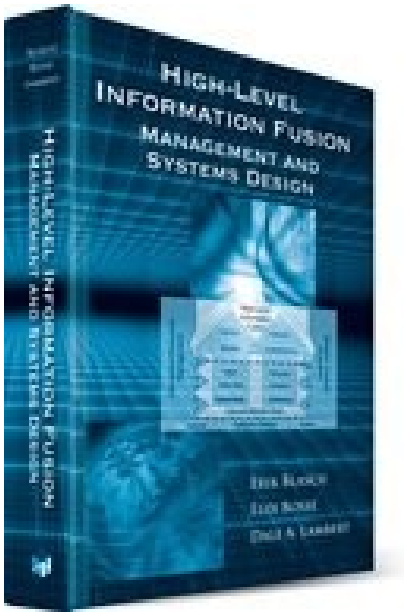
High-Level Information Fusion Management and Systems Design

Lesson 1: HLIF Overview and Motivation



Erik Blasch

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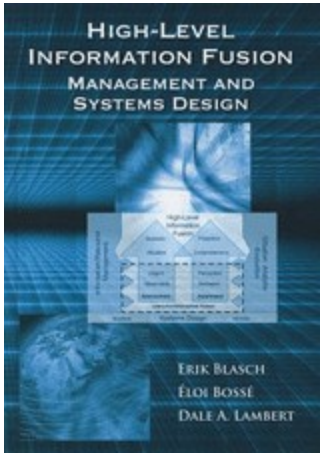
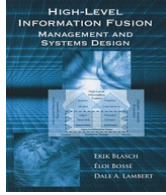
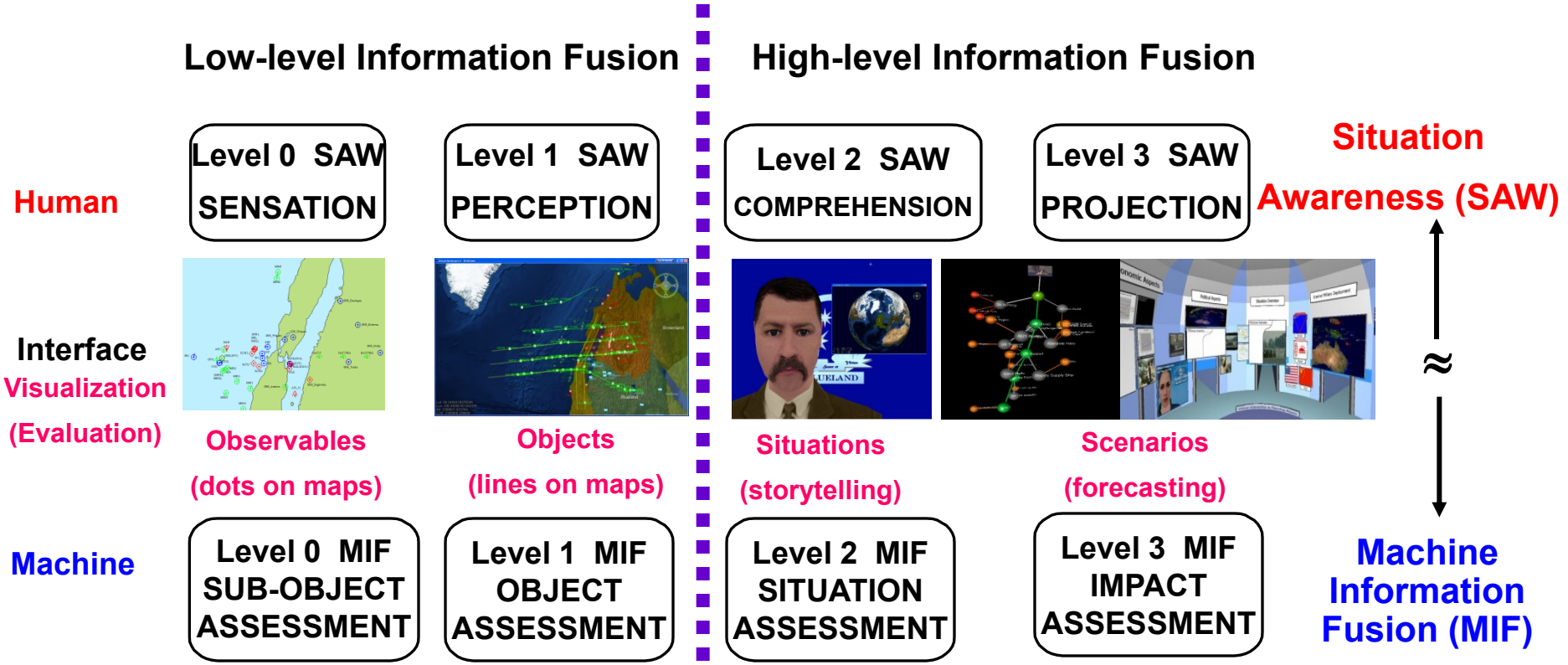


Overview



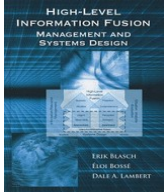


Decompose problem into elements of **LLIF** and **HLIF**

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
The Role of Information Fusion Management to Support High-Level Fusion. Coalition Distributed Information Fusion Testbed. Information Fusion and Resource Management Testbed. The Legal Agreement Protocol.

Part III: Human-System Interaction
User-Defined Operating Picture (UDOP). User Information Fusion Decision Making Analysis with the Cognitive Observe-Orient-Decide-Act (C-OODA) Model.

Part IV: Scenario-Based Design
Scenario-Based Design for Situation Analysis. A Coalition Approach to Higher-Level Fusion. Operating Condition Scenario Modeling for Information Fusion Assessment.

Part V: Measures of Effectiveness
A Toolbox for the Evaluation of Surveillance Strategies Based on Interpreted Systems. Measuring the Worthiness of Situation Assessment. Measures of Effectiveness for High-Level Information Fusion.

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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.

