Human Systems Integration Assessment of Network Centric Command and Control

Operational Environment

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Human Systems Integration (HSI)

FOCUS

- **Integrates human capabilities and limitations into system definition, design, development, and evaluation to optimize human-system performance under operational conditions**
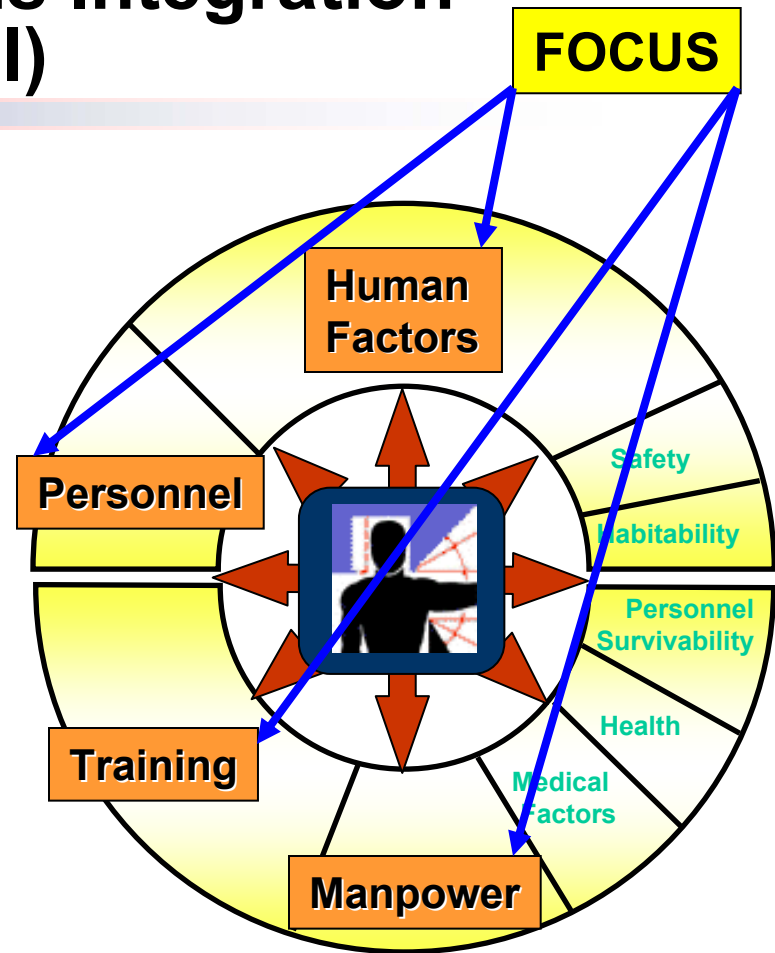
Operational Environment

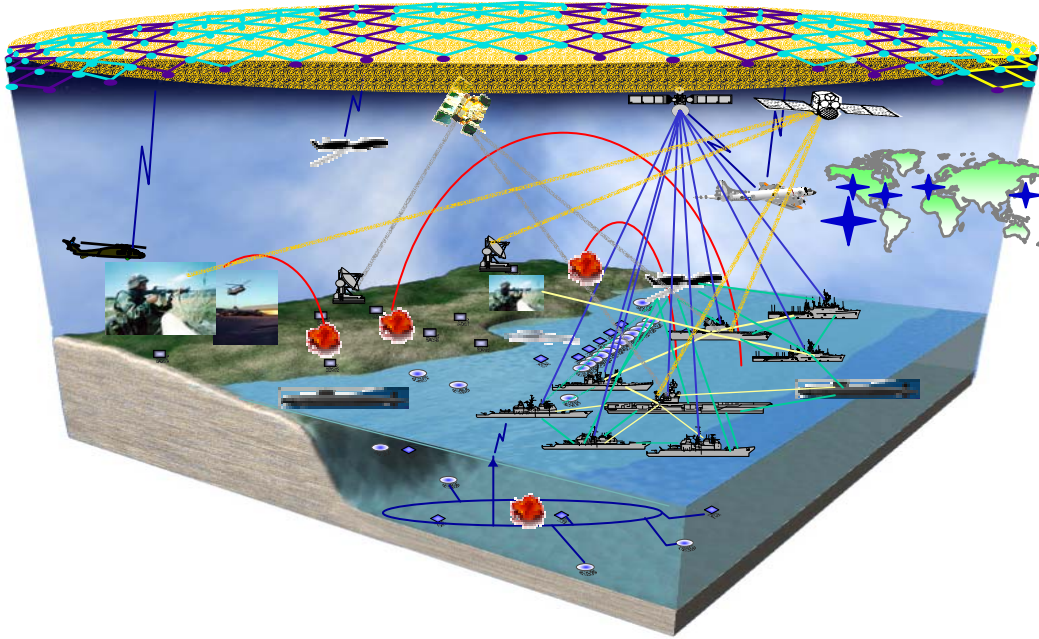**Warfighter**

Mission Tasks

Displays/ Interfaces

Human Factors

Personnel

Safety

Habitability

Personnel Survivability

Health

Training

Medical Factors

Manpower

- **Part of <u>total systems engineering</u> approach to analysis, design, development, and test of a product or system**

