Lesson 1: HLIF Overview and Motivation

Erik Blasch
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Overview

Decompose problem into elements of **LLIF** and **HLIF**

Determine the **user (situation awareness)** and **machine (computation)**

Discussion on **evaluation/visualization and projection**
Overview

High-level information fusion is the ability of complex systems to capture awareness by utilizing direct sensing exploitations and tacit reports, reasoning over past and future events, and discerning the usefulness and intention of results to meet system-level goals. This authoritative book serves as a practical reference for researchers, developers, and users of data fusion services that must relate the most recent theory to real-world applications. This unique volume describes alternative theories to represent and model situations, provides methods of information management, and demonstrates design component implementations of information fusion systems. Designers find expert guidance in applying current theories, selecting algorithms and software components, and measuring expected performance of high-level information fusion systems.

Contents Overview:

Part I: Information Fusion Concepts
Situation Assessment and Situation Awareness. The State Transition Data Fusion Model. Formalization of Situational Analysis Through Interpreted Systems Semantics.

Part II: Distributed Information Fusion and Management

Part III: Human-System Interaction

Part IV: Scenario-Based Design

Part V: Measures of Effectiveness

Erik Blasch is an information fusion evaluation engineer at the United States Air Force Research Laboratory, Rome, NY. He holds a Ph.D. in electrical engineering and an MBA from Wright State University, and is a graduate of Air War College, and has completed numerous other graduate degrees.

Éloi Bossé has served as head of the Decision Support Systems Section at Defence Research and Development Canada Valcartier. He holds a Ph.D in electrical engineering from Université Laval.

Dale A. Lambert is the research leader of intelligence processing and analysis within Australia's Defence Science and Technology Organisation. He holds a Ph.D. in artificial intelligence, a graduate certificate in management, and undergraduate degrees in computer science, philosophy, and mathematics.

Include bar code
ISBN 10: 1-60807-151-0

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High-Level Information Fusion

Scenario
Situation

Object
Observable

Assessment

Projection
Comprehension

Perception
Sensation

Awareness

Low-Level Information Fusion

Situation Analysis

Evaluation

Information/Resource Management

Systems Design

Machine

Human
GOALS

Goals:

1) STUDENT
   Listen and think about the LLIF-HLIF problem definitions
   Try to think through “Information fusion reasoning”

2) FACILITATOR
   Continue to organize and synthesize the material
   Develop methods and solutions for High-level Information Fusion
   Organize developments in HLIF for future generations

3) COMMUNITY
   Collaborate to motivate design/management solutions
   Reflect of systems-level issues of information fusion design

HERE IS MY EFFORT TO ORGANIZE THE MATERIAL … .
HLIF Book Outline

Information Fusion Concepts and Representations

- 2. The IFSA Model
- 3. The STDF Model
- 4. Interpreted Systems

Distributed Information Fusion and Management

- 5. Role of Information Management
- 6. Coalition Testbed
- 7. INFORM Testbed
- 8. Legal Agreement Protocol

Human System Interaction

- 9. UDOP
- 10. C-OODA

Information Fusion Evaluation

- 15. Measures of Worthiness
- 16. Measures of Effectiveness

Scenario-Based Design

- 11. SBD Applications
- 12. Coalition Approach
- 13. Operation Condition Model
1. Overview the **HLIF problem** (~ 1 hour)
   - Architecture, domain, algorithms, purpose (**SA Approaches**)

2. Methods for **Situation Awareness** (~ 1 hour)
   - Set up analysis of SAW/SA (functional)
   - Describe three types of approaches
     - Process, Interpreted, and State Transition
   - Develop notions of SA Prediction/Projection

3. Develop a **IF Management and System Level Design** (~ 1 hour)
   - Present System Management and Testbeds
   - Human Factors issues (C-OODA, UDOP)

4. Demonstrate **HLIF Evaluation and Scenario Design** (~ 1 hour)
   - Determine the design, testing, scenarios, and operability
   - Evaluation Methods
Caveat

1. Three years of discussion
   Focused on the main issues in HLIF
   See companion paper in Fusion Panel Studies
   See other tutorial on Evaluation

