Pursuing Situational Awareness

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What is Situational Awareness?

"Anyone who sits on top of the largest hydrogen-oxygen fueled system in the world; knowing they’re going to light the bottom— and doesn’t get a little worried— does not fully understand the situation."

—John Young, when asked if he was worried about making the first space shuttle flight
1. SA: Definitions
2. SA: Design Implications
3. SA: Industry Examples
4. SA: Qualitative Characteristics
5. SA: Enabling Technologies
6. SA: Case Studies
7. Conclusion
What is Situational Awareness?

OODA (Boyd*) Loop:

Observe – Orient – Decide - Act

Observe – Orient:

- Perception
- Comprehension
- Projection

Perception != Reality:

“OUT OF THE LOOP”

*Developed by USAF Colonel John Boyd
~1976
From a System Development Perspective, Maximizing SA Involves 4 Aspects:

1. **Specify**
   - Know what you need to know

2. **Process**
   - Extract what you need to know

3. **Sense**
   - Acquire what you need to know

4. **Present**
   - Display what you need to know

**Knowledge Engineering**
- Technology
- Measurements
- Human Factors
Goal Directed Task Analysis (GDTA)

1. Identify Goals
2. Identify Critical Decisions
3. Identify SA required to make those decisions
Mica Endsley

Chief Scientist of the United States Air Force (current)
Past President and CEO of Situation Awareness Technologies

Designing for Situation Awareness (2nd edition)
Design Implications – Specification

PHM Design Methodology – Part 1
Design Analysis and Asset Definition

- Reliability Analysis, FMEA, PRA
- Drawings, specifications, schematics
- Functional descriptions posed in terms of user requirements
• Functional Failure descriptions ensure that the PHM system detects what users care about

• What evidence exists of the failure?

• What sensor suite is required to eliminate ambiguity?

Describe each Functional Failure (in terms of performance specifications, quality specifications, and safety/environmental requirements)

In what ways might the asset fail to perform its defined functions?

Take advantage of any previous RCM and FMEA analyses

Falling Capability (deterioration, disassembly, dirt, human error, etc.)

Increased Expectation or Applied Stress (sustained and deliberate, sustained and unintentional, and spontaneous unintentional)

Identify Failure Effects (what happens as a result of the failure)

Not the same as Failure Consequences

In what ways (if any) does event affect safety, environment, availability, production?


Defines Event Detection Algorithms

Cont’d
Design Implications – Specification

PHM Design Methodology – Part 3
Failure Consequences, Criticality, and Event Propagation

- How serious are the effects?
- Did something break? Is the system down? Did something spill? Does anyone get hurt?
- What could be done to avoid the consequences?
- Ready to do fault modeling

Consider Failure Consequences (why does it matter, and what should you do about it?)

Risk Assessment to determine whether proactive or preventative actions are appropriate

Are there any safety or environmental consequences?

What are the operational consequences?

What is the cost of repair?

Would Proactive Maintenance be necessary and cost effective?

How Probable are the failure consequences? What can I do to lower the probability?

Assess Criticality and Risk

Consider Event Symptoms, Physics of Failure, and Specify Event Detection based on Criticality

Consider Event Propagation and Subsystem Interactions and Build Fault Trees

Cont’d
• Define the usage monitoring requirements and parameters

Goal: Transform data into information and knowledge based on operational context, leveraging all available wisdom
SA should improve with technology innovation

1. New sensor technologies
2. New displays
3. New algorithms
4. Improved data acquisition and storage
5. Faster processors
6. Improved understanding of processes and missions
7. Advancements in reasoning software applications
Increased technology doesn't increase situational awareness.
Extracting what you need to know

Data Mining and Feature Extraction
Advanced Database and Information Management Systems
Model and Case-Based Reasoning, model switching
State estimation and prediction
Bayesian Sensor and Information Fusion
Neural and Statistical Pattern Recognition
Expert Systems based Decision Support
Genetic Algorithm based Optimization
Machine Learning Systems
Autonomous Software Systems
Human Machine Interface (HMI) Design: The Good, The Bad, and The Ugly (and what makes them so)

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1. Contrast: things that are different should look very different