US Navy Network Centric Warfare (NCW): FORCEnet

"FORCEnet is the operational construct and architectural framework for Naval Warfare in the Information Age which integrates **WARRIORS***, sensors, networks, command and control, platforms and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space and sea to land." ***
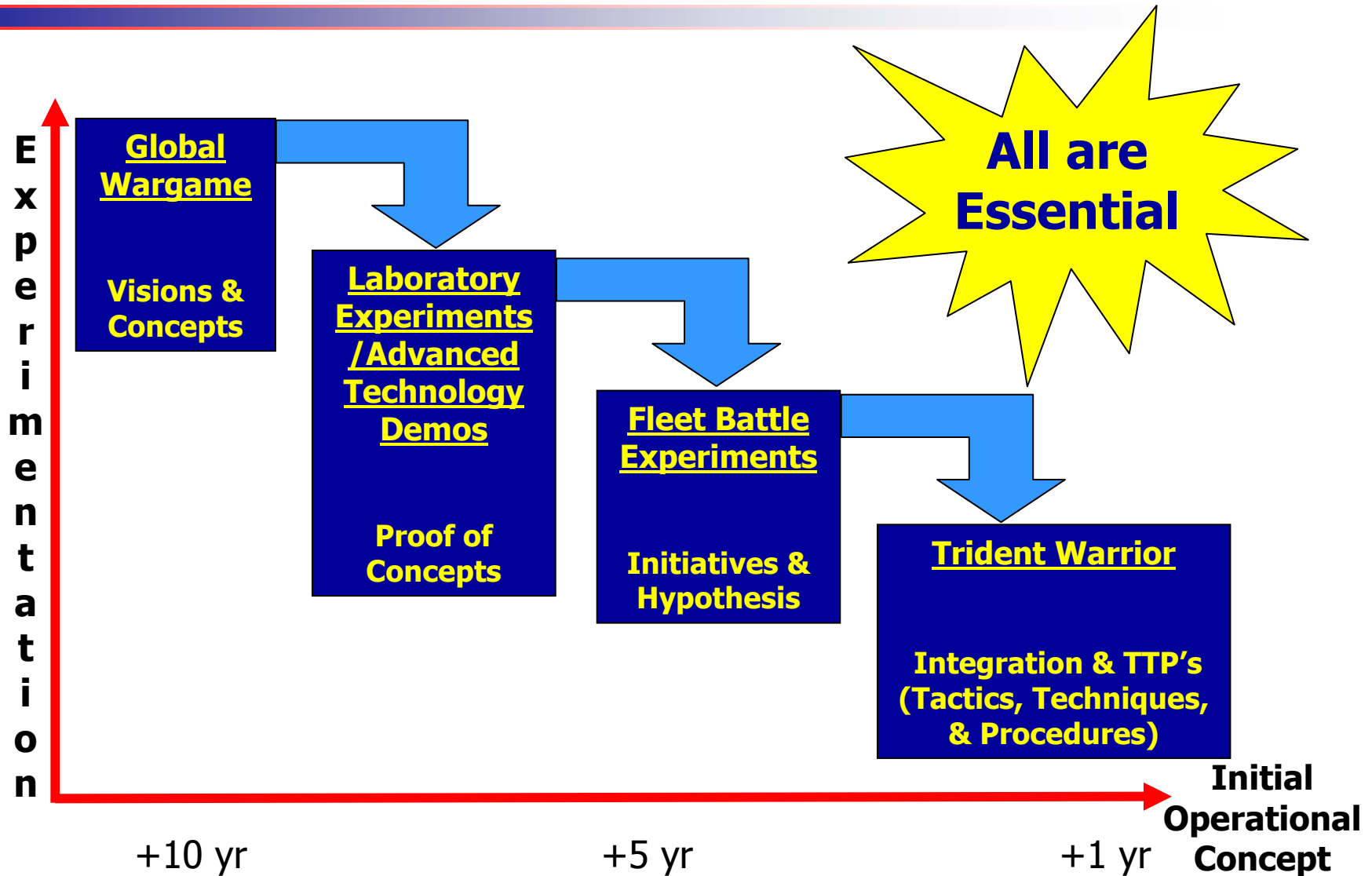
* CNO's Strategic Study Group – XX definition from 22 July 02 CNO Briefing

"Currently, FORCEnet is not on track. It needs to become more warrior centered, assume an enterprise-wide culture, and develop/apply metrics." **SSG-XXII, July 2004**

"The real need (in FORCEnet) is to examine Decision Making, Cognition, and C2 - the human element. The current FORCEnet capabilities packages are too narrow ... The focus should be on increased speed of action, distributed forces, and goals… …need to examine the alignment of requirements, resources, and providers to create mutually reinforcing technological requirements

➤ **Evaluate system of systems performance (an integration of factors and dimensions)**

➤ **Assess effective engagement and operations (human understanding, decision making, and C2) …"**
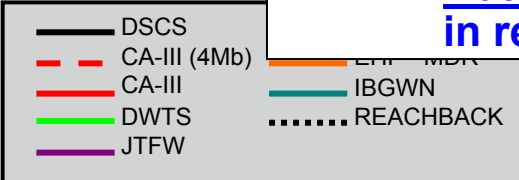
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FORCEnet Assessment Continuum

Experimentation

Global Wargame

Visions & Concepts

Laboratory Experiments /Advanced Technology Demos

Proof of Concepts

Fleet Battle Experiments

Initiatives & Hypothesis

Trident Warrior

Integration & TTP's (Tactics, Techniques, & Procedures)

All are Essential

+10 yr   +5 yr   +1 yr   Initial Operational Concept

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SPAWAR
055 HSI

GCCS-M
EMAIL

ADOCS
JTFWARNET

MA
ENA
TSC
PAC

MA
MS

SH-60
AIR RELAY

H-60
RELAY

AFATDS
GCCS-M
TFW/WEBCOP
FORCEview
EMAIL
CHAT
VTC

HSI Objectives

- **Establish HSI requirements and identify HSI deficiencies for FORCEnet technologies**

  - **Shared Situation Awareness. A common perception and understanding of the tactical battlespace and of the roles, responsibilities, and actions of other Warfighters**

  - **Efficiency of Asset Utilization. Length of time needed to assign an asset, time needed to complete a mission, number of tasks accomplished**

  - **Speed of Command. Time from when an event occurred until the ordered action was completed**

  - **Adaptability. The extent and speed of an organization's change in response to changing tactical situations**

——	DSCS
― ― ―	CA-III (4Mb)
——	CA-III
——	DWTS
——	JTFW

IBGWN
REACHBACK

HSI Measures

Performance	Task Performance Situation Awareness (SA) Decision-Making (Speed of Command)
Usability	Ease of Use Frequency and Context of Use Scalability/Tailorability of Displays Efficiency of Use Effectiveness of Use Error prevention and Handling Visibility Consistency/Familiarity of HCI Satisfaction/Preference
Information Transfer and Knowledge Management	Ability to Share Information/Access Information Quality of Information Exchanged during Collaboration Process Shared Understanding of Missions, Roles, and Tasks Efficiency of Information Exchange Effectiveness of Information Exchange Reliability/Credibility of Information
Training	Amount of Training Provided and Required Value of Training Proficiency Documentation and Online Help
Manpower and Personnel	Manpower Required to Operate/Administer Systems Availability Match between Personnel and System Requirements

- **Lack of a <u>concept of operations</u> for FORCEnet technologies; reduced shared situation awareness and ability to adapt to changing demands**

- **<u>User interfaces</u> need improvement: display configurations, workspace layouts, inefficiencies in how information was transferred within and between command centers; legibility of shared displays, and access to task-relevant information**

- **While <u>training</u> was provided on individual FORCEnet systems, no instruction was available on how to employ systems for maximal operational effectiveness resulting in operational inefficiencies**

- **Insufficient <u>manpower</u> available for new FORCEnet capabilities without removal of legacy systems**

Trident Warrior: Looking Forward

TW-03

6 Mar 2003
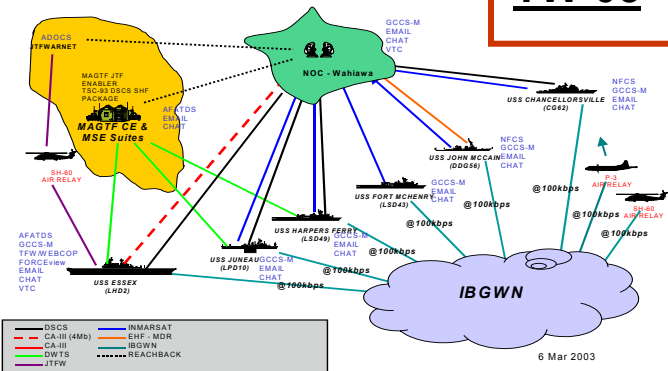
– **Expeditionary, multi-tiered weapon and sensor information (Call For Fires)**