2. Collaboration (SUM)
   Sensor Management - HLIF is about different INTs
   User – HLIF is about a collection of users
   Mission – HLIF is about focusing on the goal (Top-Down)

3. Each Coordination brought together ideas
   Technical panels – C3I, Info Mgt, User, and Testbeds
   Countries and perspectives – each had end-to-end solution

4. Developments fostered from the Grand Challenges
   Issues to explore in the next decade
Lesson 01: HLIF Overview

1. Overview the **HLIF problem** (~ 1 hour)

**HLIF Architectures:** JDL to Data Fusion Information Group (DFIG)

**Grand Challenges**
- **Paradigm, Semantic, Epistemic:** HLIF Purpose
- **Interface, System:** HLIF Management
- **Design, Evaluation:** HLIF Design
  Set up analysis of SAW/SA (functional)

**SA Approaches**
- **Process (DFIG) – US** [Blasch, Salerno, Tangney]
- **Interpreted Systems (IS) /ODDA – Canada** [Bosse, Jousselme/Maupin, Valin]
- **State Transition Data Fusion (STDF) – AUS** [Lambert]

**Common Issues:** Metrics, Design, Future Concentrations

2. Methods for **Situation Awareness** (~ 1 hour)

3. Develop a **IF Management and System Level Design** (~ 1 hour)

4. Demonstrate **HLIF Evaluation and Scenario Design** (~ 1 hour)
High Level Fusion
Adapted from E. Waltz and J. Llinas, *Multisensor Data Fusion*, Artech House, Norwood, MA [1990]

Low-Level Processing

- Sensor 1
  - Detection
- Sensor 2
  - Detection
- Sensor 3
  - Detection

Data Association

State Estimation

- Predicted States of Targets in Track

Attribute Classification

Low-Level Assessment

- Estimated Tracks
- Target Identities

High-Level Processing

Assessment

- Detection of Pattern of Behavior
- Association of Entities and Events
- Prediction of Future Behavior
- Classification of Situation

High-Level Assessment On Situation

- Behavior
- Future Activities
- Intent
User Fusion Model

DFIG - Fusion Model
(Data Fusion Information Group), Fusion 2006 (from 2004)

E. Blasch, I. Kadar, J. Salerno, M. M. Kokar, S. Das, G. M. Powell, D. D. Corkill, and E. H. Ruspini,
Low Level Information Fusion (LLIF)

**Level 0 – Data Assessment:** estimation and prediction of signal/object observable states on the basis of pixel/signal level data association (e.g. information systems collections);

**Level 1 – Object Assessment:** estimation and prediction of entity states on the basis of data association, continuous state estimation and discrete state estimation (e.g. data processing);

High Level Information Fusion (HLIF)

**Level 2 – Situation Assessment:** estimation and prediction of relations among entities, to include force structure and force relations, communications, etc. (e.g. information processing);

**Level 3 – Impact Assessment:** estimation and prediction of effects on situations of planned or estimated actions by the participants; to include interactions between action plans of multiple players (e.g. assessing threat actions to planned actions and mission requirements, performance evaluation);

**Level 4 – Process Refinement** (an element of Resource Management): adaptive data acquisition and processing to support sensing objectives (e.g. sensor management and information systems dissemination, command/control).

**Level 5 – User Refinement** (an element of Knowledge Management): adaptive determination of who queries information and who has access to information (e.g. information operations) and adaptive data retrieved and displayed to support cognitive decision making and actions (e.g. human computer interface).

**Level 6 – Mission Management** (an element of Platform Management): adaptive determination of spatial-temporal control of assets (e.g. airspace operations) and route planning and goal determination to support team decision making and actions (e.g. theater operations) over social, economic, and political constraints.

