

Situation Awareness in the Bulk Power System

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SA Technologies

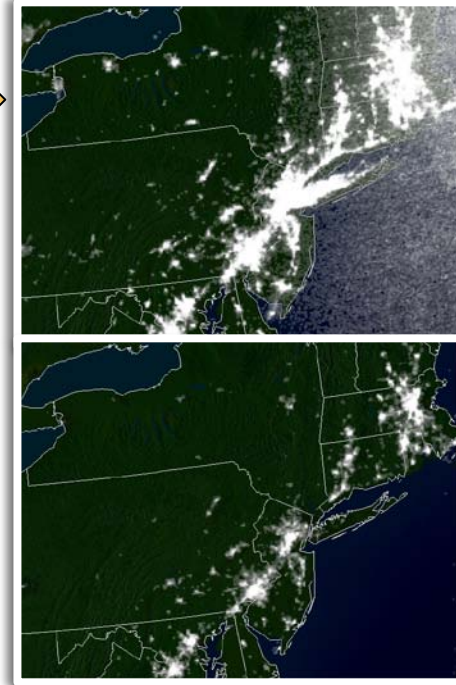
2001
Woman Owned
Business
Of the Year
-NASA-



Situation Awareness is Critical to Power Transmission & Distribution



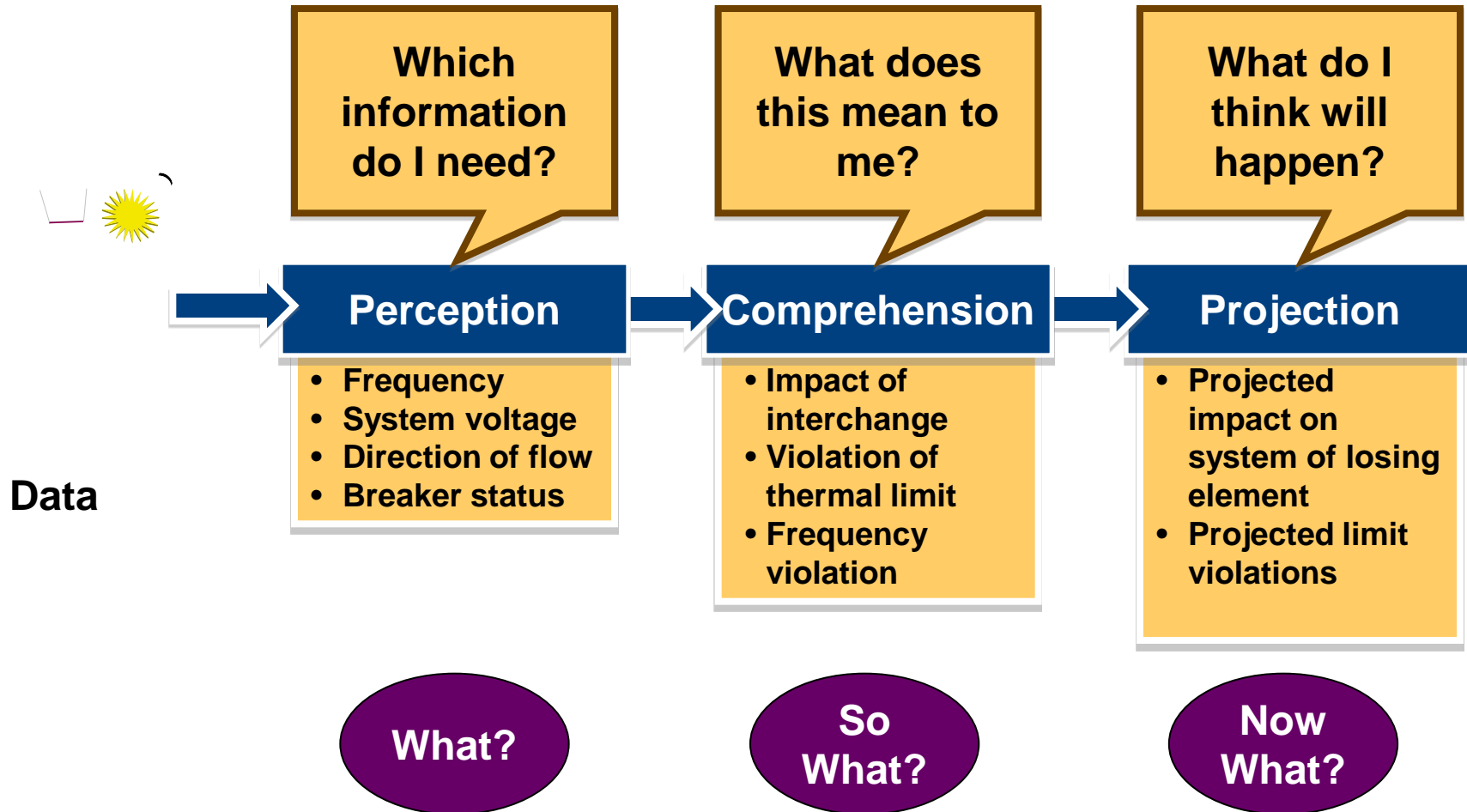
- **August 14, 2003 - Northeast US/Canada**
 - “Inadequate situation awareness”
- **August 10, 1996 - Western US**
 - “train operators to make them aware of system conditions and changes”
 - “develop displays that give operators immediate information on changes in status”
- **July 2, 1996 - Western US**
 - “review need ... to monitor operating conditions on a regional scale”
- **July 13, 1965 - Northeast US/Canada**
 - “System control centers should be equipped with display and recording equipment which provide the operator with as clear a picture of system conditions as possible”



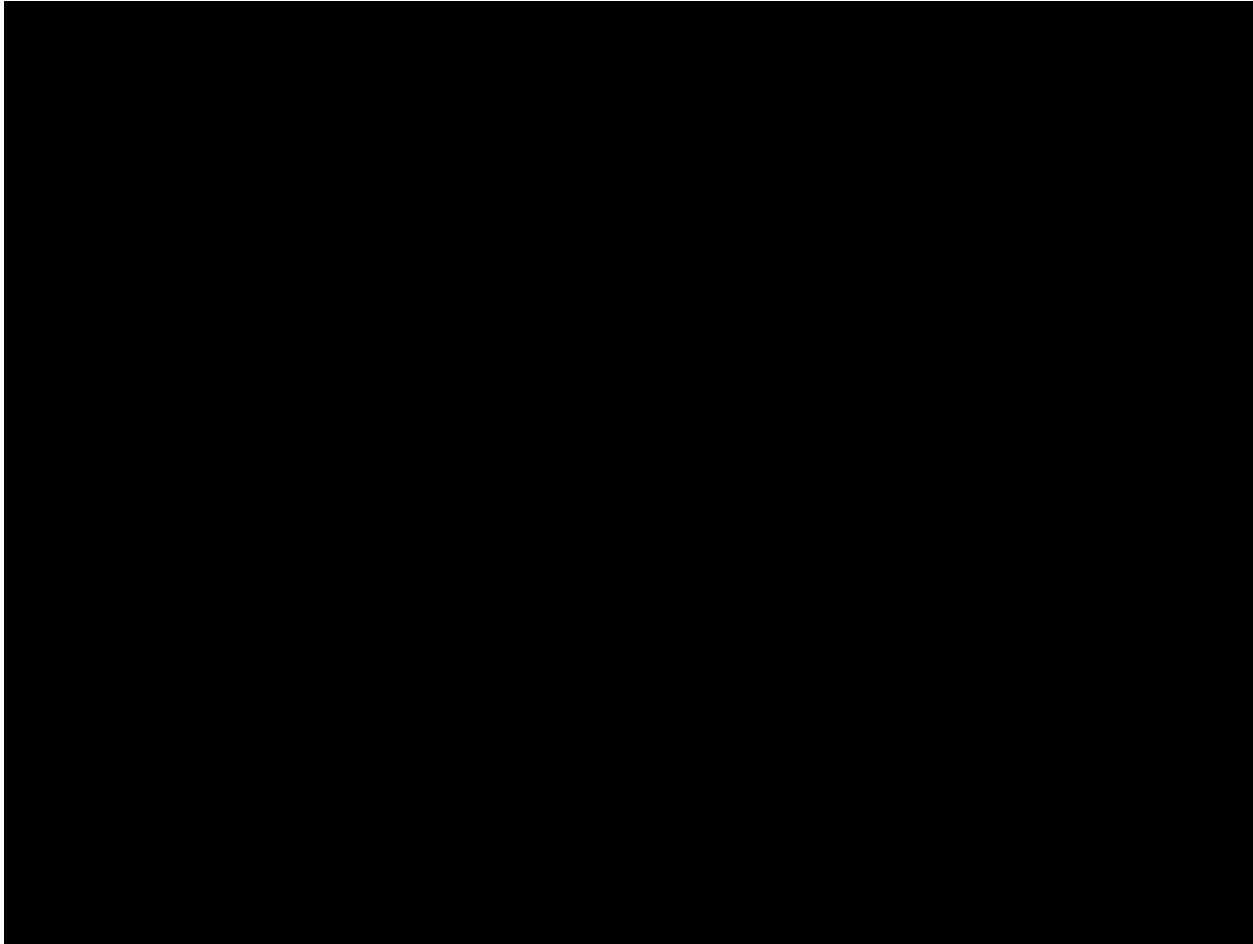
What is Situation Awareness?



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.*

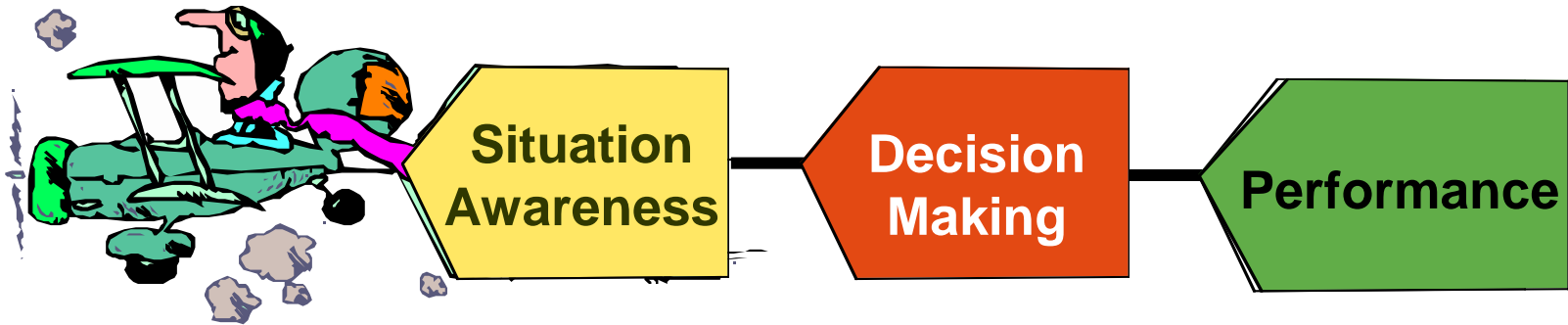


Got SA?