– **Distributed, collaborative command and control (C2 / Collaboration)**

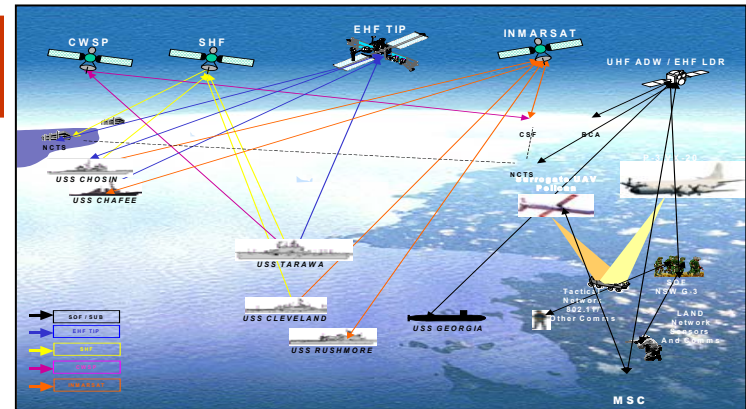– **Dynamic, multi-path and survivable networks (Network Operations)**

HSI = "Come as you are"

TW-04

– **Networks**

– **Web-Enabled Warfighter**

– **Sea Warrior (Focus on Sailor career)**

– **ISR/fires**

HSI = Specific Objectives

Shared Situation Awareness, Speed to Command, Efficient Use of Warfighter

TW-05

HSI = Real Opportunities

• *Multi-Echelon*

• *Split Staff*

• *Shared SA of Intel Analysis*

– **Carrier Strike Group**

– **Coalition Networks**

– **Multi-Level Security Systems**

– **Inter-Force Wireless Networks**

– **Joint Distributed C2**

Model of Situation Awareness

Recognition System

Event → External Sensors → Perception Sensory Register

Analysis Process

Comparison With Memory → Decision Making

Action

MACHINE

HUMAN

Outcome of Decision

1. All data in the environment
2. Data detected by technological systems
3. Data available on local C2 systems
4. Data perceived by decision maker
5. Comprehension of decision maker
6. Projection of decision maker

