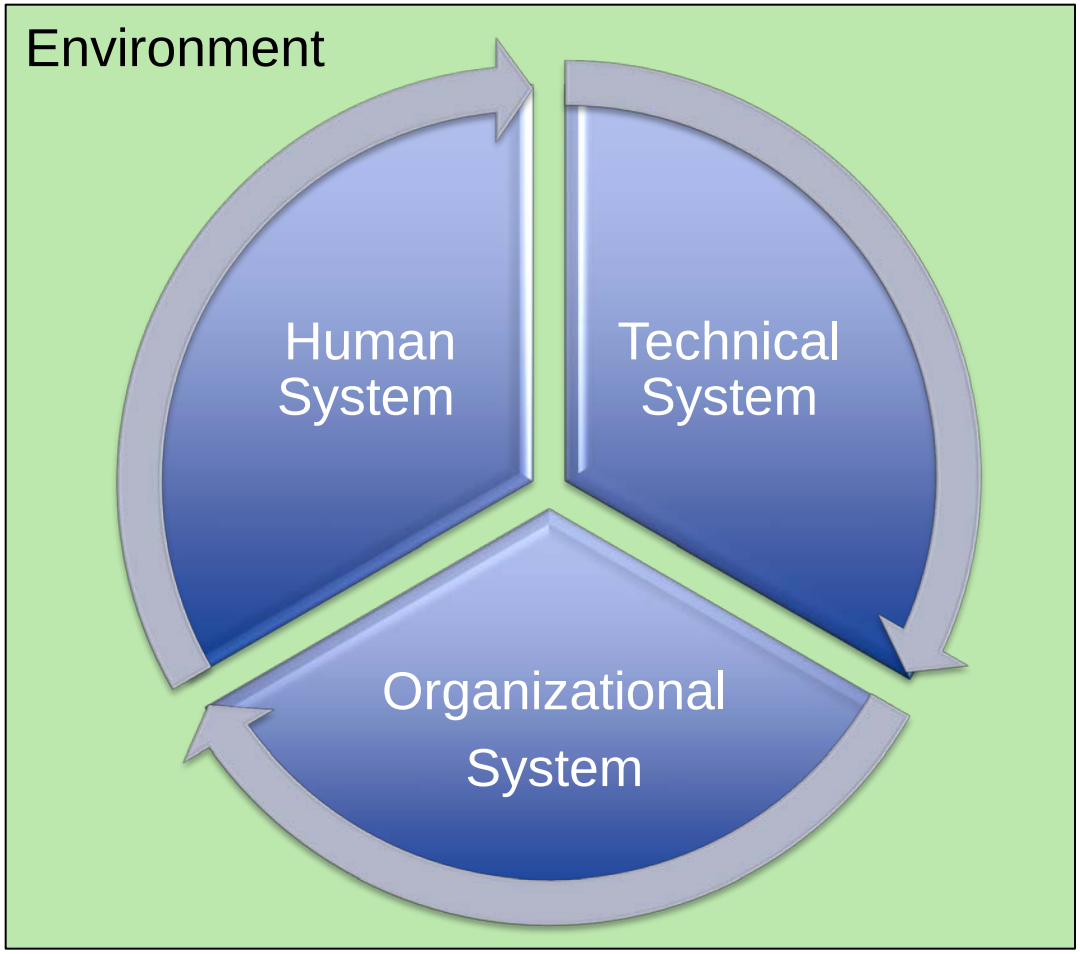
The Role of Situation Awareness and Cognitive Engineering in Future Weapon Requirements, Design and Operation

Mica R Endsley, PhD
SA Technologies, Inc

A Systems Perspective



= System Performance

High Levels of Performance Requires That

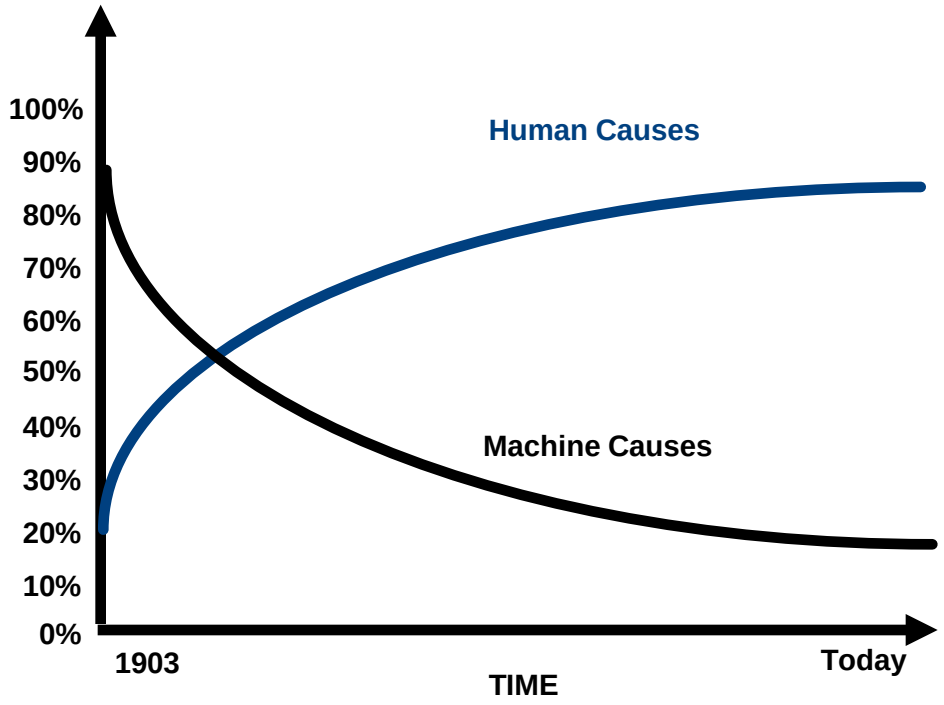
The Technical System Work well with the Human Operators

Within the Constraints of the Environment

Complex System Accidents: Human Error?

SA Technologies

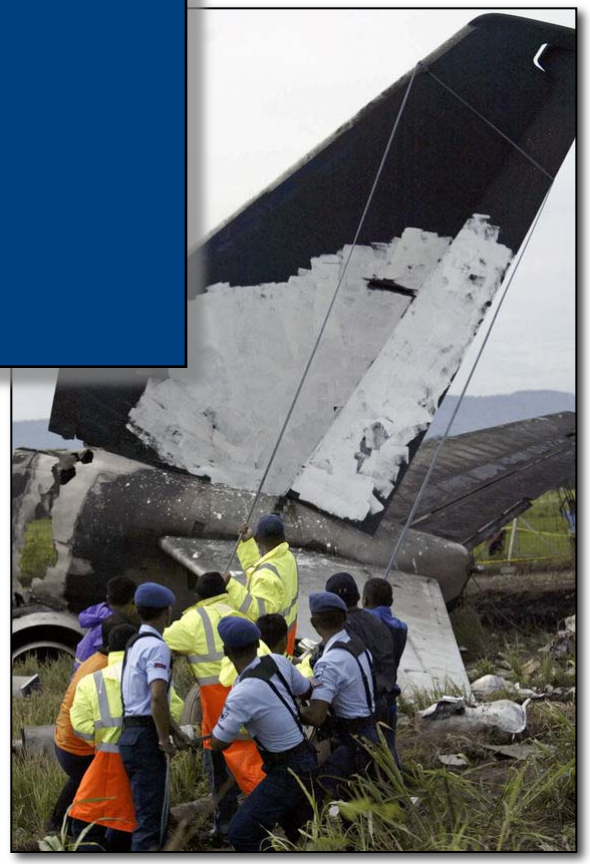
Typically 60-80% of errors are attributed to the human operator



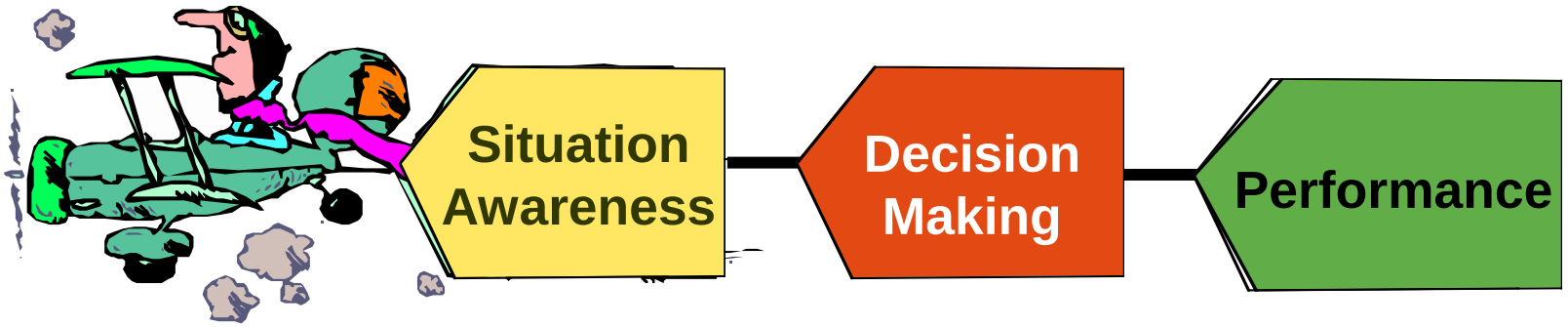
Most of these are actually induced by poor system design

Consequences of Poor SA

As much as 88% of human error is due to problems with situation awareness



Human Performance



Situation awareness is key to good decision making and good performance

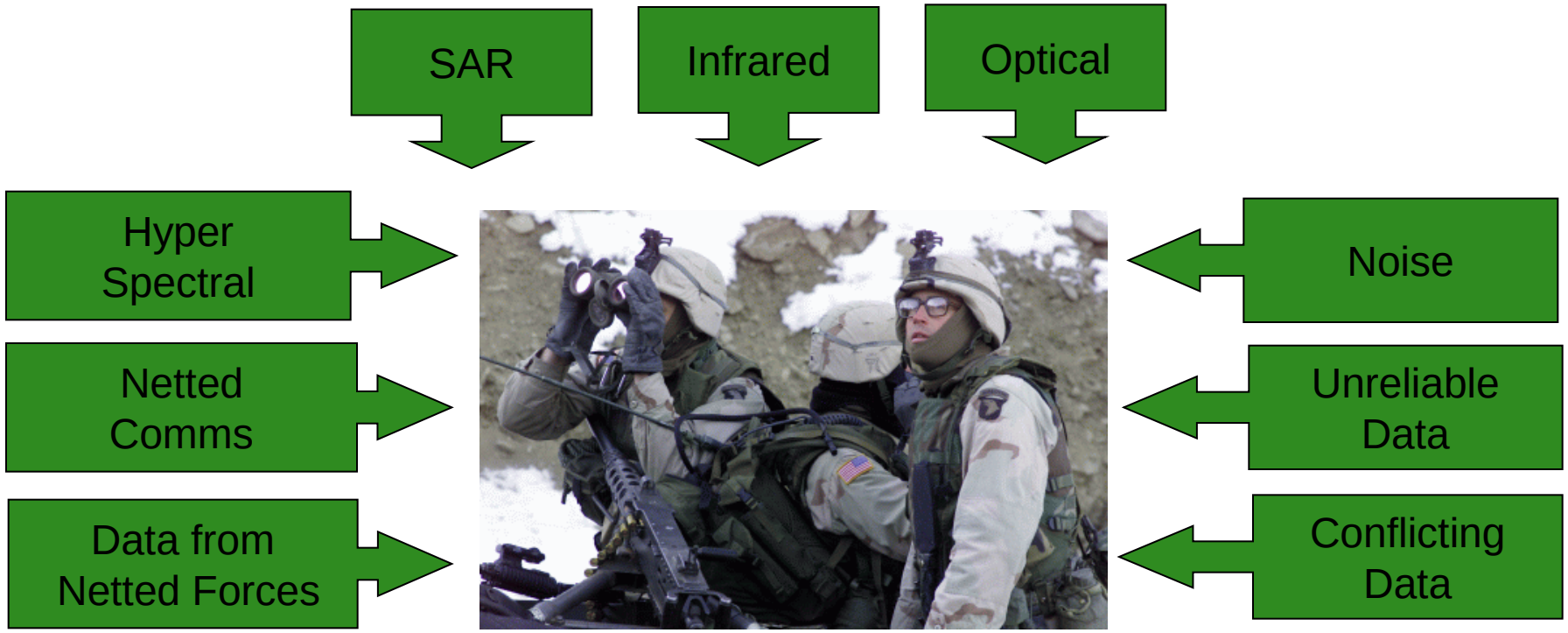
Situation Awareness is Critical in a Wide Variety of Domains.

