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Human Factors Engineering–An Enabler for Military Transformation Through Effective Integration of Technology and Personnel

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SSC San Diego

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The major institutions of national security were designed in a different era to meet different requirements. All of them must be transformed

President George W. Bush

National Security Strategy

September 20, 2002

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Outline

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- Military Transformation – Key Enabler
- Transformation Limits - Budget Pressure
- C4ISR Transformation – Critical Nexus
- Human Factors Engineering – Results
- Transformational Tradeoffs
- The C4ISR Transformation Challenge

When asked what single event was most helpful in developing the theory of relativity, Albert Einstein is reported to have answered, "Figuring out how to think about the problem"

Men, Women, Messages and Media:

Understanding Human Communication

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Military Transformation Enabler for Warfighting Effectiveness

- Transformation pressures
  - New systems compete with legacy systems
  - Desire to field systems with fewer people
- Building systems around the warfighter
  - Testing the limits of human performance
  - Building cost-effective systems and platforms
- Fighting the next war – not the last one
- Accelerating new technology insertion

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I know that transforming our military is a massive undertaking…The real goal is moving beyond marginal improvements – to replace existing programs with new technologies and strategies. To use this window of opportunity to skip a generation of weapons systems

President George W. Bush

Citadel Speech

September 23, 1999

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Transformation Pressures

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- Transformational systems often compete with existing legacy systems
- "Burden of proof" often falls to these systems to prove their value-added
- Metrics to measure transformational systems often not well-developed
- Built-in inertia of existing systems and desire to make incremental changes

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Building Systems Around The Warfighter

- New systems will need to be developed around the warfighter
- Changes already underway at several levels (example: NAVSEA 03)
- Methodology implies that objective, metric-based analysis will be done
- Nexus of budgets, technology, and personnel costs

Limits to Military Transformation: Budget Pressures for all Nations

- New technologies often offer great promise
- Transition to new systems requires tradeoffs
- Budget pressures often suggest either/or paths must be taken
- Metrics to determine “what a pound of C4ISR is worth” are not robust

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In today's world it is *inconceivable* that anything could be accomplished outside of a coalition operation

Dr. David Alberts

Seventh International ICCRTS

September 16, 2002

New Technology vs. More People Important Tradeoffs

- Costs of new systems and platforms
- Costs of manning legacy systems
- Manpower part of systems costs
- Systems designed “around the human”

Costs of New Systems and Platforms

- New technologies appear to offer substantial manpower savings benefits
- Discipline of Human Factors Engineering now part of the design process
- Process *assumes* objective and quantifiable tradeoffs are made
- Acquisition community seeking metrics to balance new systems costs

Costs of Manning Legacy Systems

- USN Study – last two decades:
  - USN TOB has declined by 40%
  - USN ship count has declined by 45%
- USN Operations and Support Costs (O&S)
  - O&S Costs have remained constant
  - Personnel costs comprise over 50% of O&S

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C4ISR: Critical Nexus for Military Transformation

- C4ISR systems – leading edge technology
- Navy & DoD impetus to transform rapidly
- Technology substitutions often complex
- Role of warfighters may need to change

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C4ISR Systems Create Opportunities for Military Transformation

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- C4ISR systems offer high-payoffs to replace manpower with technology
- U.S. Navy has established this as an important goal of Sea Power 21
- Complex naval missions rarely enable "simple" substitution of technology for operators
- Key appears to be shifting the role of warfighters from manual control and data input to strategic thinking and planning

Cost Comparisons: Man vs. Machine

- Must account for mission processes that contain mixed-initiative systems
- In these systems, the task is sometimes human and other times automated
- Examining interactions within mixed-initiative systems supports effective HCI
- Design techniques have been tested to enable various levels of automation

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Human Factors Engineering: Leading C4ISR Transformation

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- Making better decisions
- Making decisions faster
- Using fewer personnel

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Office of Naval Research Sponsored Research

- Research spans two decades under the auspices of Future Naval Capabilities
  - Knowledge Superiority and Assurance
  - Capable Manpower
- Research products focused on:
  - Human-computer interface (HCI) design
  - Architectures for human-computer interaction
  - Effective human factors design process

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Lessons Learned and HFE Results