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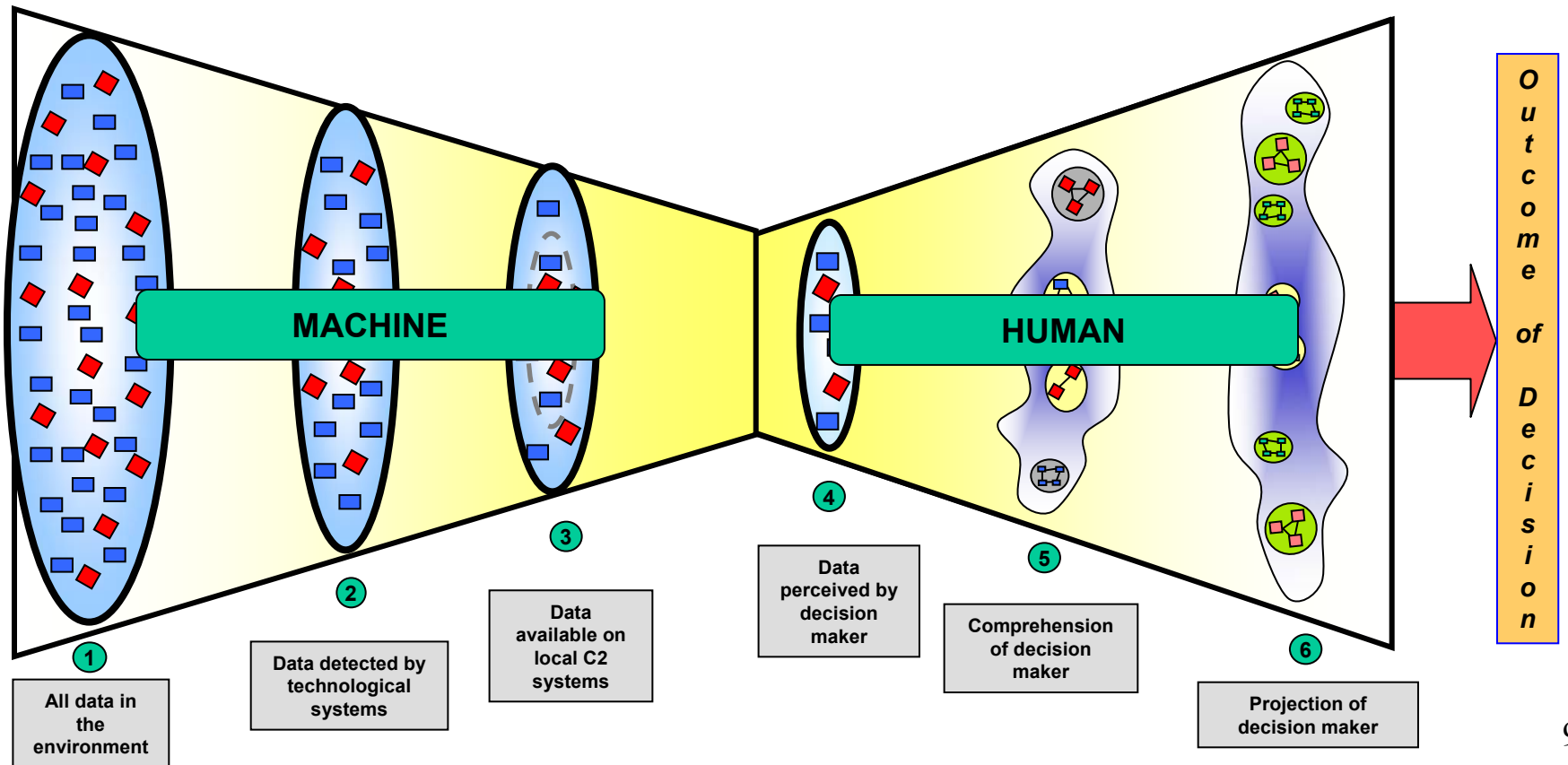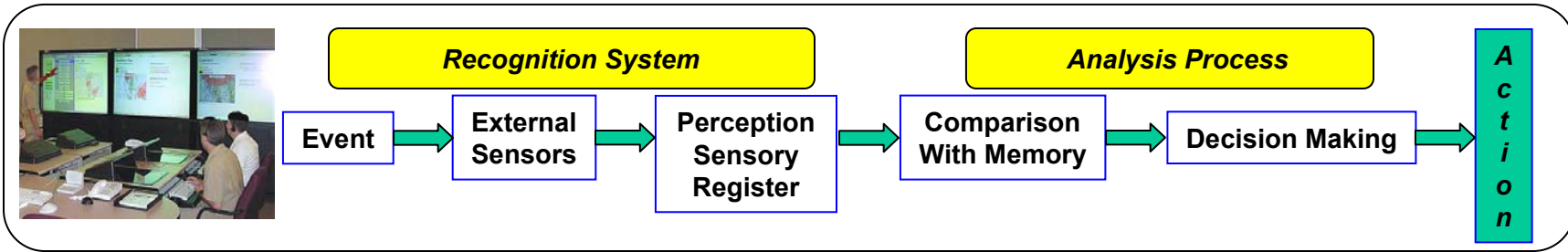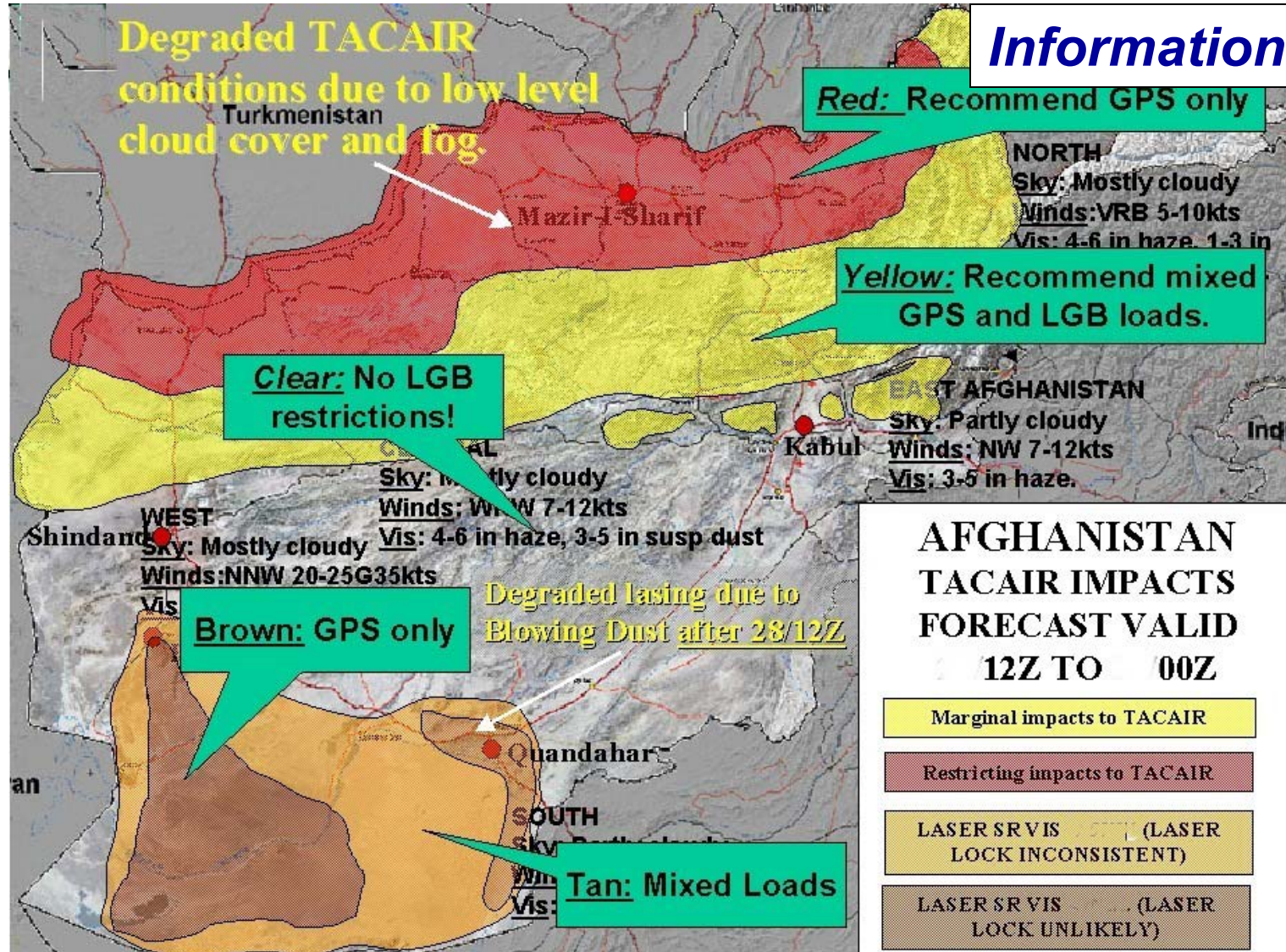
HSI – Example K-Web Overview Page (shows status across mission areas)
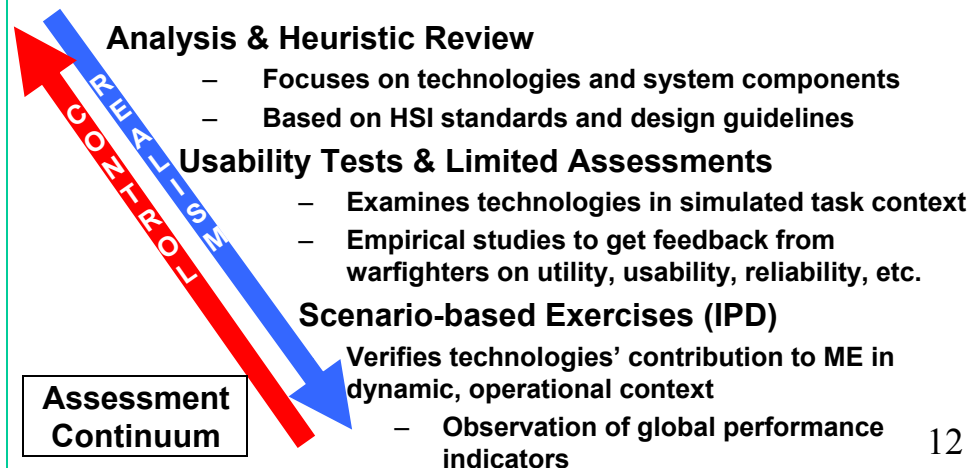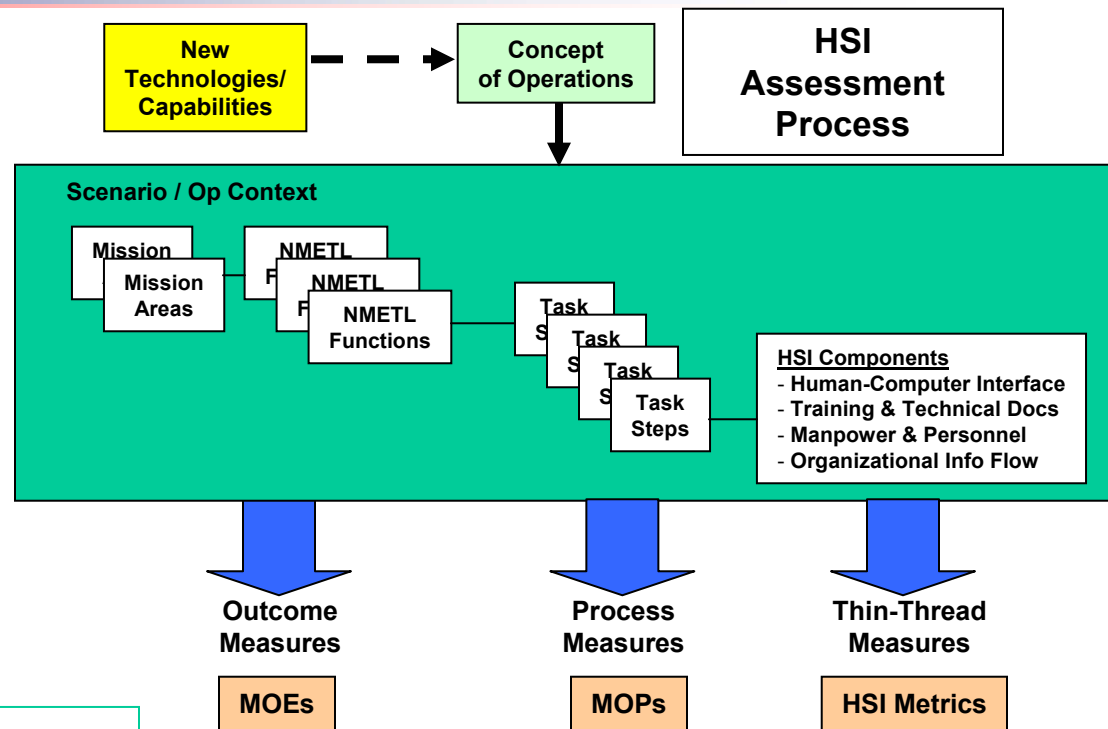