## Fusion Model Comparisons


<table>
<thead>
<tr>
<th>Activity</th>
<th>DFIG</th>
<th>SAW Model</th>
<th>OODA</th>
<th>C-OODA</th>
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<tbody>
<tr>
<td>Command Execution</td>
<td>Level 6</td>
<td>Resource Tasking</td>
<td>Act</td>
<td>Action Implementation</td>
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<tr>
<td>Decision Making</td>
<td>Level 5</td>
<td>User Control User Refinement</td>
<td>Decide</td>
<td>Recall Evaluate</td>
</tr>
<tr>
<td>Sensor Management</td>
<td>Level 4</td>
<td>Decision Making</td>
<td></td>
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<tr>
<td>Impact Assessment</td>
<td>Level 3</td>
<td>Projection</td>
<td>Orient</td>
<td>Projection</td>
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<tr>
<td>Situation Assessment</td>
<td>Level 2</td>
<td>Comprehension</td>
<td></td>
<td>Comprehension</td>
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<tr>
<td>Object Assessment</td>
<td>Level 1</td>
<td>Object Assessment</td>
<td></td>
<td>Feature Matching</td>
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<tr>
<td>Signal/Info Processing</td>
<td>Level 0</td>
<td>Signal/Feature Processing</td>
<td>Observe</td>
<td>Perception</td>
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<tr>
<td>Data Acquisition</td>
<td></td>
<td>Sensing Registration</td>
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<td>Data Gathering</td>
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</table>


*C-OODA* (Cognitive Observe, Orient, Decide, Act) – *Fusion11*, 2011
Lesson 01: HLIF Overview

1. Overview the HLIF problem (~ 1 hour)

   HLIF Architectures: JDL to Data Fusion Information Group (DFIG)

   Grand Challenges
   - Paradigm, Semantic, Epistemic: HLIF Purpose
   - Interface, System: HLIF Management
   - Design, Evaluation: HLIF Design
   - Set up analysis of SAW/SA (functional)

   SA Approaches
   - Process (DFIG) – US [Blasch, Salerno, Tangney]
   - Interpreted Systems (IS) /ODDA – Canada [Bosse, Jousselme/Maupin, Valin]
   - State Transition Data Fusion (STDF) – AUS [Lambert]

   Common Issues: Metrics, Design, Future Concentrations

2. Methods for Situation Awareness (~ 1 hour)

3. Develop a IF Management and System Level Design (~ 1 hour)

4. Demonstrate HLIF Evaluation and Scenario Design (~ 1 hour)
High Level Information Fusion Challenges

Focus of the text

**Paradigm Challenge:** How should the interdependency between the sensor fusion and information fusion paradigms be managed?

**Semantic Challenge:** What symbols should be used and how do those symbols acquire meaning?

**Epistemic Challenge:** What information should we represent and how should it be represented and processed within the machine?

**Interface Challenge:** How do we interface people to complex symbolic information stored within machines to provide decision support?

**System Challenge:** How should we manage information fusion systems formed from combinations of people and machines?

**Design Challenge:** How should we design information fusion systems formed from combinations of people and machines?

**Evaluation Challenge:** How should we evaluate the effectiveness of information fusion systems?
## Australia Contributions (1)
### State Transition Data Fusion (STDF)

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Conceptual Theory</th>
<th>Theory Representation</th>
<th>Theory Implementation</th>
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<tr>
<td><strong>Paradigm</strong></td>
<td>State Transition Data Fusion (STDF) Model (Ch 3)</td>
<td><strong>Unifying human and machine functional models</strong> across level 0 to level 3 situation awareness and fusion</td>
<td>Signal/Text/Image processing with a distributed multi-agent architecture</td>
</tr>
<tr>
<td><strong>Semantic</strong></td>
<td>Mephisto Semantic Framework ([11])</td>
<td><strong>Axiomatic semantics</strong> in First Order Logics (FOLs) and Description Logics (DLs) covering various metaphysical, environmental, functional, cognitive and social concepts</td>
<td>Prolog, Racer, FOL Definitions Interpreter</td>
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<td><strong>Epistemic</strong></td>
<td>ATTITUDE ([4]) and ATTITUDE TOO Cognitive Models</td>
<td><strong>Cognitive agents</strong> with semantic, epistemic (declarative facts and rules) and episodic (procedural cognitive routines) long-term memories</td>
<td>Prolog, Racer, FOL Definitions Interpreter</td>
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<td><strong>Interface</strong></td>
<td>Higher Common Operating Pictures (HiCOP) ([4, 12, 13])</td>
<td><strong>Interactive virtual news</strong> engaging virtual advisers, virtual battlespace, virtual interactive planning rooms, virtual video, virtual newspapers (web pages), Lexpresso controlled natural language</td>
<td>Commercial and indigenous Natural Language Processing, Text To Speech, Speech to Text, various indigenous animation developments</td>
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Erik Blasch –Fusion15
Australia Contributions (2)
State Transition Data Fusion (STDF)