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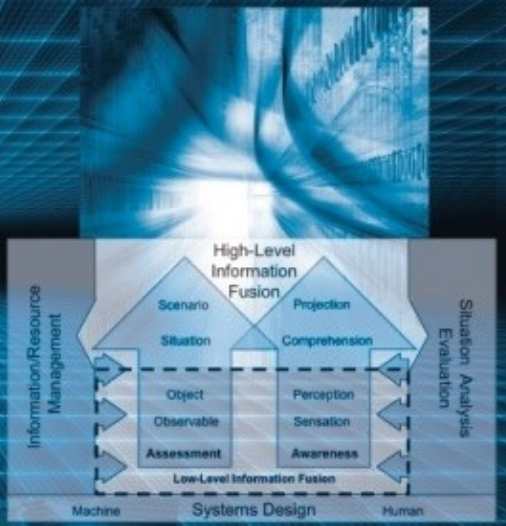
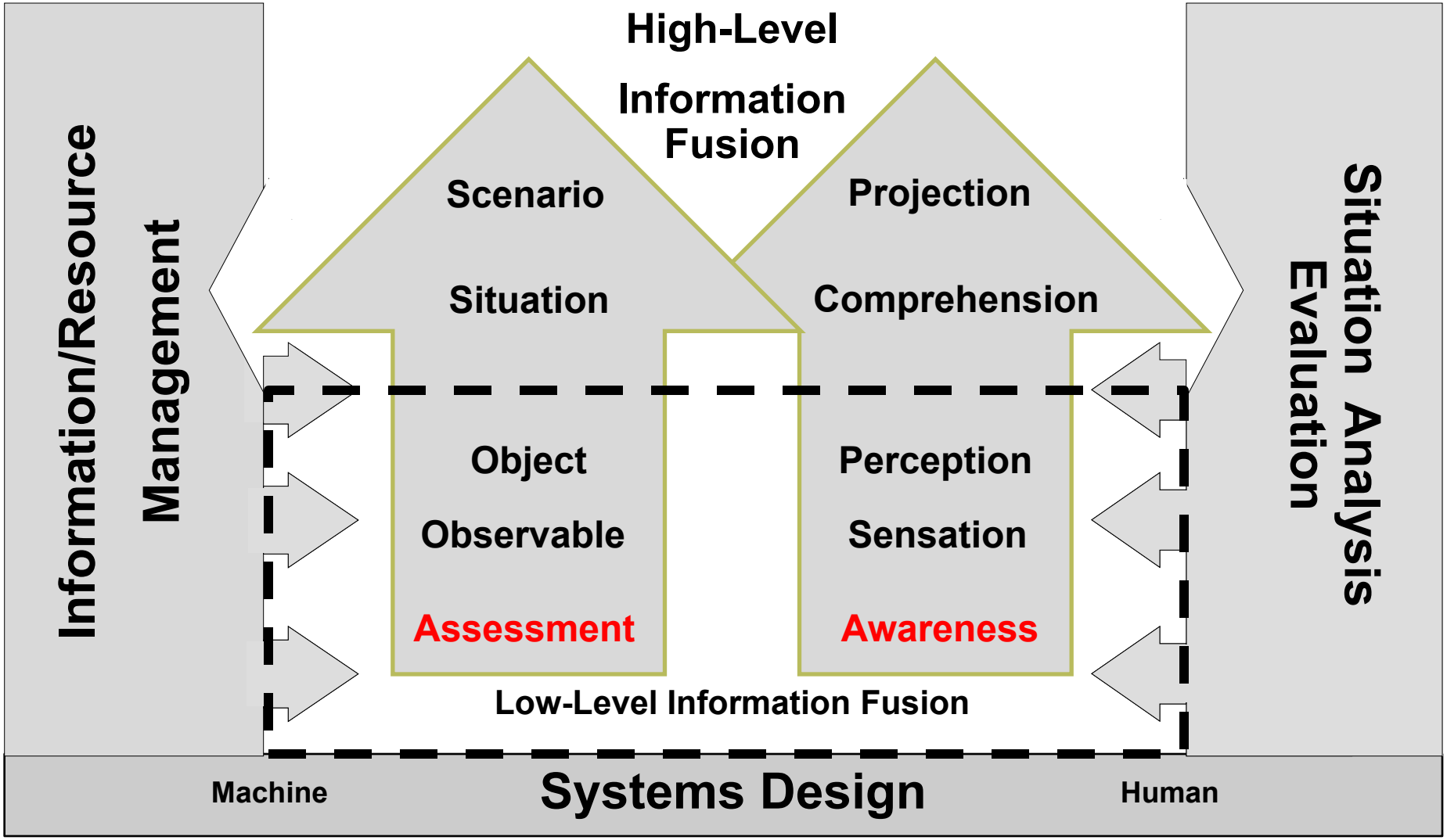
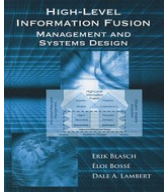


ERIK BLASCH
ÉLOI BOSSÉ
DALE A. LAMBERT

Final Book Cover



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

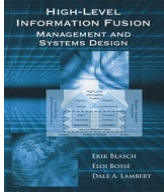
3) COMMUNITY

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

Distributed Information Fusion and Management

2. The IFSA Model

3. The STDF Model

4. Interpreted Systems

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

Scenario-Based Design

14. Int. Sys. Evaluation Toolbox

15. Measures of Worthiness

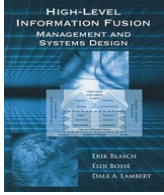
16. Measures of Effectiveness

11. SBD Applications

12. Coalition Approach

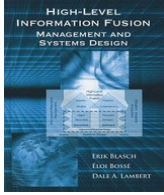
13. Operation Condition Model

High-Level Information Fusion
Management and Systems Design



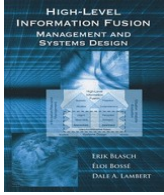
1. Overview the HLIF problem (~ 1 hour)
   - Architecture, domain, algorithms, purpose (SA Approaches)
2. Methods for Situation Awareness (~ 1 hour)
   - Set up analysis of SAW/SA (functional)
   - Describe three types of approaches
   - Process, Interpreted, and State Transition
   - Develop notions 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

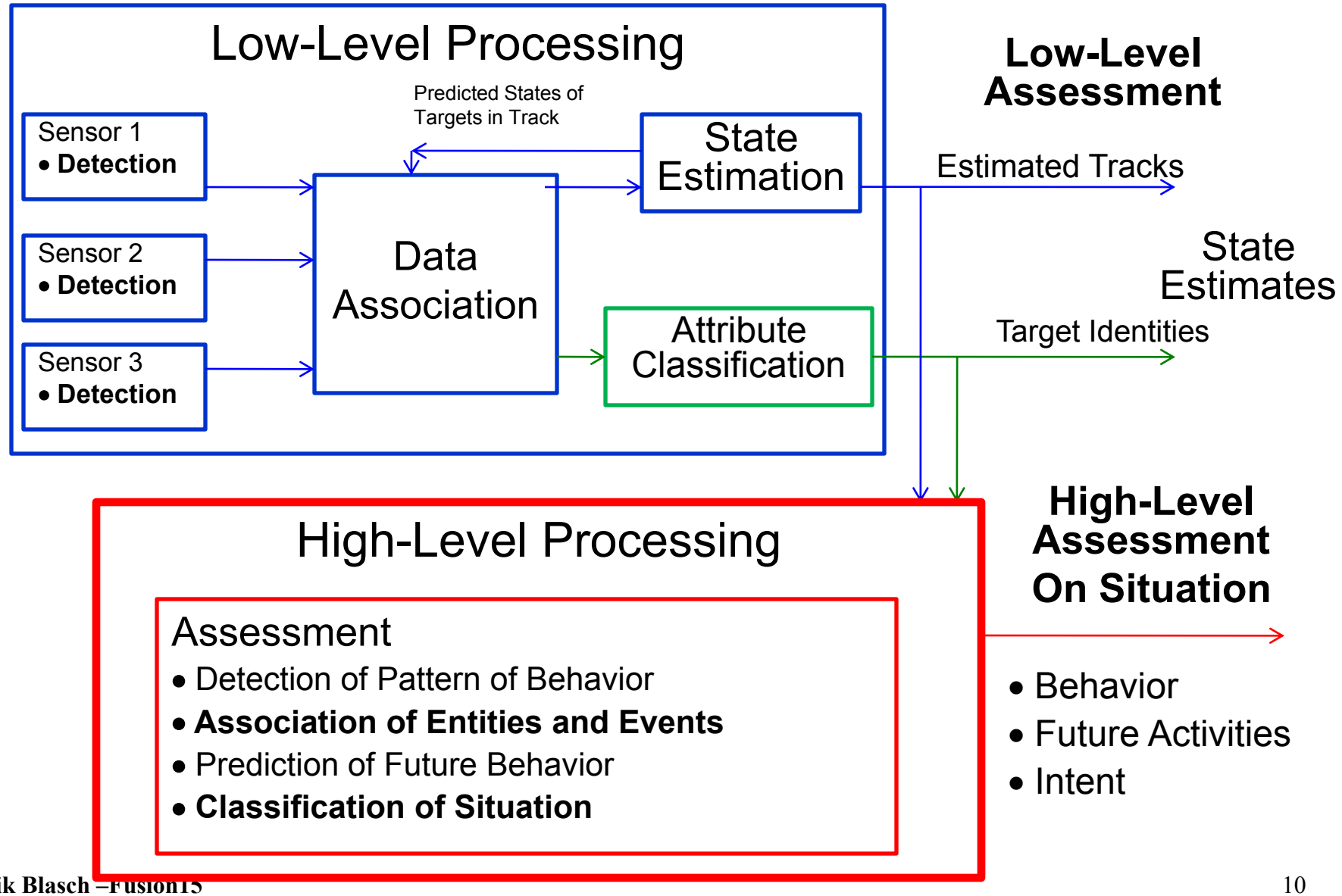
2. Methods for Situation Awareness (~ 1 hour)