Knowledge Management

Assessment Approach

CHALLENGES

- **Functionality "between" stovepipes**
  - Design
  - CONOPS
- **Skills**
  - Required level
  - Individual vs. Team
  - Training/Experience
- **Workload**
  - Cognitive and physical
  - Manpower
- **Acquisition**
  - Formal acquisition programs
  - Non-acquisition programs
- **Human performance**
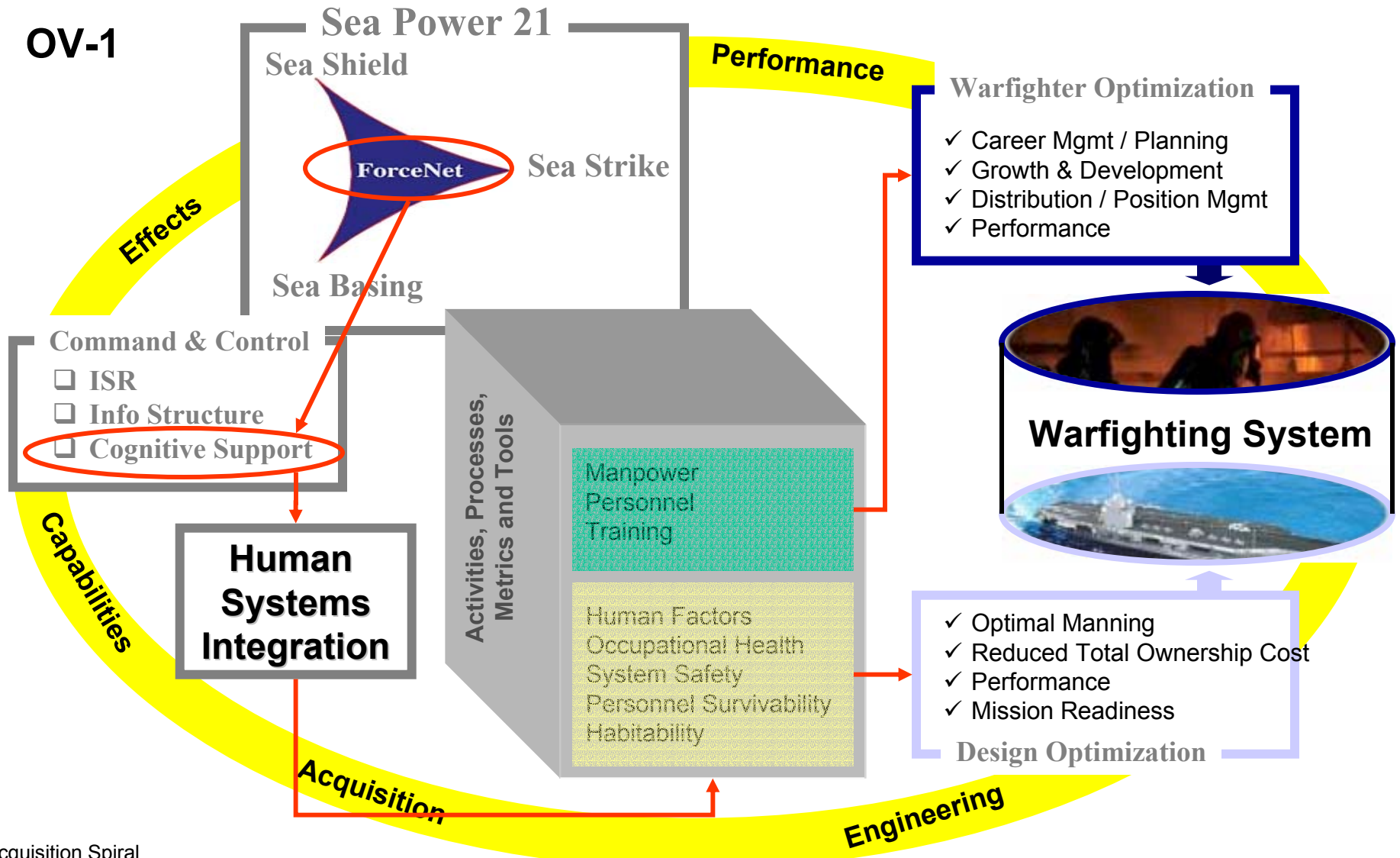 - Demonstrated improvements
  - Quantifiable measures

APPROACH

- **Integrated, multi-method assessment**
  - Takes advantage of available assessment opportunities
- **Linked with mission, tasks, and jobs**
  - Extends ongoing MPT efforts in system acquisition
- **Transferable across technologies**
  - Easily expanded to incorporate future developments
- **Addresses all facets of human performance in complex systems**
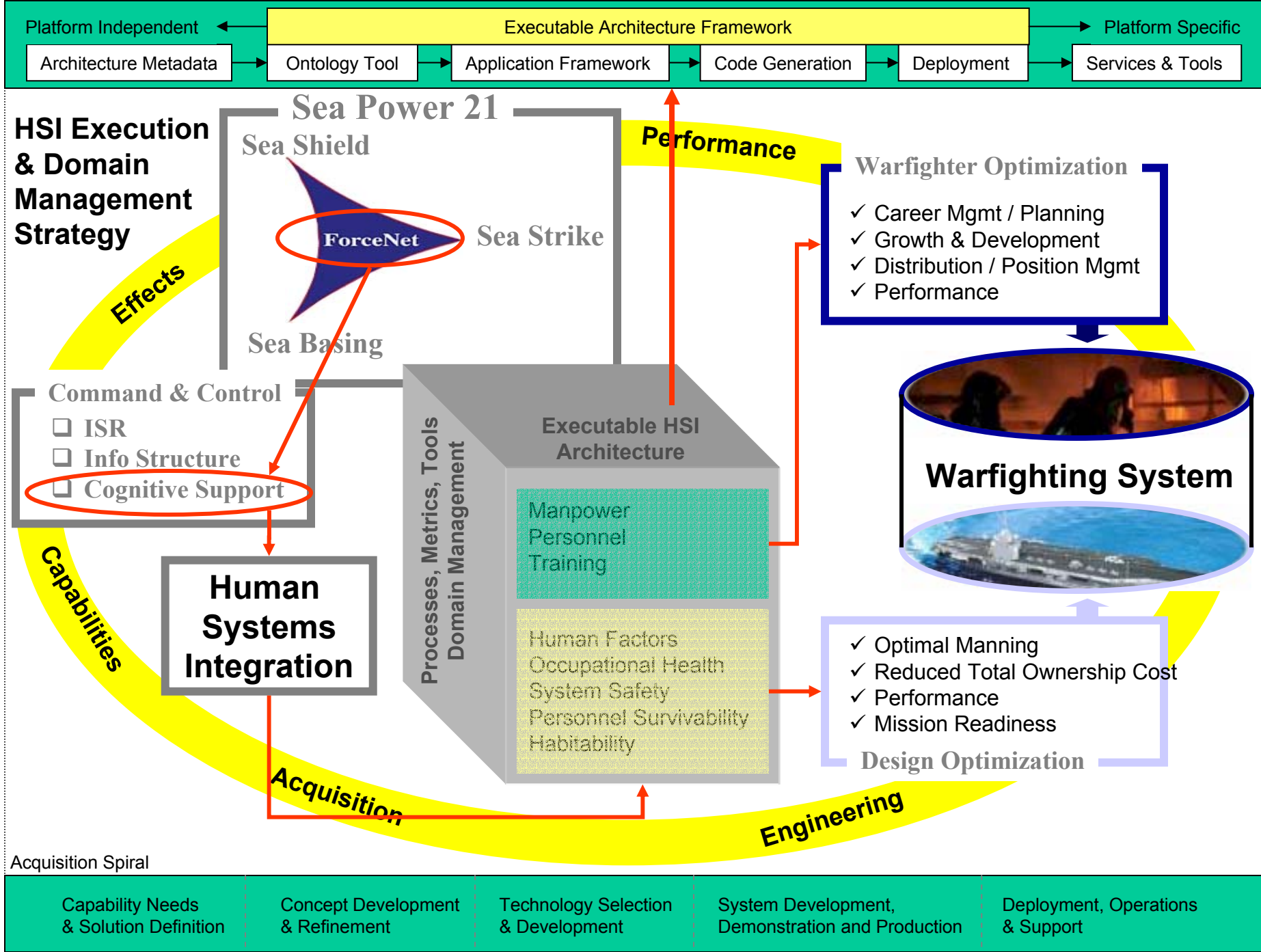 - Recognizes complex relationship between Technology, HF, MPT, etc.