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<td>System Challenge</td>
<td>Legal Agreement Protocol (LAP) (Ch 8) on the Coalition Distributed Information Fusion Testbed (CDIFT) (Ch 6)</td>
<td>Legal agreements between combinations of CDIFT connected human and machine cognitive agents based on formal semantic theories</td>
<td>LAP through agent cognitive routines on CDIFT using HLA, JBI, CoABS grid, Elvin, XMPP, XACML</td>
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<td>Design Challenge</td>
<td>Synthetic North Atlantis Environment (Ch 12)</td>
<td>Use of synthetic development environments containing track data, intelligence reports, and various domain knowledge</td>
<td>Stage, domain knowledge, track data, GIS, Lexpresso reports, and agents on CDIFT</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Evaluation of Situation Assessment ([14])</td>
<td>Probabilistic propositional set disparity measures based on random inference networks</td>
<td>Mephisto, Prolog</td>
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<td>Paradigm Challenge</td>
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<tr>
<td>Interpreted Systems (Ch 4)</td>
<td>Formal models across level 0 to level 3 fusion</td>
<td>Pursuit-evasion in graphs (Ch 14)</td>
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<td>Interpreted Systems (Ch 4)</td>
<td>Axiomatic semantics in Modal Logics covering various metaphysical, environmental, and functional concepts (Ch 4)</td>
<td>Game-theoretical analysis (Ch 14)</td>
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<td>Cognitive Observe, Orient, Decide, Act Model (Ch 10) Interpreted Systems (Ch 4)</td>
<td>User (agent) with semantic, epistemic (facts and rules), and episodic (procedural) interactive goals. Belief Theory (Ch 4, Ch 7, Ch 14)</td>
<td>Control theory for semantic interactions (Ch 7), Scenario-Based design (Ch 11), model-checking techniques (Ch 14)</td>
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<tr>
<th>Interface Challenge</th>
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<tr>
<td>Command and Control Graphical User Interface (Ch 7, Ch 14)</td>
<td>Semantic and symbology presentation, visualization, and interactive sensor and mission management (Ch 6, Ch 7, Ch 9)</td>
<td>UML operational-primed decision making for a defined scenario (Ch 11)</td>
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<tr>
<td>INFORM Testbed (Ch 7)</td>
<td>OODA-based agent (Ch 7), state-space approach, belief networks (Ch 4, Ch 7, Ch 14)</td>
<td>XML, GIS, J2SE</td>
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**Canada Contributions (2)**

*Interpreted System (IS) and OODA Agents*

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<tr>
<td>Synthetic North Atlantis Environment (Ch 11, Ch 12)</td>
<td>Track data, intelligence reports, various domain knowledge, simulations (Ch 6, Ch12)</td>
<td>Stage, GIS, agents on CDIFT (Ch 6, Ch12)</td>
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<tr>
<th>Evaluation Challenge</th>
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<td>Theoretical development of measures of effectiveness (MOE) (Ch 14, Ch 16)</td>
<td>OODA agents operate in a distributed feedback loop (Ch 7) Model checking techniques (Ch 14)</td>
<td>Information quality measures and MOEs (Ch 16), “what-if” analyses (Ch 7)</td>
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**Awareness**

\[ A, \phi \]

**Implicit Knowledge**

\[ K, \phi \]

**Explicit Knowledge**

\[ X, \phi \]
## United States Contributions (1)
Information Fusion Situation Awareness (IFSA)