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- Direct and causal link between effective HFE and personnel costs
- Increased workload imposed by poor design = reduced mission effectiveness
- This manifests itself by inducing error and delays during peak mission task loads
- Pairing of task analysis with improved HCI design dramatically improves results

Human-Computer Interaction Key Areas

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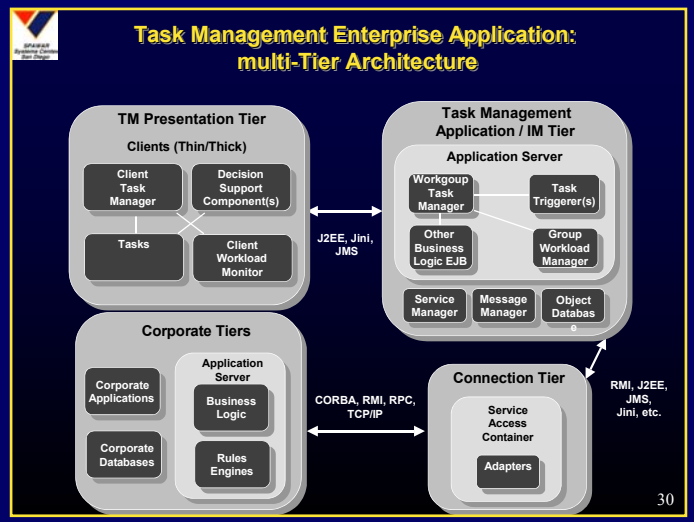
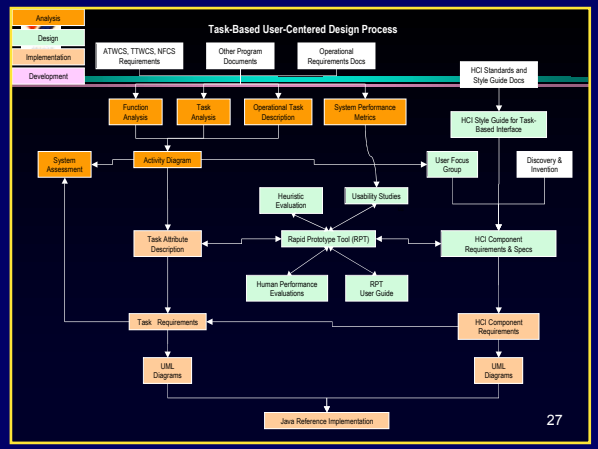
- *Common & Reusable Process Supervision Aids*
- *Common Procedures and simple training*



Reusable Task Management & Information Architecture across C4I Levels



Task-Centered Design Process

- *Team/Individual Workspace*
- *Productive & Efficient Teams*
- *Team/Individual Performance Metrics*

Crew Optimization

- Supervisory Control Design Requirements.
  - Human performance gains - speed/accuracy/reliability
  - Mission process gains.
  - Training simplification.
- Use design lessons learned from R&D.
- Use iterative design process with frequent testing.
- Challenges:
  - Raising design expectations and reducing risk.
  - Existing design process & procurement.
  - Design issues with cooperative automation.
  - Design issues with distributed team workload & perform.

Software Produces Quality Work Products

- TTWCS water & land routes
- Missile cell allocation plan
- Flex-target missile re-allocation plan

Other Examples:

- Strike Mission Plan
- Air Defense Battlegroup Track Reports
- Target Weaponeering plan
- Ship transit & logistics plan
- Communications plan
- Force positioning plan
- Electrical/propulsion underway sequence

Products are harder to draft when multiple systems hold the information required!!

G-WIS HCI Model

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C2 Information Hierarchy

Operations View -
Across Missions

Mission View -
Across Systems

Mission View -
Specific Goals/Work Tasks

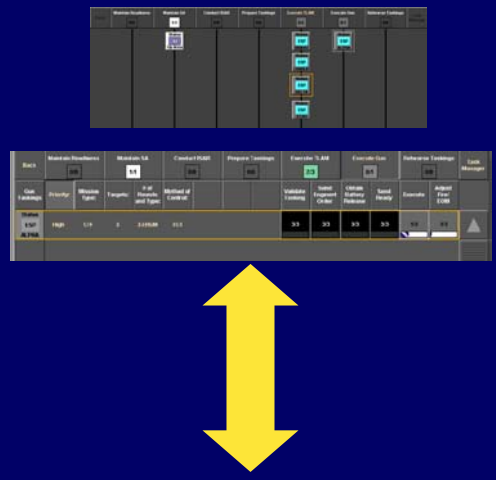
Planning	Execution
Monitoring	Re-planning

Work Task Details

Work Products

Alternatives & Explanations

Mission and Situation Visualization



Cognitive Requirements

What do I do next?