HSI Assessment Process

New Technologies/ Capabilities → Concept of Operations

Scenario / Op Context

Mission | Mission Areas | NMETL F | NMETL F | NMETL Functions | Task S | Task S | Task S | Task Steps

HSI Components
- Human-Computer Interface
- Training & Technical Docs
- Manpower & Personnel
- Organizational Info Flow

Outcome Measures	Process Measures	Thin-Thread Measures
MOEs	MOPs	HSI Metrics

REALISM / CONTROL

Assessment Continuum

Analysis & Heuristic Review
- Focuses on technologies and system components
- Based on HSI standards and design guidelines

Usability Tests & Limited Assessments
- Examines technologies in simulated task context
- Empirical studies to get feedback from warfighters on utility, usability, reliability, etc.

Scenario-based Exercises (IPD)

Verifies technologies' contribution to ME in dynamic, operational context
- Observation of global performance indicators

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Future Directions: HSI Enterprise Architecture

OV-1

Sea Power 21

Sea Shield

ForceNet

Sea Strike

Sea Basing

Effects

Performance

Capabilities

Acquisition

Engineering

Command & Control
- ❑ ISR
- ❑ Info Structure
- ❑ Cognitive Support

Human Systems Integration

Activities, Processes, Metrics and Tools

Manpower
Personnel
Training

Human Factors
Occupational Health
System Safety
Personnel Survivability
Habitability

Warfighter Optimization
- ✓ Career Mgmt / Planning
- ✓ Growth & Development
- ✓ Distribution / Position Mgmt
- ✓ Performance

Warfighting System

- ✓ Optimal Manning
- ✓ Reduced Total Ownership Cost
- ✓ Performance
- ✓ Mission Readiness

Design Optimization

Acquisition Spiral

Capability Needs & Solution Definition	Concept Development & Refinement	Technology Selection & Development	System Development, Demonstration and Production	Deployment, Operations & Support

Platform Independent ← Executable Architecture Framework → Platform Specific

Architecture Metadata → Ontology Tool → Application Framework → Code Generation → Deployment → Services & Tools

HSI Execution & Domain Management Strategy

Sea Power 21

Sea Shield

ForceNet   Sea Strike

Sea Basing

Effects

Performance

Warfighter Optimization

✓ Career Mgmt / Planning
✓ Growth & Development
✓ Distribution / Position Mgmt
✓ Performance

Command & Control
❑ ISR
❑ Info Structure
❑ Cognitive Support

Capabilities

Processes, Metrics, Tools
Domain Management

Executable HSI Architecture

Manpower
Personnel
Training

Warfighting System

Human Systems Integration

Human Factors
Occupational Health
System Safety
Personnel Survivability
Habitability

✓ Optimal Manning
✓ Reduced Total Ownership Cost
✓ Performance
✓ Mission Readiness

Design Optimization

Acquisition

Engineering

Acquisition Spiral

| Capability Needs & Solution Definition | Concept Development & Refinement | Technology Selection & Development | System Development, Demonstration and Production | Deployment, Operations & Support |

Conclusions

- **The Warfighter is a critical component of Network Centric Warfare (NCW)**

- **HSI Assessment in TW04 and other NCW events**
  - **Comprehensive HSI data collection and analysis**
  - **Comparisons to TW03 and other exercises to see trends**
  - **Aggregation across FORCEnet tests to determine HSI impacts**

- **Greater focus on development of TTP / ConOps**

- **Standard set of HSI measures and metrics**

- **Predictive analysis of HSI issues for new systems, design options, manning, training, etc.**

- **HSI Enterprise Architecture to structure HSI performance taxonomy and data repository**

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Back-Up Slides

FORCEnet Processes and Technologies

- **Call For Fires**
  - **Automated Deep Operations Coordination System (ADOCS)**
  - **Advanced Field Artillery Tactical Data System (AFATDS)**
  - **Naval Fire Control System (NFCS)**
- **Command and Control / Collaboration**
  - **FORCEview**
  - **Global Command and Control System–Maritime (GCCS-M)**
  - **Task Force Web (TFW)**
  - **Web Common Operational Picture (WebCOP)**
  - **Collaboration Tools (Chat and MS NetMeeting)**
- **Network Operations**
  - **Automated Digital Network Switch (ADNS)**
  - **High Frequency Automatic Link Establishment (HF ALE)**
  - **Intra-Battle Group Wireless Network (IBGWN)**
  - **Super High Frequency / Commercial Wideband Satellite Program (SHF/CWSP)**

Call For Fires – 1

Performance

- **Very limited shared SA among Flag Plot, SACC, and LFOC.**
- **SACC**
  - Drawbacks: did not hold BDA on targets once the target was issued to a Fires resource. Flag Plot did not know about every target being taken until SACC asked for BDA.
- **ADOCS: Supplies adequate amount of task-relevant information**
  - Drawbacks: very slow when running other software, including C2PC.
- **AFATDS: Works well if operator is well trained: maintains COP, deconflicts fires, and has good interoperability. Simplifies identification of force locations and status.**
  - Drawbacks: a need to enter database and IP addresses and slow processing speed.
- **NFCS: Presents information so it can be readily understood.**

User Interface

- **ADOCS: No specific usability problems were noted. Displays are easy to read.**
- **AFATDS: The better trained, frequent users rated AFATDS as very usable. Displays were easy to read, and information was presented logically.**
  - Drawbacks: limited error prevention and detection, inconsistent color-coding, use of non-standard commands, and incomplete user feedback.

