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Multi-Hypothesis Structures and Taxonomies for Combat Identification Fusion

Tod M. Schuck, J. Bockett Hunter, Daniel D. Wilson

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Agenda

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- Taxonomy f-refinement
- Partition Refinement
- Canonical Mapping
- Response Mapping
- CID Realization of JDL Model
- CID Bayesian Network
- CID Situational Awareness Fusion Expansion
- Conclusions and Future Work

Presentation Objective

We want to answer the question, "How can we establish the *relationship* between information sets such as needed for a fusion process????"

- Address movement of information across multiple hypothesis classes
  - Relate it to developing the identification of objects
  - Describe how it can be combined both within and between JDL levels
- Result will be an information architecture that is naturally adaptive to information regardless of quality, level, specificity

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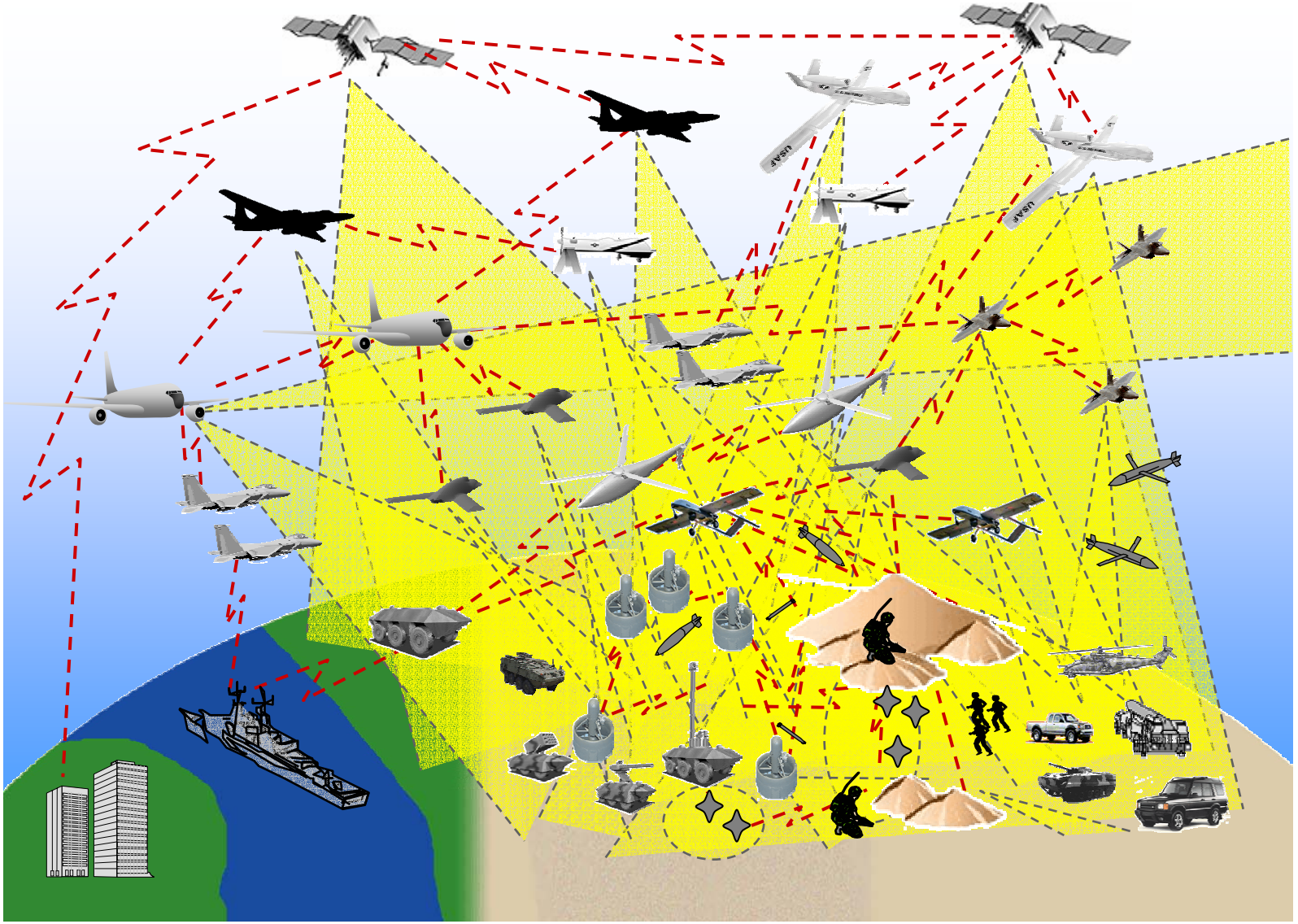
An Environment of Disparate Information…



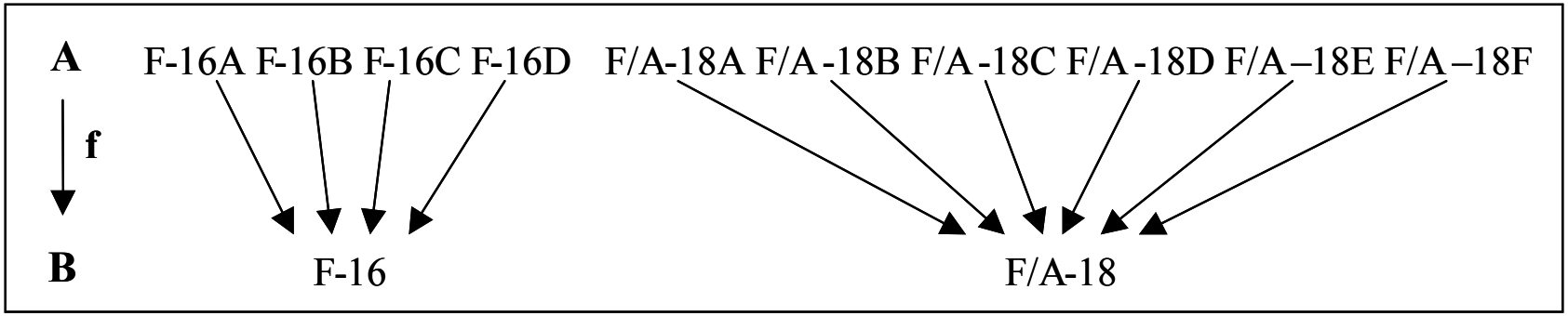
Solution Requires Good Architecture Definition

- Defining architecture requires investigation into detailed *taxonomic relationships* between information sets and subsequent canonical mappings
- Subsequent *response mapping* can be defined
- Results can be tied into JDL model

- Taxonomy – a classification scheme for objects with mutually exclusive labels (parallels study of ontologies)
  - CID {Friend, Assumed Friend, Hostile, etc.}
  - Nationality {US, Russia, France, Iraq, etc.}
  - Category {Air, Sea, Land, etc.}
  - Platform {Fighter, Bomber, Civil, etc.}
  - Type {F-14, F/A-18, F-22, etc.}
  - Class {F-14A, F/A-18D, etc.}

Taxonomy f-refinement

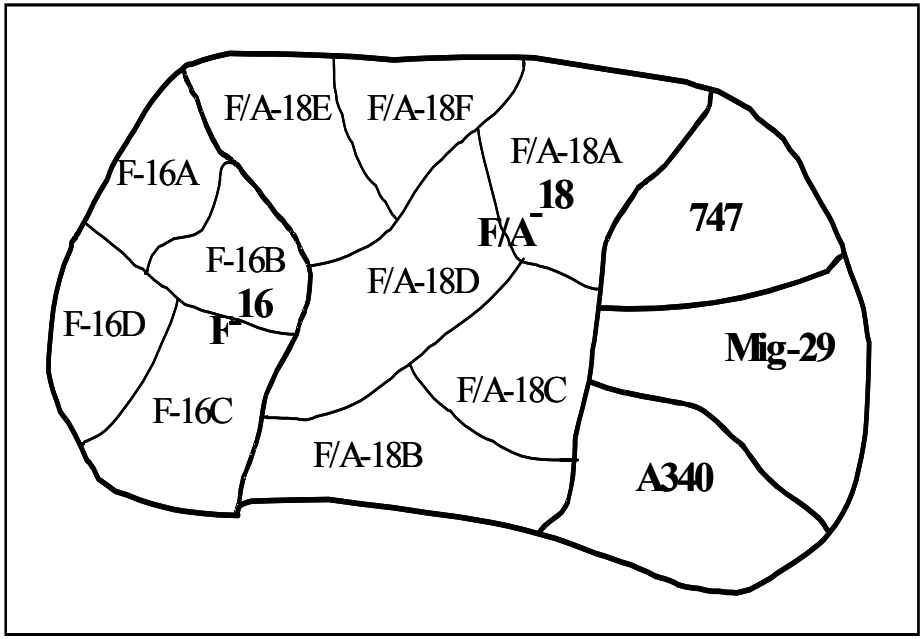
- Taxonomy A is an ***f-refinement*** of taxonomy B if:
  - ***f*** is a function $f : A \rightarrow B$ such that if $b_1 \neq b_2$ then $f^{-1}(b_1) \cap f^{-1}(b_2) = \varphi$ where φ = empty set



- If a taxonomy of A is an f-refinement of taxonomy B and $a \in A$, $b \in B$, and $f(a) = b$, we say that *a* is an *f-refinement* of *b*
  - Example: F/A-18A in the Class taxonomy is a refinement of F/A-18 in the Type taxonomy

Partition Refinement

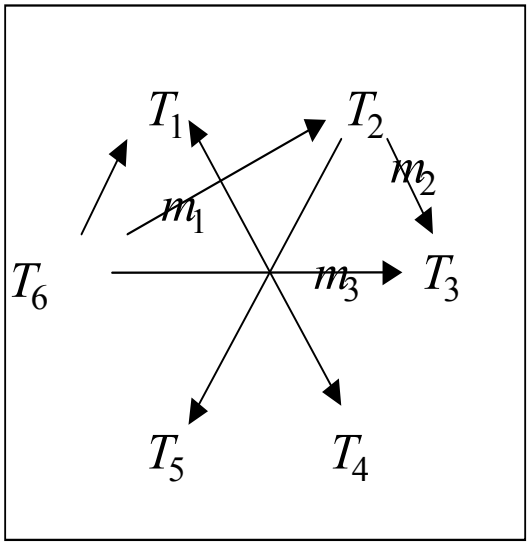
- Given a set *S* of objects, a taxonomy imposes a partition on the set
- Each element of the partition is the set of all elements of *S* for which a single element of the taxonomy is the appropriate name
- Example: an element of the partition imposed on aircraft by the Type taxonomy is the set of all F-15s, all 747s, etc.
- A taxonomy T_1 is a refinement of another taxonomy T_2 if the partition imposed by T_1 is a refinement of the partition imposed by T_2



Canonical Mapping

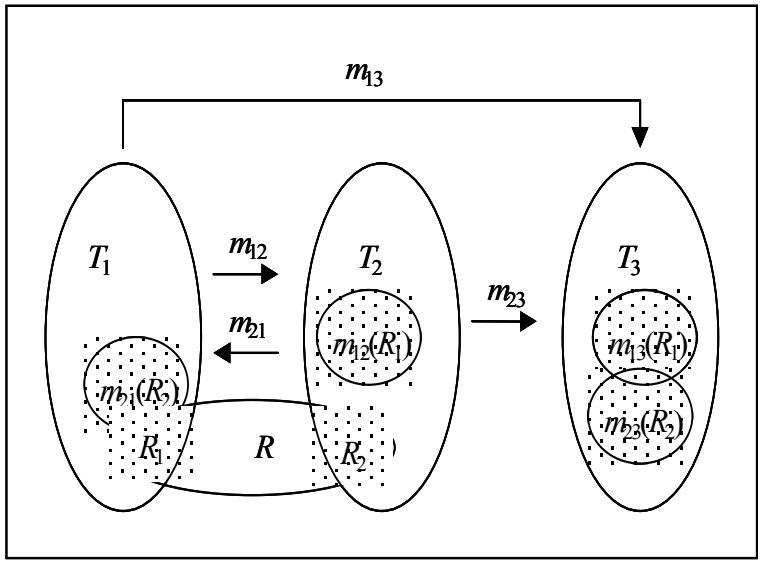
- Canonical mappings provide a way to exploit information about an object from different taxonomies to categorize the object in one of those taxonomies, or in another, completely different, taxonomy
- Set of canonical mappings must be defined between any two related taxonomies

- In the case of a collection of taxonomies that are successive refinements, the canonical mappings reflect the hierarchical nature of the taxonomies themselves
- Example: sets T_6 and T_3 are related through both the mapping m_3 and the composite mapping $m_2 * m_1$ (so not a true canonical mapping)

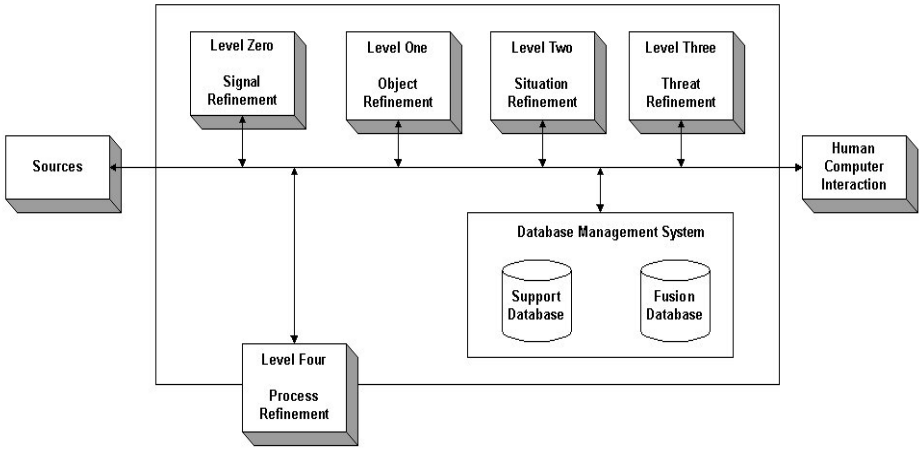


Response Mapping

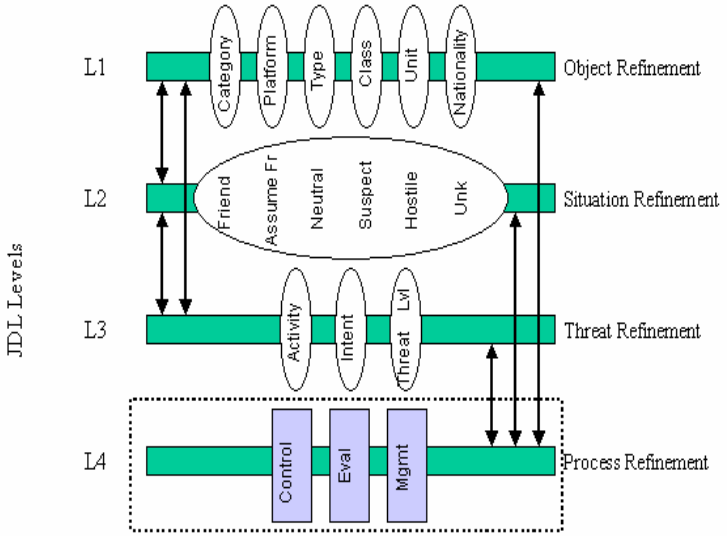
- Response mapping is a way to interpret a response with elements from one taxonomy in terms of another taxonomy
- Provides a means of interpreting a response with elements from more than one taxonomy in the various referenced taxonomies
- Example: let R be a response from a source of information composed of a set of attributes, let the canonical mapping from taxonomy T_i to taxonomy T_j be m_{ij} - Each taxonomy potentially has elements that are part of the response (R_1 and R_2 in the figure), as well as elements that are the images, under a canonical mapping, of elements in other taxonomies ($m_{12}(R_1)$, $m_{21}(R_2)$, $m_{13}(R_1)$, $m_{23}(R_2)$



JDL Model and CID Realization

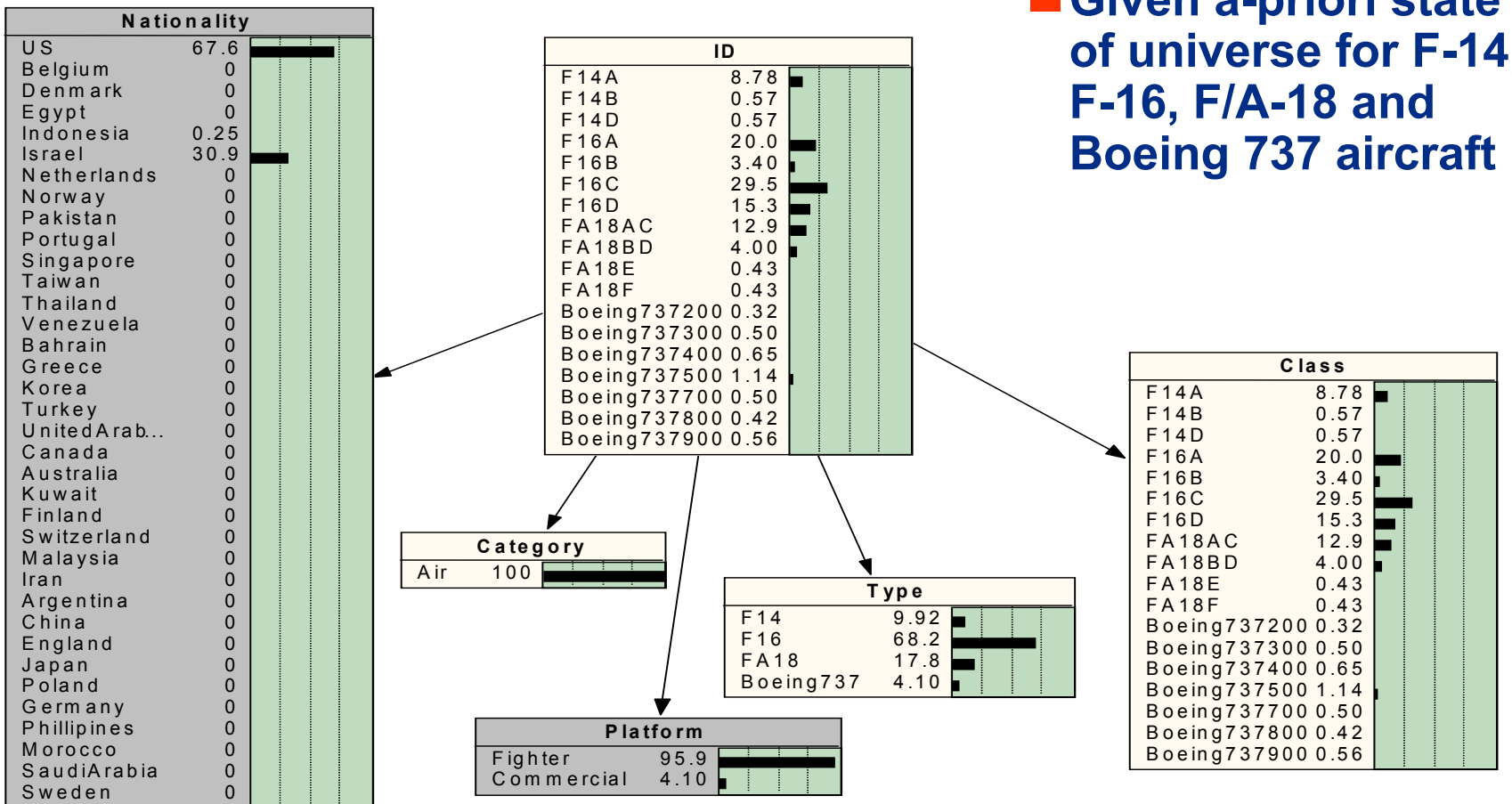


JDL Model



CID Implementation

A priori CID Bayesian Network (Level 1)

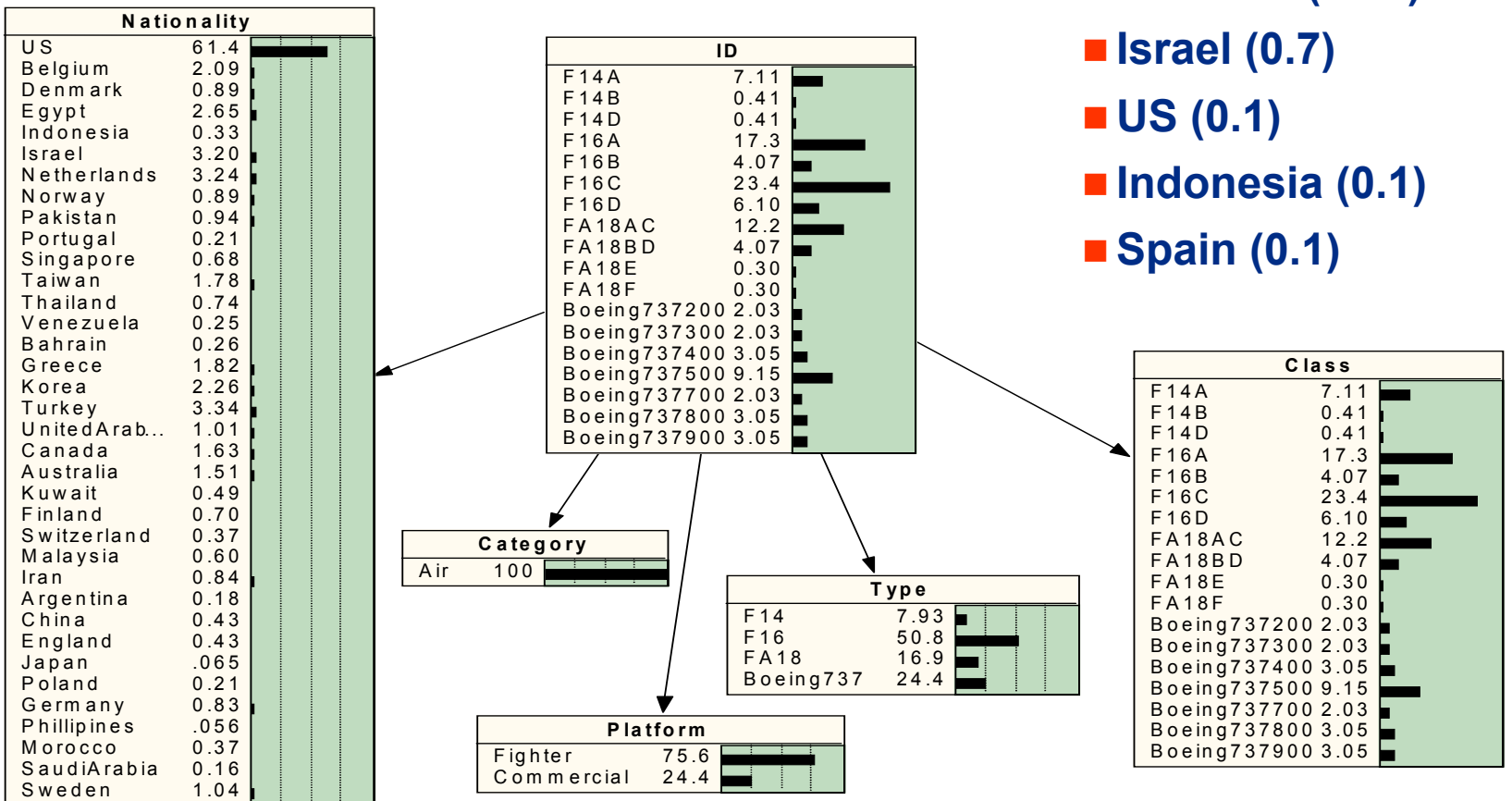


- Given a-priori state of universe for F-14, F-16, F/A-18 and Boeing 737 aircraft

- Shaded areas (Nationality and Platform) represent where new info will be inputted

A priori CID Bayesian Network (Level 1)

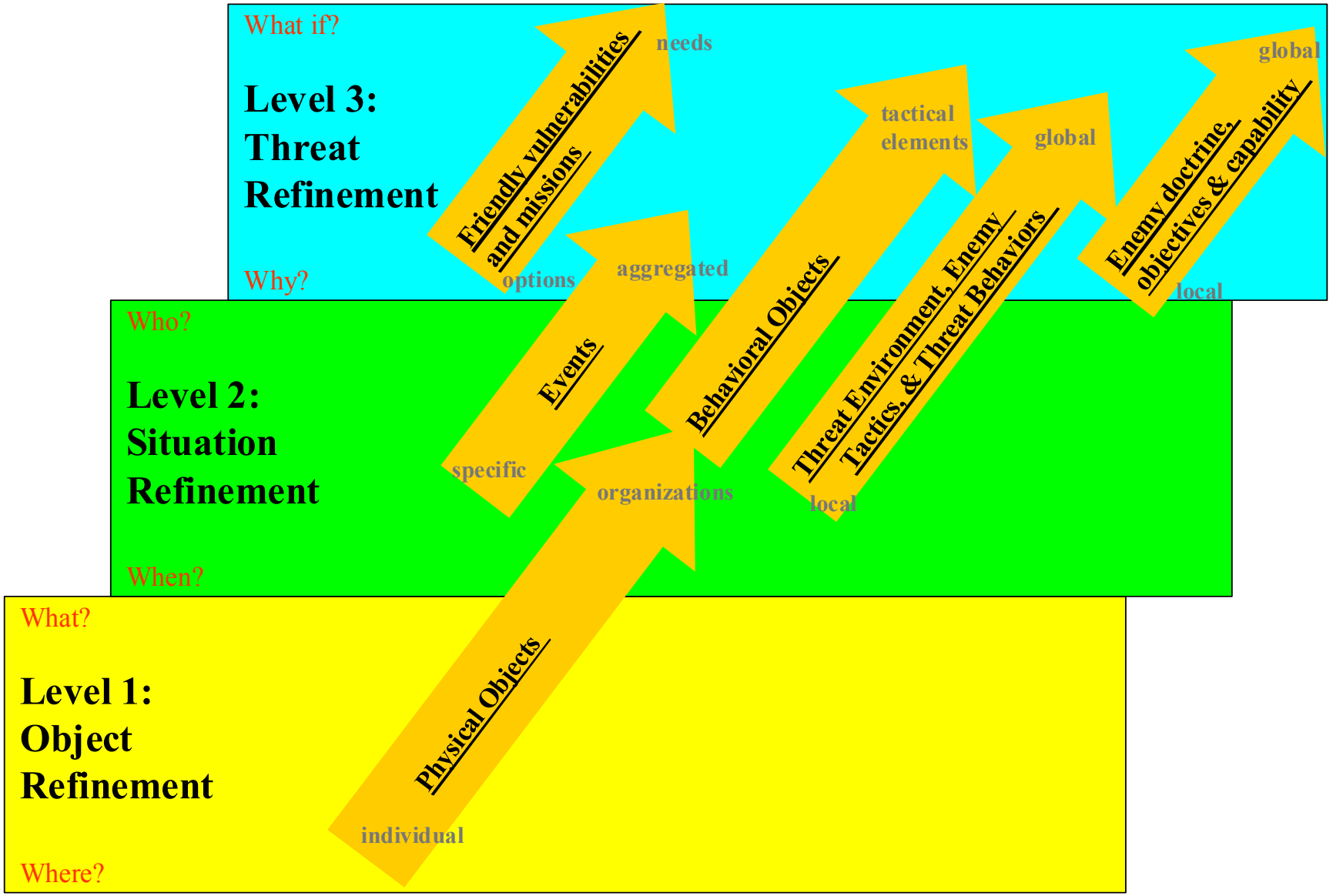
- BN after new sensor inputs:
  - Fighter (0.85)
  - COM Air (0.15)
  - Israel (0.7)
  - US (0.1)
  - Indonesia (0.1)
  - Spain (0.1)



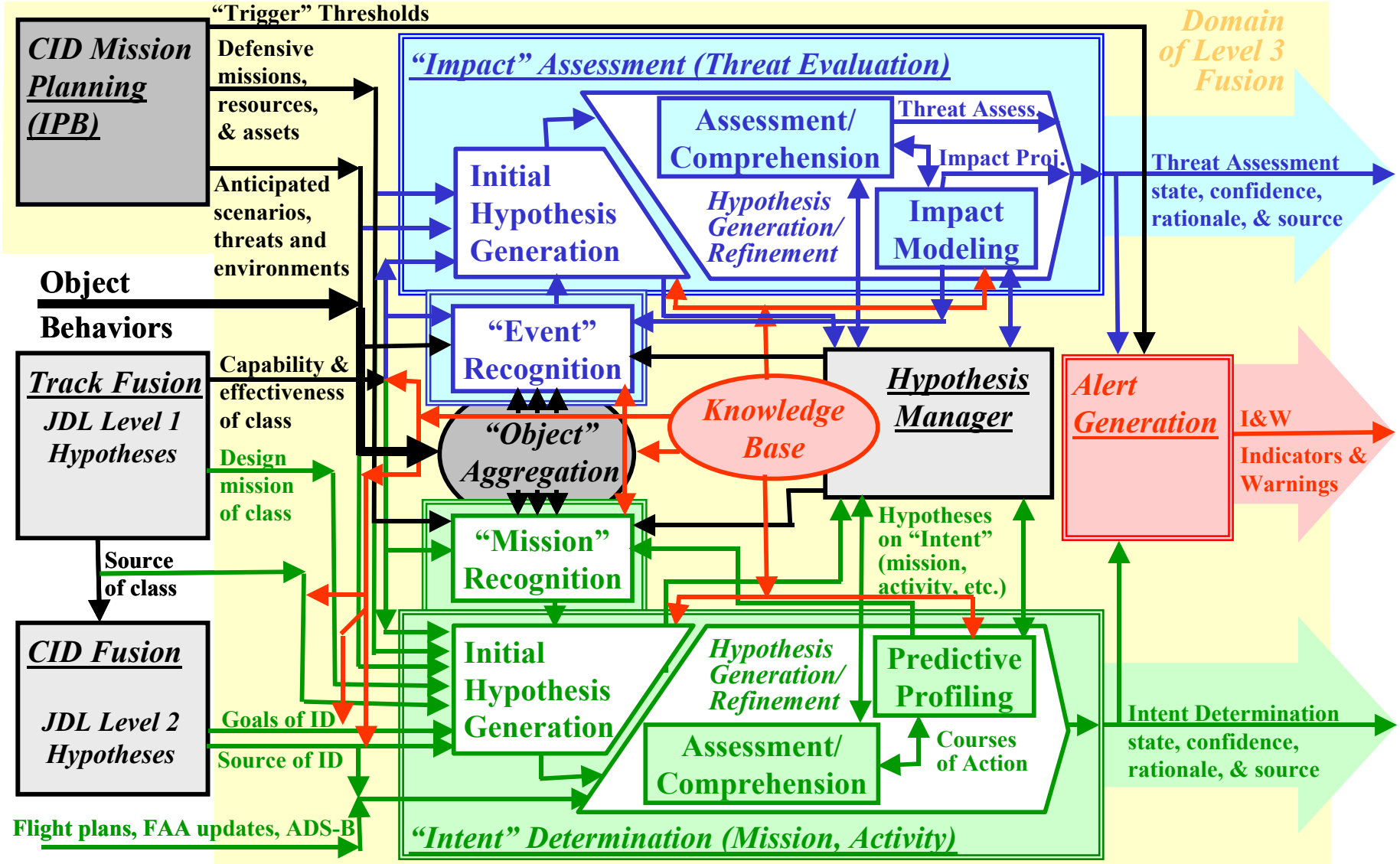
CID Situational Awareness (SA) Fusion Expansion

- Level 1 SA: Perception of the environmental elements – The identification of key elements of "events" that, in combination, serve to define the situation
  - JDL – numeric processing of tactical components
  - SA – symbolic processing of these entities
- Level 2 SA: Comprehension of the current situation – This combines level 1 events into a comprehensive holistic pattern (or tactical situation)
  - JDL and SA virtually identical
- Level 3 SA: Projection of future status – Projection of the current situation into the future, so as to predict the course of an evolving tactical situation
  - SA more general than JDL, includes projection of ownship/aircraft/etc., and friendly intent

Tactical Elements Employed by Fusion Level



Proposed Threat Evaluation Tool



Conclusions and Future Work

- Contextual relationship of information is paramount
- Fusion process must incorporate these relationships
- CID information wrt context, time, timeliness, quantity, and quality must be known
- Future work:
  - Metrics for information value, completeness, and costs of decisions can be developed and integrated
  - Contextual reasoning leading to predictive SA

Author Information

Tod Schuck *is a Lead Member of the Engineering Staff at Lockheed Martin MS2, Moorestown, NJ. He is the recipient of numerous awards for his technical work including the '01 Lockheed Martin MS2 Author of the Year, finalist for best paper by OASD C3I at the 7th International Command and Control Research Technology Symposium (ICCRTS) '02, best paper (2nd place) IEEE National Aerospace and Electronics Conference (NAECON) '00, and a group award winner of Vice President Al Gore's "Silver Hammer" Award for Extraordinary Effort for Changing the Way That Government Does Business (July '97) as the technical lead for the Mk 17 NATO SeaSparrow radar SDP. His areas of expertise are in identification sensor design and development, fusion algorithm development, information architecture design; and requirements generation, and testing. He holds a BSEE from Georgia Tech, an MSEE from Florida Tech, and is pursuing a Ph.D. from Stevens Institute of Technology in Systems Engineering.*

tod.m.schuck@lmco.com

J. Bockett Hunter *is a Senior Member of the Engineering Staff at Lockheed-Martin MS2, Moorestown, NJ. He has been on the faculty of Indiana University, worked on Navy operations research problems, and a wide variety of intelligence systems. His areas of expertise include algorithm development, systems engineering for very large systems including system concept definition, requirements development, design, and testing. He holds a BS in mathematics from Caltech and an MA in mathematics from Indiana University.*

john.hunter@lmco.com

Daniel D. Wilson *is a Principal Systems Engineer at Lockheed-Martin MS2, Burlington, MA. He has worked on Military Operations Research problems in support of numerous DoD programs. His areas of expertise include C4ISR systems, operations analysis, knowledge fusion, predictive situational awareness, dynamic replanning strategy development, collaborative mission planning, system effectiveness modeling, decision analysis, risk analysis, and cost estimation. He holds a BS in Computational Mathematics from the University of Vermont and an MS in Operations Research from Stanford University.*

danwilson@mitre.org