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<td>Paradigm Challenge</td>
<td>Information Fusion Situation Assessment (IFSA) Model</td>
<td><strong>Operational process models</strong> across level 0 to level 5 fusion</td>
<td>Signal/Text/Image processing with a SA/SAW architecture (Ch 15)</td>
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<tr>
<td>Semantic Challenge</td>
<td>Development of IFSA taxonomy</td>
<td><strong>Operational semantics</strong> of computational models to infer meaning over environmental, functional, cognitive and social concepts (Ch 2, Ch 13, Ch 15)</td>
<td>Numeric and Language fusion integration in a image (Ch 10) and cyber system (Ch 15)</td>
</tr>
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<td>Epistemic Challenge</td>
<td>Information Management Model</td>
<td><strong>Agents</strong> for workflow and service-based semantic, epistemic (facts and rules) and episodic (procedures) information processing (Ch 5)</td>
<td>Agent routines in CDIFT (Ch 6) using HLA, JBI, CoABS grid, XML, XACML</td>
</tr>
<tr>
<td>Interface Challenge</td>
<td>User Defined Operating Pictures (UDOP) (Ch 9) with operational conditional assessment (Ch 13)</td>
<td><strong>Visualizations</strong> for a Common Operational Picture (COP) with symbologies, information management, and collaboration tools (Ch 9). <strong>User refinement</strong> support to fusion methods with cognitive theory (Ch 10)</td>
<td>Visualization tools to support SA for maritime surveillance (Ch 7), image analysis (Ch 10), target classification (Ch 13) and cyber threats (Ch 15)</td>
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## United States Contributions (2)

### Information Fusion Situation Awareness (IFSA)

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<td>Information Management Model (Ch 5) for the Coalition Distributed Information Fusion Testbed (Ch 6)</td>
<td>Use of ontologies and workflow/service/human agents for the CDIFT. Coordination of user/machine fusion methods based on information needs and tools (Ch10, Ch13, Ch16)</td>
<td>Agent routines in CDIFT (Ch 6) using HLA, JBI, CoABS grid, XML, XACML and user refinement (Ch 10, Ch13, Ch15, Ch16)</td>
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<td>Evaluation Challenge</td>
<td>Development of theoretical measures of effectiveness (MOE) (Ch 16)</td>
<td>Bayes networks to measure probabilistic variations from Operational Conditions (Ch 13) and derivation of MOEs from performance measures (Ch 10)</td>
<td>Development of MOEs for cyber analysis, (Ch15) and coastal surveillance (Ch 16)</td>
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**Diagram:**

[Diagram of information fusion process with labels for Explicit Fusion, Tacit Fusion, Situation Analysis, Knowledge of Us, and Human Decision Making.]
<table>
<thead>
<tr>
<th>Challenge</th>
<th>AUS</th>
<th>CAN</th>
<th>US</th>
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<tr>
<td><strong>Paradigm Challenge</strong></td>
<td>Unifying human and machine <strong>functional models</strong> across level 0 to 3 (STDF Ch3)</td>
<td>Formal models across level 0 to level 3 fusion (IS/ODDA – Ch 04)</td>
<td><strong>Operational process models</strong> across level 0 to level 5 fusion (DIFG/IFSA Ch02)</td>
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<td><strong>Semantic Challenge</strong></td>
<td><strong>Axiomatic semantics</strong> in First Order Logics (FOLs) and Description Logics (DLs) covering various metaphysical, environmental, functional, cognitive and social concepts</td>
<td><strong>Axiomatic semantics</strong> in Modal Logics covering various metaphysical, environmental, and functional concepts (Ch 4)</td>
<td><strong>Operational semantics</strong> of computational models to infer meaning over environmental, functional, cognitive and social concepts (Ch 2, Ch13, Ch 15)</td>
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<td><strong>Cognitive agents</strong> with semantic, epistemic (declarative facts and rules) and episodic (procedural cognitive routines) long-term memories</td>
<td><strong>User (agent)</strong> with semantic, epistemic (facts and rules), and episodic (procedural) interactive goals. Belief Theory (Ch 4, 7, Ch14)</td>
<td><strong>Agents</strong> for workflow and service-based semantic, epistemic (facts and rules) and episodic (procedures) information processing (Ch5)</td>
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<td><strong>Interface Challenge</strong></td>
<td><strong>Interactive virtual news</strong> engaging virtual advisers, battlespace, interactive planning rooms, video, &amp; newspapers (web pages), Lexpresso controlled natural language</td>
<td><strong>Semantic and symbology</strong> presentation, visualization, and interactive sensor and mission management (Ch 6, Ch 7, Ch 9)</td>
<td><strong>Visualizations</strong> for a Common Operational Picture (COP) with symbologies, info.management, and collaboration tools (Ch 9). <strong>User refinement</strong> support to fusion methods with cognitive theory (Ch10)</td>
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<td><strong>System Challenge</strong></td>
<td>Legal <strong>agreements between combinations of CDIFT connected human and machine cognitive agents</strong> based on formal semantic theories</td>
<td><strong>OODA-based agent</strong> (Ch 7), state-space approach, belief networks (Ch 4, Ch 7,Ch 14)</td>
<td>Use of <strong>ontologies</strong> and workflow/service/human agents for the CDIFT. Coordination of user/machine fusion methods based on information needs and tools (Ch10, Ch13, Ch16)</td>
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<td>Use of <strong>synthetic development environments</strong> containing track data, intelligence reports, and various domain knowledge</td>
<td><strong>Track data, intelligence reports, various domain knowledge, simulations</strong> (Ch 6, Ch12)</td>
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<td><strong>Evaluation Challenge</strong></td>
<td><strong>Probabilistic propositional set disparity measures</strong> based on random inference networks</td>
<td><strong>OODA agents</strong> operate in a distributed feedback loop (Ch 7) Model checking techniques (Ch 14)</td>
<td><strong>Bayes networks</strong> to measure probabilistic variations from Operational Conditions (Ch 13) and derivation of MOEs from MOPs (Ch 10)</td>
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</table>
Paradigm Challenge: How should the interdependency between the sensor fusion and information fusion paradigms be managed?