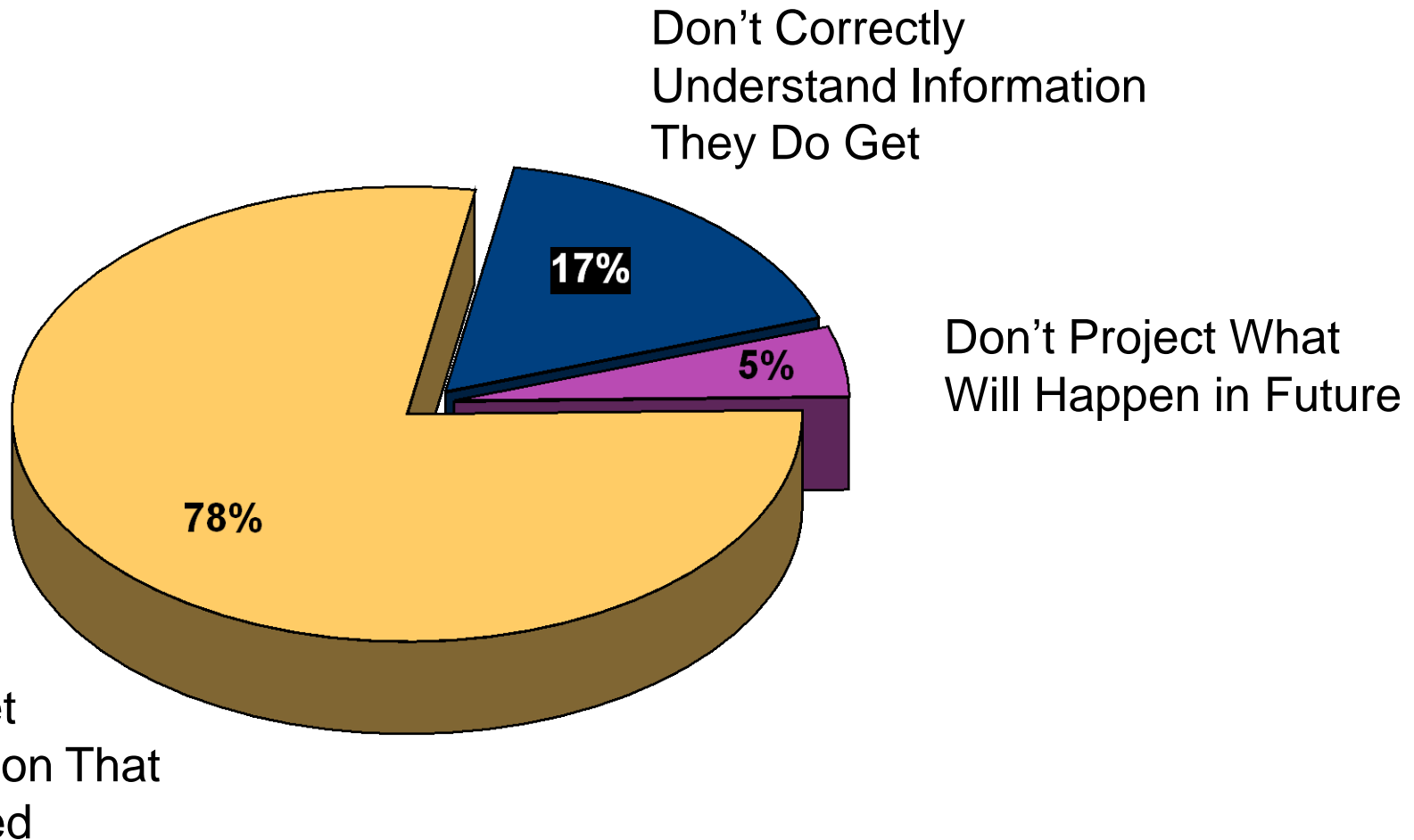
As much as 88% of human error is due to problems with situation awareness



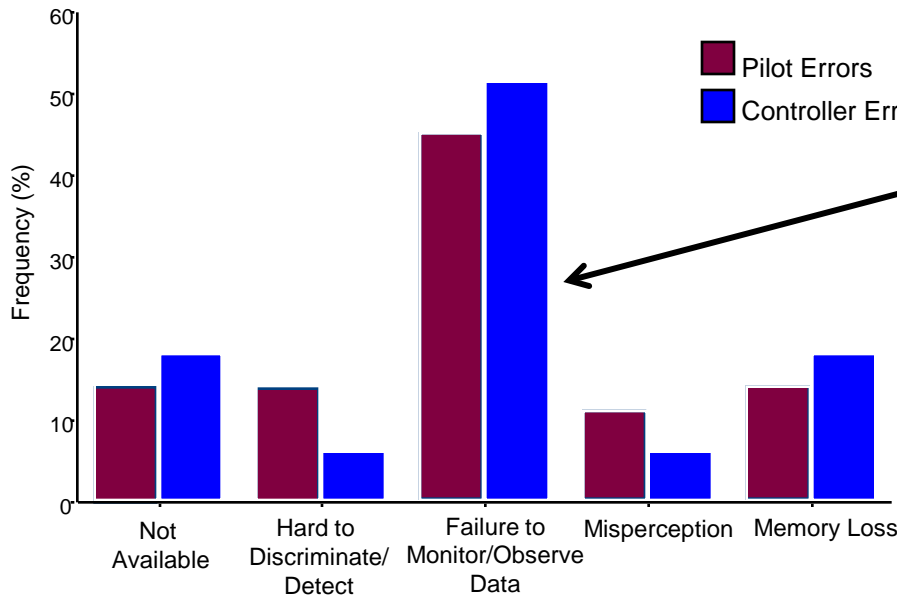


***Situation awareness is key to
good decision making and
good performance***

What Kinds of SA Problems Do People Have?

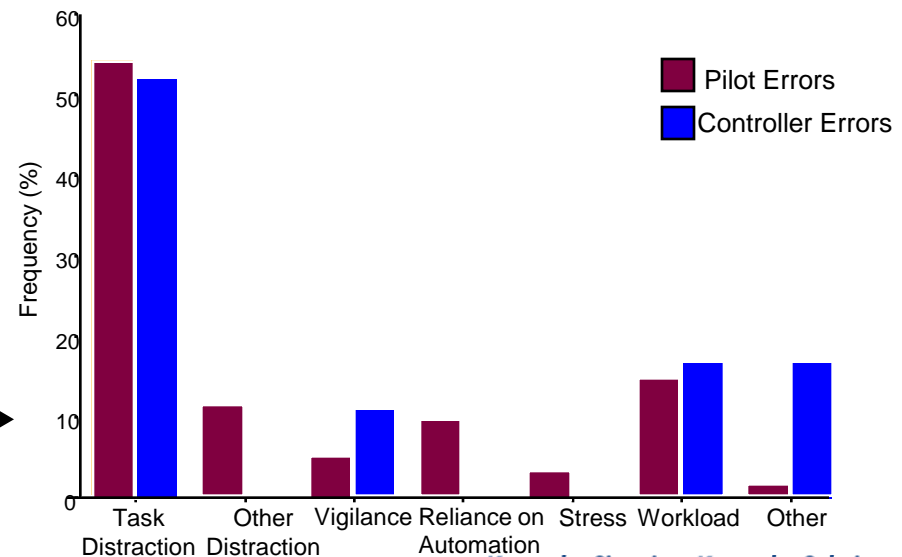


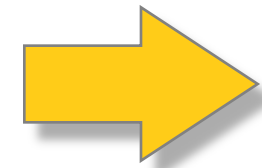
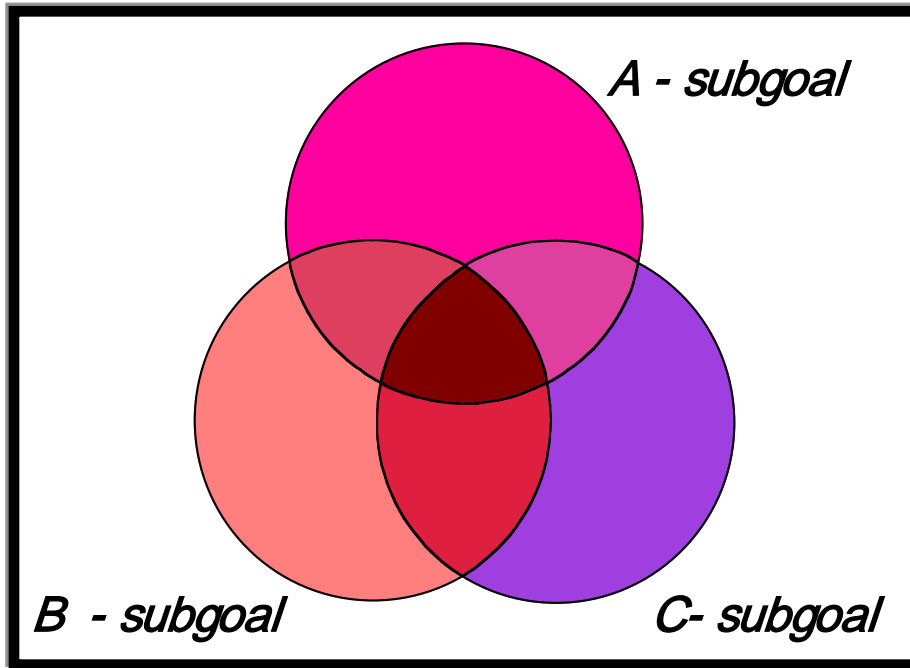
SA Errors



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%)

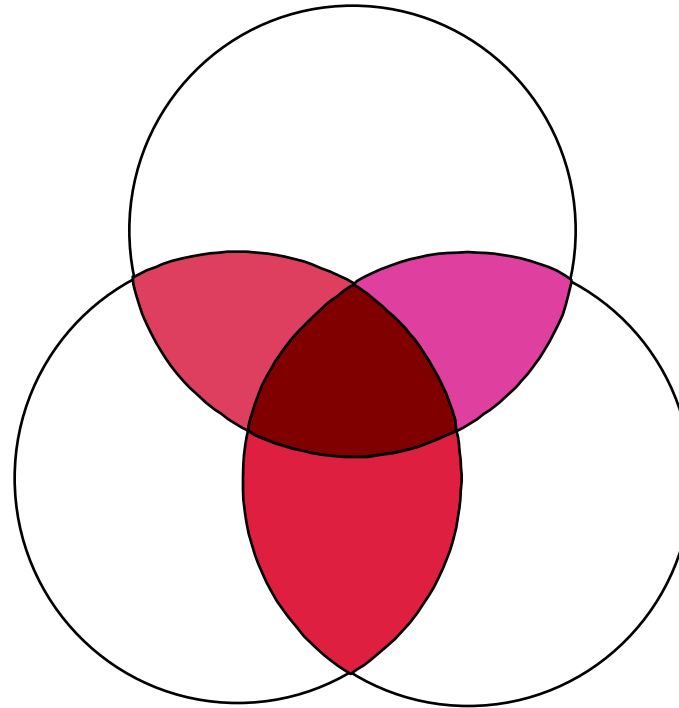
Biggest Single Cause is "Task Distraction"