Information Transfer

- **Technical integration across systems for fires process worked very well.**
  - **Drawbacks: Problems observed in transferring information between SACC and ESG. Only way to exchange information between SACC, LFOC, and Flag Plot was via Chat.**
- **Time Sensitive Targeting messages were often sent directly from JIC to SACC.**
  - **Drawbacks: Flag Plot was not always aware of TST in progress.**
- **ADOCS: 2/3 of users felt that ADOCS did not enhance SA and did not help to identify force locations, understand status of users and equipment, and track tasking and scheduling.**
  - **Drawbacks: Problems noted in understanding status of other users and their equipment, estimating opposing forces capabilities, anticipating responses to Blue actions, identifying and resolving scheduling conflicts, time lag between SA and real events, and shared SA among team members.**
- **AFATDS: Supported SA and helped to identify force locations, understand status of users and equipment, and track tasking and scheduling.**
  - **Drawbacks: Potential SA problems noted in monitoring critical events; resolving scheduling and resource conflicts, and anticipating responses to blue actions.**
- **NFCS: Presents information so it can be readily understood.**

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Training

- **A systems integration guide is needed to show how individual CFF technologies relate to each other from an operational (task) perspective.**

- **ADOCS: Training was described as inadequate. Procedures were not well understood and users wanted more training.**

- **AFATDS: More extensive formal training is needed. Users often did not understand AFATDS procedures or find job aids useful. The number of requests for technical assistance (to setup the system) was excessive.**

- **NFCS: More training needed to gain competence (4 hours training provided).**

Manpower/Personnel

- **Manpower was only one-deep for most CFF technologies.**

Performance

- **The Flag Plot watch team took 14 minutes to find the right format for an NBC-1 Report and 12 minutes to draft the message.**

- **The best SA was gained through the voice SITREPS.**

- **Chat:**

  - **Drawbacks: Multiple Chat tools caused confusion. Several users noted that monitoring several chat rooms increased their workload. Navy Enterprise Portal helps to consolidate chat rooms, but does not work with all chat programs.**

- **GCCS-M: Frequent users can reduce the time needed to organize information and decide what actions to take.**

- **NetMeeting:**

  - **Drawbacks: Requires a lot of bandwidth. Consistent availability is an issue. Whiteboard slowed system down too much, creating unacceptable time lags. The 10 user limit was a serious shortcoming. File transfers were rated disorganized and ineffective.**

- **WebCOP: Worked well; used for briefs in Flag Plot.**

  - **Drawbacks: Occasionally, COP was lacking: (a) COP in Flag Plot was did not match COP on the Chancellorsville; and (b) specific objects could not be located or their map locations were inaccurate.**

User Interface

- **Ergonomic deficiencies in the Flag Plot workspace:**
  - High traffic and noise levels hindered task performance and development of SA.
  - Traffic flow intermittently blocked view of large screen displays at front of Flag Plot.
  - Legibility of text on large screen displays at front of Flag Plot was poor for observers seated in the back of Flag Plot.
  - Locations of some displays produced difficult viewing angles.
- **Technical incompatibilities among the different Chat systems.**
- **Flag spaces need larger displays for watch-standers.**
  - Multiple-screen console (e.g., Multi-Modal Watch Station or Knowledge Desk) would be helpful.
- **Chat: Good screen legibility, information presentation, and navigation.**
  - Drawbacks: (a) inadequate feedback, (b) poor error prevention and recovery, (c) difficulties in gaining SA without viewing entire chat sequence (scrolling issues), (d) limited formatting capabilities, and (e) pressing the Enter key inadvertently sends Chat message. MS Chat deficiencies included no authentication, no time stamp, and no auto logging.
- **GCCS-M:**
  - Drawbacks: non-standard and/or inconsistent icons, menus, buttons, navigation, operating procedures, and commands. Large amount of information clutters its display. Inadequate error prevention and recovery.
- **NetMeeting:**
  - Drawbacks: information presentation, navigation, and error detection and recovery. A single user was required to participate in different chat rooms to talk to different

Information Transfer

- **Much 'sneaker net' occurred between key watch standers in the JIC and LFOC going to and from the Flag Plot.**

- **Chat: Chat generally reduced time and effort needed to identify users, exchange information, and support coordination among users.**
  - **Drawbacks: Confusion occurred when orders sent via Chat were not acknowledged. Timely messages dependent on typing skills of sender. BWC had to approve all chat dialogue before it was sent.**

- **GCCS-M: Generally, simplified identifying force locations.**
  - **Drawbacks: SA problems: (a) Keeping track of tasking, scheduling, and critical events; (b) Identifying scheduling and resource conflicts; (c) Tracking progress toward objectives, and (d) Anticipating responses to blue actions. Some users felt their SA lagged significantly behind actual events. (Catastrophic effect if GCCS is used to provide track information for fire support systems.)**

- **WebCOP: Kept track of mission goals and objectives, critical events, and goals and actions.**
  - **Drawbacks: SA ratings were moderately negative.**

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Training

- **Crew was mostly unaware of capabilities of Fn technologies.**
- **A new concept of operations, and staff familiarity with it, is needed within the ESG to promote effective collaboration using the Fn technologies.**
- **The tempo of operations in Flag Plot was very high, due in part to confusion over the use of the new C2 Fn technologies.**
- **Lack of standardized message posting procedures on the ESG web site complicated finding information.**
- **Chat: Most users reported no formal training on Chat, but only 3 wanted additional training.**
- **GCCS-M:**
  - **Drawbacks: Many users did not understand its procedures, felt inadequately trained, and that documentation and online help needed improvement.**
- **NetMeeting: Most felt they had received adequate training, with half reporting that documentation and online help were all the training needed.**
- **Task Force Web:**
  - **Drawbacks: All users felt they had not received adequate training and that the online help was not sufficient training by itself.**

Manpower/Personnel

- **Chat:**
  - **Drawbacks: More simultaneous chat rooms were in use than could be effectively monitored and serviced by the assigned staff.**
- **GCCS-M, NetMeeting: The number of calls for technical assistance was**

Network Operations

Performance

- **ADNS: Stable; no trouble calls reported during TW03.**
- **HF ALE: The Marines' HF ALE radios do both voice and data.**
  - **Drawback: Shipboard radios could not handle data, voice only.**
- **SHF/CWSP:**
  - **Drawbacks: SHF was difficult for the operators/administrators to manage. If the hardware is powered down, all configuration settings are lost, requiring increased workload to reconfigure.**

User Interface

- **IBGWN:**
  - **Drawbacks: Very complex, non-intuitive interface. When switching between configuration displays, different screens would contradict each other for established connections.**

Training

- **Network Systems:**
  - **Drawbacks: Training for the new network technologies was marginal. Training for most of the new technologies was left to the individual ships and groups. ITs were not given training on the Network Operations system as a whole. Single technology expertise is inadequate since network technologies are becoming highly interrelated.**
- **IBGWN:**
  - **Drawbacks: No technical representatives available during TW03 for training or information.**

Manpower/Personnel

MOE Summary

HSI Process	Measure of Effectiveness				
	Performance	User Interface	Information Transfer	Training	Manpower& Personnel
Call For Fires	G	G	Y	Y	Y
C2 / Collaboration	Y	Y	Y	Y	G
Network Operations	G	⊘	⊘	Y	⊘

G **Fully functional. Meets requirements but can be improved with minor modifications.**