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

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

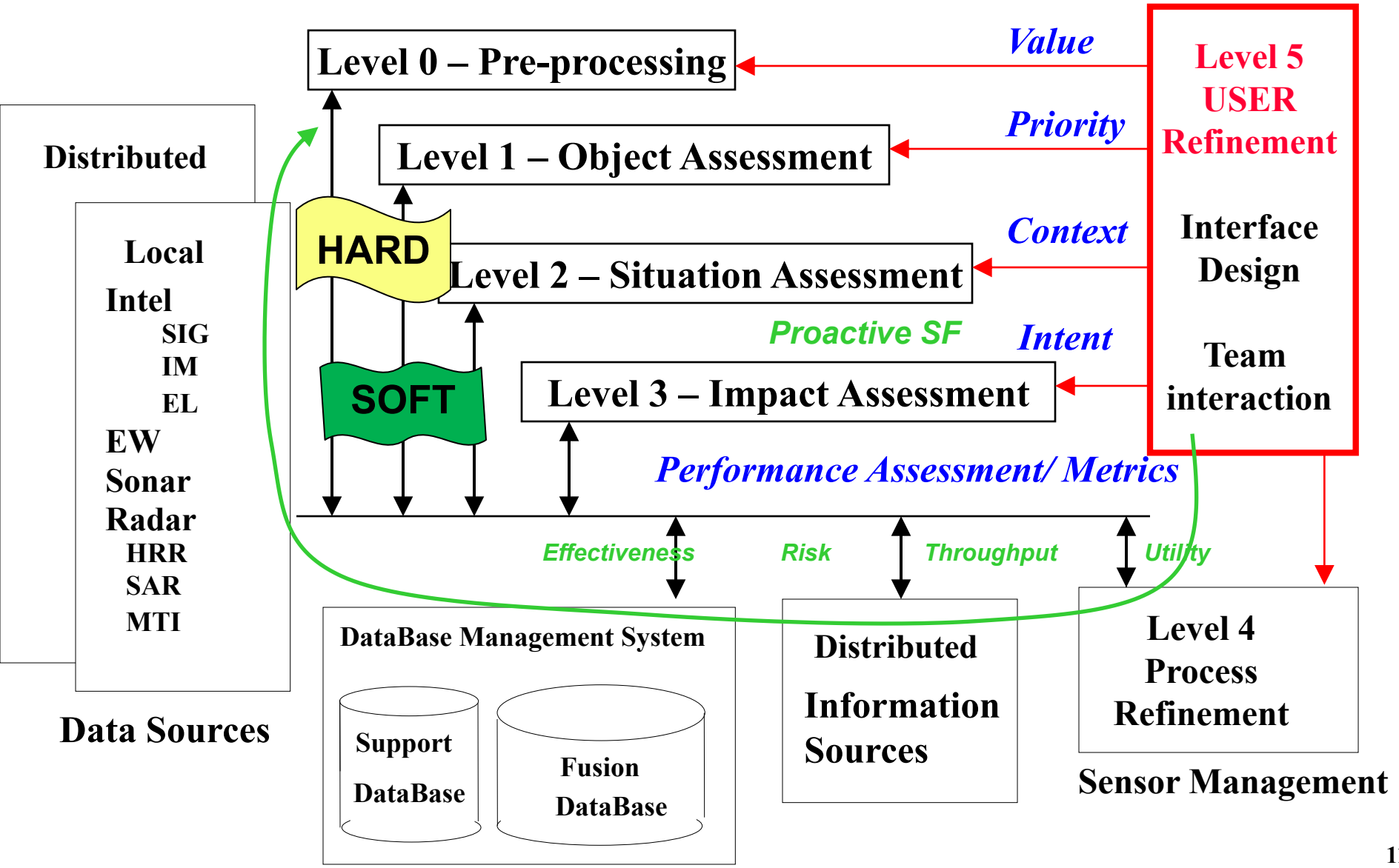
High Level Fusion

Adapted from E. Waltz and J. Llinas, *Multisensor Data Fusion,* Artech House, Norwood, MA [1990])



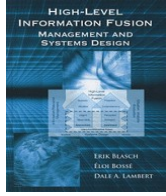
User Fusion Model

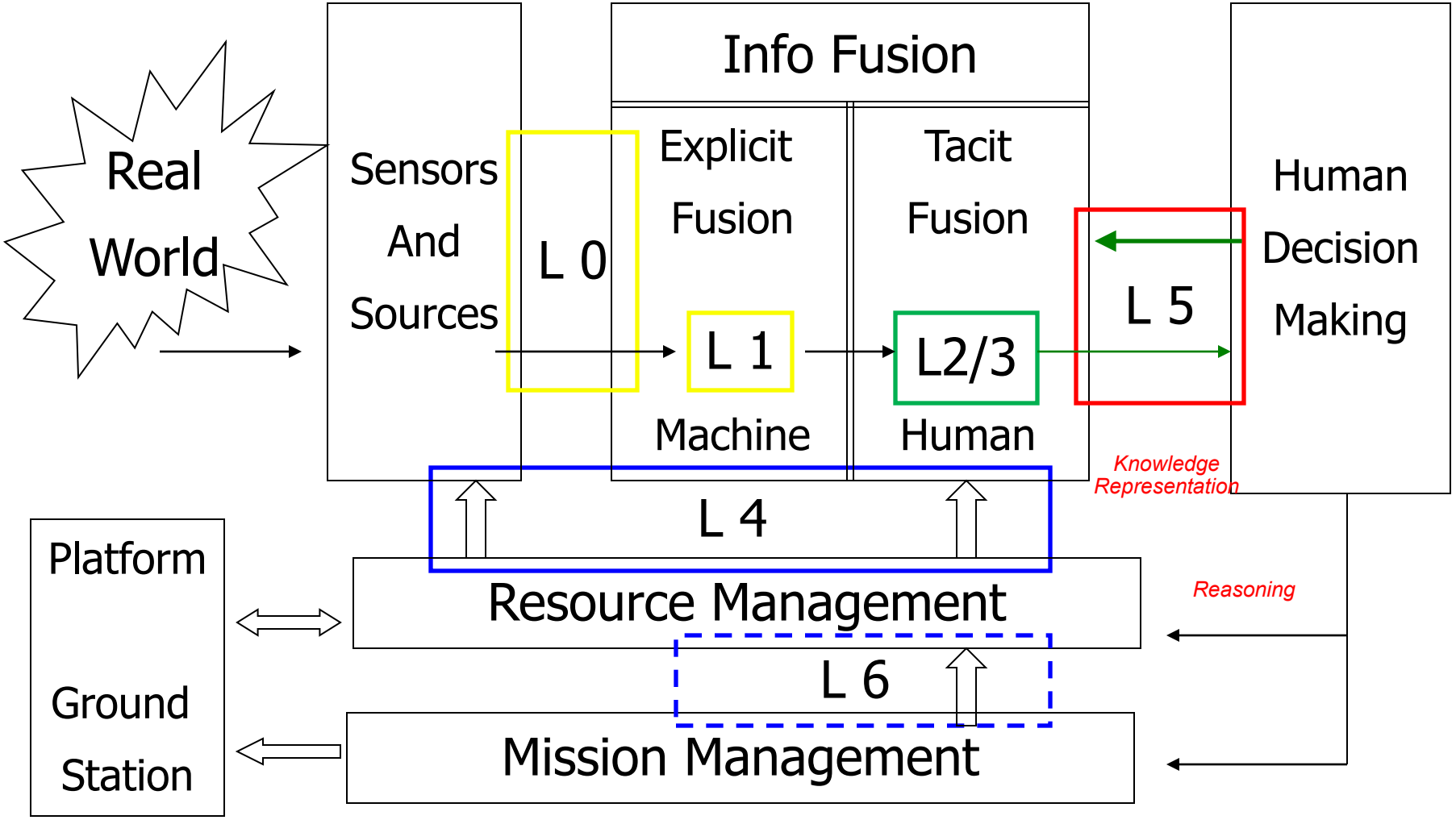
From E. Blasch and S. Plano, "DFIG Level 5 (User Refinement) issues supporting Situational Assessment Reasoning," *Int. Conf. on Info Fusion - Fusion 05*, July 2005.