**TEAM
GOAL**

**The Degree to Which Every Team Member
Possesses the SA Required for his/her Job**



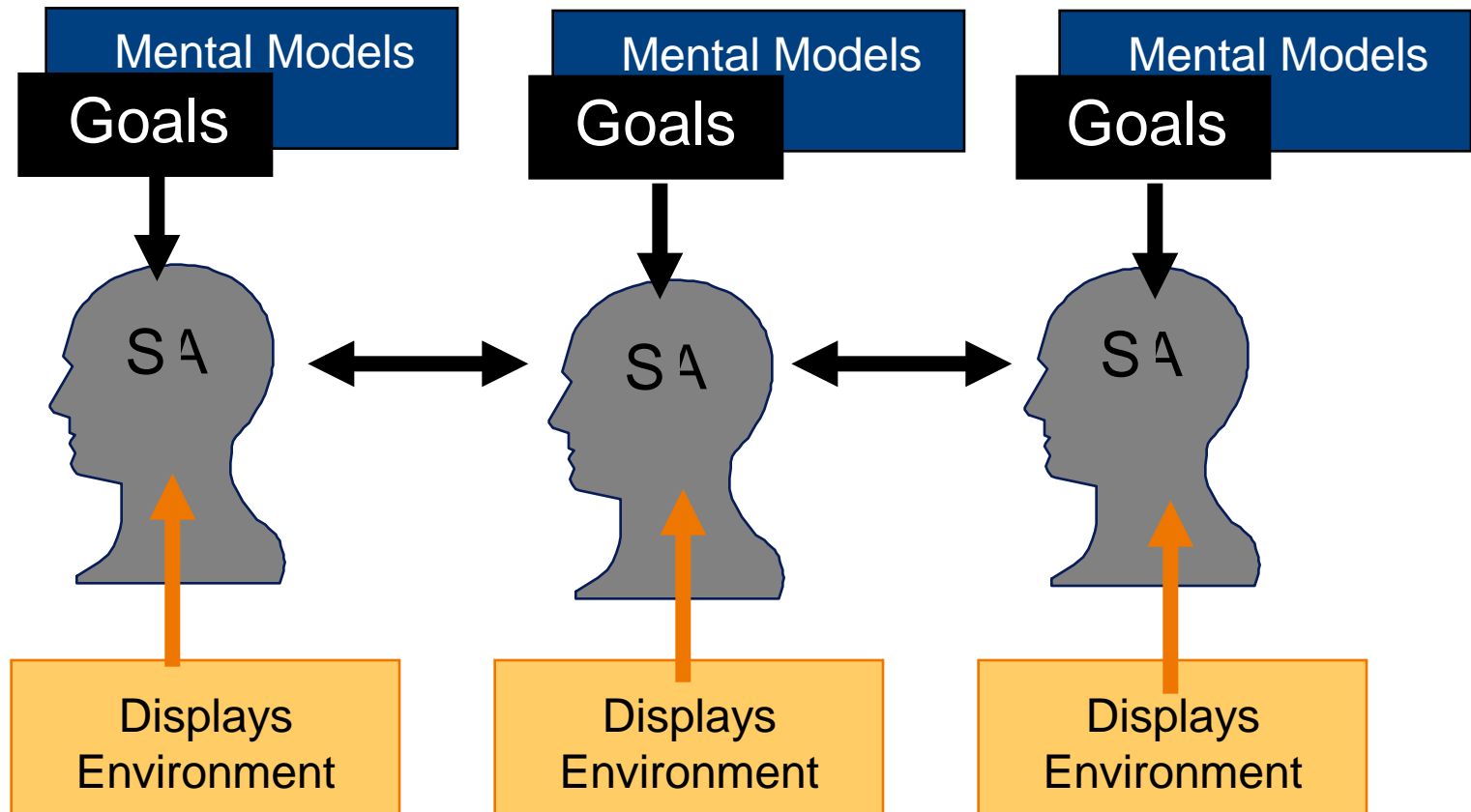
**The Degree to Which Team Members Possess
the Same SA on Shared SA Requirements**

Getting on the Same Page



- **What is the current status of the system?**
- **What has been done so far?**
- **What are they doing now?**
- **How will that affect my tasks?**
- **How does what I'm doing affect them?**
- **What will they do next?**

Individual SA vs. Team SA

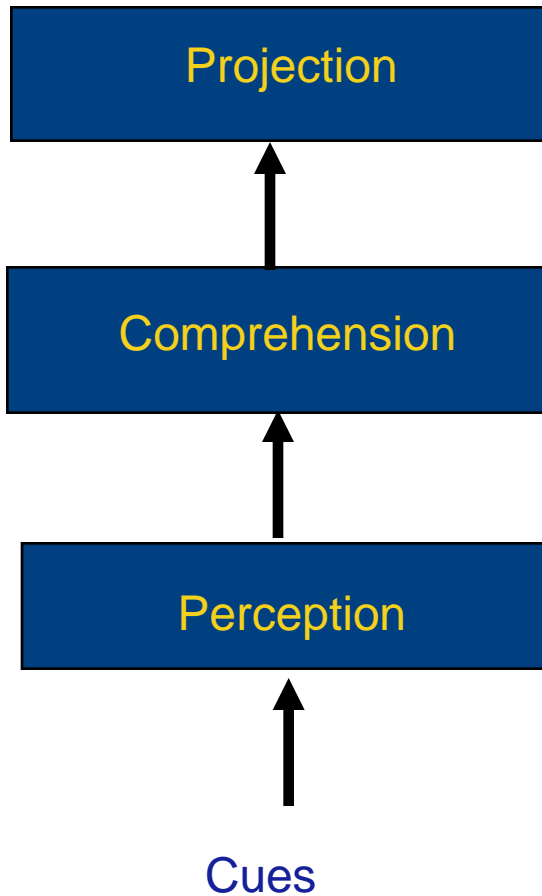


Sometimes we just talk past each other.....



- Off the coast of Newfoundland in October, 1995.
- **Americans: Please divert your course 15 degrees to the North to avoid a collision.**
- **Canadians: Recommend you divert YOUR course 15 degrees to the South to avoid a collision.**
- **Americans: This is the Captain of a US Navy ship. I say again, divert YOUR course.**
- **Canadians: No. I say again, you divert YOUR course.**
- **Americans: THIS IS THE AIRCRAFT CARRIER USS LINCOLN, THE SECOND LARGEST SHIP IN THE UNITED STATES' ATLANTIC FLEET. WE ARE ACCOMPANIED BY THREE DESTROYERS, THREE CRUISERS AND NUMEROUS SUPPORT VESSELS. I DEMAND THAT YOU CHANGE YOUR COURSE 15 DEGREES NORTH, THAT'S ONE FIVE DEGREES NORTH, OR COUNTER-MEASURES WILL BE UNDERTAKEN TO ENSURE THE SAFETY OF THIS SHIP.**
- **Canadians: This is a lighthouse. Your call.**

Failures in Team SA



Is same projection of actions formed to guide expectations?

Is information interpreted in the same way?

Is needed information clearly passed?

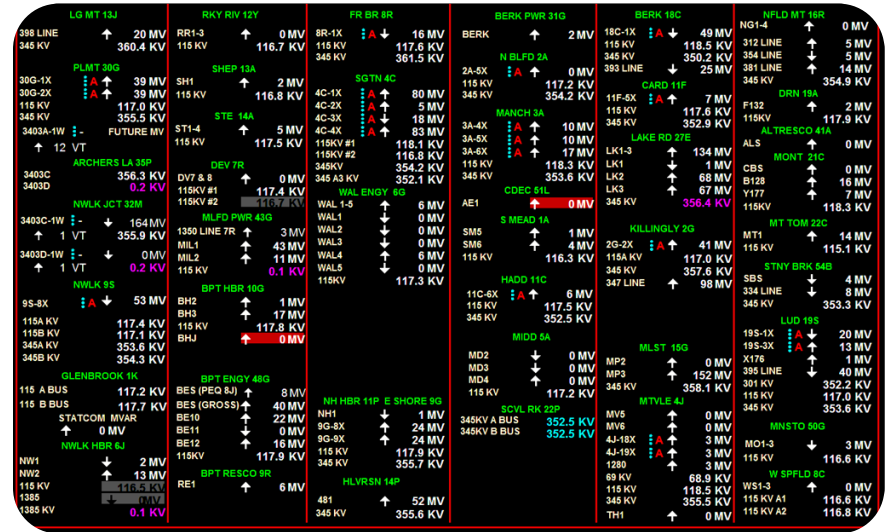
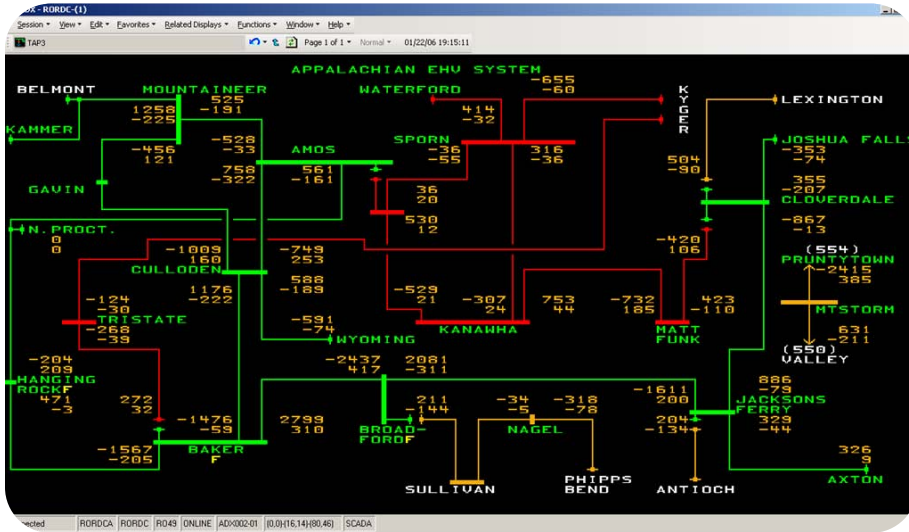