Models: US IFSA framework (Ch 2); the AUS STDF framework (Ch 3); and the Canadian IS framework (Ch 4).

COMMON:
• Promote situations as a fundamental construct of the world.
• Utilize the machine interpretation of situations and the machine prediction of situations in the world.
• Represent situations in machines through states and time stepped transitions between states.

CONTRAST:
• Situations: represented very formally under the IS and STDF frameworks less formally under the IFSA framework.
• Machine processing of situations is characterized by formal logics under the IS and by functional architecture process models under the STDF and IFSA
**Semantic Challenge:** What symbols should be used and how do those symbols acquire meaning?

**Meaning:** US IFSA framework (Ch 2); the AUS STDF framework (Ch 3); and the Canadian IS framework (Ch 4).

**COMMON:**
- **States** are implemented as knowledge representations within the machine.
- Knowledge representations can express sophisticated concepts well beyond sensed characteristics.
- **Transitions** between states are understood as graphs.

**CONTRAST:**
- **Semantics:** IS and IFSA implement state vectors with operational semantics, **STDF:** *Mephisto* engages propositional formulae with axiomatic semantics.
- **State Transitions:** IS and IFSA models use directed graphs.
  - **STDF:** graphs, expressed as regular expression cognitive routines with procedural semantics (see Ch 12 for example), but actual state transitions are simply expressed through knowledge base content.
Epistemic Challenge: What information should we represent and how should it be represented and processed within the machine?

Complexity: Social Relationships

COMMON:

- Processing emphasis shifts from the world to the machine.
- LLIF processing is machine extracting content from information sensed.
- HLIF processing is machine imposing content on the sensed information.
- HLIF machines are termed agents.

- HLIF agent can only infer that a sensed airborne object poses a threat if it imposes background knowledge about alliances, possible targets, et cetera.

CONTRAST:

- Cognition:
  - STDF: ATTITUDE TOO Cognitive Model
  - IS/C-OODA: Cognitive-OODA model (Ch 10)
  - IFSA: User refinement composes cognitive refinement (UDOP)
**Interface Challenge:** How do we interface people to complex symbolic information stored within machines to provide **decision support**?

**Linking:** Human Situation Awareness with Machines

**COMMON:**

- **Pairing** involves **interfaces across** the different levels of fusion
- **Interface technology** moves beyond the traditional “dots on maps” and “lines on maps” technology of LLIF (UDOP in Ch 9, command and control graphical user interface in Ch 7 and HiCOP in [4, 12, 13]).