2. Repetition: repeat visual elements

3. Alignment: every element should have some visual connection with another

4. Proximity: things that belong together should be placed together, those that are different should not
Industry Examples

1. Aircraft and Aerospace
2. Battlefield and Warfighting
3. Naval
4. Power Generation
5. Process Industries
6. Transportation
7. Enterprise
8. Consumer
1. Aerospace – early warplanes

Sopwith Camel Cockpit

Nieuport 28 Cockpit

*www.mapsairmuseum.org

*www.airminded.net
1. Aerospace – later aircraft

Boeing B29 Cockpit

*www.strangedangers.com

North American X-15 Cockpit

*www.militaryfactory.com
Industry Examples

1. Aerospace – later aircraft

Boeing 777 Cockpit
*www.777boeing.com

Lockheed Martin F-35 Cockpit
*www.strikefighterconsultinginc.com
Industry Examples

1. Aerospace – Rockwell International SSC Endeavor
2. Warfighting

Virtual Battlespace 2

*www.army.mil
Industry Examples

3. Naval

WWII Naval Combat Information Center

*flyhistoricwings.com
Industry Examples

3. Naval

DDG-51 Naval Combat Information Center

*www.arlut.utexas.edu
Industry Examples

4. Nuclear

U.S.S. Long Beach CGN-9

*Swww.leroyjonesnavyhistory.com*

S5W Reactor Plant Consoles

*Swww.emmitsburg.net*
4. Nuclear

PAKS Nuclear Plant - Hungary

*www.chinadaily.com
Industry Examples

5. Process Industries

Typical Process HMI – 1990’s

High Performance HMI – 2014

*www.automationworld.com

*www.novatechweb.com
6. Transportation

NY DOT Command Center  MTBA Boston Transit Control

*streetsblog.org  *www.oobject.com
Industry Examples

7. Enterprise

*SAS® BI Dashboard*

**Key Metrics**
- Customer Satisfaction
  - 87%, 90%, 95%, 100% satisfied or better
- Key Staff Turnover
  - 7% turnover last 12 months

**Sales Forecast**

**Revenue By Country Information**

<table>
<thead>
<tr>
<th>Country</th>
<th>Sales by Month</th>
<th>Average Cost of Sale</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU</td>
<td></td>
<td>$3,569</td>
</tr>
<tr>
<td>ES</td>
<td></td>
<td>$8,673</td>
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<tr>
<td>FR</td>
<td></td>
<td>$9,167</td>
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<td>IT</td>
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<td>$6,463</td>
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<tr>
<td>NL</td>
<td></td>
<td>$5,227</td>
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<tr>
<td>US</td>
<td></td>
<td>$13,943</td>
</tr>
</tbody>
</table>

**Product Profit Detail**

**Country Detail Market Share**

*www.enterprise-dashboards.com*
7. Enterprise
Industry Examples

7. Enterprise

Accidents vs. Worker Pay

Calendar

Planned Revenue

Revenue by Employee and Salary

Revenue by State

Planned Revenue by Employee

*www.enterprise-dashboards.com
8. Consumer

*www.econais.com
What can interfere with SA?

1. Repetition
2. Ambiguity
3. High Stress
4. Low Stimulation
5. Confusion
6. Impatience
7. Peer Pressure
8. Unfamiliar Situations
9. Fixation/Distraction
10. Violation of rules and policy
Enablers

What can help maximize SA?

1. Experience
2. Training
3. Orientation
4. Ability to process information
5. Better understanding of what the user needs to know
6. Transformation of data to information and knowledge
Enablers

Enabling Technologies

Data Mining and Feature Extraction
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Machine Learning Systems
Autonomous Software Systems
Case Study: PHM Systems

PHM Systems are evolving to meet higher expectations

What should PHM Systems do?
- Determination of Health and its impact on system functions
- Monitor early warning of incipient failures
- Predictions of Remaining Useful Life
- Leveraging of advanced “reasoners”
  - Signal processing for event detection and sensor validation
  - Algorithms for event correlation and sensor fusion
  - Expert Systems and rule-based architectures
  - Advanced neural and statistical classifiers
  - Real-time state estimators
  - Model-based Reasoning
  - Real-time regime recognition and model switching
- Supervisory-level intelligence / logic
- Estimation and understanding of system state within operational context
- Decision support to assist operators in maintaining operational availability
- Optimize scheduling of maintenance and corrective actions according to the principals of condition-based maintenance
Case Study: NASA Rocket Engine Testing
<table>
<thead>
<tr>
<th>ID #</th>
<th>Item-Functional Identification</th>
<th>Function</th>
<th>Failure Modes and Causes</th>
<th>Mission Phase-Operational Mode</th>
<th>Failure Effects</th>
<th>Failure Detection Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Process Equipment</td>
<td>Fluid feed subsystem</td>
<td>Leak</td>
<td>Sealed subsystem maintaining pressure</td>
<td>Pressure leak</td>
<td>Identify sealed subsystem, and check pressure sensors for decreasing pressure.</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Leak**
  - a-subcomponent-of
  - an-isolation-valve-of

- **Pressure Leak**
  - encompassing
  - pressure_sensor

- **Decreasing Pressure**
  - isolated-by
Case Study: NASA Rocket Engine Testing

Description of NASA_ISOLATED_SUBSYSTEM_32X_357

- a nasa_isolated-subsystem
  - This is assigned to module HM-APPLICATION.
  - The following items are a subcomponent of this nasa_isolated-subsystem.
    - a hm-instrumented-pipe-segment
      - a hm-pipe
        - PT-14013-LO, a hm-pressure-sensor
        - LT-14015-LO, a hm-level-sensor
      - a hm-pipe
        - a hm-fluid
        - a hm-pipe
      - a hm-instrumented-pipe-segment
        - PT-14018-GO, a hm-pressure-sensor
      - a hm-pipe
        - PI-14036-GO, a hm-pressure-indicator
    - The following items are an-isolation-valve of this nasa_isolated-subsystem.
      - SV-14012-LO-AB, a hm-subworkspace-valve
      - SV-14017-LO-AB, a hm-subworkspace-valve
Case Study: NASA Rocket Engine Testing

Subsystem not Leaking
Subsystem Leaking
Case Study: Advanced Arresting Gear
Hierarchical Goal-Oriented PHM Design

Proposed Layered Architecture

ISO 13374 Standard

Machine condition assessment data processing & information flow blocks.

Technical Riggers & Information Presentation

Vehicle

Operating Base

Enterprise

Data Acquisition

Data Aggregation and Management

Event and State Detection

Health Assessment

Condition Indicator Update

Fatigue and Load Monitoring

CRT Update

RUL Prediction

FLM

IETM Automation

Mission Planning

Download Cable

Ground Station

WAN

Depot

Logistics

Vehicle

Operating Base

Enterprise
Fatigue Life Management

- Structural Analysis
- Reliability Analyses (FMECA, RCM)
- Service Life Determination
- Remediation
- Systems Engineering
- Updated Component Retirement Times (CRT)
- Inspection, Evaluation, and Validation
- Depot Database And Manipulation
- AMIS
- Maintenance Plan
- ADR Data
- Other Telemetry Data
- Flight Parameters
- Regime Recognition
- Load Monitoring
- Event and State Detection (CI)
- Health Assessment (HI)
- Ground Station
- Predicted Component RUL
- Updated Usage Spectrum
- Measured Usage and Flight State Classification
- Health Impacts
- Updated Condition/Health Indicators

i-PCGRID Workshop 2014 March 28, 2014
Case Study: Integrated Threat Detection

- Integrated Smart Sensor Network
- Wide-area Monitoring including Video Data
- Automated Analysis of Chemical and Biological Sensor Data
- Real-time Situational Awareness
- POC installed at Liberty Island
Case Study: Factory Drilling

- Intelligent solutions for both drilling and production
- Provide expert decision in support of “the big crew change”
- Goal is to embed intelligence into the bit
- Automatic switching of algorithms based on changing conditions
Case Study: Fleet Distance Support

• Integration with data from existing critical shipboard systems and services

• Leverages Object Oriented Model-based Reasoning

• Online health assessment

• Offline analysis to support creation of “condition indicators”

• New CI’s are then pushed back out to the fleet

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Questions?

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