SA Challenges in Power T&D

- **Lack of real time information on global state of system**
 - Data is piece-meal
- **Plethora of alarms, many with high false alarm rates**
 - Leads to reduced usage of tools
- **Support for diagnostics and projection of future events/contingencies is limited**
 - Automation that is not integrated into tasks and for which SA over state of automation is low
- **Lack of shared SA across various control centers and reliability coordinators**
 - Even though systems are inter-related



SA Demons Present in Power Systems



Data Overload

- Tremendous Volume of Information
- Swift Rate of Change of Information
- Limited Bandwidth for Input
- Humans can only process so much

Misplaced Salience

- Attention drawn by pre-attentive features
 - Color, lights, movement
 - Loud noises, size, etc.
- Inappropriate use draws attention to less important information
- Overuse fights for attention



Complexity Creep

Systems with too many features make it difficult to develop an accurate mental model of how the system works



Out of the Loop Syndrome

Low SA on how the automation is performing

Low SA on the state of the system

- **Slow to detect problems with system or automation**
- **Slow to regain understanding of what it is doing and taking over manually**



**Technology has
taken us from here**

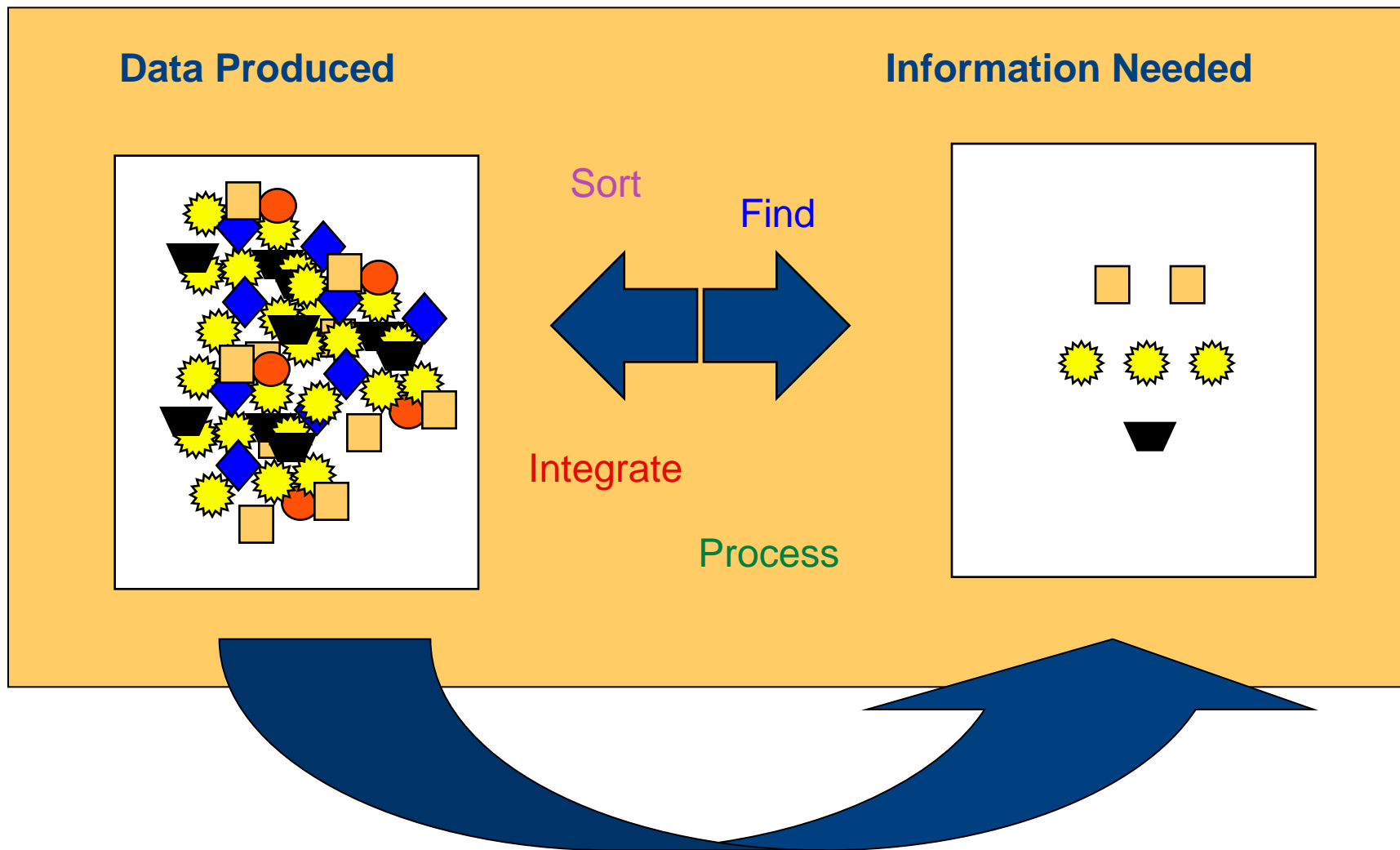


to here.

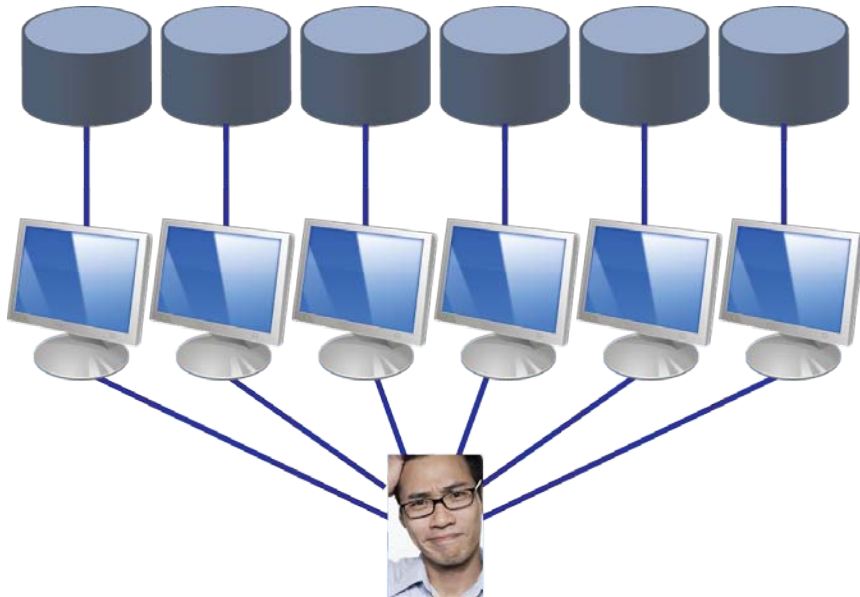
**But we still can't
find what we really
want to know.....**



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

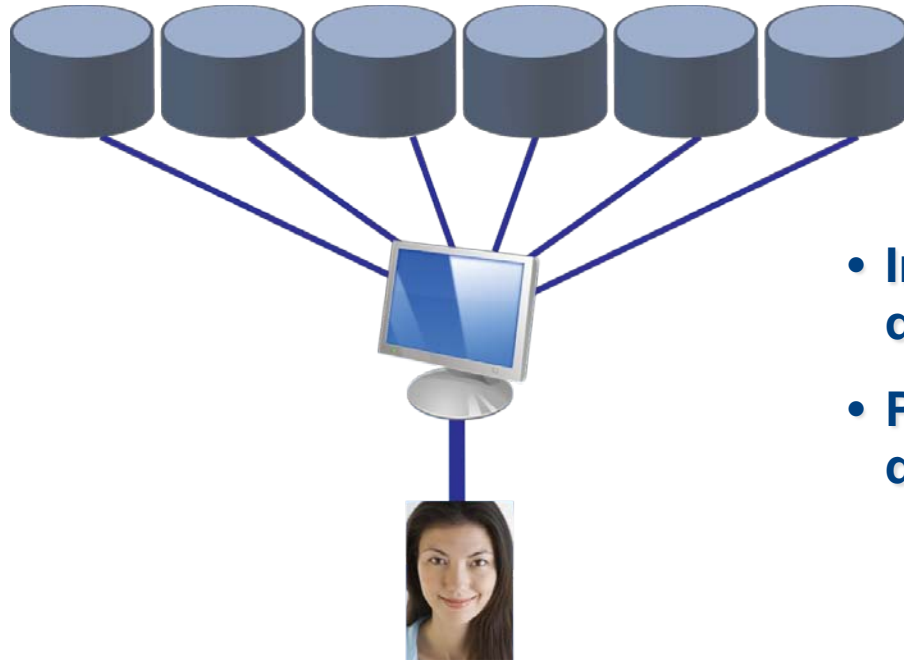
Technology Centered Design

Design Technologies

Let Human Adapt

Fatal Flaw

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



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

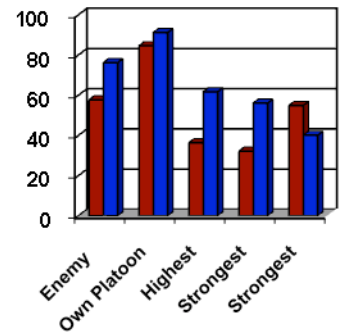
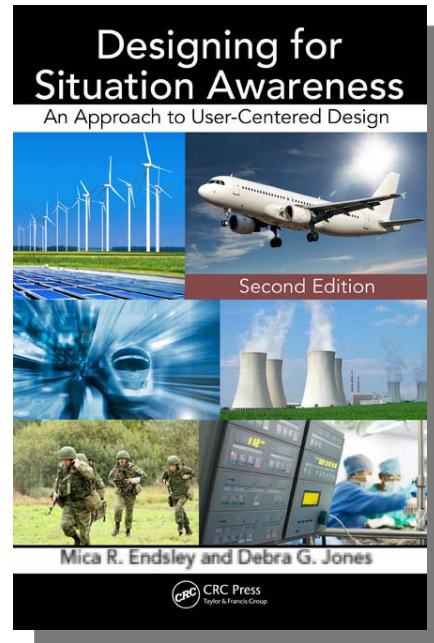


Goals

Decisions

- Projection Requirements
- Comprehension Requirements
- Data Requirements

50 Design Principles



Goal Directed Task Analysis (GDTA)

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

Drives Design
Drives Training
Drives Evaluation



System Reliability Coordinator



To keep all elements and voltages within limits in real time for first contingencies