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, "Issues and challenges of knowledge representation and reasoning methods in situation assessment (Level 2 Fusion)", *J. of Advances in Information Fusion,* Dec. 2006.

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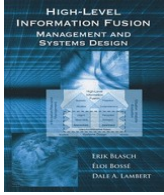


Low Level Information Fusion (LLIF)

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).

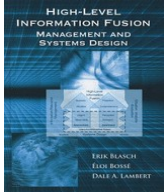
Level 5 – User Refinement (an element of Knowledge Management): adaptive determination of who queries information and who has access to information (e.g. information operations) and adaptive data retrieved and displayed to support cognitive decision making and actions (e.g. human computer interface).

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.

E. Blasch, I. Kadar, J. Salerno, M. M. Kokar, S. Das, G. M. Powell, D. D. Corkill, and E. H. Ruspini, "Issues and challenges of knowledge representation and reasoning methods in situation assessment (Level 2 Fusion)", *J. of Advances in Information Fusion,* Dec. 2006.

Fusion Model Comparisons

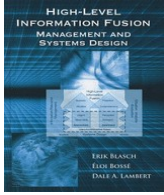
E. Blasch, R. Breton, P. Valin, and E. Bosse, "User Information Fusion Decision Making Analysis with the C-OODA Model," *Int. Conf. on Info Fusion - Fusion11*, 2011.



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

* **DFIG** (Data Fusion Information Group), SA(Situation Assessment) - *J. of Adv. in Info. Fusion*, Dec. 2006.
* **C-OODA** (Cognitive Observe, Orient, Decide, Act) – *Fusion11*, 2011

Lesson 01: HLIF Overview



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Grand Challenges

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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]

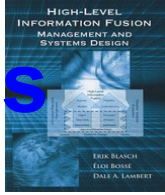
Common Issues: Metrics, Design, Future Concentrations

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?

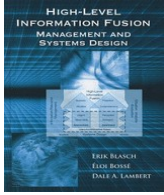
System Challenge: How should we manage information fusion systems formed from combinations of people and machines?

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)

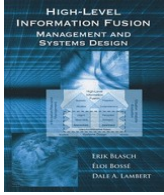
State Transition Data Fusion (STDF)



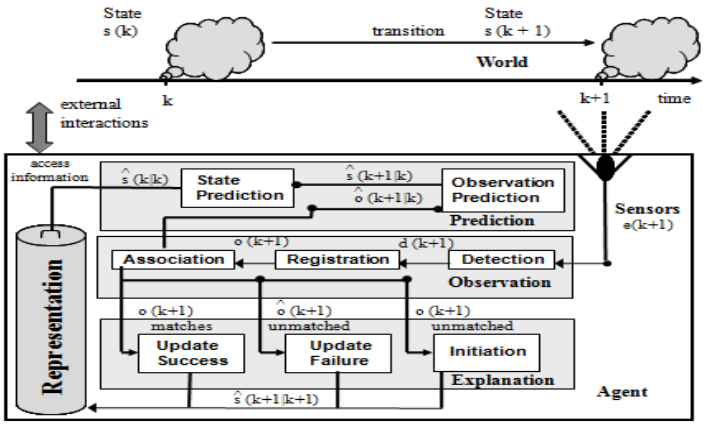
	Conceptual Theory	Theory Representation	Theory Implementation
Paradigm Challenge	State Transition Data Fusion (STDF) Model (**Ch 3**)	**Unifying human and machine functional models** across level 0 to level 3 situation awareness and fusion	Signal/Text/Image processing with a distributed multi-agent architecture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

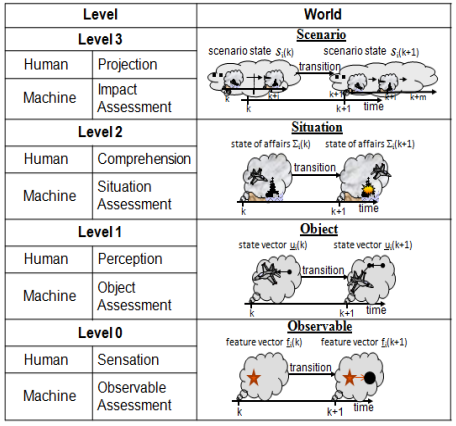
Australia Contributions (2)

State Transition Data Fusion (STDF)



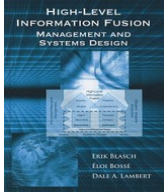
	Conceptual Theory	Theory Representation	Theory Implementation
System Challenge	Legal Agreement Protocol (LAP) (**Ch 8**) on the Coalition Distributed Information Fusion Testbed (CDIFT) (**Ch 6**)	Legal **agreements between combinations of** CDIFT connected **human and machine cognitive agents** based on formal semantic theories	LAP through agent cognitive routines on CDIFT using HLA, JBI, CoABS grid, Elvin, XMPP, XACML
Design Challenge	Synthetic North Atlantis Environment (**Ch 12**)	Use of **synthetic development environments** containing track data, intelligence reports, and various domain knowledge	Stage, domain knowledge, track data, GIS, Lexpresso reports, and agents on CDIFT
Evaluation Challenge	Evaluation of Situation Assessment ([14])	**Probabilistic propositional set disparity measures** based on random inference networks	Mephisto, Prolog





Canada Contributions (1)

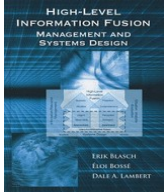
Interpreted System (IS) and OODA Agents



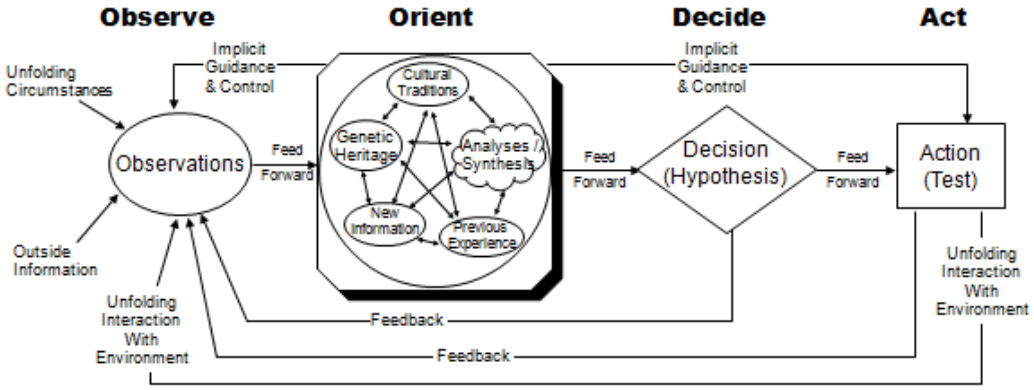
	Conceptual Theory	Theory Representation	Theory Implementation
Paradigm Challenge	Interpreted Systems (**Ch 4**)	**Formal models** across level 0 to level 3 fusion	Pursuit-evasion in graphs (**Ch 14**)
Semantic Challenge	Interpreted Systems (**Ch 4**)	**Axiomatic semantics** in Modal Logics covering various metaphysical, environmental, and functional concepts **(Ch 4)**	Game-theoretical analysis (**Ch 14**)
Epistemic Challenge	Cognitive Observe, Orient, Decide, Act Model (**Ch 10**) Interpreted Systems (**Ch 4**)	**User (agent)** with semantic, epistemic (facts and rules), and episodic (procedural) interactive goals. Belief Theory (**Ch 4, Ch 7, Ch14**)	Control theory for semantic interactions (**Ch 7**), Scenario-Based design (**Ch 11**), model-checking techniques (**Ch 14**)
Interface Challenge	Command and Control Graphical User Interface (**Ch 7, Ch 14**)	Semantic and symbology presentation, visualization, and interactive sensor and mission management (**Ch 6, Ch 7, Ch 9**)	UML operational-primed decision making for a defined scenario (**Ch 11**)
System Challenge	INFORM Testbed (**Ch 7**)	**OODA-based agent** (**Ch 7**), state-space approach, belief networks (**Ch 4, Ch 7,Ch 14**)	XML, GIS, J2SE

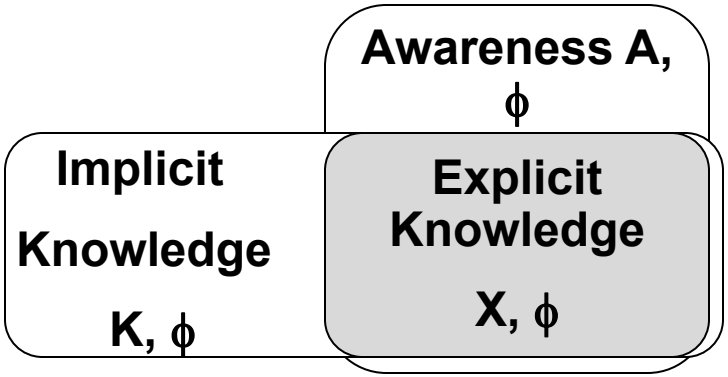
Canada Contributions (2)

Interpreted System (IS) and OODA Agents



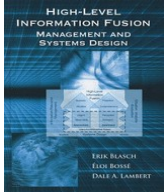
	Conceptual Theory	Theory Representation	Theory Implementation
Design Challenge	Synthetic North Atlantis Environment (**Ch 11, Ch 12**)	**Track data, intelligence reports**, various domain knowledge, simulations (**Ch 6**, **Ch12**)	Stage, GIS, agents on CDIFT (**Ch 6, Ch12**)
Evaluation Challenge	Theoretical development of measures of effectiveness (MOE) (**Ch 14, Ch 16**)	**OODA agents** operate in a distributed feedback loop **(Ch 7)** **Model checking** techniques **(Ch 14)**	Information quality measures and MOEs (**Ch 16**), "what-if" analyses (**Ch 7**)





United States Contributions (1)

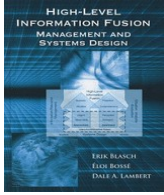
Information Fusion Situation Awareness (IFSA)



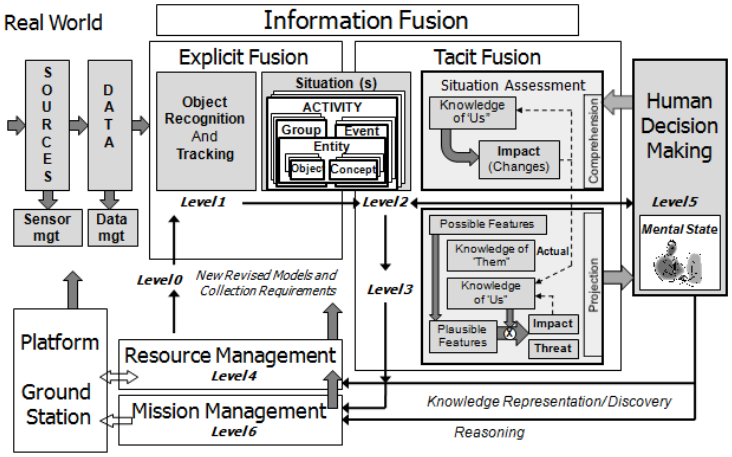
	Conceptual Theory	Theory Representation	Theory Implementation
Paradigm Challenge	Information Fusion Situation Assessment (IFSA) Model (**Ch 2**)	**Operational process models** across level 0 to level 5 fusion	Signal/Text/Image processing with a SA/SAW architecture (**Ch 15**)
Semantic Challenge	Development of IFSA taxonomy (**Ch 2**)	**Operational semantics** of computational models to infer meaning over environmental, functional, cognitive and social concepts (**Ch 2, Ch13, Ch 15**)	Numeric and Language fusion integration in a image (**Ch 10**) and cyber system (**Ch 15**)
Epistemic Challenge	Information Management Model (**Ch 5**)	**Agents** for workflow and service-based semantic, epistemic (facts and rules) and episodic (procedures) information processing (**Ch5**)	Agent routines in CDIFT (**Ch 6**) using HLA, JBI, CoABS grid, XML, XACML
Interface Challenge	User Defined Operating Pictures (UDOP) (**Ch 9**) with operational conditional assessment (**Ch 13**)	**Visualizations** for a Common Operational Picture (COP) with symbologies, information management, and collaboration tools (**Ch 9**). **User refinement** support to fusion methods with cognitive theory (**Ch10**)	Visualization tools to support SA for maritime surveillance (**Ch 7**), image analysis (**Ch 10**), target classification (**Ch 13**) and cyber threats (**Ch15**)

United States Contributions (2)

Information Fusion Situation Awareness (IFSA)

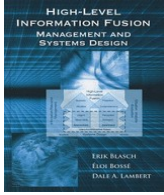


	Conceptual Theory	Theory Representation	Theory Implementation
System Challenge	Information Management Model (**Ch 5**) for the Coalition Distributed Information Fusion Testbed (**Ch 6**)	Use of **ontologies** and workflow/service/human agents for the CDIFT. Coordination of user/machine fusion methods based on information needs and tools (**Ch10, Ch13, Ch16**)	Agent routines in CDIFT (**Ch 6**) using HLA, JBI, CoABS grid, XML, XACML and user refinement (**Ch 10**, **Ch13, Ch15, Ch16**)
Design Challenge	Synthetic North Atlantis Environment (**Ch 12**)	Track data, intelligence reports, various **domain knowledge** (**Ch 6, Ch12**)	Stage, **GIS**, agents on CDIFT (**Ch 6, Ch12**)
Evaluation Challenge	Development of theoretical measures of effectiveness (MOE) (**Ch 16**)	**Bayes networks** to measure probabilistic variations from Operational Conditions (**Ch 13**) and derivation of MOEs from performance measures (**Ch 10**)	Development of MOEs for cyber analysis, (**Ch15**) and coastal surveillance (**Ch 16**)



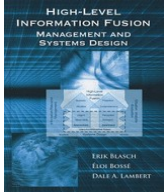
Joint HLIF Contributions

HLIF Perspectives for Paradigm Challenges



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

HLIF Compare and Contrast (1)



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).