△ **Functional but requires substantial modifications.**

R **Largely non-functional and needs major modifications.**

⊘ **Inadequate data were available for valid assessment.**

MOEs, MOPs, and Metrics Examples

MOE: Performance

- **MOPs**
  - **Task Performance: Extent of support for required tasks**
    - **Metrics:**
      - **Extent of usage of tool/application to support task**
      - **User rating of usefulness of tool to support task**
      - **User rating of task efficiency – timeliness to complete task**
      - **Observer, SME, or superior rating of task efficiency – timeliness to complete task**
      - **User rating of task effectiveness/quality – task accuracy**
      - **Observer, SME, or superior rating of effectiveness/quality – task accuracy**
      - **User rating of workload associated with performing task**
  - **Situation Awareness (SA): Understanding of relevant aspects of operational situation, relationship between these with each other and evolving situation, and how the situation and events will unfold in the future**
    - **Metrics:**
      - **Accuracy and timeliness of answers to questions embedded in scenario communications**
      - **Accuracy of answers to questions at "stopping points" of scenario**
  - **Decision-making: Availability and extent of use of tools to support decision-making; timeliness and accuracy of decision making (Speed of Command)**
    - **Metrics:**
      - **Availability of tools/application to support decision-making**
      - **Use of tool/application to support decision-making**
   - **Observer, SME, or superior rating of accuracy and timeliness of decisions**

Major HSI Findings in TW 03

- **Loss of SA**
  - **Displays did not support Flag Plot functions**
  - **Poor workspace layout (screen real estate)**
  - **No standardization/no functional analysis on decision making process**
    - **Unclear where to find or post info**
    - **Many websites/portals/chatrooms to monitor**
- **Impaired Speed of Command**
  - **26 minutes for NBC report**
  - **8 minutes to assess hostile intent of track**
- **Information Exchange Shortcomings**
  - **Chat used to pass orders; not always acknowledged**
- **Little or no system integration training provided for new Fn systems**
- **Manpower analysis for new Fn systems not addressed; legacy systems remain**

Insufficiently developed concept of operations for integrating Fn technologies with current information transfer procedures. Warfighter unable to fully understand how to employ Fn capabilities.

Situation Awareness

- **Situation Awareness**
  - **Assembling information across multiple agents over extended time … asynchronous, distributed environment**
  - **Piece together scraps to form likely scenario or course of action**
  - **Ensure a shared perspective (and projection)**
- **Ideal SA: The information and knowledge requirements defined by experts***
- **Achievable SA: the subset of Ideal SA available to the decision makers***
- **Actual SA: The subset of Achievable SA inferred from measurement or observation***

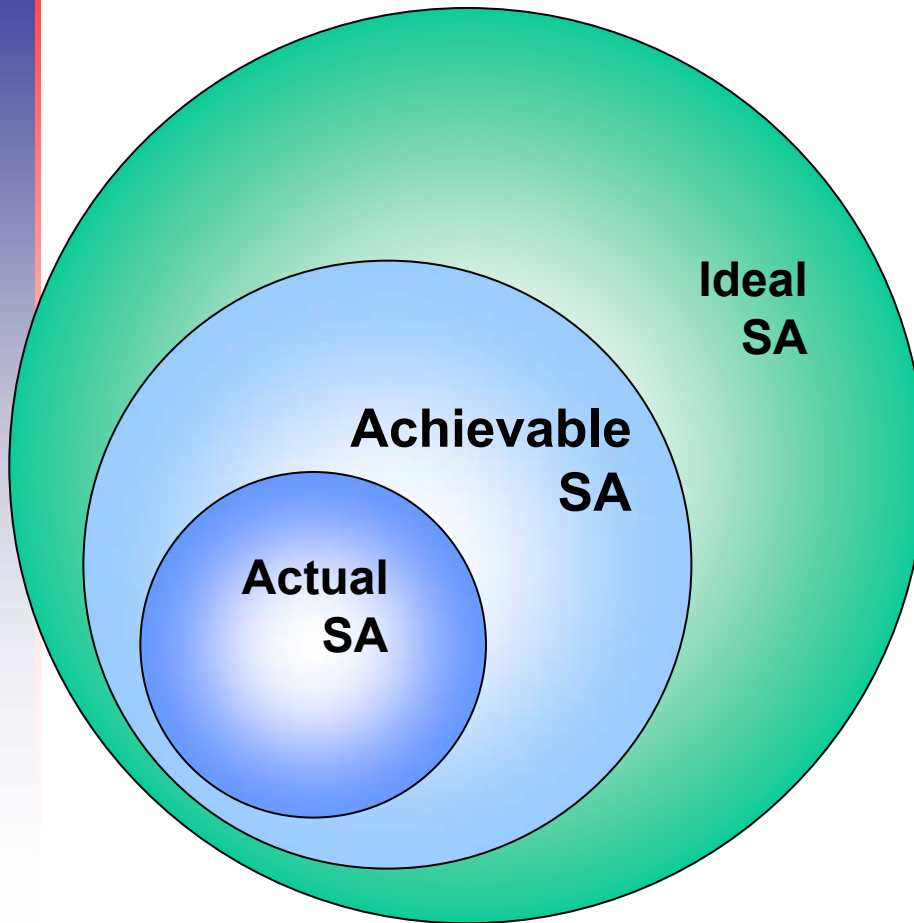*Ideal SA / Achievable SA / Actual SA (nested circles diagram)*
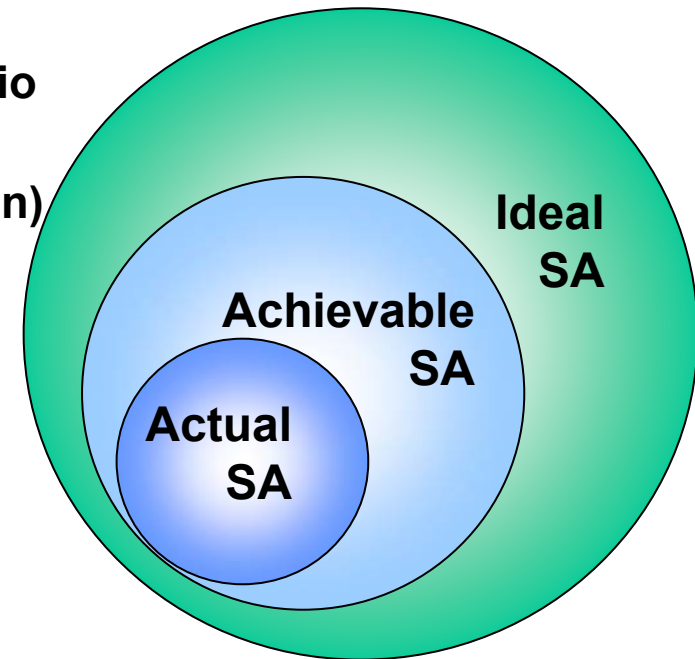
*Pew, 2000
Situation Awareness (SA) is
(1) the perception of elements in the environment within a volume of time and space,
(2) the comprehension of their meaning, and
(3) their status in the near future."   *(Endsley, 1988)*

UNDERSTANDING SA

Situation Awareness (According to Pew (2000))

Ideal SA: The information and knowledge requirements defined by experts, often after the fact.

Achievable SA: The subset of ideal SA that is available to the decision makers.

Actual SA: Inferred from measurement or observation and is a subset of achievable SA.