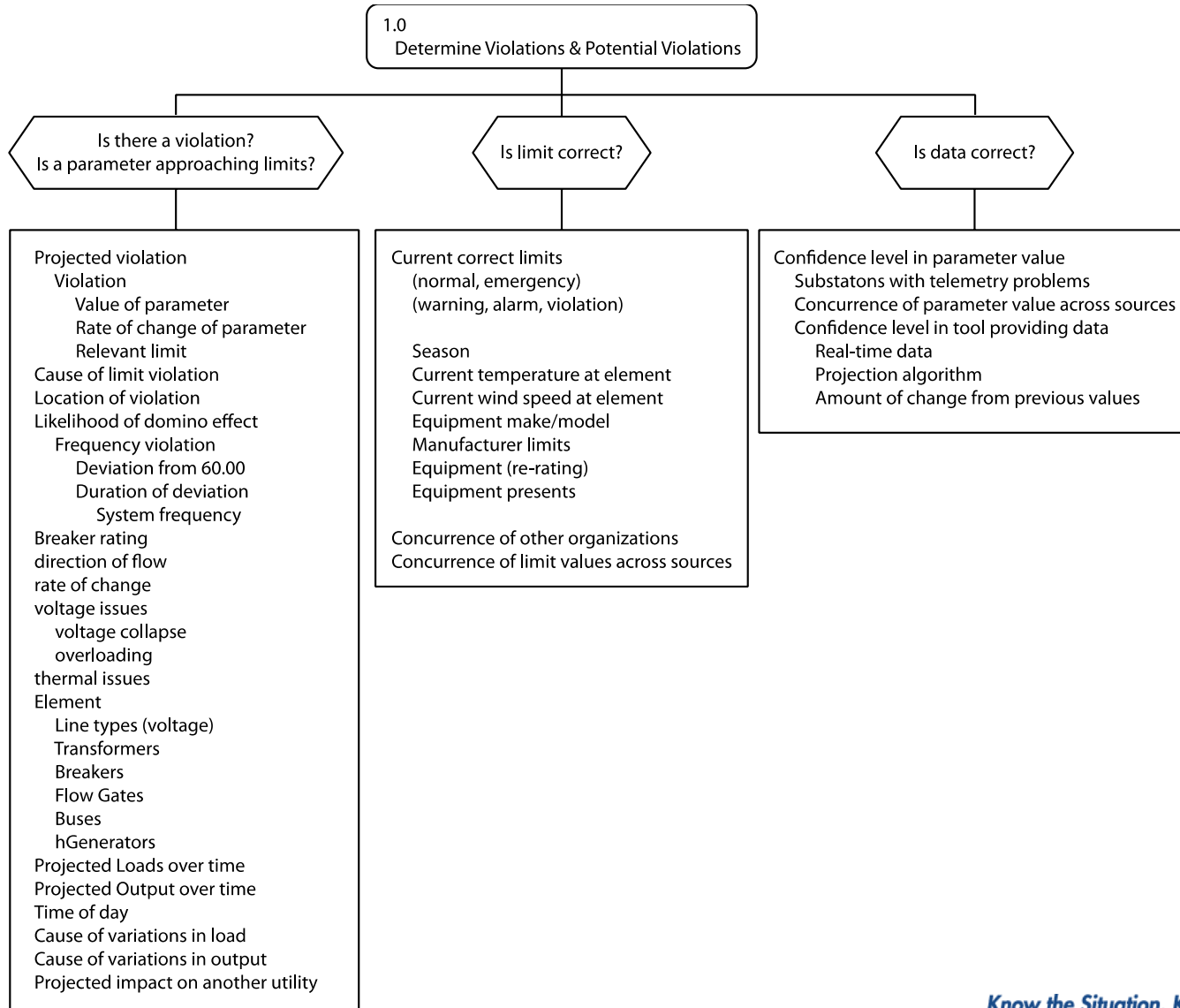
1.0
Determine Violations & Potential Violations

2.0
Determine cause of violation/potential violation

3.0
Determine Remediation

4.0
Ensure Remediation Complete

Determine Violations & Potential Violations



SA Requirements
Analysis

SA-Oriented
Design

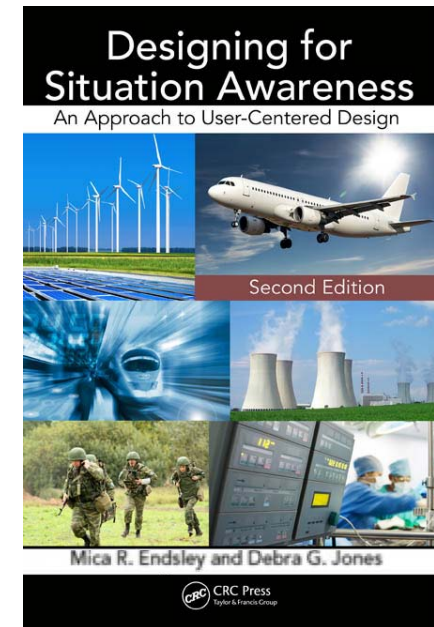
SA Measurement

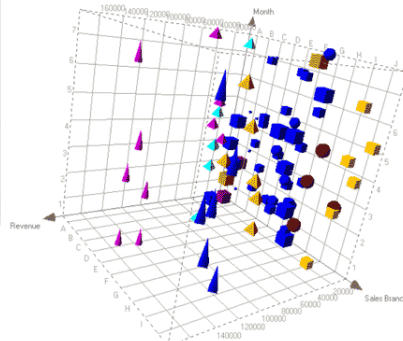
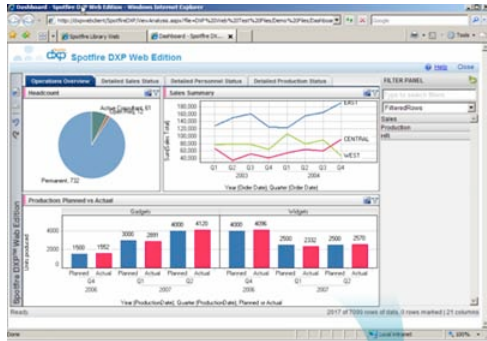


SA-Oriented Design Principles

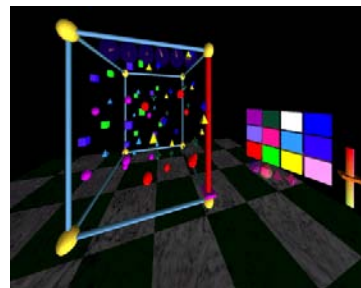
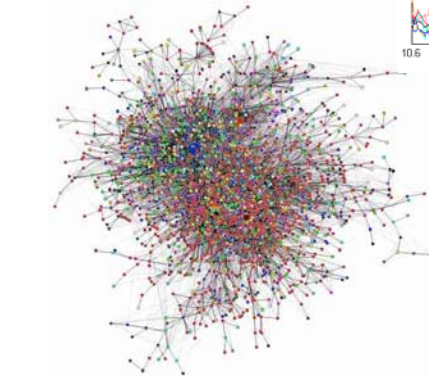
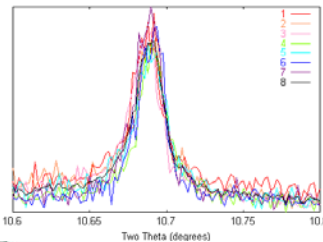
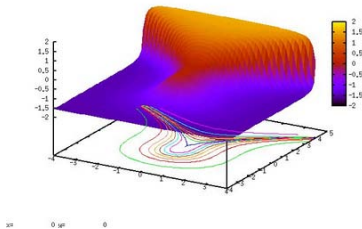
- **General Principles**
- **Confidence and Uncertainty**
- **Dealing with Complexity**
- **Alarms, Diagnosis and SA**
- **Automation and SA**
- **Supporting SA in Multi-Person Operations**
- **SA for Unmanned and Remotely Operated Vehicles**
- **SA Oriented Training**

50 Design Principles





- 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

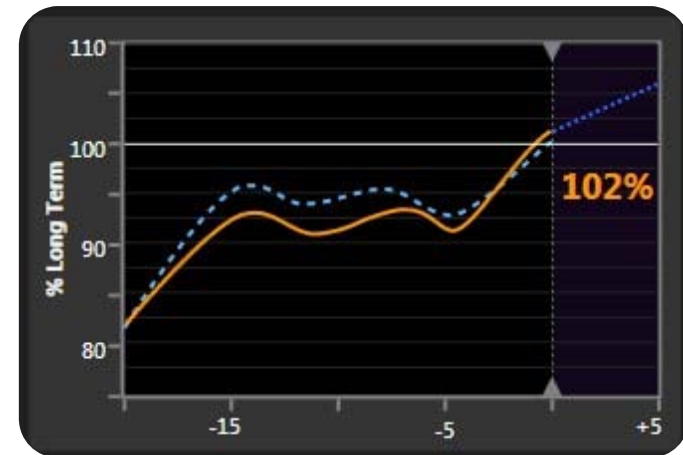
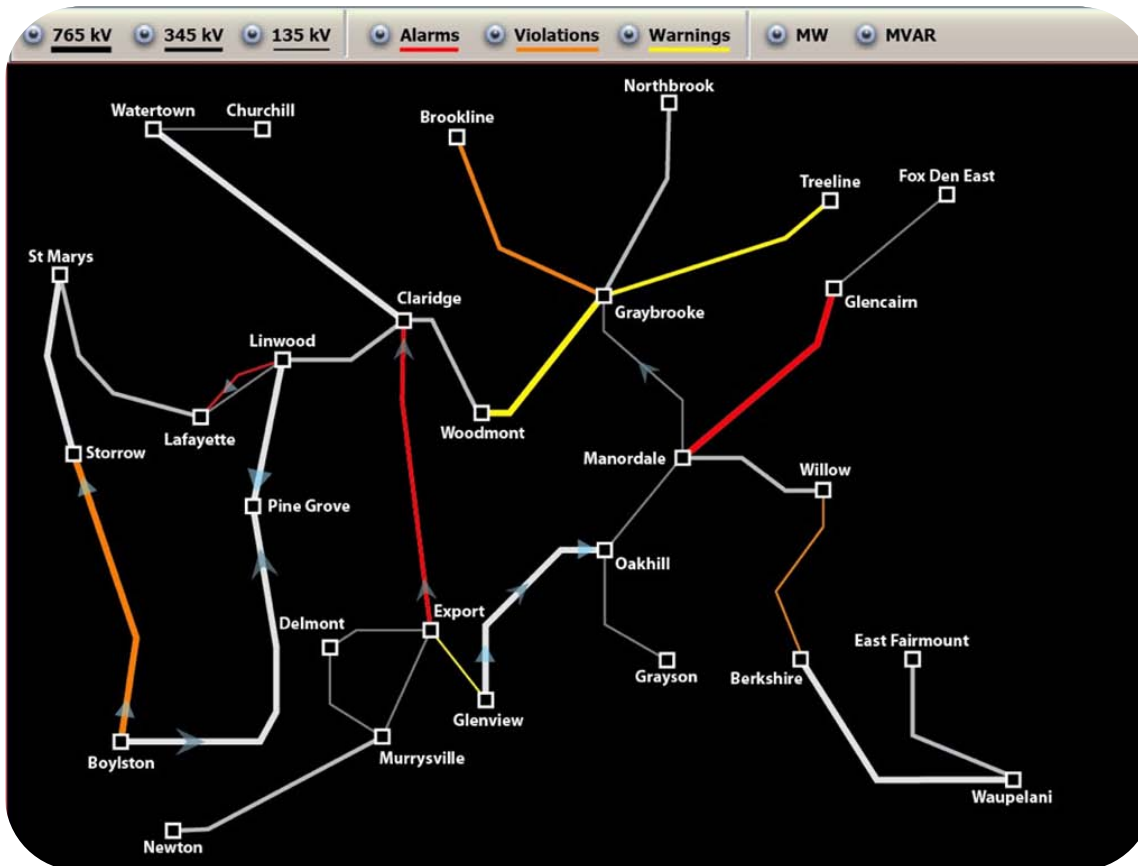
50 Design Principles



- ***Principle 1 - Organize Information Around Goals***
 - Central organizing feature
 - Flexible to meet changing goals of operator
- ***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
- ***Principle 7 - Take Advantage of Parallel Processing***
- ***Principle 8 - Use information filtering carefully***

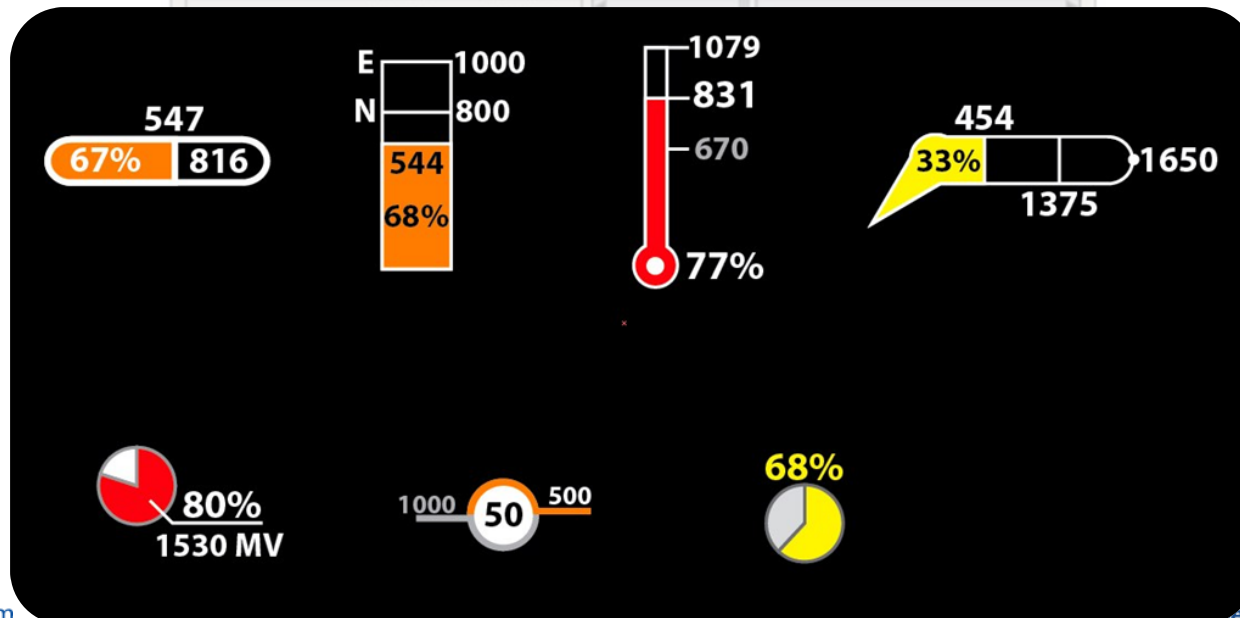
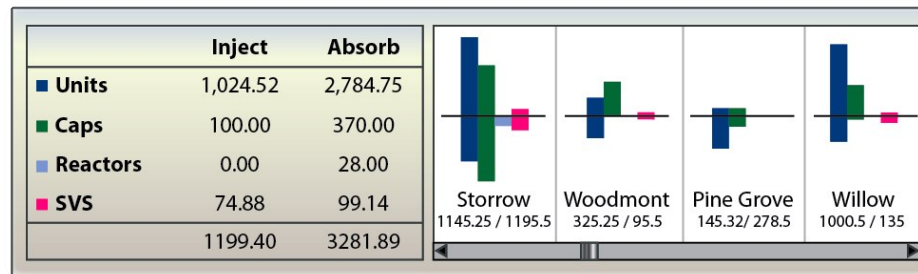
SA-Oriented Designs for Power Systems

Reservation of color to improve data salience
Minimal use of animation/motion



SA-Oriented Designs for Power Systems

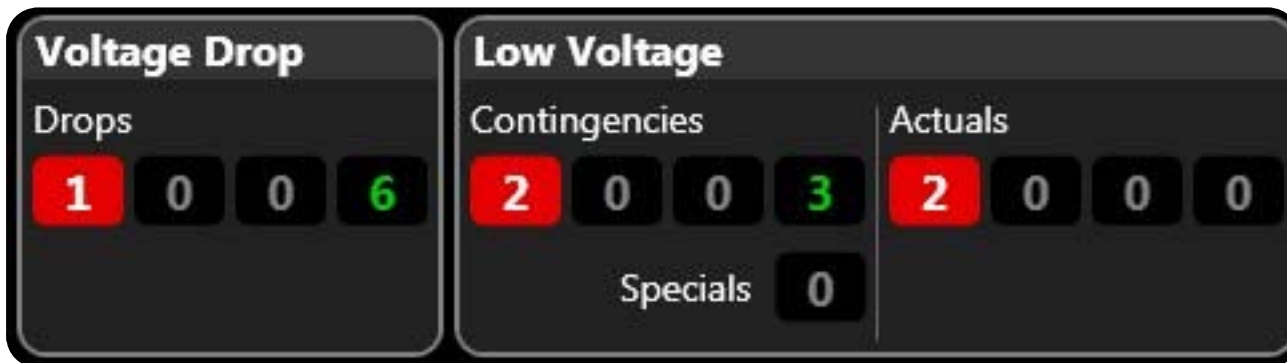
Data Visualizations to Support Comprehension (Level 2 SA)



SA-Oriented Designs for Power Systems



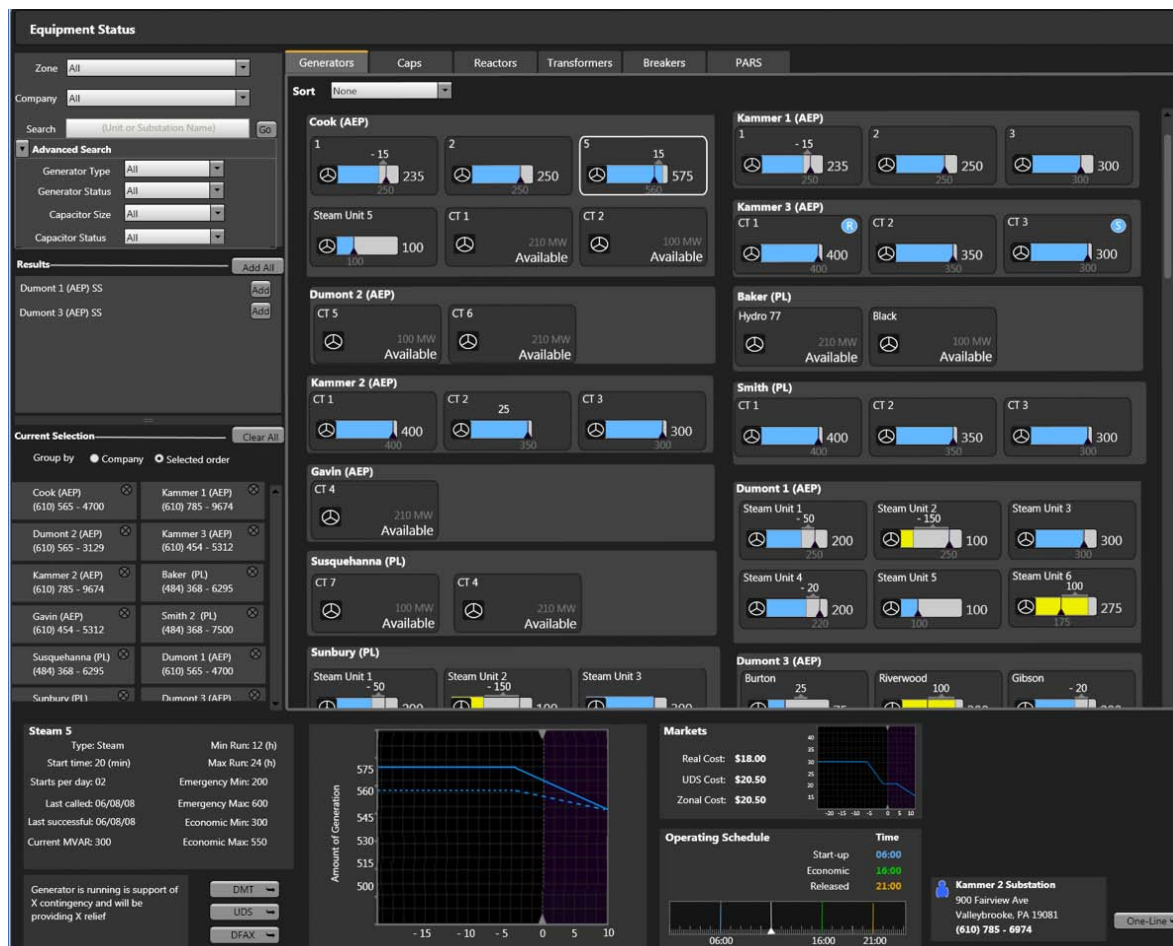
Organizing information to support goals and provide mechanisms for quick assimilation



SA-Oriented Designs for Power Systems



Integrated Information Dashboards to Support SA “at a glance”



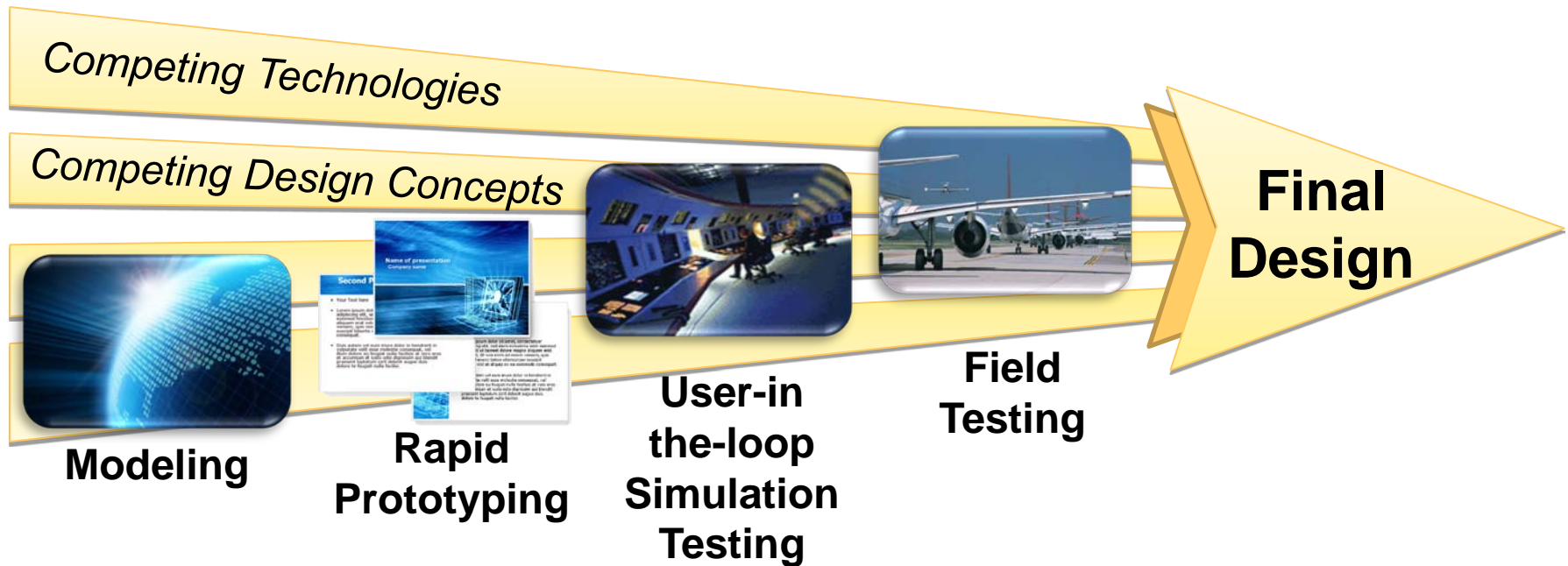
SA Requirements
Analysis

SA-Oriented
Design

SA Measurement



Test & Evaluation in the Design Process

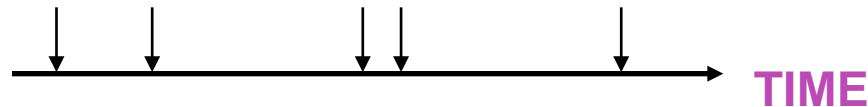


- ✓ Human Performance
- ✓ Decision Making
- ✓ Workload
- ✓ Situation Awareness

Situation Awareness Global Assessment Technique (SAGAT)

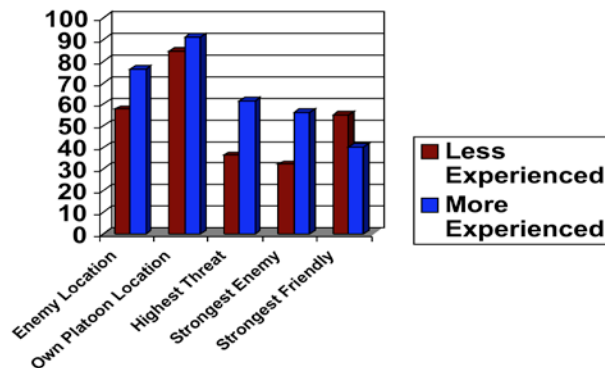
Objective measure of SA

- 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*

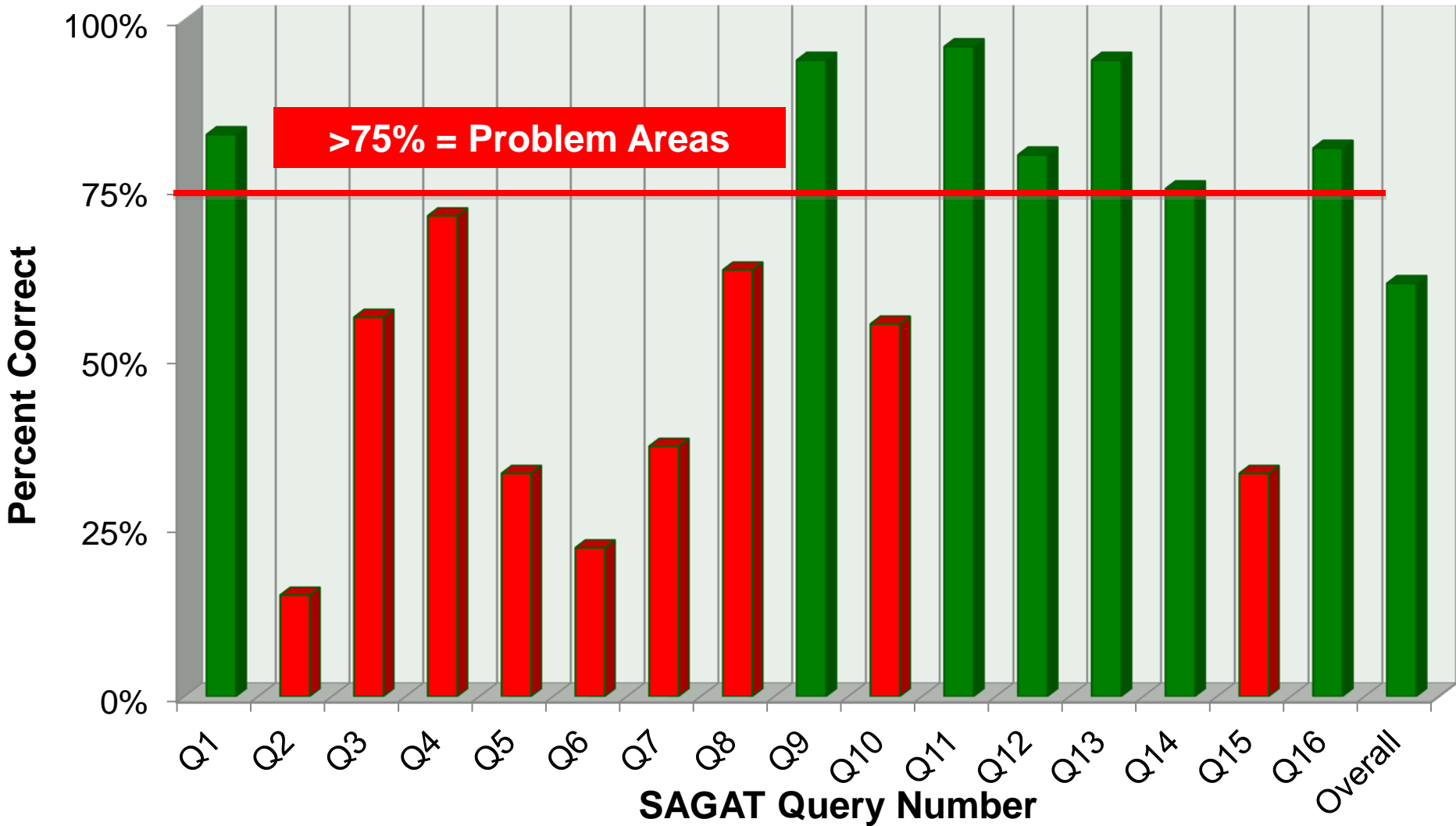


Power Systems SAGAT Results



SAGAT Query	Correct
1 What value is closest to [the utility's] current load ramp?	83%
2 What is the current load for [the utility]?	15%
3 What percent of [region] load is [the utility's] load?	56%
4 What is the direction of flow for [area] interchange?	71%
5 Which interface currently has the highest transfer?	33%
6 Roughly how many alarms were there in the last 10 min period?	22%
7 Of the most recent contingency solution set, what type of equipment was affected most?	37%
8 In the last hour, how has the system frequency been running on average compared to 60 Hz?	63%
9 Where is the actual [region] load in relationship to the forecasted load?	94%
10 Is [the region] currently importing more than it is exporting?	55%
11 Where is [the utility's] load in relationship to the forecasted load?	96%
12 In the past 10 minutes, which substation has had the majority of alarms?	80%
13 Within the past 15 minutes, were there any unsolved contingencies?	94%
14 Of the past 7 alarms, were more than one related to the same unit/element?	75%
15 In the most recent contingency set, of what type were the majority?	33%
16 Which direction do you expect [the utility's] load to trend in the next 15 minutes?	81%

Power Systems SAGAT Results



- **Situation Awareness is critical for effective decision making**
- **Many challenges for SA exist in Power T&D operations**
- **Situation Awareness can be directly enhanced through improved systems design to enhance information sharing and integration**
- **Tools for objectively measuring SA can be used to validate OCC system designs and training programs**



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10 Fold Difference in SA among Experienced Personnel

SA is demanding,
frequently incomplete
and erroneous

SA is fast, can be effortless,
more complete, greater
comprehension & projection



- Limited attention
- Limited working memory

- Schema of prototypical situations
- Mental models of domain
- Automaticity of processes
- Learned skills (e.g. scan patterns, communications)

Abilities

- Spatial
- Attention
- Memory
- Perceptual
- Cognitive

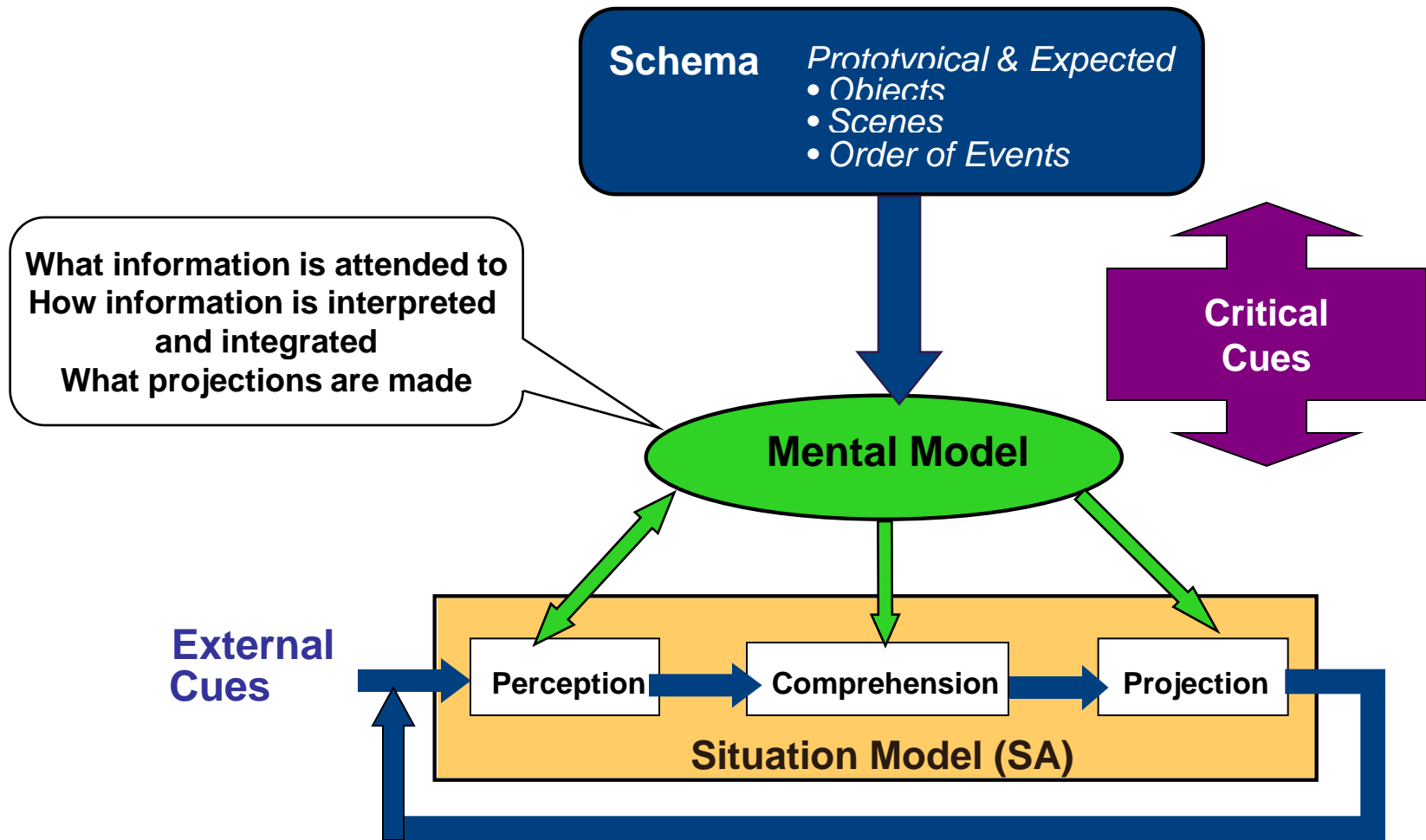
Knowledge

- Mental models
 - Schema
 - Critical cues
- Goals
- Preconceptions and objectives

Skills

- Information management
- Communication
- System operations
- Scan patterns
- Planning

What Allows People to Achieve High Levels of SA?



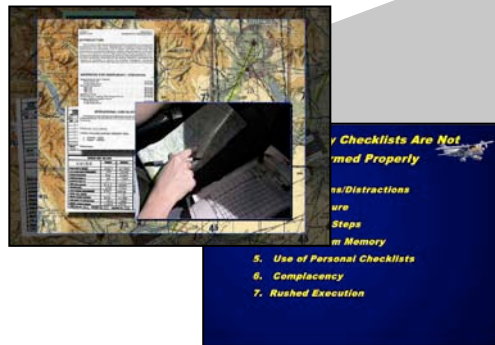
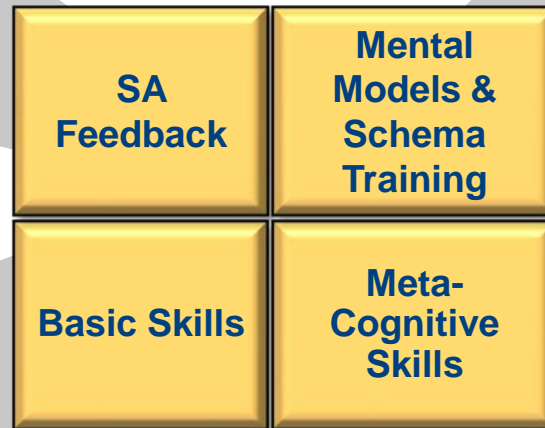
Training Situation Awareness Knowledge, Skills, & Behaviors



Virtual Environment Situation Awareness Rating System (VESARS)



Interactive Situation Awareness Trainer (ISAT)



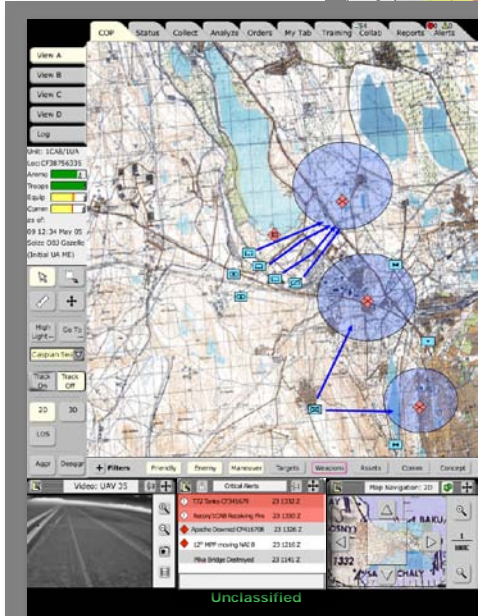
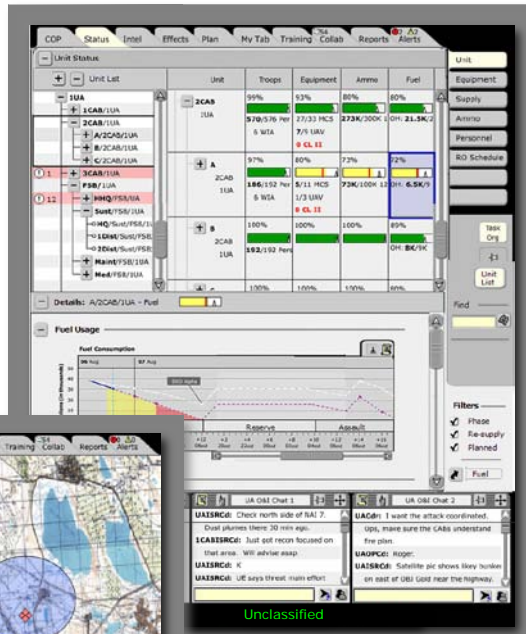
SA Trainer



Situation Awareness Virtual Instructor (SAVI)

- **Heavily Validated**
 - **Content Validity**
 - Inclusive of SA elements
 - (Endsley, 1990a)
 - **Construct Validity**
 - Does not impact on performance
 - (Endsley, 1989, 1990)
 - **Criterion Validity**
 - Predictive of performance
 - (Endsley, 1990b; Jones & Endsley, 2004)
 - **High Reliability**
 - (Endsley & Bolstad, 1994)
- **Sensitive to Differences in**
 - **Display Designs**
 - Hardware
 - Software - GUI
 - **Avionics Systems**
 - **Operational paradigms**
 - **Automation LOAs**
 - **Individual Differences**
 - **Aging**
 - **Training Approaches**
- **Developed and used in**
 - **Aviation**
 - **UAV/Robotics**
 - **ATC**
 - **Military Command & Control**
 - **Infantry Operations**
 - **Medical**
 - **Driving**
 - **Power Systems**
 - **Cyber**
 - **Homeland Defense**
- **Best in Simulation Studies**
 - has been used in Field Studies in some domains
- **Variants**
 - **SACRI (d' sensitivity scoring)**
 - **QUASA (adds confidence ratings)**
 - **SAVANT (adds time to respond)**
 - **SALSA (weights information)**

Command and Control



Unclassified

UA O&I Chat 1
UA O&I Chat 2

UA O&I: Check north side of RAJ 7
Dust plumes there 30 min ago.
1CABSRCE: Just set recon focused on that area. Will advise asap.
UA O&I: x
UA O&I: UE says threat main effort

UA O&I: I want the attack coordinated.
Ugs, make sure the C&B understand free plan.
1ADPCE: Roger.
UA O&I: Satellite pic shows heavy horizon on east of O&I Gate near the highway.

Unclassified

REFERENCE: 02 0000 0000 0000
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- 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
- Intelligent assistance to manage workload without being intrusive

Approved for Public Release, Distribution Unlimited, TACOM 22 NOV 2006, case 06-274.

Bringing Systems to Support SA to the CDC BioPHusion Center



View

US World

Region

Event

Type

Criticality

Time

Map Layers

Terrain

Weather

Infrastructure

Population

Resources

MAP SUMMARY TIMELINE EVENT

MAP SUMMARY TIMELINE EVENT

ID	Event	Criticality	Location	Description	Confidence	Response	Updated	View
FB-88 outbreak	Salmonella outbreak - raw tomatoes	High	Western United States	Multiple cases of suspected in 8 western states	Suspected	Monitor	13:00 1/10/10	View
ND-88 New	Chlorine spill	High	Shamong, NJ	>17K fatalities > 100K exposed	Confirmed	Monitor	21:00 1/10/10	View
OE-95 New	Tsunami - Magnitude 1	High	Eureka, CA	53 fatalities; Potential water contamination	Confirmed	Monitor	21:00 1/10/10	View
WF-33	Wildfire - Type 1	High	Zion National Park, UT	2 fatalities; smoke hazard	Confirmed	CDC Consult	12:40 1/10/10	View

MAP SUMMARY TIMELINE EVENT

Suspected case

ID	Event	Criticality	Location	Description	Confidence	Response	Updated	View
FB-88 outbreak	Salmonella outbreak linked to raw tomatoes	High	Western United States	Multiple cases of suspected Salmonella infections in 8 western states.	Suspected	Monitor	13:00 1/10/10	View

MAP SUMMARY TIMELINE EVENT

Timing Details Graphics

Criticality	Activity	Duration (days)	January									
			1	2	3	4	5	6	7	8	9	10
High	Salmonella illnesses begin. (ProMed)	74	[Yellow bar from Jan 1 to Jan 10]									
High	Epi-X report indicates that this is the day illnesses began says "health officials said people began feeling sick" on this date.	68	[Yellow bar from Jan 1 to Jan 10]									
High	Health officials announce 31 people in New Mexico have been confirmed to have the St. Paul strain of Salmonellosis.	6	[Yellow bar from Jan 1 to Jan 10]									
High	Link to tomatoes determined.	4	[Red bar from Jan 1 to Jan 10]									
High	23 States with persons infected with Saint Paul strain, 228 person infected.	3	[Green bar from Jan 1 to Jan 10]									
High	FDA warns consumers not to eat raw tomatoes. CDC holds press release.	2	[Blue bar from Jan 1 to Jan 10]									

ID	Narrative	View
AI-32 outbreak	Since Nov 2010, 228 persons infected with <i>S. Saintpaul</i> with the same genetic fingerprint have been identified in 23 states: Arizona (19 persons), California (2), Colorado (1), Connecticut (1), Florida (1), Georgia (7), Idaho (3), Illinois (29), Indiana (7), Kansas (5), Michigan (2), Missouri (2), New Mexico (55), New York (1), Oklahoma (3), Oregon (3), Tennessee (3), Texas (68), Utah (2), Virginia (9), Vermont (1), Washington (1), and Wisconsin (3). These were identified because clinical laboratories in all states send strains from persons with salmonellosis to their State public health laboratory for characterization.	View