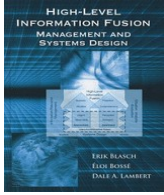
COMMON:

- 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 I**S** and by functional **architecture process models** under the **STDF** and I**FSA**

HLIF Compare and Contrast (2)



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).

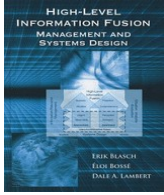
COMMON:

- **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.

HLIF Compare and Contrast (3)



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

Complexity: Social Relationships

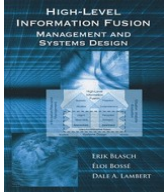
COMMON:

- *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)

HLIF Compare and Contrast (4)



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

Linking: Human Situation Awareness with Machines

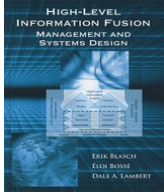
COMMON:

- **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.

HLIF Compare and Contrast (5)



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 (Ch08)

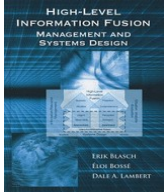
COMMON:

- **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.

HLIF Compare and Contrast (6)



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

Content: Role of Agent

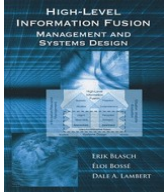
COMMON:

- **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

HLIF Compare and Contrast (7)



Evaluation Challenge: How should we evaluate the effectiveness of information fusion systems?

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

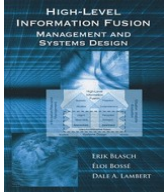
COMMON:

- *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]

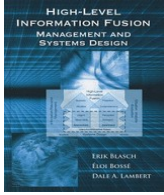
Common Issues: Metrics, Design, Future Concentrations

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

Distributed Information Fusion and Management

2. The IFSA Model

3. The STDF Model

4. Interpreted Systems

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

Scenario-Based Design

14. Int. Sys. Evaluation Toolbox

15. Measures of Worthiness

16. Measures of Effectiveness

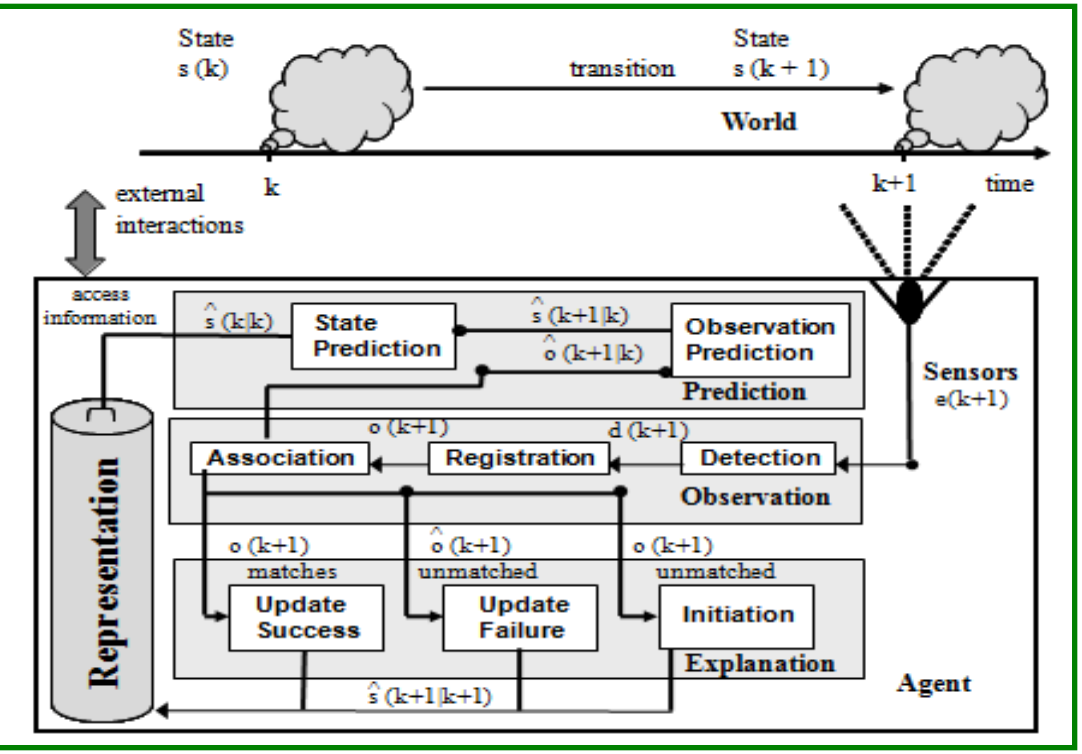
11. SBD Applications

12. Coalition Approach

13. Operation Condition Model

Australia Contributions

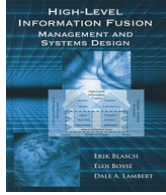
State Transition Data Fusion (STDF)