- Aviation
- Air Traffic Control
- Maintenance
- Medicine
- Military Command & Control
- Intelligence
- Space Flight
- Power Systems
- Oil & Gas
- Transportation

Situation Awareness

- **Situation awareness is central to operations in which distributed warfighters must interact to make time-critical decisions in complex, uncertain environments.**
- **Must get the right information to the right person at the right time**
  - ***in a form that is rapidly understandable and usable***

New Technologies Provide Potential for Data Overload



Effective C4ISR requires that Data be turned into Information

What is Situation Awareness?

Situation Awareness is the *Perception* of elements in the environment within a volume of time and space, the *Comprehension* of their meaning, and the *Projection* of their status in the near future.*

*Endsley, 1988

SA Requirements Are Defined For Each Role In C4ISR

SA Technologies

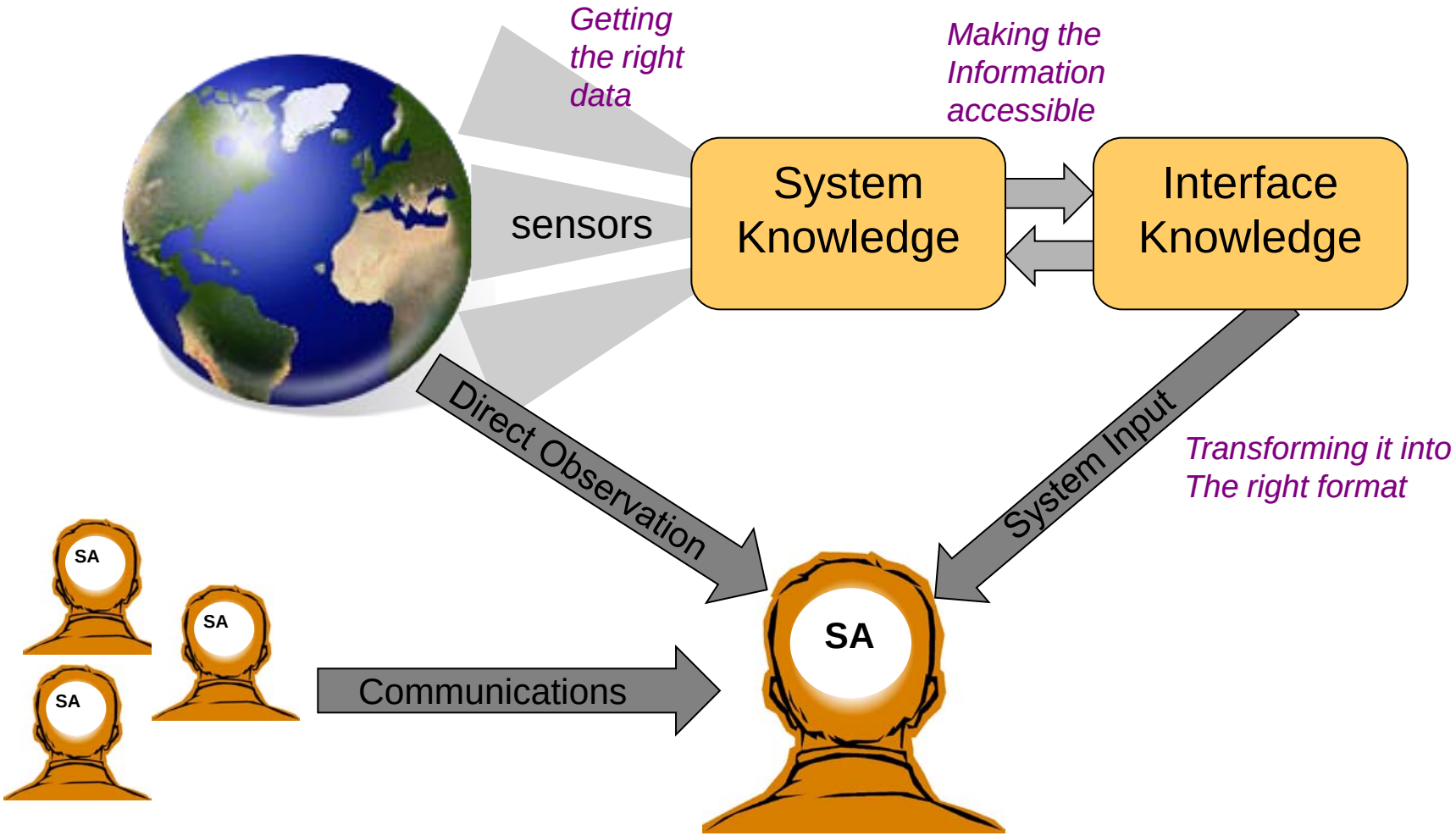
Situation Awareness

Where are we?
Where are they?
What is the weather?
What is the terrain?

Highest priority threat
Deviation from plan
Combat readiness
Level of risk to assets
Priority of information
Areas needing coverage

Predicted enemy COAs
Predicted friendly COAs
Predicted impact of friendly actions on enemy COAs
Predicted location of weapons systems
Predicted effects of weather
Predicted effects of terrain
Predicted enemy objectives

Situation Awareness only exists in the mind of the operator



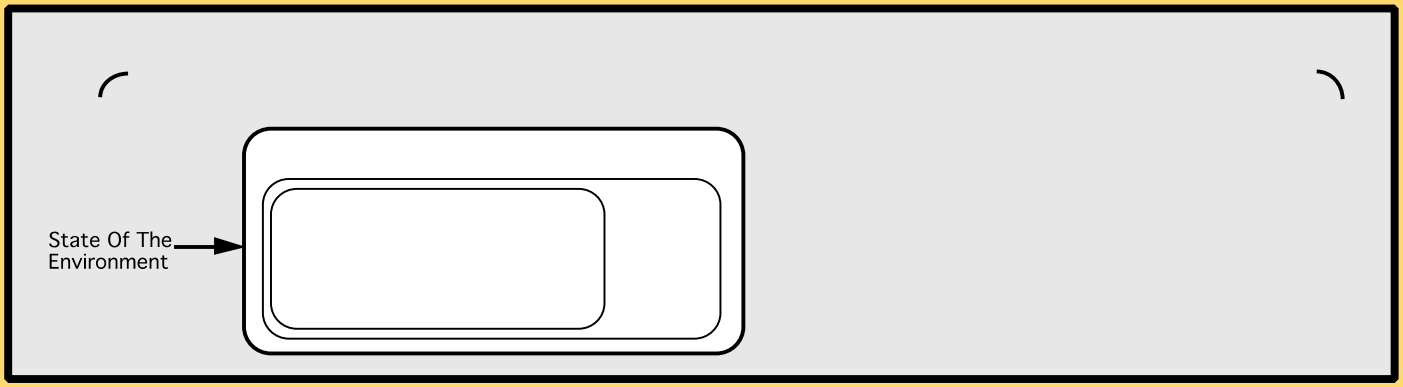
The last 18” are critical

- Limited bandwidth for taking in information
- Limited system for processing data to form SA and make decisions

The development of effective information visualizations and user interfaces to support the way that people work is essential

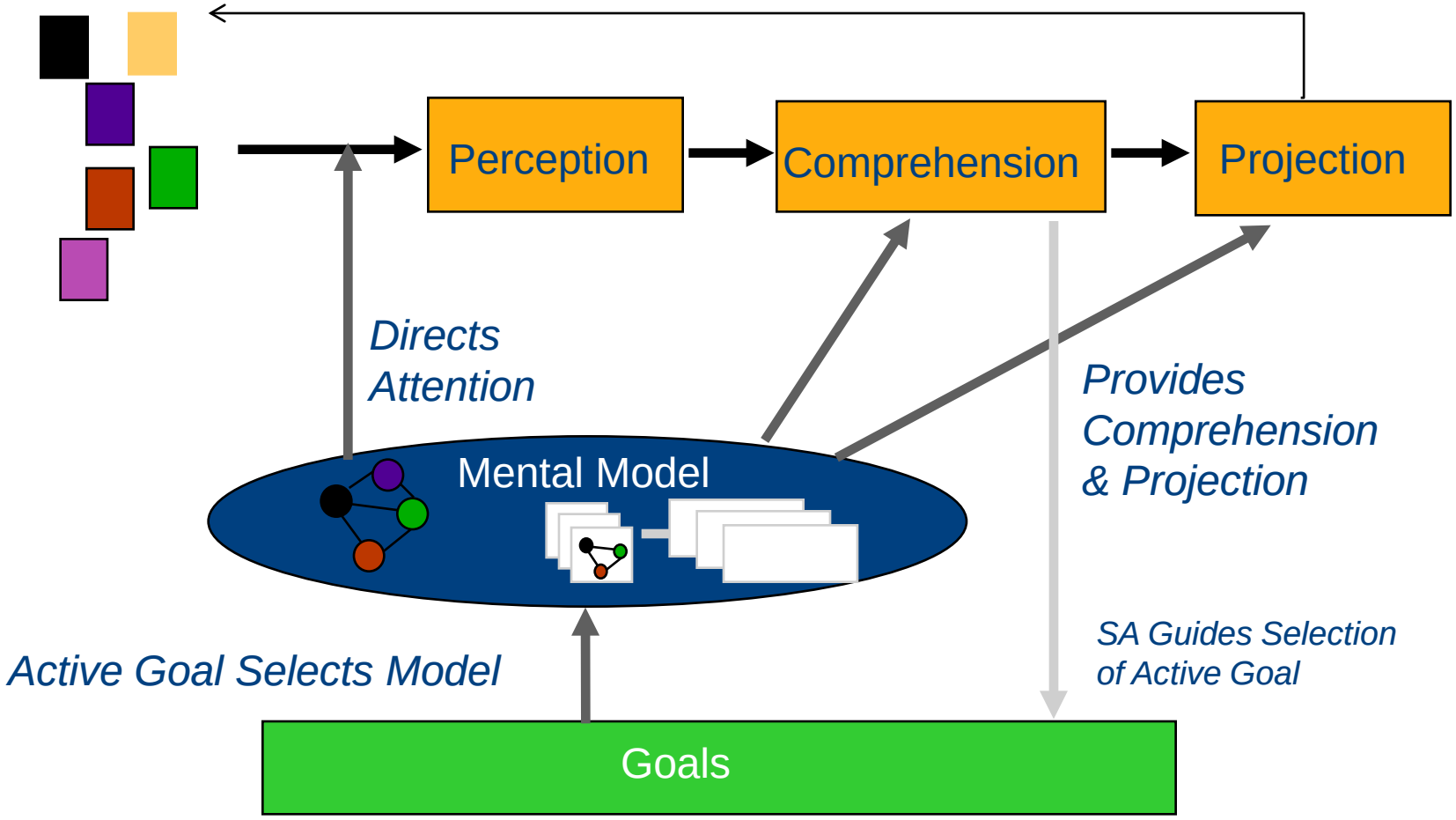
Model of SA

pability
- Interface Design
- Stress & Workload
- Complexity
- Automation

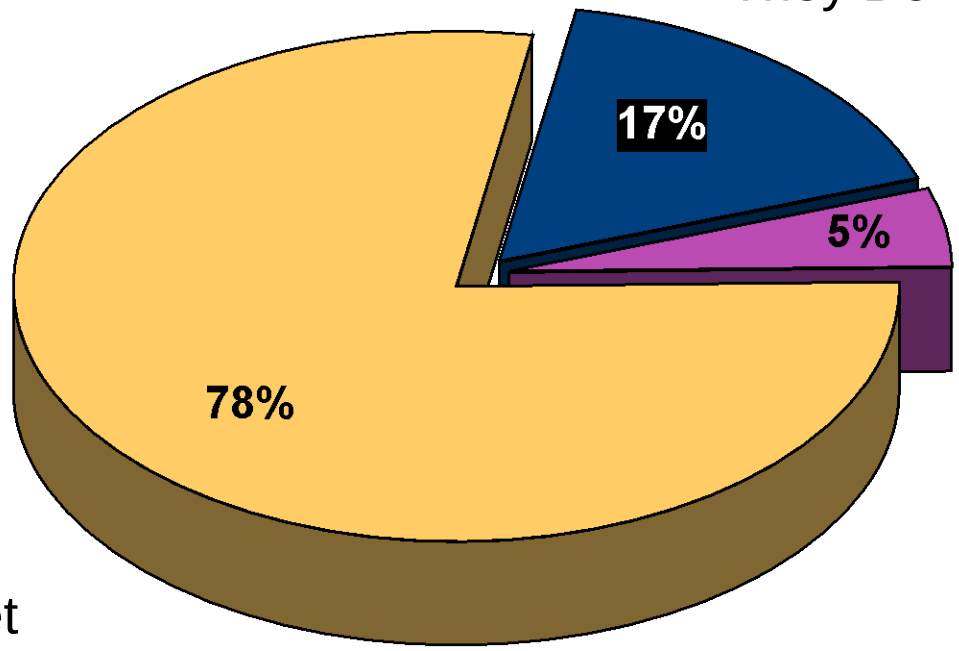


Endsley, 1988, 1995

Mechanisms of SA



What Kinds of SA Problems Do People Have?

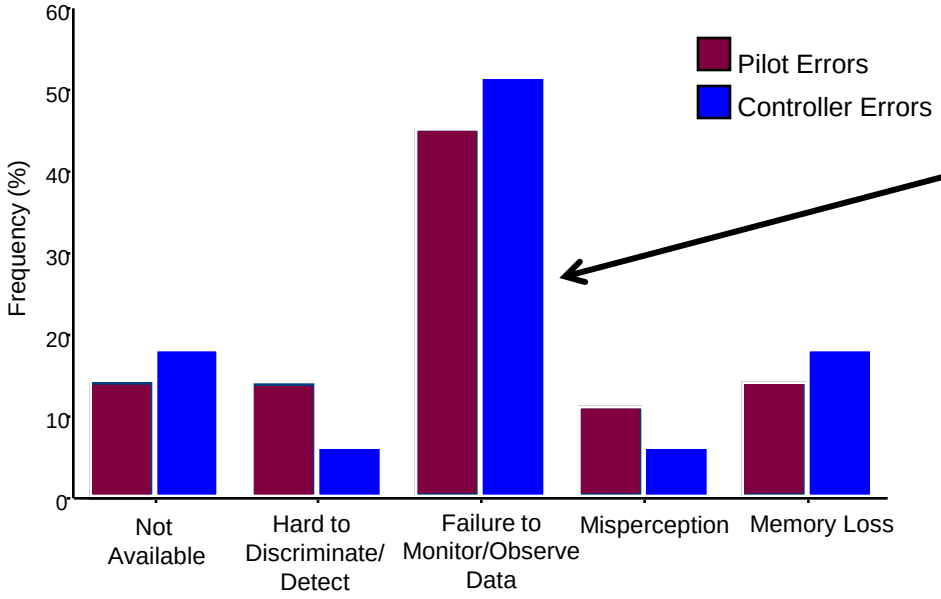


Don't Correctly Understand Information They Do Get

Don't Project What Will Happen in Future

Don't Get Information That Is Needed

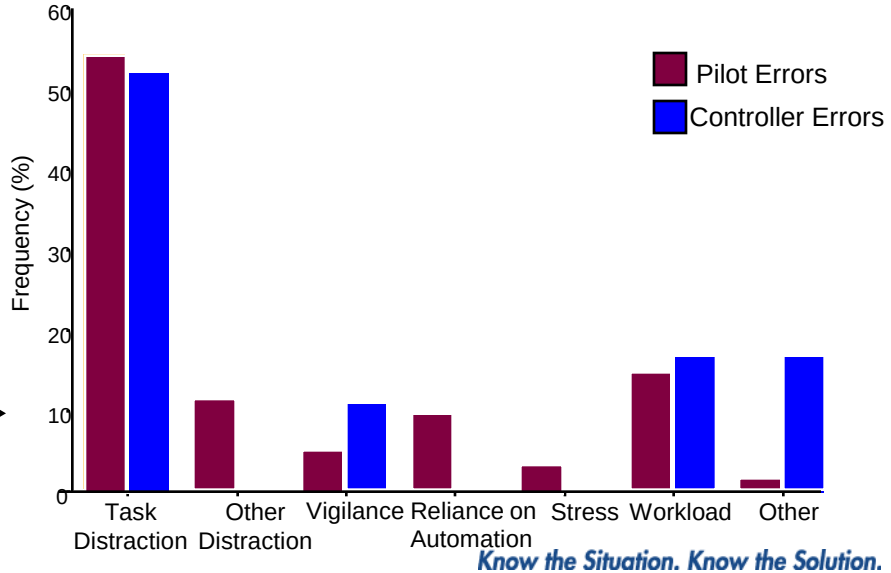
SA Errors



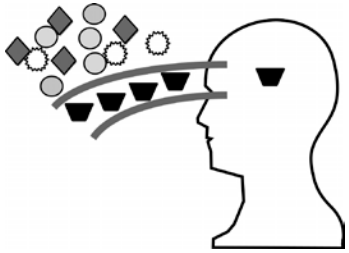
Majority of Level 1 Errors Due to failure to Monitor or Observe Data That is Present (50%)

- Highest single cause of all SA error (30%)

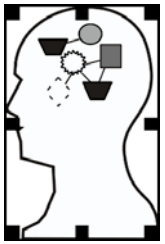
Biggest Single Cause is “Task Distraction”



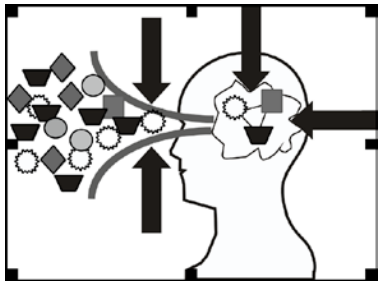
SA Demons



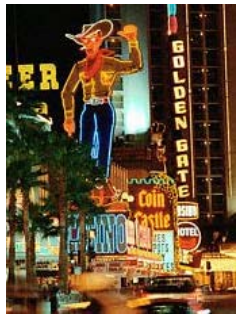
Attentional Tunneling



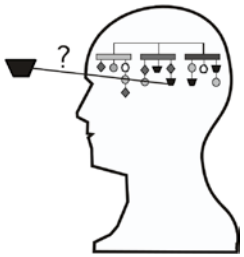
Requisite Memory Trap



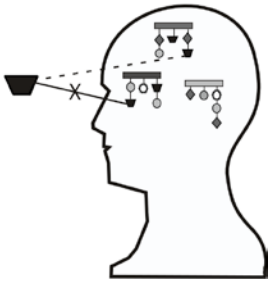
WAFOS: Workload, Fatigue & Other Stressors



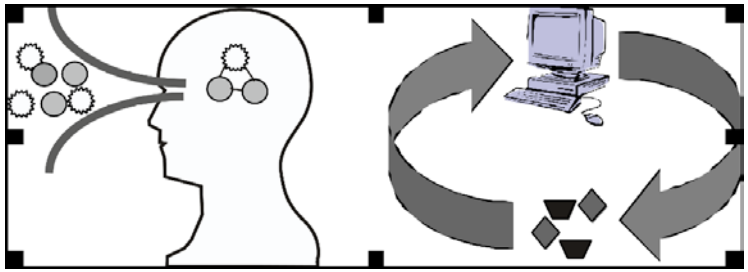
Misplaced Salience



Complexity Creep



Errant Mental Models



Out-of-the-loop Syndrome

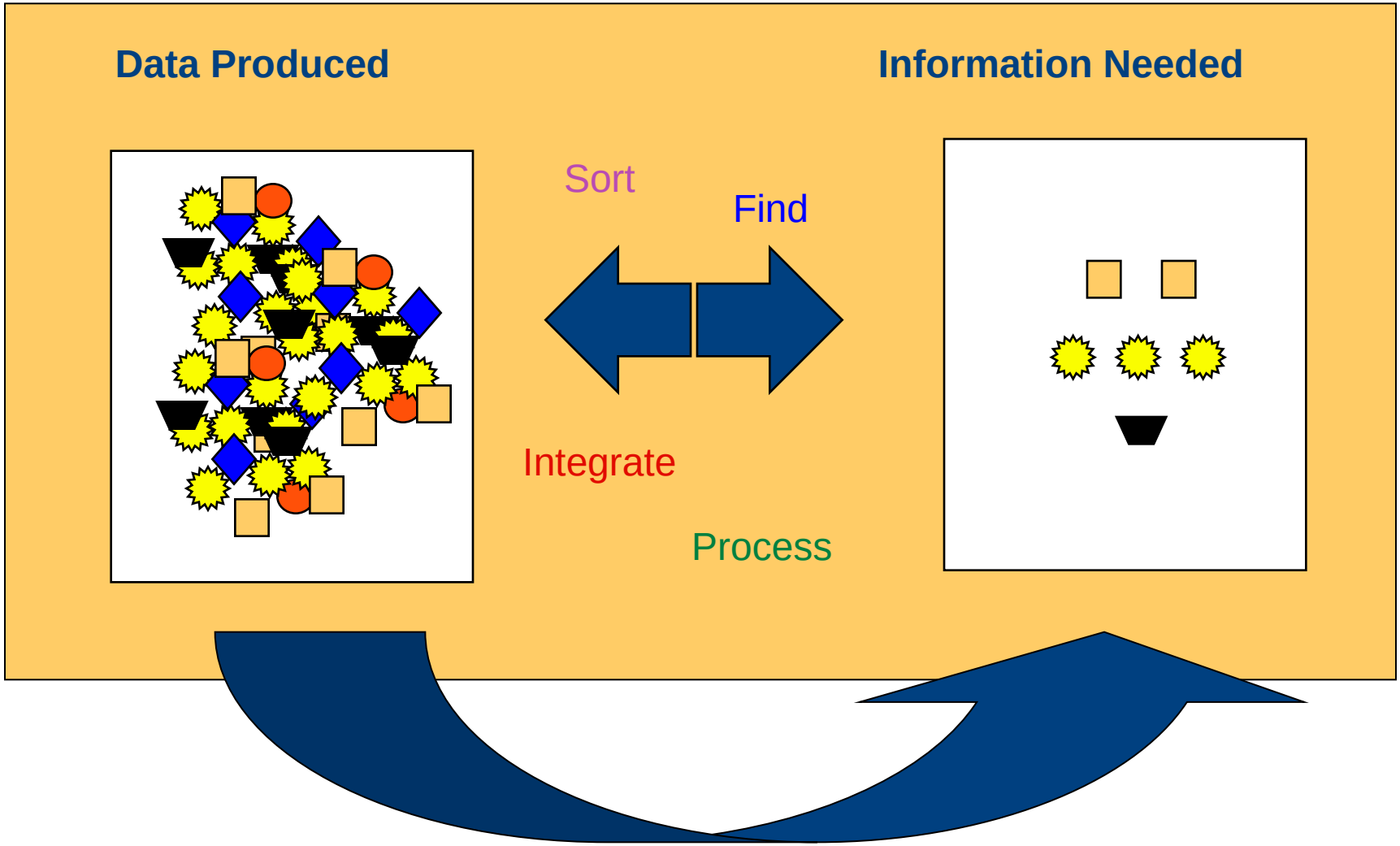
Data Overload

Technology has taken us from here

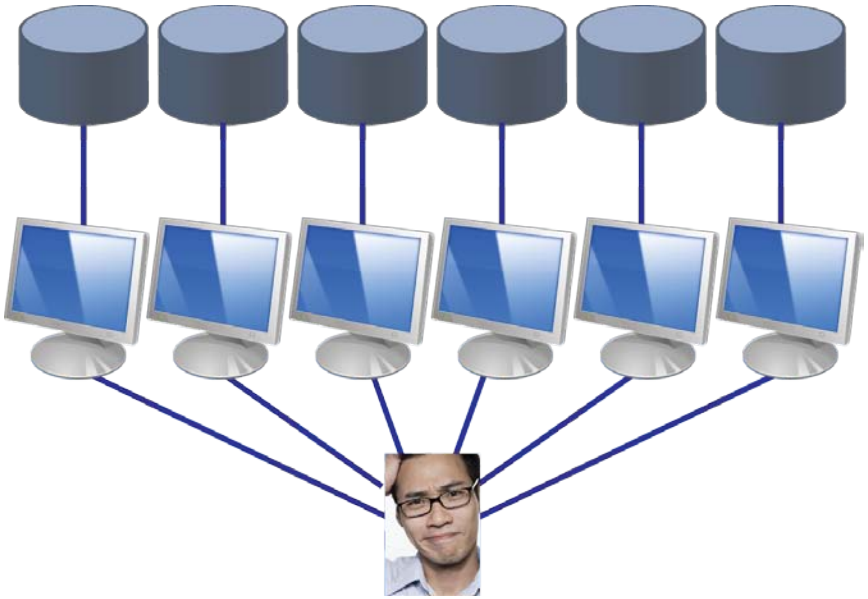
to here.

But we still can't find what we really want to know……

Information Gap



Why the Information Gap?



- Data is gathered and presented from different systems & sources
- Each new system is just added on
- Data not integrated or transformed into real needs of user
- Decision maker left to figure it out

Technology Centered Design

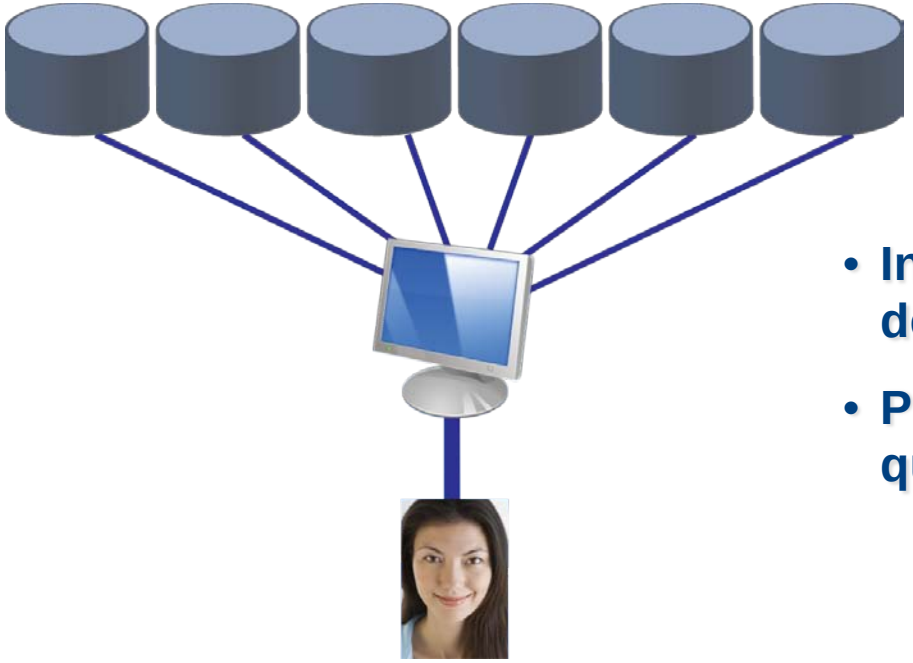
Design Technologies

Let Human Adapt

Fatal Flaw

- Human can only adapt so far
- "Human Error"
- Resultant System is Sub-Optimized

User-Centered Design Philosophy



Design technology to fit capability of humans

- Integrate data around real needs of decision makers
- Present information in ways that are quickly understood and assimilated

Result

- Better Decision Making
- Improved Safety/Reduced Injury
- Improved User Acceptance & Satisfaction
- Improved Productivity

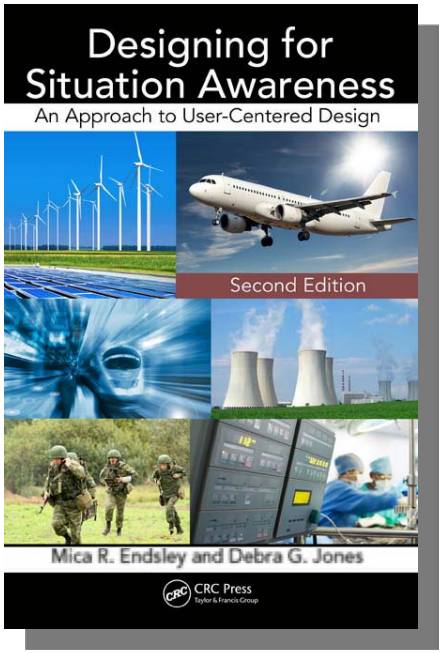
SA-Oriented Design

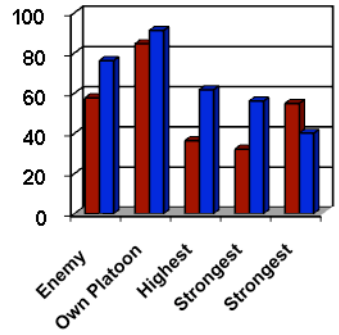
SA Technologies

SA Requirements Analysis → SA-Oriented Design → SA Measurement

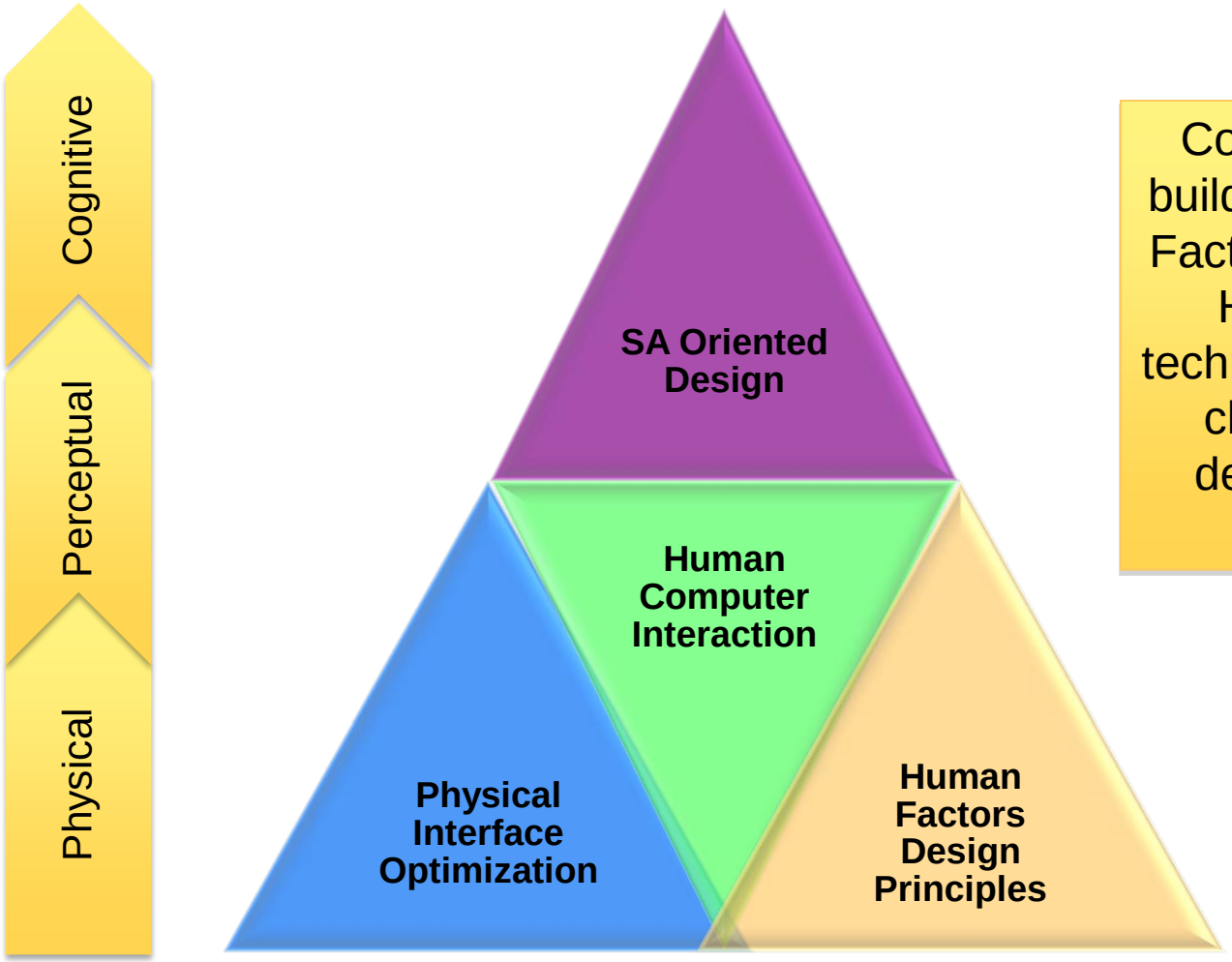
- Goals
- Decisions
- •Projection Requirements
  - •Comprehension Requirements
    - •Data Requirements

50 Design Principles





Addressing the needs of Cognitive Work

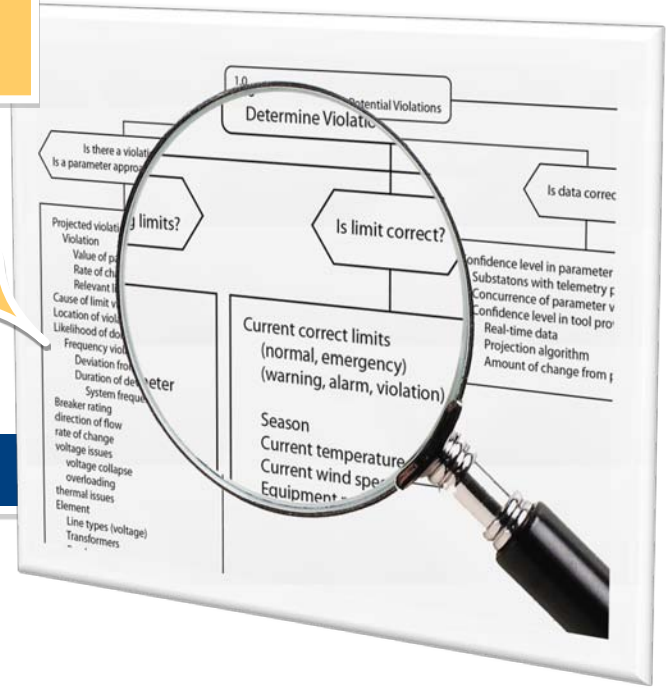


Cognitive Engineering builds upon other Human Factors, Ergonomics and HCI principles and techniques to address the challenges of highly demanding cognitive work

SA Requirements Analysis

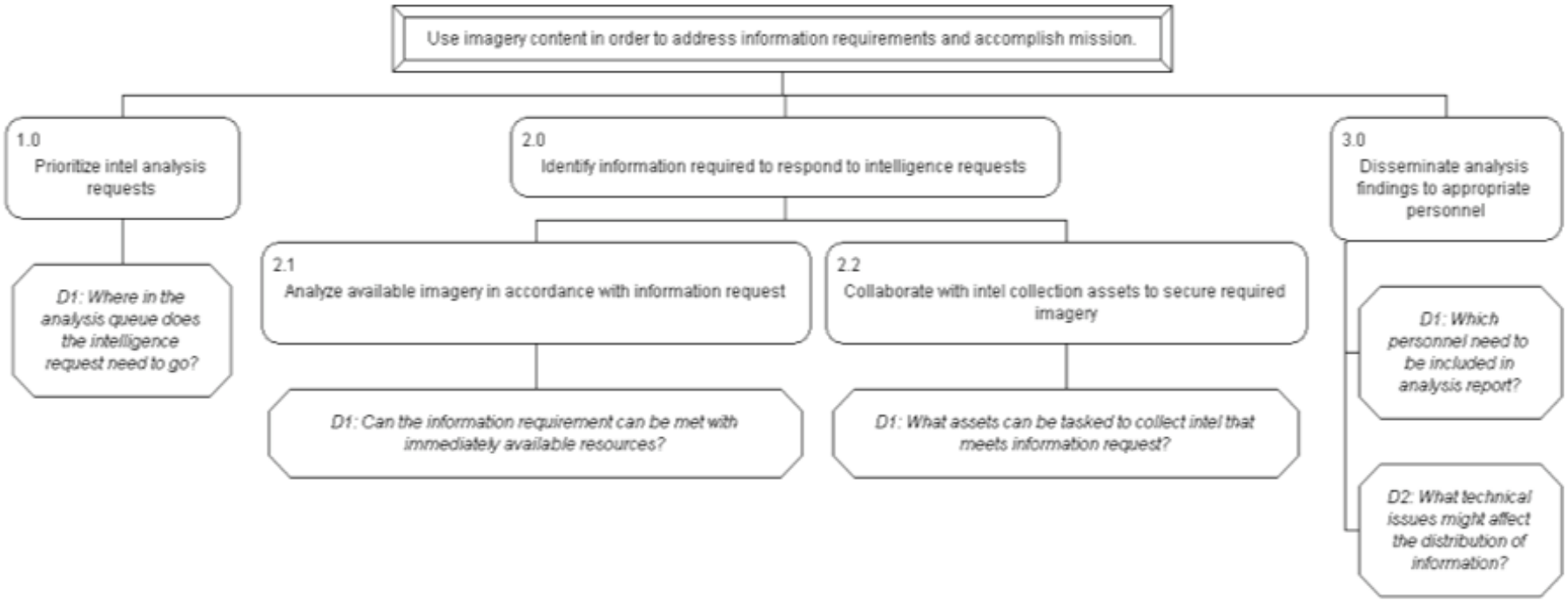
Cognitive Task Analysis

- Goals
  - Subgoals
    - Decisions
      - Projection Requirements
      - Comprehension Requirements
      - Perception Requirements

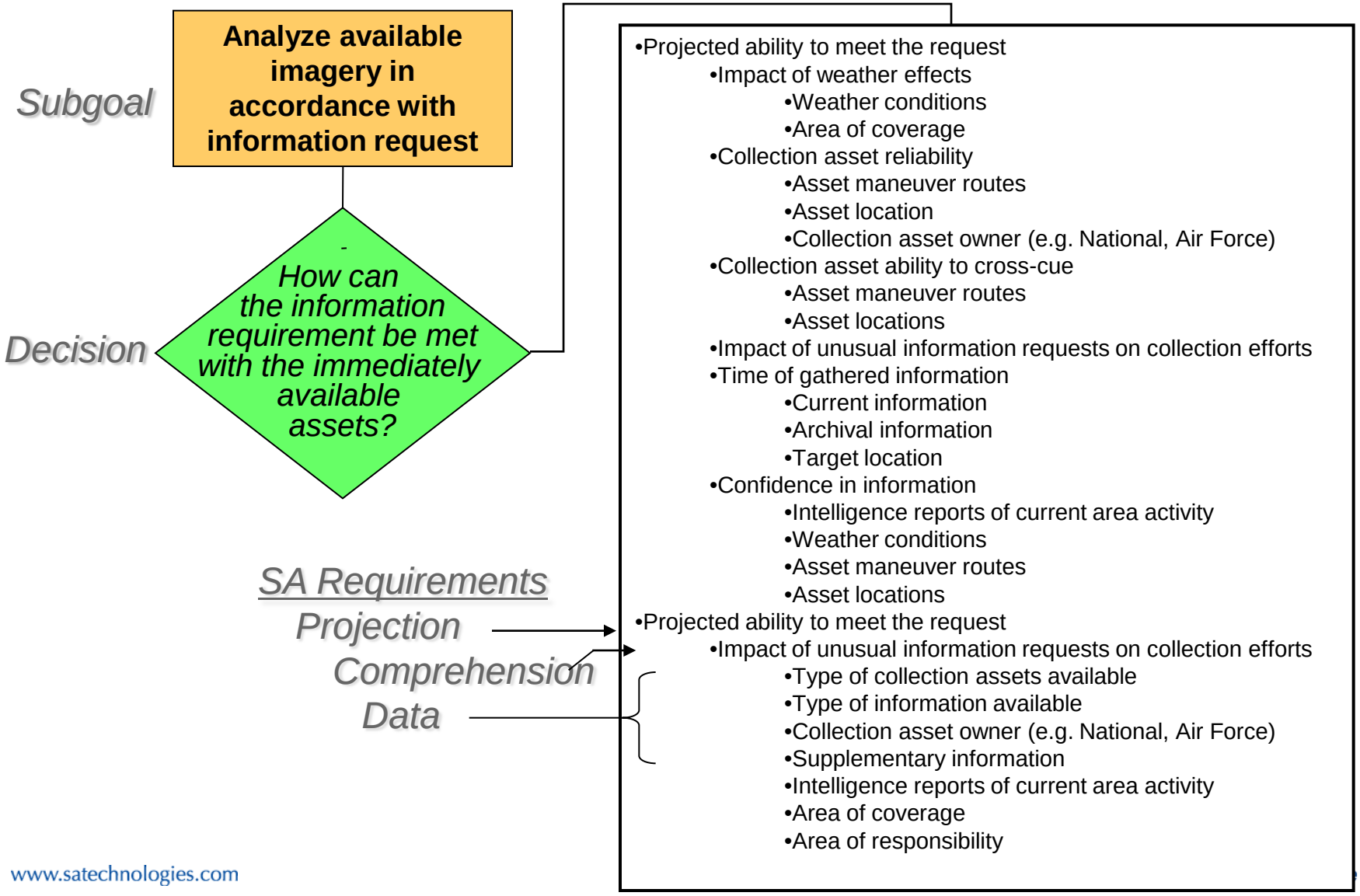


Drives Design
Drives Training
Drives Evaluation

GDTA: Imagery Analysis



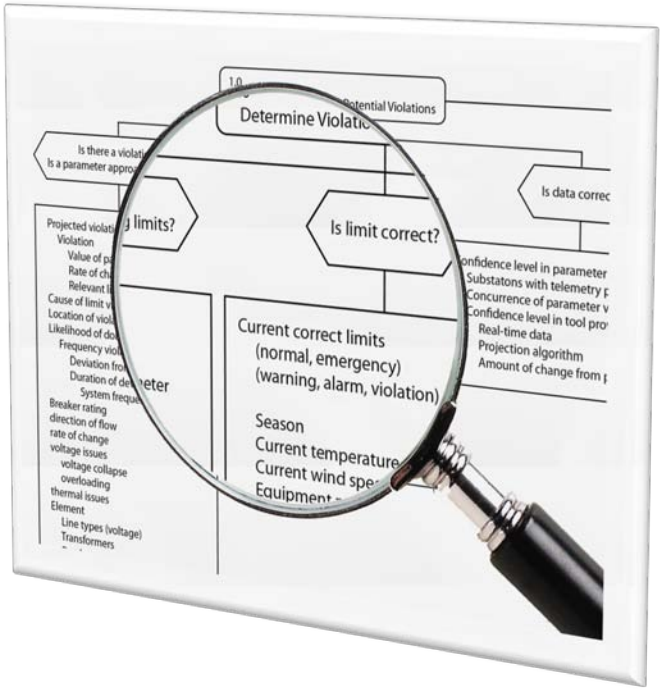
Example – Imagery Analysis



Advantages of the GDTA

- **Technology Independent**
  - **Concentrates on *what* people need to know, not *how* they know it which changes with situations, individuals and new technologies**
- **Provides clear roadmap for system design**
  - **No artificial ceiling effect**
  - **What the operators ideally want to know**
- **Role-based analysis provides clear delineation of who needs what**
  - **Avoids overload problems**
  - **Provides for customized designs**
  - **Modular nature allows for easy assessment of future role combinations**
- **Can be combined with traditional function analysis (what tasks need to be done) for complete design input**

GDTA provides key input to Requirements Definition



- **Primary Information Requirements**
- **Secondary Information Requirements**
- **Functional Requirements**

Example

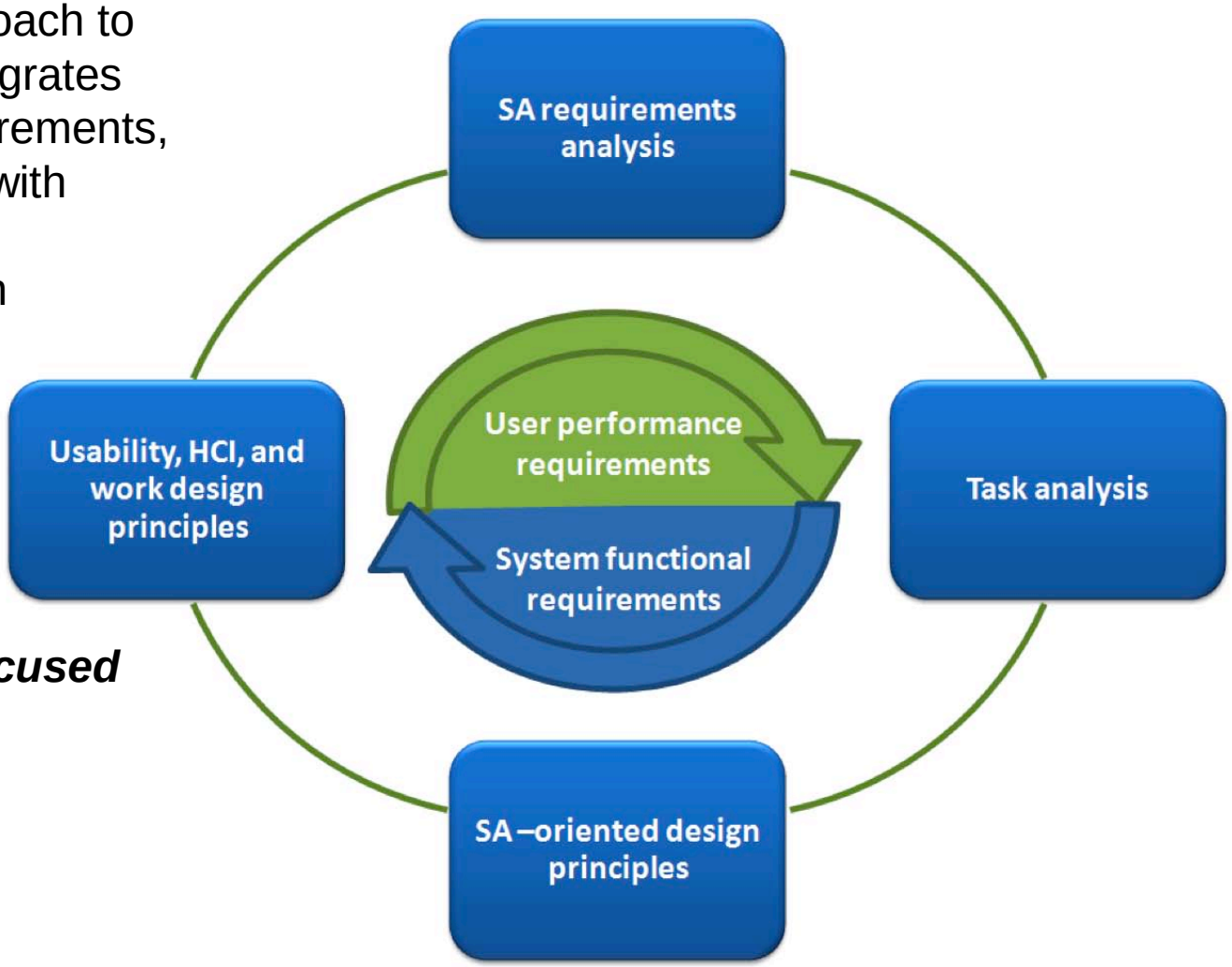
- Provide the dispatcher with a record of generator unit history.
- Provide the dispatcher with a means to manipulate time scale of generator unit history.
- Alert the dispatcher that logging should occur for generator units.
- Allow the dispatcher to record status/reasons for deviations from schedule.
- Provide the ability to change generation parameters (i.e., maximum/minimum generation, schedule, limits).

Integrating other guidelines for extending requirements statements

SA Technologies

A comprehensive approach to **requirements** that integrates SA principles, SA requirements, and design guidelines with other forms of task analysis and HF design standards promotes requirements that are:

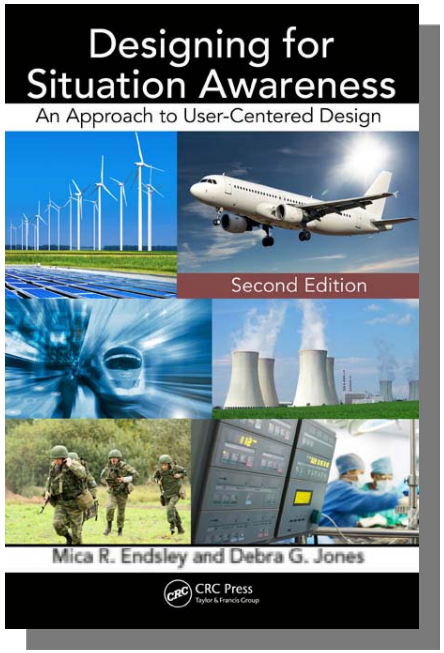
- ***Robust***
- ***Measurable***
- ***Specific***
- ***Performance-focused***



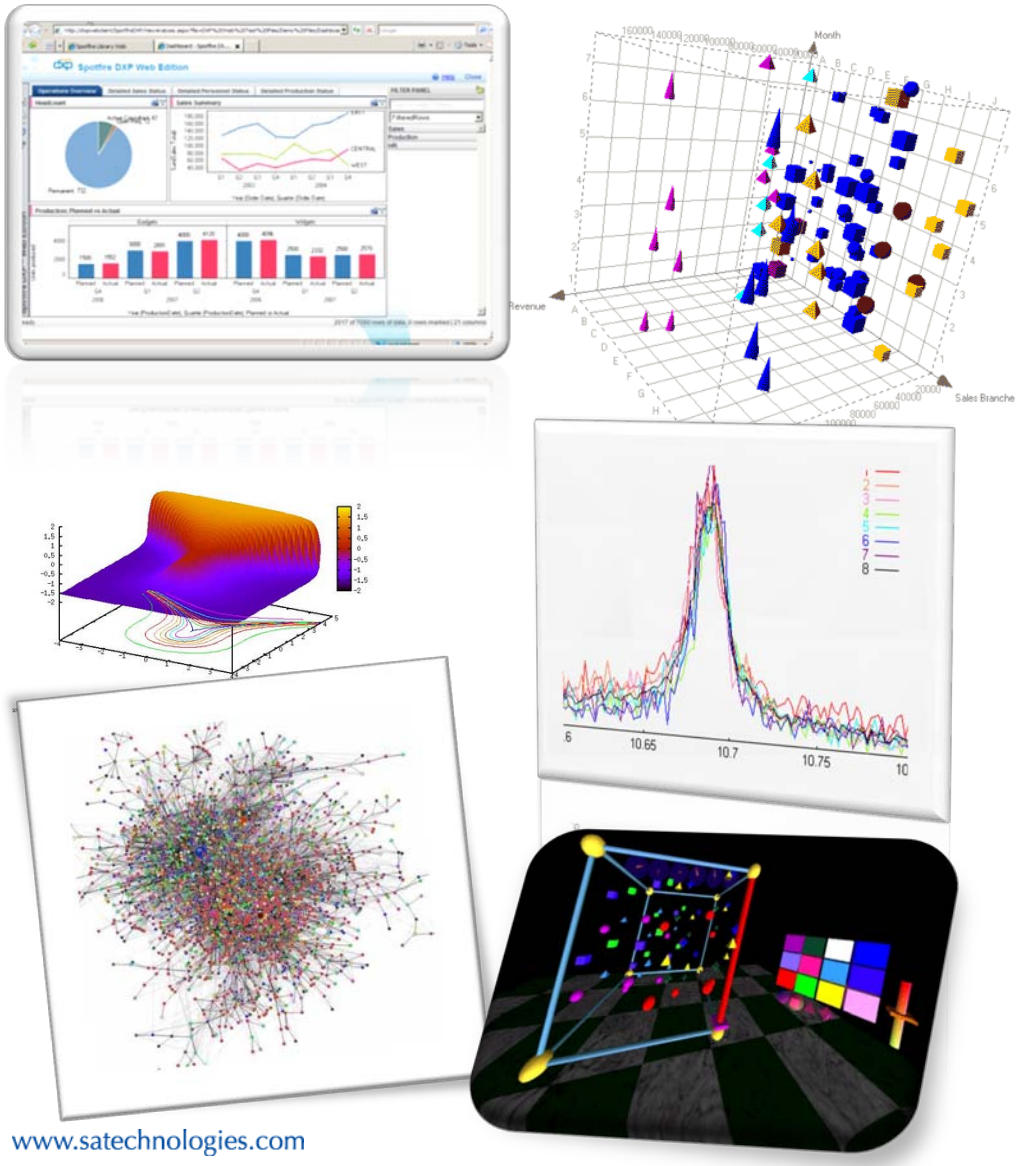
SA-Oriented Design Principles

- General Principles
- Confidence and Uncertainty
- Dealing with Complexity
- Alarms, Diagnosis and SA
- Automation and SA
- Supporting SA in Multi-Person Operations
- SA for Unmanned and Remotely Operated Vehicles
- SA Oriented Training

50 Design Principles



Common Pitfalls



Requires more than putting data on the same display

- Must be the “right” data
- Must be transformed into true meaning
- Like beauty “information” is in the eye of the beholder

Cool is not necessarily functional

- Useful information display must be based on good human factors
- Must optimize decision making processes
  - Support Situation Awareness

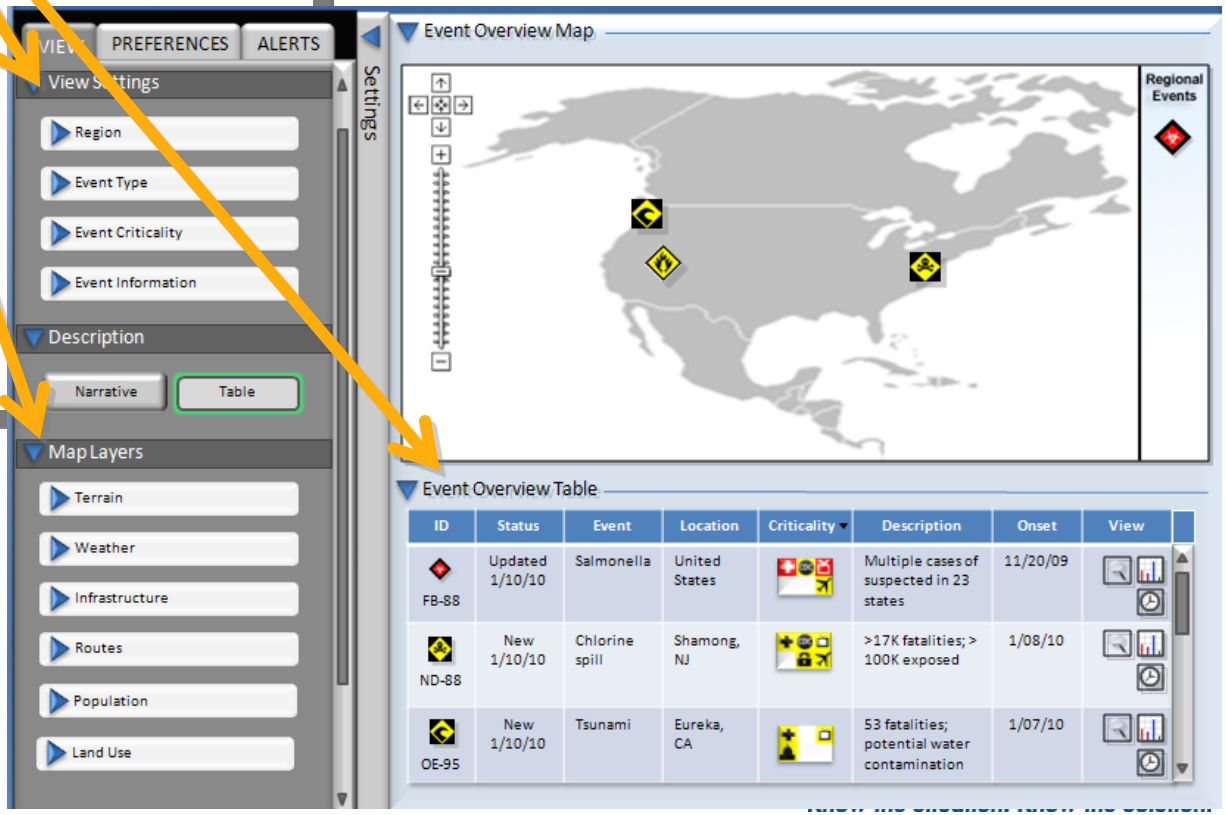
SA Oriented Designs
50 Design Principles

SA Technologies

- ***Principle 1 - Organize Information Around Goals***
  - **Central organizing feature**
  - **Flexible to meet changing goals of decision maker**
- ***Principle 2 - Support Comprehension - Present Level 2 SA Directly***
  - **Focus on integrated information**
- ***Principle 3 - Support Level 3 Projections***
  - **Cognitively taxing & difficult for novices**
- ***Principle 4 - Support Global SA***
  - **Awareness of status across goals**
- ***Principle 5 - Support Tradeoffs Between Goal Driven and Data Driven Processing***
  - ***Avoid attentional narrowing***
- ***Principle 6 - Make critical cues for Schema Activation Salient***
  - ***Determine key breakpoints and classes of situations***

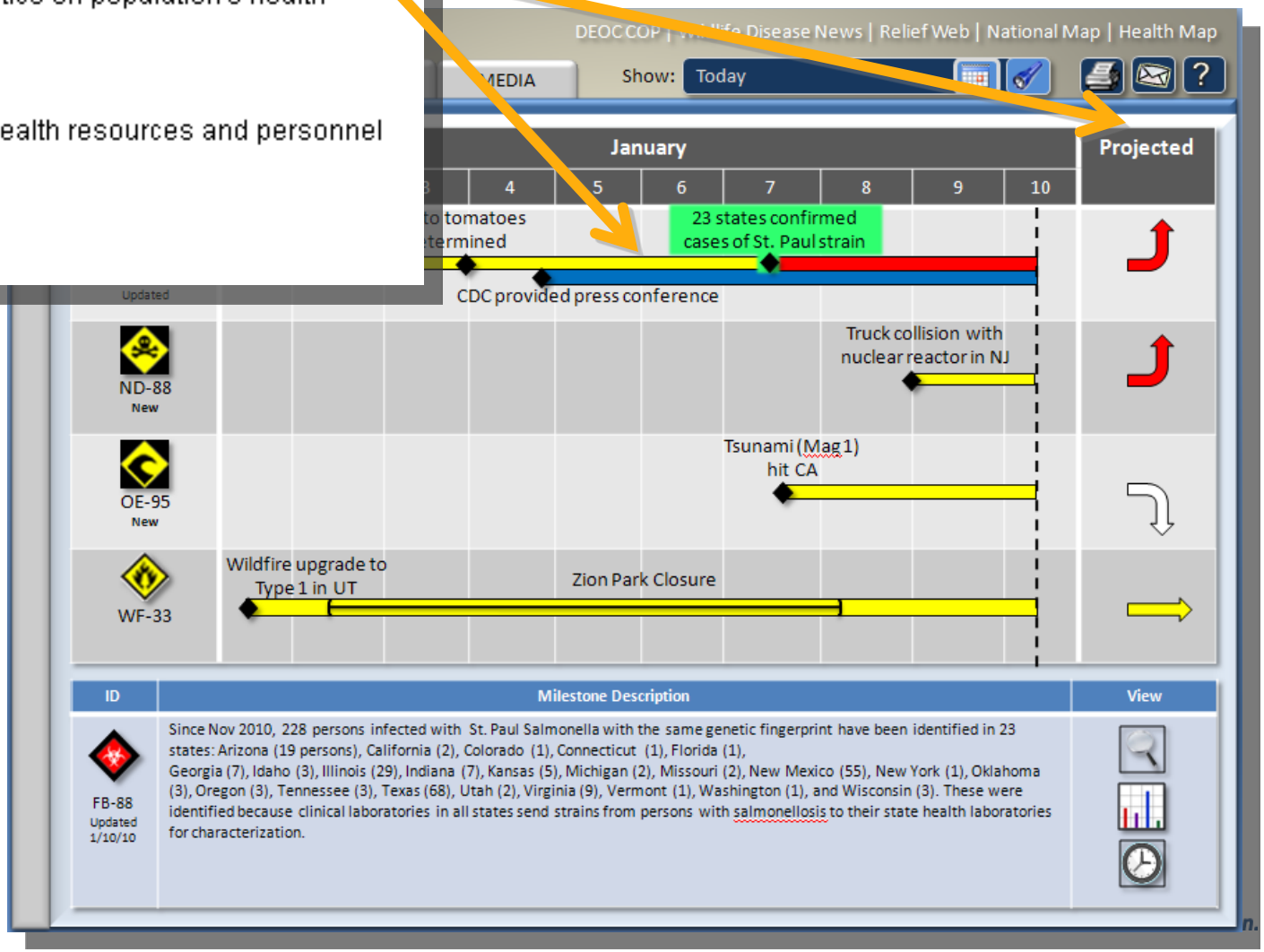
Displays Directly Support Integrated Comprehension of Current Situation

- Impact of event characteristics on population's health
  - Event characteristics*
  - High risk populations**
  - Early indicators***
- Impact of event on public health resources and personnel
  - High risk populations**
  - High risk areas****
  - SNS status*****
  - Resources availability
    - National
    - State
    - Local
  - CDC personnel
    - Location
    - Availability



Displays Directly Support Integrated Projection of future status

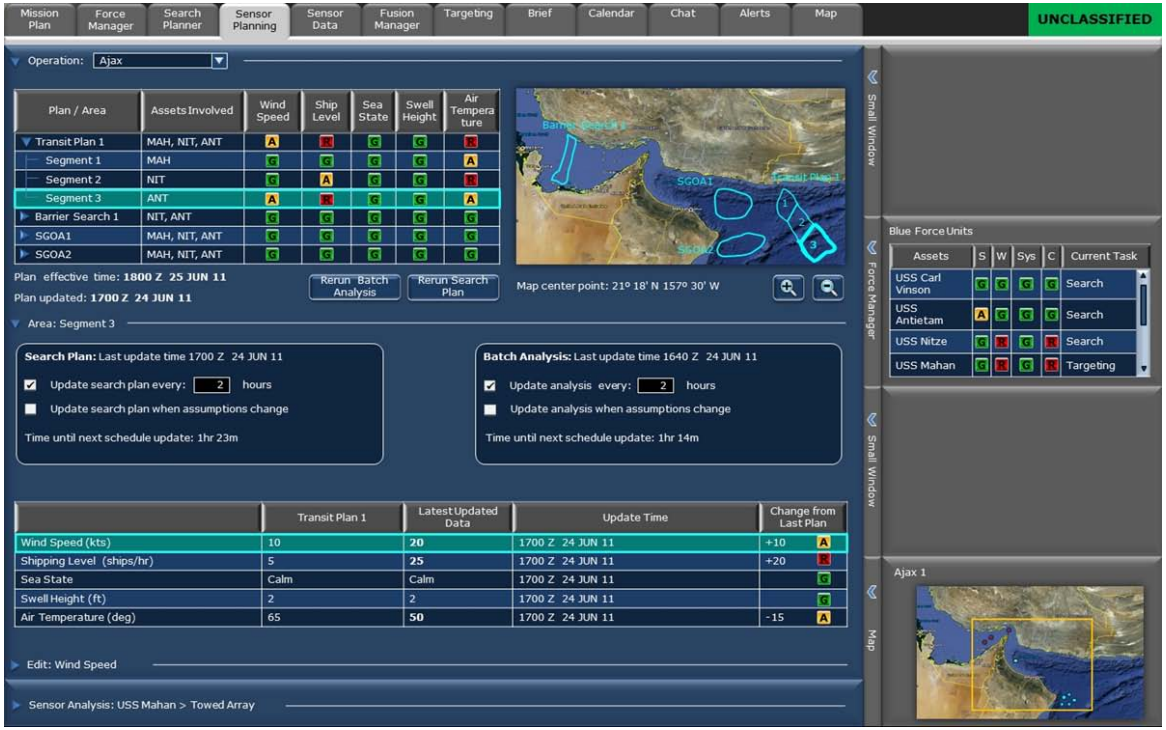
- Projected impact of high priority events on public health
  - Impact of event characteristics on population's health
    - Event characteristics*
    - High risk populations**
    - Early indicators***
  - Impact of event on public health resources and personnel
    - High risk populations**
    - High risk areas****
    - SNS status*****
    - Resources availability



Command and Control

- Fast, easy operations on the move
- One-step access to any screen or task
- Situation understanding at a glance
- Tailored information organized and integrated around key role goals and decisions
- Easy monitoring across multiple task demands
- Integrated collaboration tools for shared situation awareness across the distributed force
- Warfighter controlled flexibility for changing needs and priorities

High Levels of Usability and Performance



Key information
Pops from the screen

Displays make common
Tasks fast and easy

System works the way
That the warfighter does

We can't automate our way out of this problem

SA Technologies

Situation Awareness

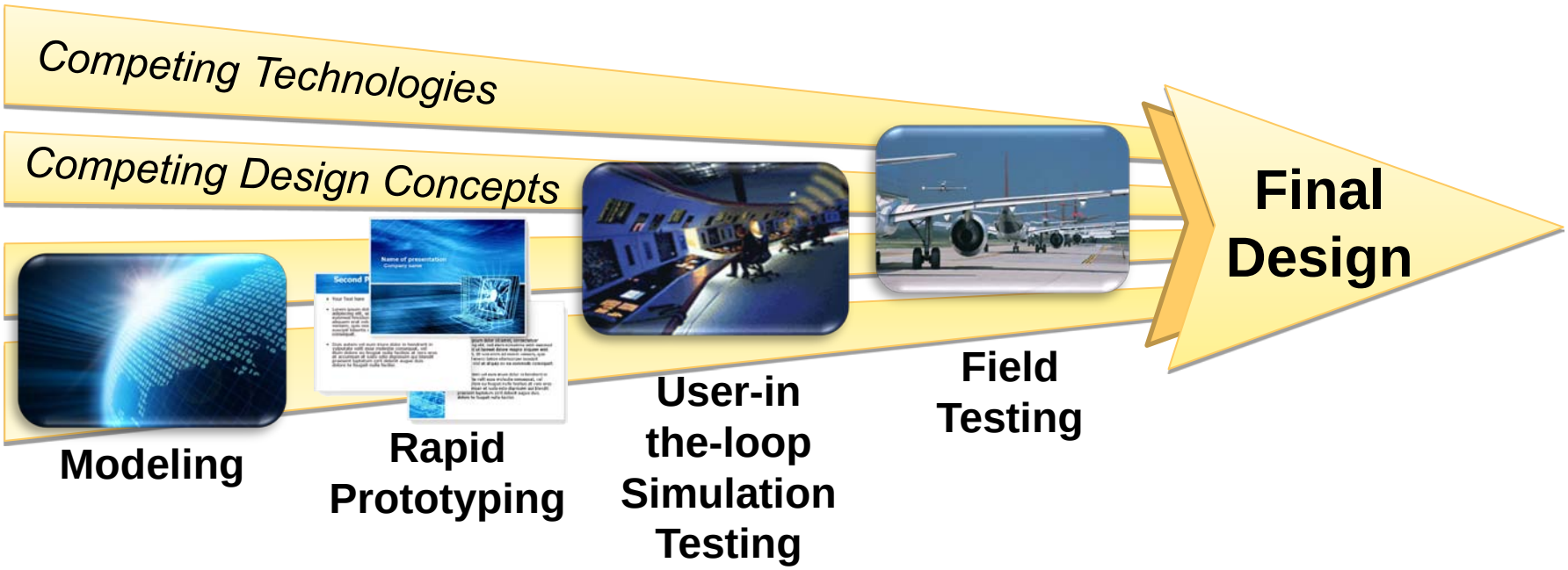
Decision Making

Task Performance

SA still critical for overseeing automation

- Intervening
  - Problem with Out-of-the-loop Performance Errors
- Overseeing & Directing
  - Problems in Understanding What Automation is Doing
  - Problems with Workload

Test & Evaluation in the Design Process

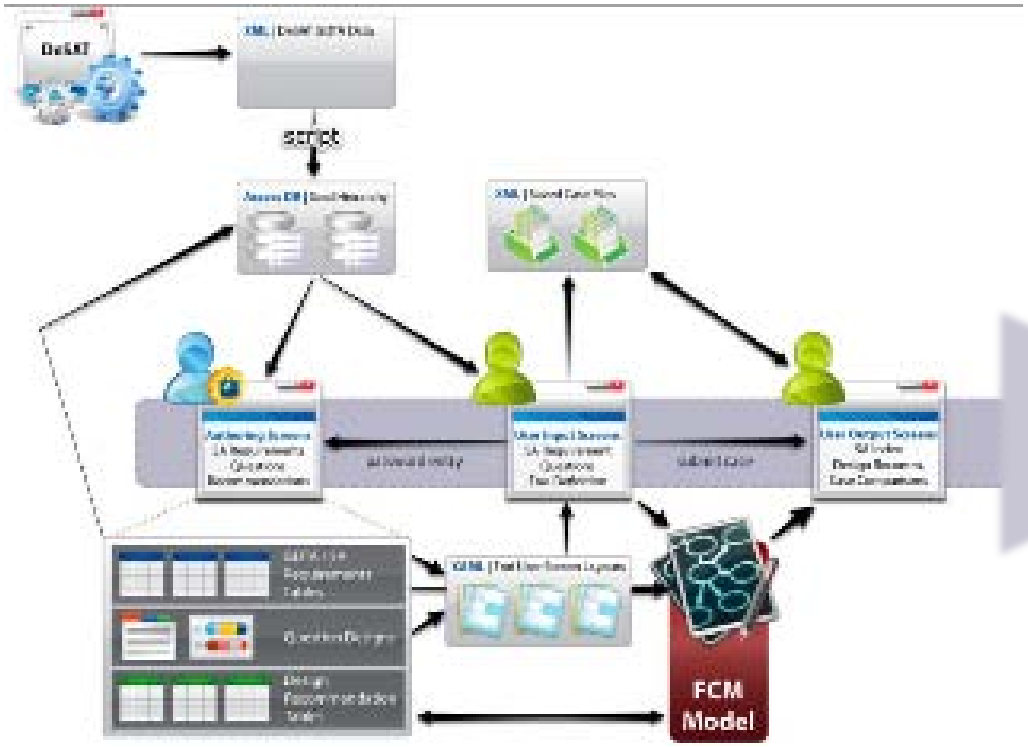


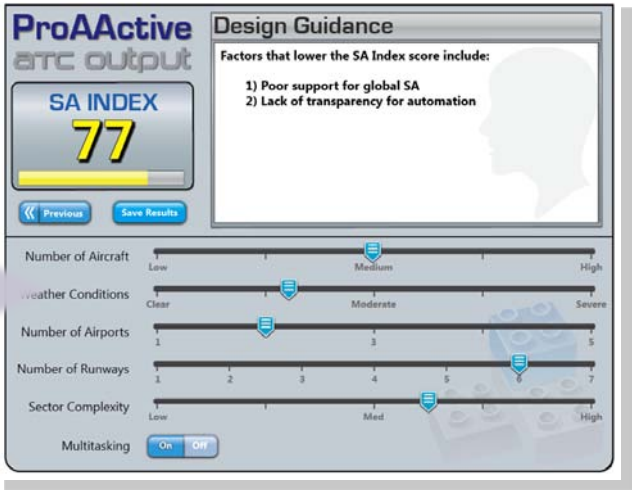
- ✓Human Performance
- ✓Decision Making
- ✓Workload
- ✓Situation Awareness

Summary of Tools/Approaches

Design Phase	Pre-Design Modeling	Rapid Prototyping	Simulation Testing	Field Testing
ProAactive	✓			
SAGAT		✓	✓	
VESARS			✓	✓
GPAT		✓	✓	✓
ACASA			✓	✓
T-CREST			✓	✓
SSAI		✓	✓	✓
MARS		✓	✓	✓

ProAActive





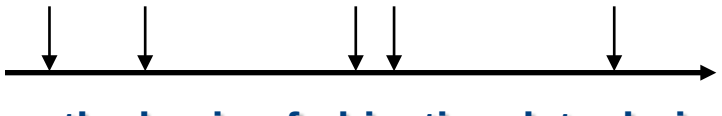
Model of SA to Predict Effect of System Designs on User SA

Situation Awareness Global Assessment Technique (SAGAT)

SA Technologies

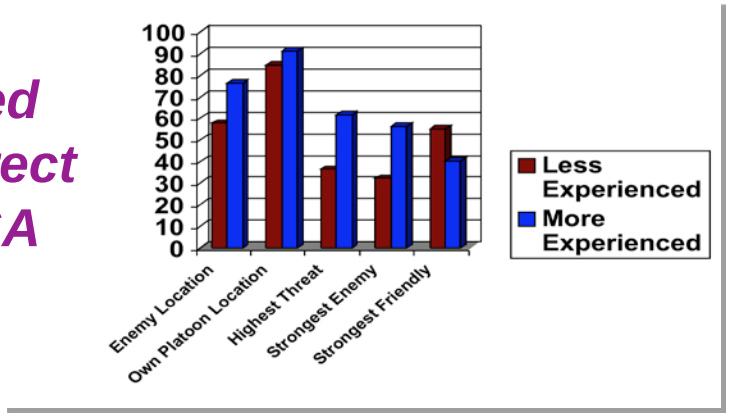
Objective measure of SA

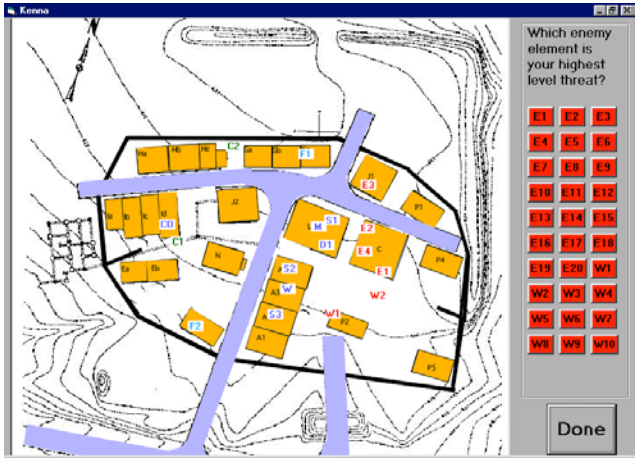
- Real-time man-in-the-loop simulation of system (rapid prototyping)
- At random times, freeze the simulation, blanking all displays
- Administer a rapid battery of queries to ascertain the subject's SA at that point in time



- Score the subject's SA on the basis of objective data derived from the simulation

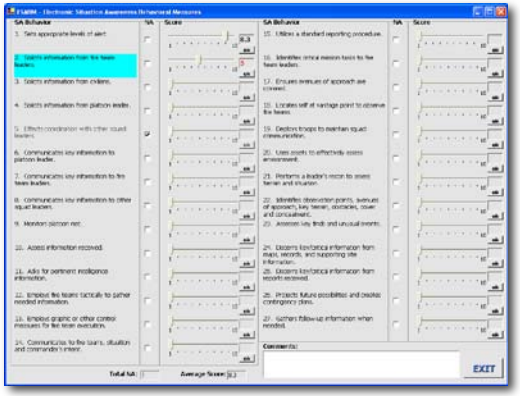
Only Validated Objective Direct Measure of SA





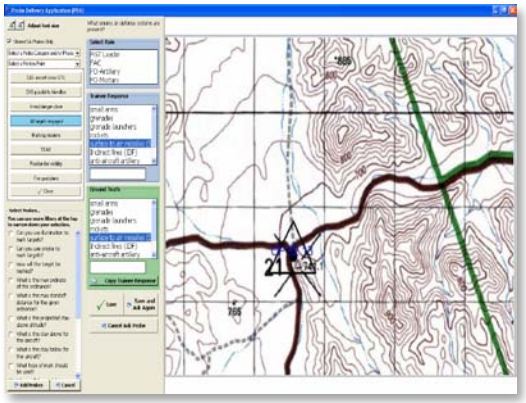
VESARS Incorporates Multiple SA Measures

SA Behavioral Measures



Dynamic ratings of behaviors needed for good SA provides diagnostics information for trainee improvements

Objective SA Measures



Real-time SA queries on the state of environment, tasks, and operational elements. Tailored to training objectives.

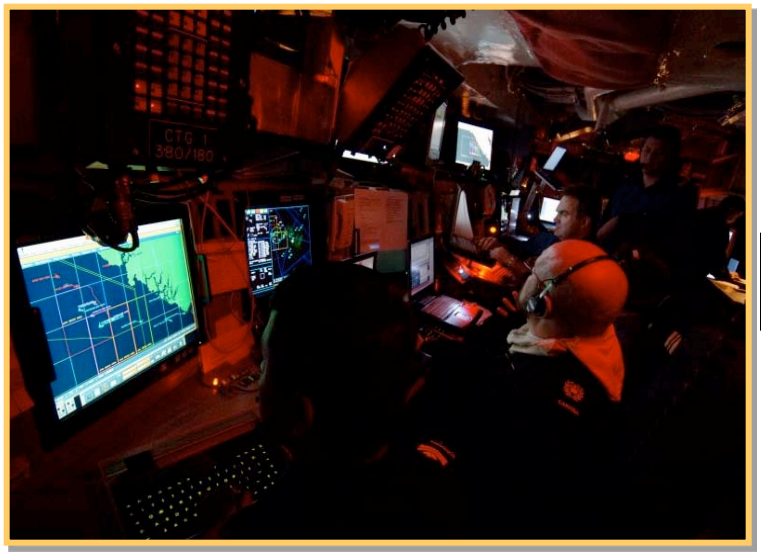
Team SA Communications

Team communication measures focus on information exchange for achieving SA within the team

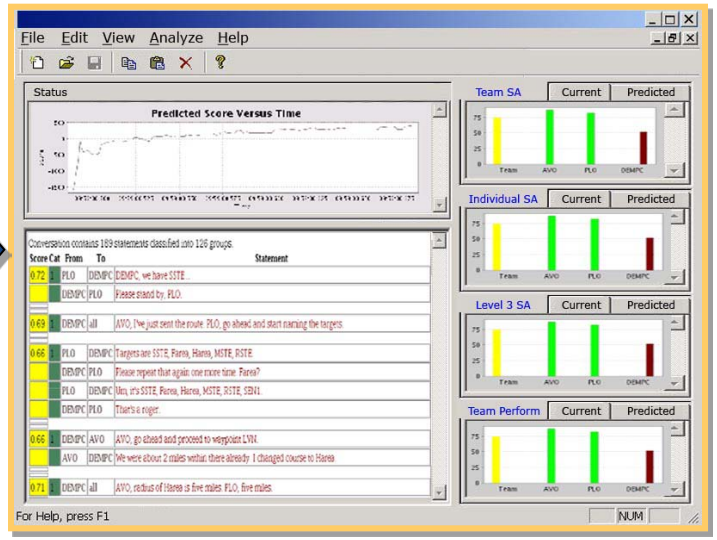
Automated Communication Analysis for Situation Awareness (ACASA)

SA Technologies

- **Real-time, unobtrusive, objective measure of team situation awareness**
- **For use in evaluating teams and validating new systems & training programs**



Real -Time



Verbal and Non-Verbal Team Communication

Quantified Situation Awareness

Key Features of Approach

SA Technologies

- **User Centered Design**
  - Detailed analysis of operator work flow, situation awareness, and human error causal factors
- **Highly Functional Information Visualizations**
  - Based on state of the art in human factors and situation awareness research
- **Objective Evaluation of Design Solutions**
  - Early, iterative user testing reduces risk and ensures that final products will meet operational needs
- **Work Collaboratively in a Team Based Approach**
  - Support multi-disciplinary teams of architects and engineers to provide human factors and ergonomics inputs as part of a total solutions
  - Develop detailed design specifications and prototypes for implementation

User-Centered Design: Components

SA Technologies

Users

Operational Needs & Realities

- Goals
- Tasks
- Decisions
- Information
- Conditions
- Strategies

Cognitive Engineering

User Interface Design

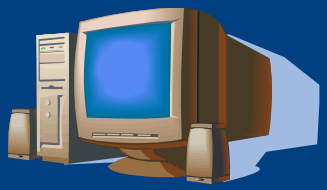
Human Performance Optimization

- Physical characteristics
- Perceptual characteristics
- Cognitive characteristics
- Display design
- Controls selection
- Workload management
- Situation awareness enhancement

H/W & S/W Engineering

Technological Capabilities

- Information Management
- Networks
- Databases
- Sensors
- Automation
- Algorithms



Conclusion

- Situation Awareness is critical for effective decision making
- Many challenges for SA exist in all forms of military operations
- Situation Awareness can be directly enhanced through improved systems design to enhance information sharing and integration
- Implementation of automation and unmanned systems has been found to be challenging for SA and must be approached carefully to avoid problems
- Tools for objectively measuring SA can be used to validate system designs and training programs