What are variables?

Pros & Cons?

What if?

Next step(s)

What's optional?

What's required?

What is status?

Dynamic Process Visualization – TTWCS

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Execute TLAM	Execute Gun	Rehearse Taskings
1/5	2/2	0/0

Validate Tasking	Plan Routes	Allocate Missiles	Power Missiles	Execute Launch	Monitor

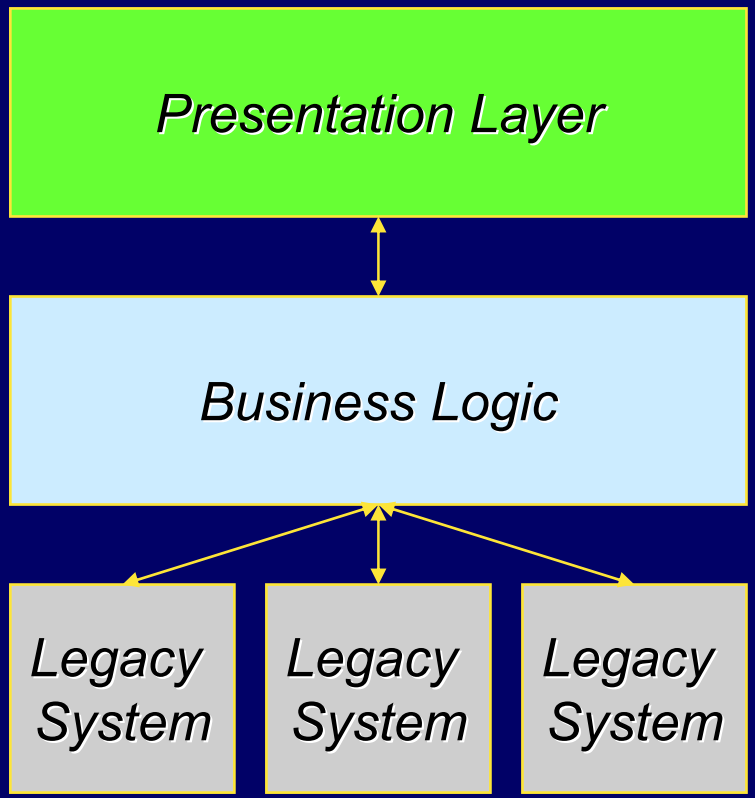
Back	Maintain Readiness 0/0	Maintain SA 1/1	Conduct IS&R 0/0	Prepare Taskings 0/0	Execute TLAM 1/5	Execute Gun 2/2	Rehearse Taskings 0/0	Task Manager

TLAM Taskings	Priority:	Mission Type:	Targets:	Plans:	Primary Missiles:	RS Missiles:	BU Missiles:	Pool Missiles:	Validate Tasking	Plan Routes	Allocate Missiles	Power Missiles	Execute Launch	Monitor
Status ESP ECHO	High	CFF (LPMP)	2	2	2-III C	0	0	0	2/2	0/2	0/2	0/8	0/2 -0:00:08	0/2
Status ESP GOLF	Low	LPMP	2	2	12-III C	0	0	0	2/2	ASCM 2/2	0/12	0/8	0/12 -0:15:26	0/12
Status ESP BRAVO	Medium	Pre-Plan	7	7	10-III C	0	0	0	7/7	7/7	10/10	0/8	0/10	0/10
Status ESP CHARLIE	Medium	Pre-Plan	6	6	15-III C	0	0	0	6/6	6/6	0/15	0/8	0/15	0/15
Status ESP DELTA	Medium	LPMP	2	2	5-III C	0	0	0	2/2	0/2	0/5	0/8	0/5 -0:15:06	0/5

Strike Plan Overview

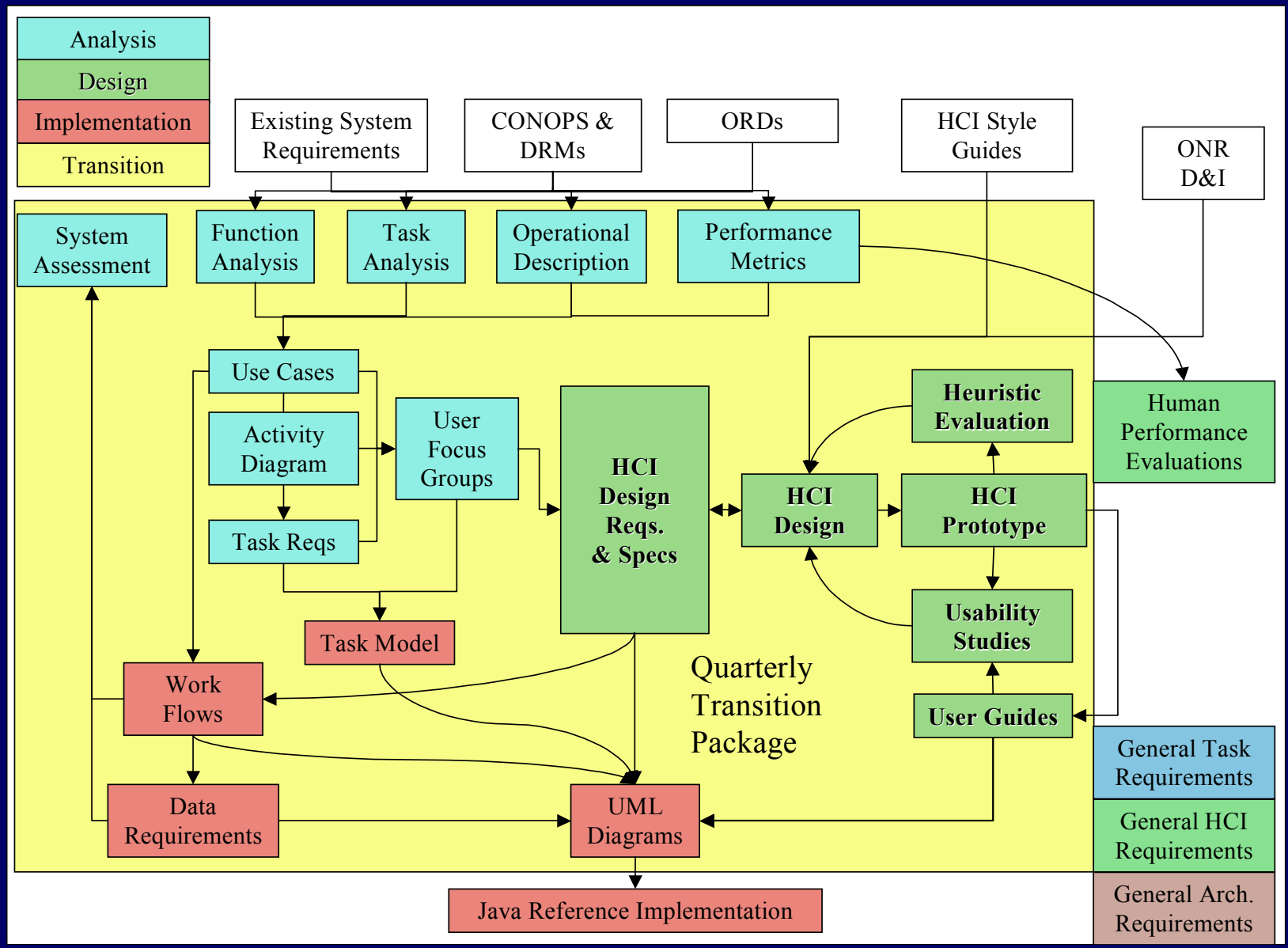
Task Progress

Separate Presentation Layer

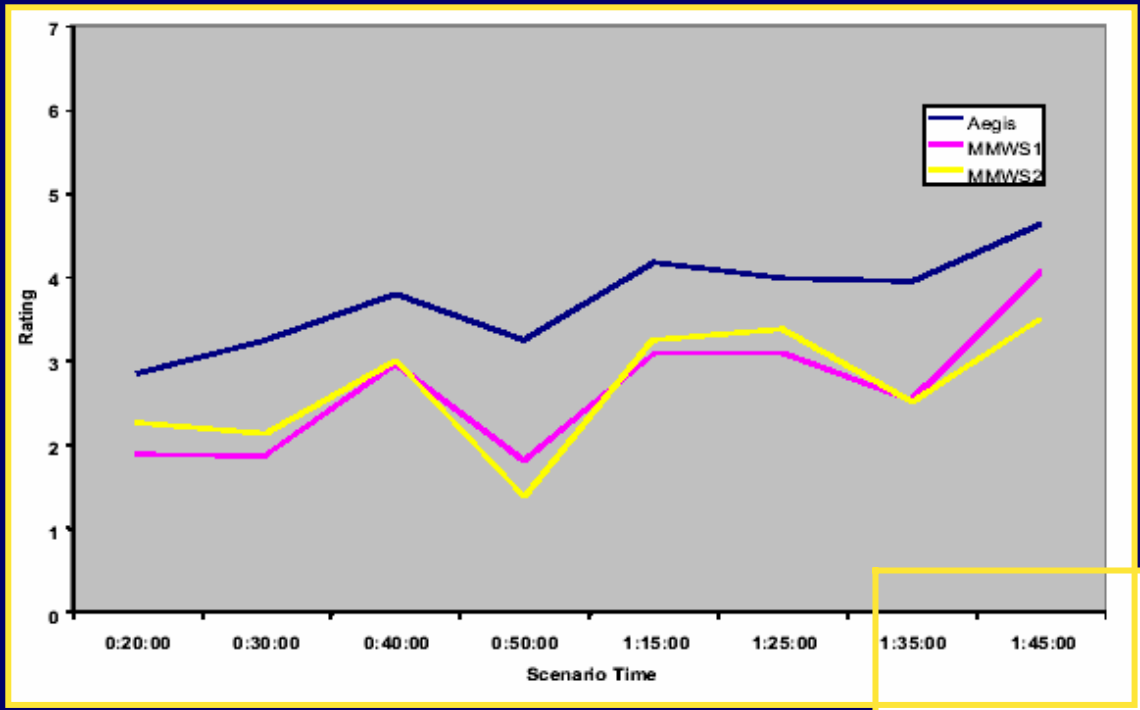


- Mods can be made to the presentation layer without effecting legacy code.
- Decision aids can be shared across legacy systems.
- Mods can be made once and apply to all legacy systems.

UCD Transition Process



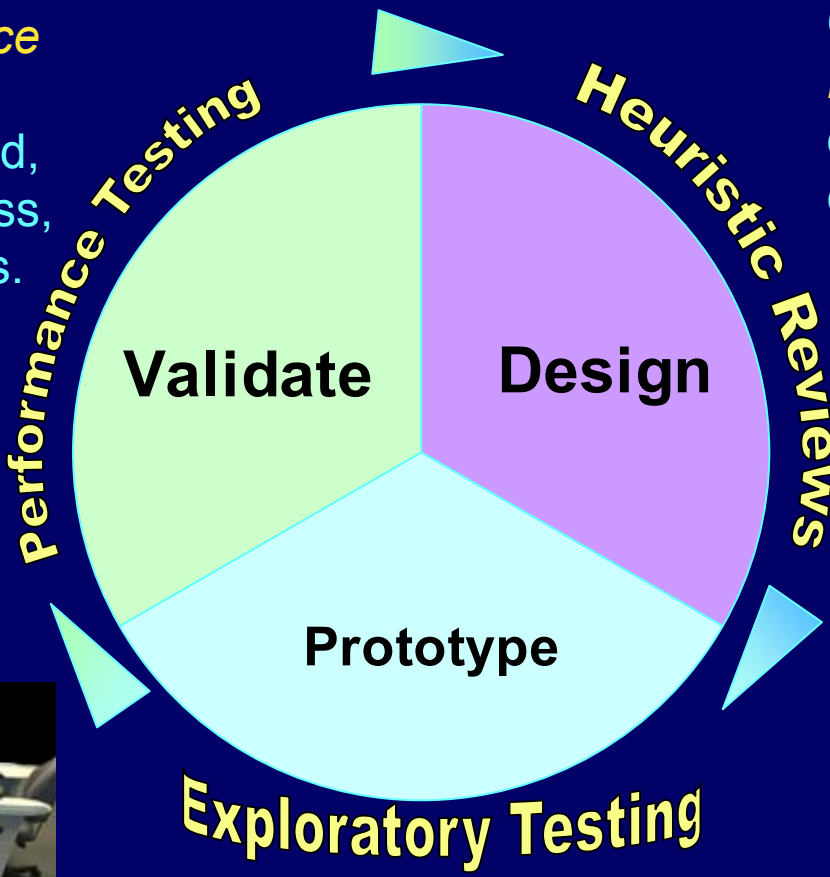
Performance Metrics



	Kinematics	Query/ Warning	Engage ASM
Aegis Teams	1 of 8	2 of 8	7 of 8
MMWS V1	6 of 6	6 of 6	6 of 6
MMWS V2	2 of 2	2 of 2	2 of 2

Fleet Usability Testing Within Spiral Development

Conduct *performance testing* to measure throughput, workload, situational awareness, and team processes.



Conduct *heuristic reviews* to ensure designs follow established Human Factors principles.

Conduct *exploratory testing* to iterate on initial designs and evaluate alternative design concepts.

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Research Summary

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- Effective design of supervisory control systems is a key force towards transformation.
- Performance, efficiency, crew size optimization and ultimately training and operational costs are affected.
- Key enablers are:
  - HCI design
  - Information architecture
  - Design process

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Transformational Tradeoffs: New Technologies or More People

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- Metrics for HFE design success are compelling
- Systems designed with reduction in crew size induced *better* performance
- Metrics for manpower costs are not as well developed or robust
- This makes technology and manpower tradeoffs more difficult to quantify

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HFE Design Success Produces Improved Results

- Metrics for HFE design success are well established and robust
- For example, with MMWS and a 50% reduction in crew size:
  - Better performance in air defense tasks
  - Less workload induced on operating team
  - Increased situational awareness
- This technology can be extrapolated to other systems and platforms
- HFE design criteria offer the potential for manpower savings in many venues

Manpower Cost Analysis Remains an "Imperfect Science"

- Metrics to quantify the costs of personnel are adequate – to a point
- CNA Study: "Insufficient organizational imperatives exist to mate technology insertion with manpower decisions"
- Manpower models quantify that which can be readily quantified
- "Other" costs are not adequately captured

Manpower Cost Analysis Remains an "Imperfect Science"

- Costs that are effectively modeled:
  - Pay
  - Benefits
  - Pro-rata retirement benefits
  - Health Service Costs
- Costs that are less well accounted for:
  - Recruiting costs
  - Training costs
  - "War zone" costs
  - "War zone" tax benefits
  - Family support services
  - Veterans affairs benefits

Manpower Cost Analysis Remains an "Imperfect Science"

- Manpower costs are "blended" across pay grades to reflect a single cost:
  - FY03 USN Officer (O-1 to O-10): $100,106
  - FY03 USN Enlisted (E-1 to E-9): $49,619
- May tend to make legacy systems appear to be more cost-effective than newer HFE designed technologies by obscuring the fact that more junior, less-experienced personnel can be trained on new systems that supplant legacy systems

C4ISR Transformation Challenge: Integrating the HFE Discipline

- Military transformation has traction
- Demand for manpower-efficiency growing
- HFE C4ISR designs offer great promise
- Tradeoffs must be objective
- Ability to measure systems design robust
- Manpower models must catch up

Military Transformation End Game: Enhanced Manpower Effectiveness

- Transformation is about more than just technology
- Technology insertion and manpower savings not a one-to-one relationship
- HFE Discipline can guide most effective manpower savings methodologies
- Ultimately, cost-benefit analysis must be applied to prioritize technology insertion

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Importance of Realizing Manpower Savings Demands Enhanced Models

- Technology insertion likely to be increasingly tied to manpower savings
- Life-cycle costs of military operators must be better quantified
- Underestimating manpower costs = less transformational technology insertion
- This could ultimately retard transforming military forces

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Summary

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- Potential to “design the system around the human” remains high
- Potential for concomitant manpower reductions remains high
- Refining manpower models one key to developing precise metrics
- Unless or until these models are refined, technology insertion will likely suffer

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Questions