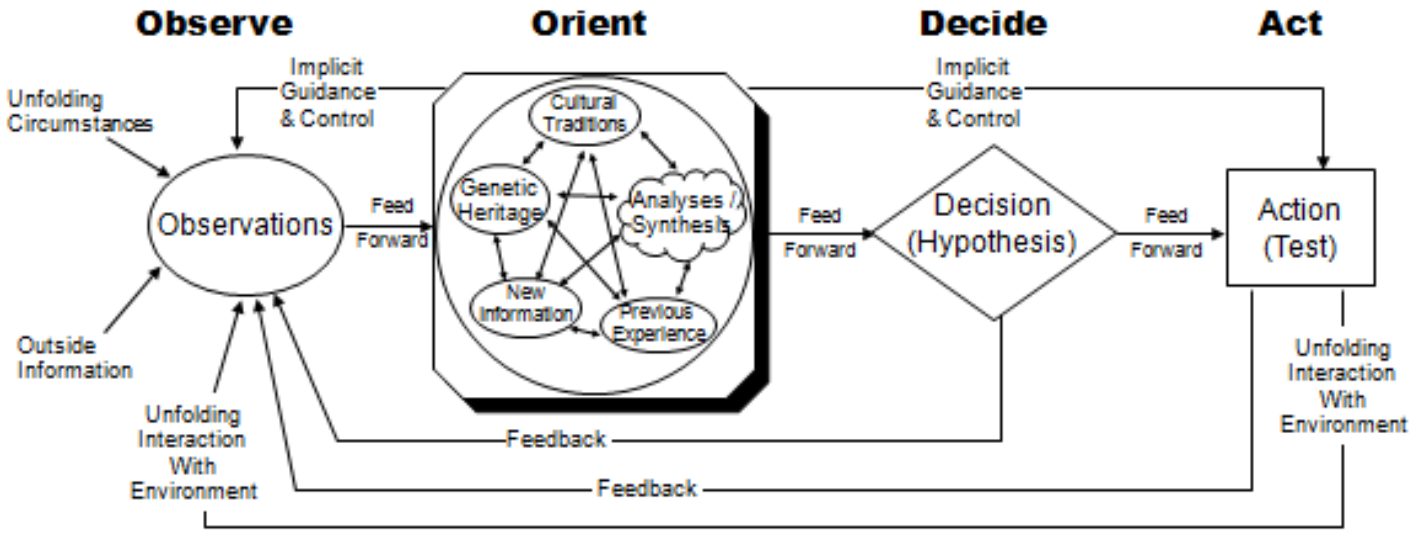


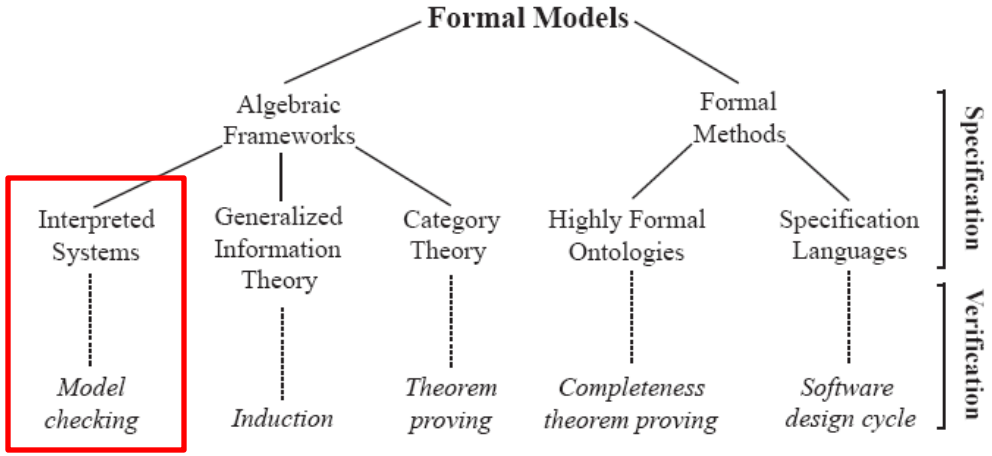
Level		World
Level 3		Scenario
Human	Projection	scenario state $S_i(k)$ scenario state $S_i(k+1)$ transition
Machine	Impact Assessment	k k+1 k+1 k+m k k+1 time
Level 2		Situation
Human	Comprehension	state of affairs $\Sigma_i(k)$ state of affairs $\Sigma_i(k+1)$ transition
Machine	Situation Assessment	k k+1 time
Level 1		Object
Human	Perception	state vector $\underline{u}_i(k)$ state vector $\underline{u}_i(k+1)$ transition
Machine	Object Assessment	k k+1 time
Level 0		Observable
Human	Sensation	feature vector $\underline{f}_i(k)$ feature vector $\underline{f}_i(k+1)$ transition
Machine	Observable Assessment	k k+1 time

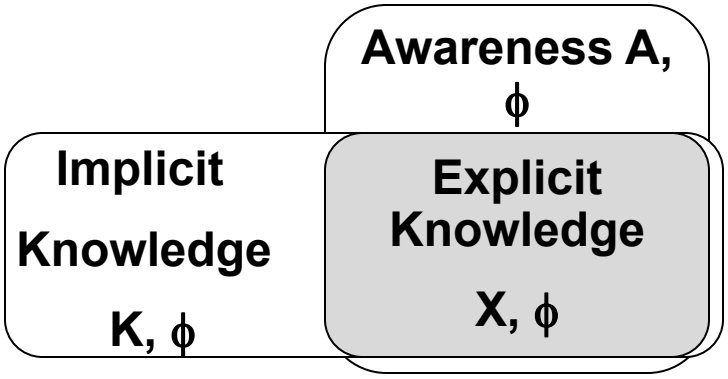
Canada Contributions

Interpreted System (IS) and OODA Agents



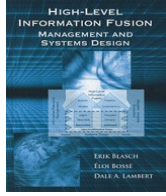






Information Fusion Situation Awareness

Data Fusion Information Group and SA Reference Model



Real World

Information Fusion

Explicit Fusion

Tacit Fusion

SOURCES

DATA

Sensor mgt

Data mgt

Object Recognition And Tracking

Situation(s)

Activity

Group

Event

Entity

Object

Concept

Situation Assessment

Knowledge of 'Us"

Impact (Changes)

Comprehension

Human Decision Making

Level 5

Level 1

Level 2

Level 3

Level 0

New Revised Models and Collection Requirements

Possible Features

Knowledge of 'Them"

Knowledge of 'Us"

Plausible Features

X

Impact

Threat

Projection

A Mental State

Platform

Ground Station

Resource Management

Level 4

Mission Management

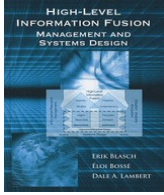
Level 6

Knowledge Representation/ Discovery

Reasoning

issue for book, not intended to be a new model

Lesson 01: HLIF Overview



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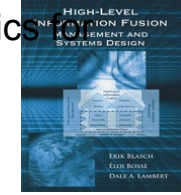
E. Blasch, M. Pribilski, B. Daughtery, B. Roscoe, and J. Gunsett, "Fusion Metrics for Dynamic Situation Analysis", *Proc. of SPIE,* Vol. 5429, April 2004.



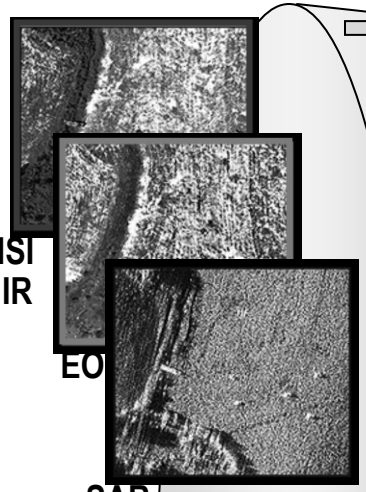
IF Quality of Service Performance Measures

COMM	Human Factors	Info Fusion	ATR	TRACK
Delay	Reaction Time	Timeliness	Acquisition /Run Time	Update Rate
Probability of Error	Confidence	Confidence	Prob. (Hit) Prob. (FA)	Probability of Detection
Delay Variation	Attention	Accuracy	Positional Accuracy	Covariance
Throughput	Workload	Throughput	# Images	No. Targets
Cost	Cost	Cost	Collection platforms	No. Assets
Stallings 2002	Wickens, 1992	Blasch, 2003	COMPASE Morrison	Blasch, (DDB) Hoffman 2000

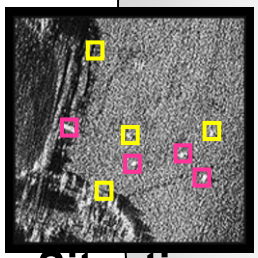
E. Blasch, I. Kadar, J. Salerno, M. M. Kokar, S. Das, G. M. Powell, D. D. Corkill, and E. H. Ruspini, "Issues and challenges of knowledge representation and reasoning methods in situation assessment (Level 2 Fusion)", *J. of Advances in Information Fusion,* Dec. 2006.

Increasing Operational Relevance and Semantic Specificity

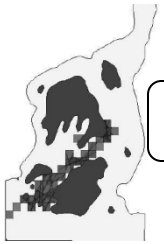
TESTBEDS



Multi-sensor Data



Situation Assessment

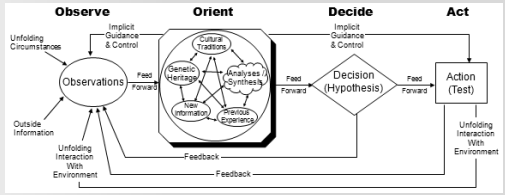


SA/SAW

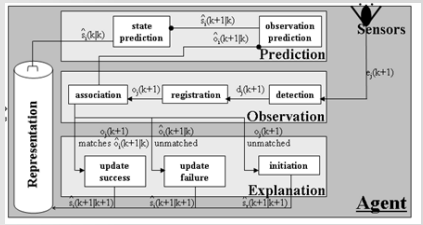
Awareness A, ϕ

Explicit Knowledge X, ϕ

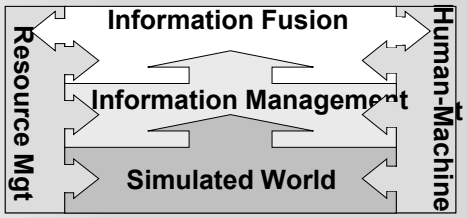
IS Model



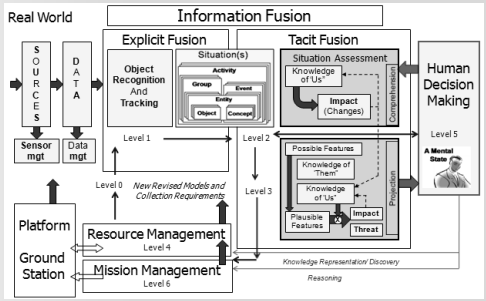
OODA Model



STDF Model



Coalition - DIFT Model

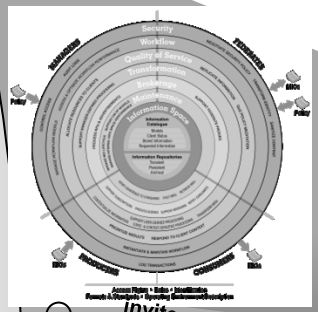


DFIG/ IFSA Model

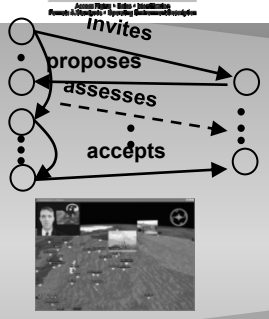
Data, Info, Management

Sensor, User Cueing

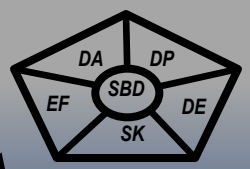
Situation Scenario Analysis



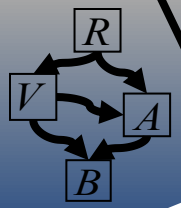
Information Management

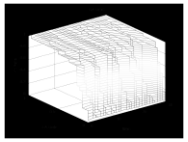


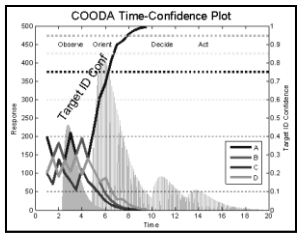
User Coordination



Scenario-Based Design



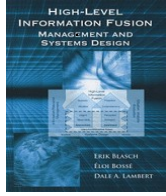




Evaluation

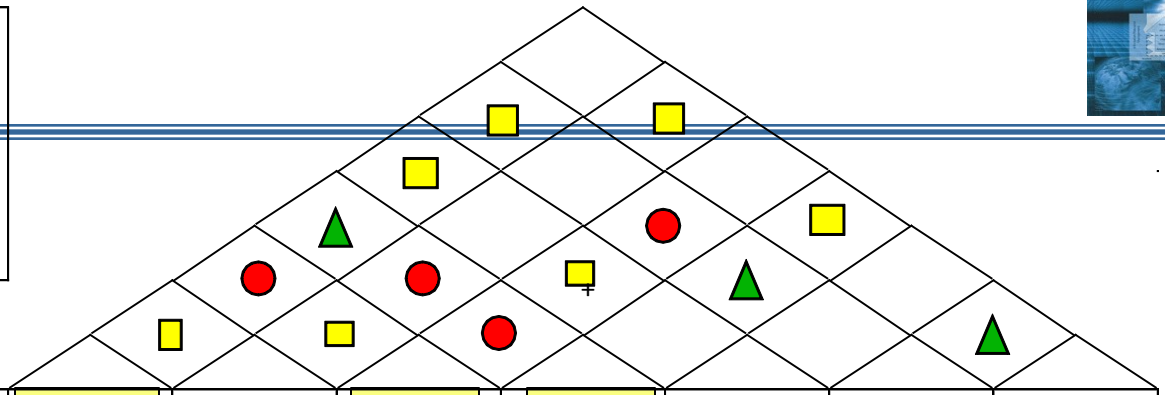
Verifying and Validating Assessment of Information Association

House of Quality



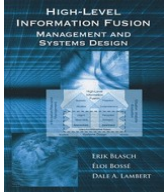
Correlation:

- Very Strong Relationship
- Strong Relationship
- Weak Relationship
- Research Selection



Engineering Characteristics		Information Quality	Knowledge Representation	Situation Awareness	Infomration Management Theory	ScenarioTesting	Human-Machine Interface	Coalition Standards Interoperable Semantics
User Requirements	Importance to User							
Accuracy	5	●	■	■	■	■		■
Timeliness	5	●		●	●		●	▲
Confidence	5	●	■	●	■	●	▲	●
Throughput	4	■	■		▲	▲	▲	
Cost	3		▲		●			
Relevance	4	■	●	■		●	■	■
Completeness	3	▲	●	●	●	■	■	■
Importance Weighting		4	4	5	5	3	3	4
Deployment		★		★	★			

Previous Texts



Focus of the text

[1] Bosse, E., Roy, J., and Wark, S., *Concepts, Models, and Tools for Information Fusion*, Artech House, Inc., Norwood, MA, 2007.

[2] Lambert, D. A., "Grand Challenges of Information Fusion," *Intl. Conf on Info. Fusion*, 2003.

[3] Blasch, E. P., Llinas, J., Lambert, D. A., Valin, P., Das, S., Chong, C-Y., Kokar, M. M, and Shahbazian, E., "High Level Information Fusion Developments, Issues, and Grand Challenges – Fusion10 Panel Discussion," *Intl. Conf on Info. Fusion*, 2010.

[4] Lambert, D. A., "A Blueprint for Higher-Level Fusion Systems," *Journal of Information Fusion*, Vol. 10, No. 1, pp. 6 – 24, 2009.

[5] Waltz, E., and Llinas, J., *Multisensor and Data Fusion*, Artech House, Norwood, MA, 1990.

[6] Blackman, S., and Popoli, R., *Design and Analysis of Modern Tracking Systems*, Artech House, Norwood, MA, 1999.

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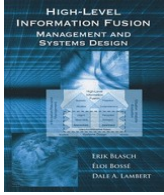
[8] Waltz, E., *Knowledge Management in the Intelligence Enterprise*, Artech House, Norwood, MA, 2003.

[9] Hall, D. L., and Jordan, J. M., *Human-Centered Information Fusion*, Artech House, Norwood, MA, 2010.

[10] Lambert, D. A., "Unification of Sensor and Higher-Level Fusion," presentation at *Intl. Conf on Info. Fusion*, 2006.

Information Not Included



Focus of the text

[10] Lambert, D. A., "Unification of Sensor and Higher-Level Fusion," presentation at *Intl. Conf on Info. Fusion*, 2006.

[11] Lambert, D. A., and Nowak, C., "The **Mephisto Conceptual** Framework," *DSTO Technical Report DSTO-TR-2162*, 2008.

[12] Wark, S., Lambert, D. A., Nowina-Krowicki, M., Zschorn, A., and Pang, D., "Situational Awareness: Beyond Dots On Maps To Virtually Anywhere," *SimTecT*, Adelaide AUS, 2009.

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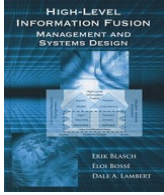
[14] Lingard, D., and Lambert, D. A., "Evaluation of the Effectiveness of Machine-based Situation Assessment," *Fourth Australian Conference on Artificial Life*, Melbourne Australia. 2009.

[15] Waltz, E., *Human Social Cultural Behavior Modeling and Fusion* – Tutorial, Oct. 2011.

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

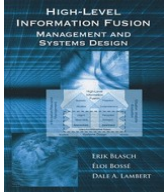
   Theory: Understanding of Situation Awareness

   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: