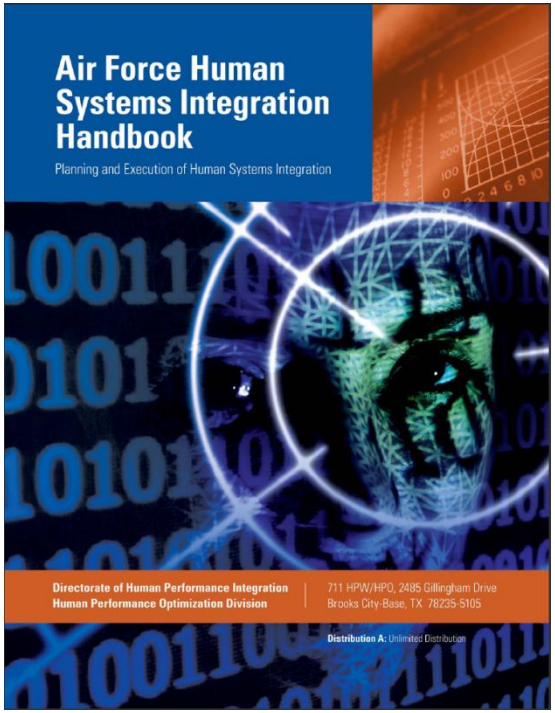
HE Activities Within the Acquisition Process



Source: Enclosure 2, DoDI 5000.02, December 8, 2008

HE Benefits to Life Cycle Costs

- Air Force estimated that after a system is fielded, 80% of all LCC are related to Human System Integration
  - 40-60% are related to Manpower, Personnel and Training
- Ensuring user needs are addressed early in the design could
  - Dramatically reduce LCC
  - Ensure LCCs are not unnecessarily inflated
    - e.g., Greater numbers of maintainers needed to cover deficiencies in design



"Because human performance exerts such a significant effect on system effectiveness, the only question is whether HSI will be paid for most affordably in advance, or at much greater expense after a newly fielded system reveals significant problems."

Source: U.S. Air Force Human Systems Integration Handbook, Sept 16, 2008

Human Engineering in Current Programs

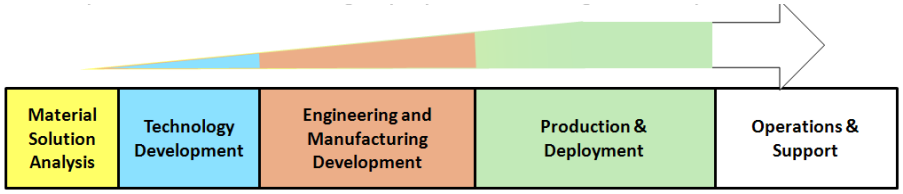
NORTHROP GRUMMAN

- Recent experience on a variety of sensor system programs highlighted the multi-dimensional context of the HE effort
  - Spanned several acquisition phases (Full EMD to small IRAD development efforts)
- Experience showed understanding user needs was one key to success
  - If that understanding is not part of an HE effort early in the development process, it must be obtained at greater expense later
  - "Standard" HE practices had to be tailored to address HE constraints and ensure user needs are addressed
- Relatively small HE efforts can help avoid costly oversights
  - Developed a "70%" solution via agile process utilizing on-call HE expertise as needed

Program #1 – Full Engineering and Manufacturing Development Effort

NORTHROP GRUMMAN

Life Cycle Focus (bias towards later phases)



Tailored HE Effort

- Through performance modeling and extensive stakeholder involvement, addressed user needs even though late in development
  - Identified within-scope GUI redesigns
- Performed extensive usability, operability and workload testing

Description and Constraints

- SoS Development
  - Added new missions and more demanding operator conditions to legacy missions
  - Added new sensors to increase fidelity, amount and timeliness of data
- HE Constraints
  - Heavy legacy component reuse
  - Limited HE in early development

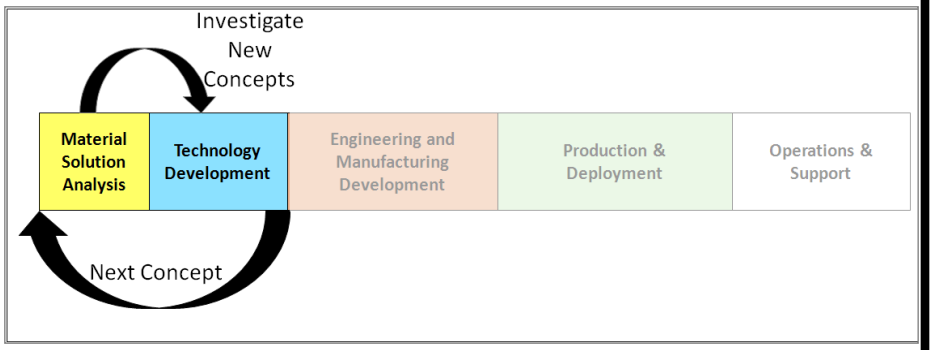
Results and Lessons Learned

- Predicting operator performance through modeling was essential to influencing design decisions
- Extensive stakeholder involvement through formal and informal meetings helped identify GUI modifications that would support usability and would be acceptable to operators

Program #2 – Applied Research to Create System Enhancements

NORTHROP GRUMMAN

Life Cycle Focus



Tailored HE Effort

- HE effort potentially benefited primarily R&D developers and analysts
- GUIs could improve efficiency of complicated or often repeated R&D-related tasks
- Visualization of data processing (e.g., missile tracks across a globe) could significantly aid developers in understanding code behavior

Description and Constraints

- R&D lab evaluating utility of new sensors and algorithms for missile defense
- HE constraints or unique attributes
  - Focused on rapid prototyping, evaluation and analysis (no need for highly polished interfaces optimized for time or accuracy)
  - System, per se, never stops evolving
  - R&D advances, when operationalized, become part of a highly automated system within a larger SoS
  - Little or no operator interactivity

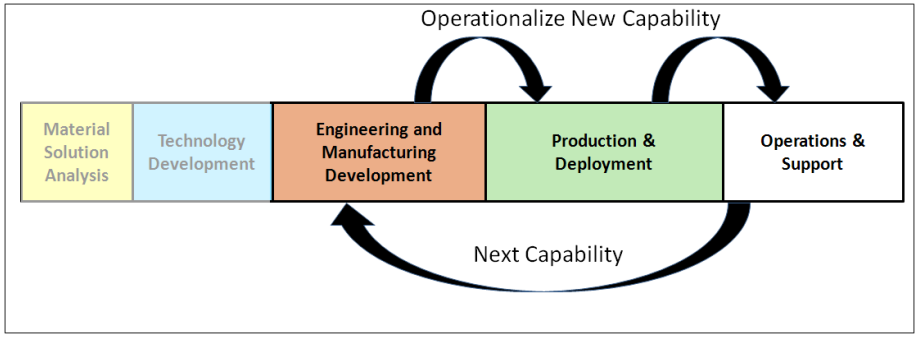
Results and Lessons Learned

- GUIs and visualization tools were ultimately incorporated into the R&D environment, but their earlier introduction would have yielded even greater benefit
- Systems Engineers must consider potential contributions of HE early and often, even in development of system enhancements involving little end user/operator interactivity

Program #3 –Rapid Deployment of System Enhancements to the Operational Environment

NORTHROP GRUMMAN

Life Cycle Focus



Tailored HE Effort

- Customer amenable to HE enhancements
- HE efforts would primarily benefit developers, maintainers and analysts
- GUIs could be developed to reduce errors associated with complicated maintenance tasks

Description and Constraints

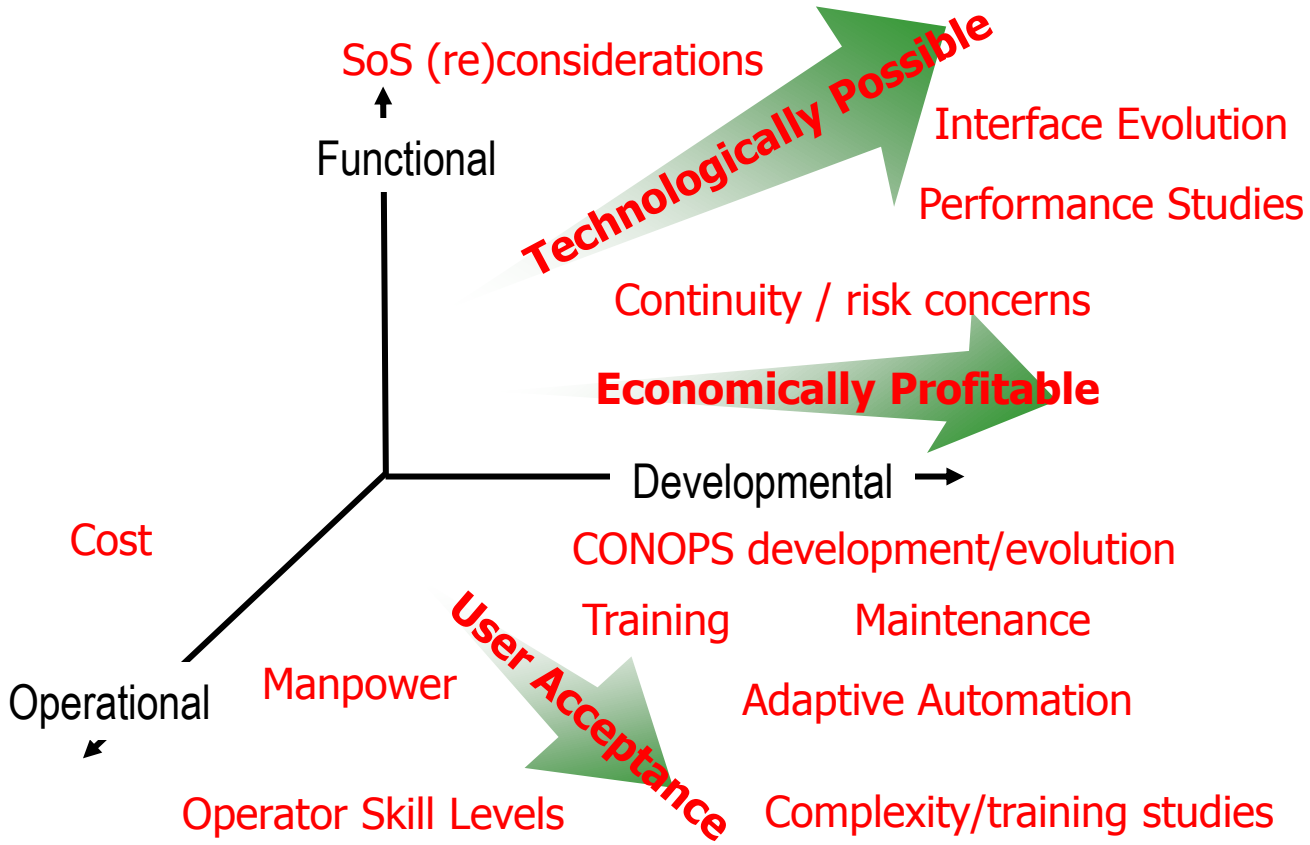
- Operationalize* use of new sensors and algorithms for missile defense
- HE constraints or unique attributes
  - Little or no operator interactivity
  - Part of a highly automated system within a larger SoS
  - System stability, maintainability and robustness of paramount importance
  - Limited customer requirements for tangible HE artifacts

Results and Lessons Learned

- GUIs, primarily geared toward system maintainers, were agreed to by the customer and incorporated into deliveries—however, lack of involvement by HE domain experts resulted in designs that violated some HE interface guidelines
- GUIs were also used to more efficiently accomplish V&V
- HE can add surprising value to system design and development—even in highly automated systems

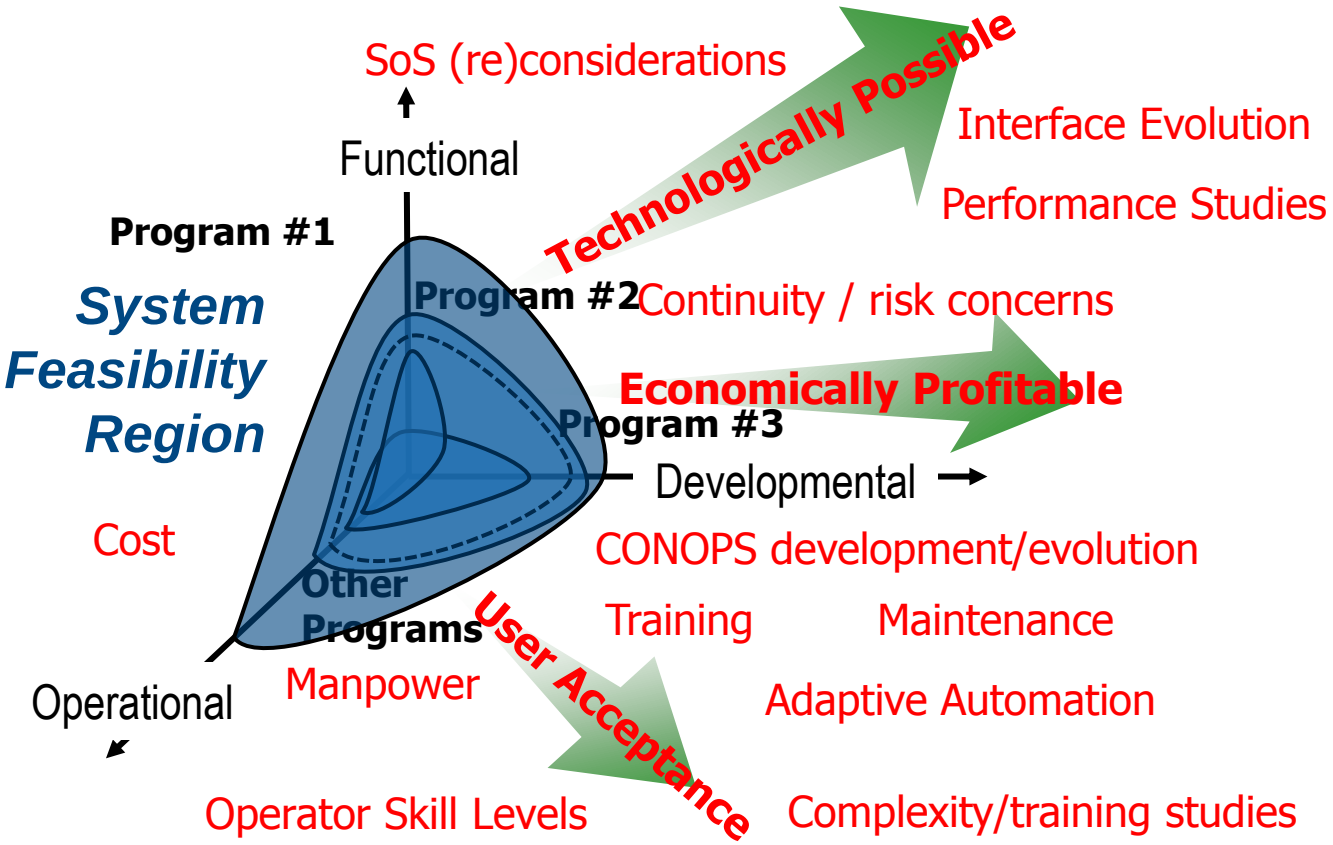
* test, harden and document prototype code, V&V, and integration with other SoS components

HE Within the Multi-Dimensional Systems Engineering Perspective



There are a full range of HE activities that can be conducted in each engineering dimension

HE Within the Multi-Dimensional Systems Engineering Perspective



HE effort in each dimension defines a System Feasibility Region that accounts for user needs

Summary

NORTHROP GRUMMAN

- HE is critical in satisfying user needs and adds the most value when applied early in a system's life cycle
- DoD acquisition process is increasing emphasis on early consideration of user needs and HE
- HE impacts each dimension of a systems engineering effort
- Automated systems benefit from HE
- Even small inputs from HE experts help avoid future design challenges