**CONTRAST:**

- **Modeling:**
  - **IS/C-OODA** and **STDF** **same** modal logic framework to both people and machines.
  - **IFSA** introduces **additional fusion** levels
- **Role of Human**:
  - **IFAS** : obtaining and utilizing **human SAW**;
  - **IS/C-OODA**: directed toward **decision support**
  - **STDF**: **agnostic** toward what is performed by humans and machines.
**System Challenge:** How should we manage information fusion systems formed from combinations of people and machines?

**Distributed:** Collections of humans and clusters of machines: CoABS (Ch 06), IS (Ch 14), and LAP (Ch 08)

**COMMON:**
- Information management is deemed fundamental (Ch 5, TTCP C3I TP3).
- Distributed infrastructure is used to facilitate interaction between clusters of fusion machines (CDIFT Ch 6 and INFORM Ch 7).
- CDIFT as common HLIF testbed (TP1) - support interoperable fusion products.

**CONTRAST:**
- Coordination: to manage multi-agent engagements
  - IS/C-OODA and IFAS use a game theoretic model for agent interaction
  - STDF: employs an agreement protocol for agent interaction
  - Ch 6 (TP3) Agent-based systems (CoABS) framework (Ch 6) employs the knowledge acquisition in automated specification (KAoS) system to resource constrain distributed agents.
**Design Challenge:** How should we design information fusion systems formed from combinations of **people and machines**?

**Content:** Role of Agent

**COMMON:**
- Agent imposing content on the sensed information
- promotion of a **scenario-based approach** to the development of HLIF
- HLIF design system cannot occur without a rich **context of the world** in mind.
- Multi-national collaboration.

**CONTRAST:**
- **Fidelity**: to manage various levels of design
  - IS/C-OODA and IFAS use a hierarchical model
    - IFSA uses **operational conditions** of sensor, target, and environment
  - STDF: employs a similar design across levels for design
Evaluation Challenge: How should we evaluate the effectiveness of information fusion systems?

**Metrics:** IFSA (Ch15), IS/C-OODA (Ch 7, Ch14), STDF [14]

**COMMON:**
- Use of goals and missions
- Measures of content similarity or disparity assessments.

**CONTRAST:**
- IFSA and IS/C-OODA includes a number of SA measures
  - MOPs: based on activities,
  - Evidential reasoning to measure probabilistic relations,
  - Game theory to measure action tradeoffs, and
  - MOEs: Information theory for situation analysis
- The Australian offering [14] promotes probabilistic measures of the disparity between sets of propositions.
Lesson 01: HLIF Overview

1. Overview the HLIF problem (~ 1 hour)

   HLIF Architectures: JDL to Data Fusion Information Group (DFIG)

   Grand Challenges
   - Paradigm, Semantic, Epistemic: HLIF Purpose
   - Interface, System: HLIF Management
   - Design, Evaluation: HLIF Design
   - Set up analysis of SAW/SA (functional)

   SA Approaches
   - Process (DFIG) – US [Blasch, Salerno, Tangney]
   - Interpreted Systems (IS) /ODDA – Canada [Bosse, Jousselme/Maupin, Valin]
   - State Transition Data Fusion (STDF) – AUS [Lambert]

   Common Issues: Metrics, Design, Future Concentrations

2. Methods for Situation Awareness (~ 1 hour)

3. Develop a IF Management and System Level Design (~ 1 hour)

4. Demonstrate HLIF Evaluation and Scenario Design (~ 1 hour)
HLIF Book Outline

Information Fusion Concepts and Representations

2. The IFSA Model
3. The STDF Model
4. Interpreted Systems

Distributed Information Fusion and Management

5. Role of Information Management
6. Coalition Testbed
7. INFORM Testbed
8. Legal Agreement Protocol

Information Fusion Evaluation

5. Role of Information Management
6. Coalition Testbed
7. INFORM Testbed
8. Legal Agreement Protocol

Human System Interaction

9. UDOP
10. C-OODA

Scenario-Based Design

11. SBD Applications
12. Coalition Approach
13. Operation Condition Model

15. Measures of Worthiness
16. Measures of Effectiveness
Australia Contributions
State Transition Data Fusion (STDF)

<table>
<thead>
<tr>
<th>Level</th>
<th>World</th>
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<td>Level 3</td>
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<tr>
<td>Machine</td>
<td>Observable Assessment</td>
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Canada Contributions
Interpreted System (IS) and OODA Agents

Formal Models
- Interpreted Systems
  - Model checking
- Algebraic Frameworks
- Generalized Information Theory
- Category Theory
- Formal Methods
  - Theorem proving
  - Completeness theorem proving
- Specification Languages
  - Software design cycle

Awareness $A$, $\phi$

Implicit Knowledge $K$, $\phi$

Explicit Knowledge $X$, $\phi$
Information Fusion Situation Awareness
Data Fusion Information Group and SA Reference Model

Real World

Information Fusion

Explicit Fusion
- Object Recognition And Tracking

Tacit Fusion
- Situation Assessment
  - Knowledge of ‘Us’
  - Impact (Changes)

Human Decision Making
- A Mental State
- Level 5

Platform
- New Revised Models and Collection Requirements

Mission Management
- Knowledge Representation/Discovery
- Reasoning

Resource Management
- Unique for book, not intended to be a new model

Ground Station
- Sensor mgt
- Data mgt

Data Fusion Information Group
- SOUICE
- DATASTA

HLIF Figure 2.8
Lesson 01: HLIF Overview

1. Overview the **HLIF problem** (~ 1 hour)

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   **Common Issues:** Metrics, Design, Future Concentrations

2. Methods for **Situation Awareness** (~ 1 hour)

3. Develop a **IF Management and System Level Design** (~ 1 hour)

4. Demonstrate **HLIF Evaluation and Scenario Design** (~ 1 hour)
### IF Quality of Service Performance Measures

<table>
<thead>
<tr>
<th>COMM</th>
<th>Human Factors</th>
<th>Info Fusion</th>
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<td>Reaction Time</td>
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<td>Acquisition /Run Time</td>
<td>Update Rate</td>
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<td>Confidence</td>
<td>Confidence</td>
<td>Prob. (Hit)</td>
<td>Probability of Detection</td>
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<td>Delay Variation</td>
<td>Attention</td>
<td>Accuracy</td>
<td>Positional Accuracy</td>
<td>Covariance</td>
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<td>Throughput</td>
<td>Workload</td>
<td>Throughput</td>
<td># Images</td>
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<tr>
<td>Cost</td>
<td>Cost</td>
<td>Cost</td>
<td>Collection platforms</td>
<td>No. Assets</td>
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Increasing Operational Relevance and Semantic Specificity

Multi-sensor Data
Situation Assessment

Information Management

User Coordination
Scenario-Based Design

Evaluating and Validating Assessment of Information Association

SAR/EO ILCD SAR OLCD EO OLCD

HSI/IR

Sensor, User Cueing

Coalition - DIFT Model

STDF Model

OOODA Model

Data, Info, Management

TESTBEDS
House of Quality

Correlation:
- **Very Strong Relationship**
- **Strong Relationship**
- **Weak Relationship**
- **Research Selection**

**Engineering Characteristics**

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<th>User Requirements</th>
<th>Importance to User</th>
<th>Information Quality</th>
<th>Knowledge Representation</th>
<th>Situation Awareness</th>
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Previous Texts

Focus of the text
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Summary

1. Overview the HLIF problem (~ 1 hour)
   - Architecture, domain, algorithms, purpose (SA Approaches)
   - Utilized the grand challenges to organize the tenets of HLIF
   - Compared and Contrasted three methods of HLIF
   - Set up analysis of SAW/SA (functional)
   - HLIF as a Science
     - Theory: Understanding of Situation Awareness
     - Modeling: Information (versus data) Management
     - Measurement: Metrics of Information Quality
     - Estimation: Develop notions of SA Prediction/Projection

2. Methods for Situation Awareness (~ 1 hour)

3. Methods for IF Management and System Level Design (~ 1 hour)

4. Demonstrate HLIF Evaluation and Scenario Design (~ 1 hour)
Lesson 01 Notes: