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BML Enabled Information Exchange Framework in SES ontology for C2

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Overview

- Motivation: ontology-based data fusion for C2
- Review
  - the Information Exchange Framework (IEF) and the System Entity Structure (SES)
  - JDL Data Fusion Process Model
  - Battle Management Language (BML)
- Approach to integrating BML into the IEF in the C2 Data Fusion Context
- Resulting Architecture for C2 Data Fusion
- Conclusions/Future Work

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C2 Needs for Ontology-based Data Fusion Framework

- C2 needs information
  - First step to plan military operations is gathering information.
  - More refined information is more valuable.
- C2 systems need an Information Exchange Framework (IEF) to supports requests for high level information as well as simple object data from various information sources
- Battle Management Language (BML) expresses user requirements and invokes information exchange process in SES ontology.

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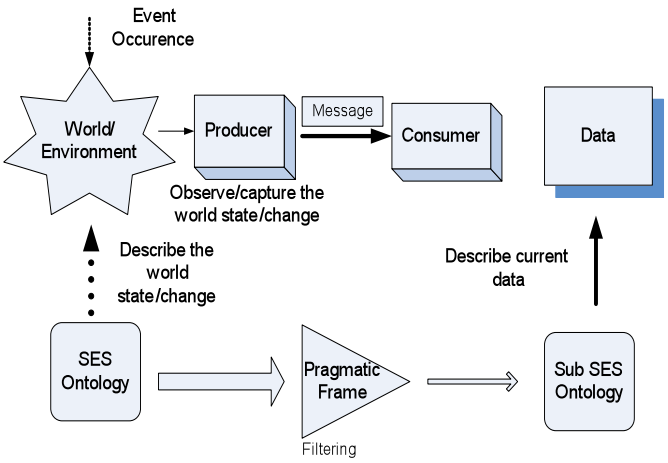
Information Exchange Framework



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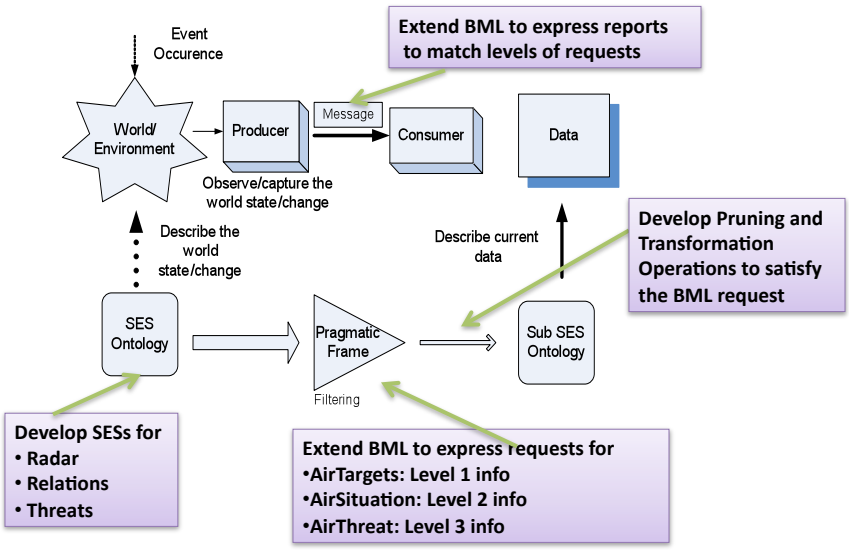
Approach to Integrating BML into the Information Exchange Framework



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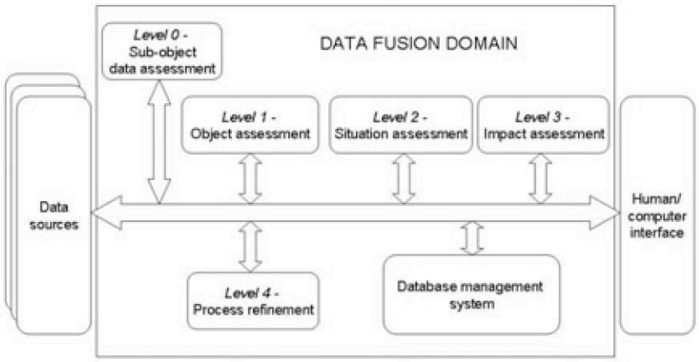
JDL Data Fusion Process Model(1/2)

Refinement processes in sensor networks mapping raw data into useable products



Joint Directors of Laboratories (JDL) Model♪

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JDL Data Fusion Process Model (2/2)

- Level 0 a preprocessing step on sensor level
- Level 1 (Object Refinement) – refine the objects or entities' representation
- Level 2 (Situation Refinement) – describe the current relationships among entities.
- Level 3 (Threat Refinement) – project current situation to the near future
- Level 5 (User Refinement) – **emphasis on user role since higher level information is related to temporal/ spatial coordinates specified by users**

→ corresponds to the pragmatic frame in IEF

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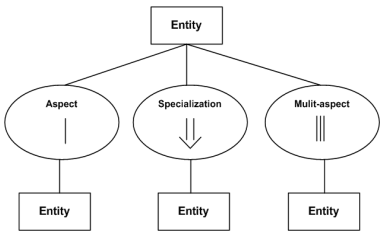
Background-System Entity Structure (SES)

A formal framework for ontology development
- **especially to enable automation in modeling and simulation**
- **applicable to complex data-engineering**
- **set-theoretically defined**
- **implemented in XML-based SES-Builder**

- **Entity**: real world objects, made of other children entities.
- **Aspect**: represents the labeled decomposition relation between the parent and the children.
- **Specialization**: labeled relation that expresses alternative choices that a system entity can take on.
- **Multi-Aspect**: is an aspect that expresses an all of one kind decomposition.
- **Variables**: are slots attached to an entity. The slots can take values in a specific type and range.
- **inheritance**: the parent and any child of a specialization combine their individual variables, aspects and specializations when pruning is activated



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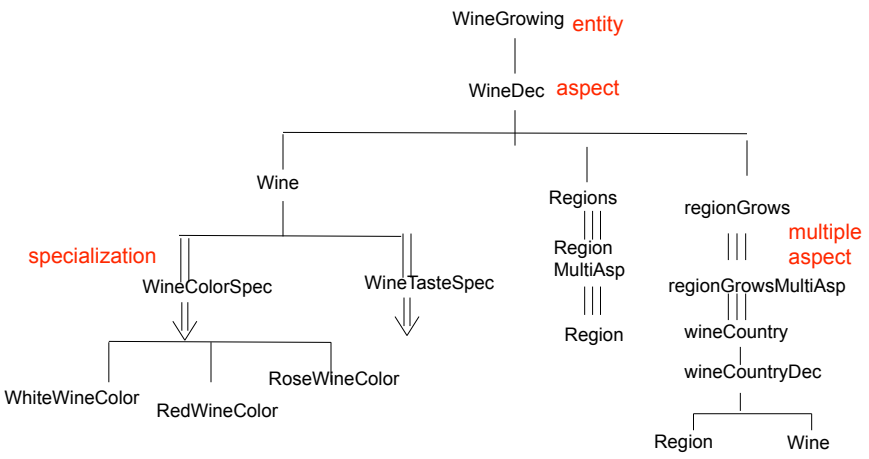
System Entity Structure: Wine Ontology Example



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SES Supports Structure Mappings

- Structural operations in SES ontology framework
  - Pruning: operation to cut off unnecessary structure in SES
    - Assign some values to specific entities
    - Trim to get entities which user requires
  - Transformation: mapping from one ontology to another.
- These operations are invoked by user requirements – the pragmatic frame in Information Exchange Framework (IEF)

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Battle Management Language (BML)

- **A formal command and control language**
  - **An unambiguous language used to command and control forces and equipment conducting military operations**
  - **to provide for situational awareness and shared, common operational pictures**
  - **understandable to humans and machines**
- **Intended to bridge gap between**
  - **C2 system (Human) and simulated forces (Machines).**
  - **C2 system (Human) and real forces (Human).**
  - **C2 system (Human) and robotic forces (Machine) in future**

- **Order and Request**
  - OB → Verb Tasker Taskee (Affected | Action) Where Start-When (End-When) Why Label (Mod)*
- **Report**
  - RB → ***task-report*** Verb Executer (Affected | Action) Where When (Why) Certainty Label (Mod)*
  - RB → ***event-report*** EVerb (Affected | Action) Where When Certainly Label (Mod)*
  - RB→ ***status-report*** Hostility Regarding (Identification Status-value) Where When Certainty Label (Mod)*

→ **Focus on Request and Report**

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Extending BML to the Information Exchange Framework

- BML is extended to express military pragmatic frames for high level information fusion in sensor networks

- **Request**
  - OB → ***request*** Contents Tasker Taskee (Affected | Action) Interest-Where (Tasker-Where) Start-When (End-When) (Interval-When) Why Label (Mod)*

  - Apply various 'Contents' for multi-level info request.
    - AirTargetsInfo: Level 1 info
    - AirSituation: Level 2 info
    - AirThreat: Level 3 info

  - Add 'Tasker-Where' and 'Interval-When' for high level info process.

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Extending BML for IEF (Cont'd)

- **Report**
  - RB→ ***status-report*** Hostility (Relations/ Situation) (Threat) Regarding (Identification Status-value) Where When Certainty Label (Mod)*
  - Add 'Relations/Situation' and 'Threat' for level 2/3 info.

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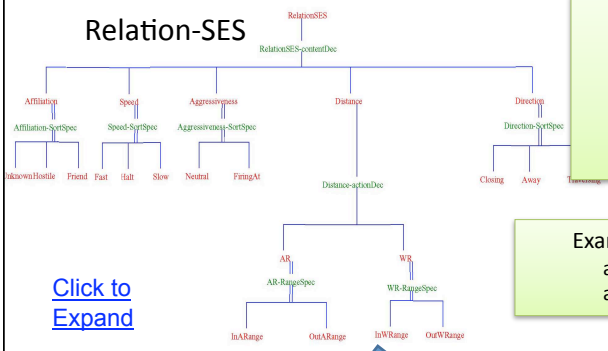
Transformation and Pruning: Relation to Threat SESs

Relation-SES



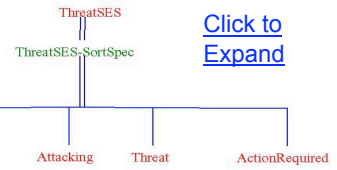
Determine Relations by features

- **Affiliation by iff**
- **Speed by velocity**
- **Aggressiveness by other reports**
- **Distance by relative distance range between targets and users**
- **Direction by relative target heading**

Click to Expand

Example: A target is hostile, slow, neutral, away, out of warning range, out of action range from the commander.

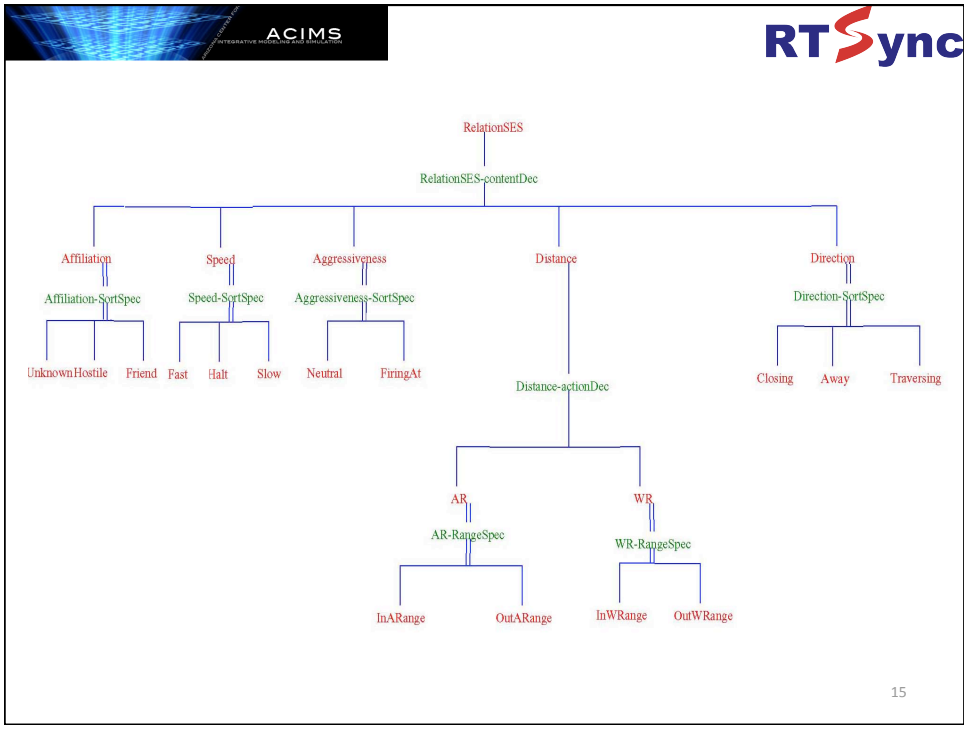
Threat-SES



Click to Expand

Predefined Rules map the set of relations to the threat types in Threat-SES

Example: The target is cautious.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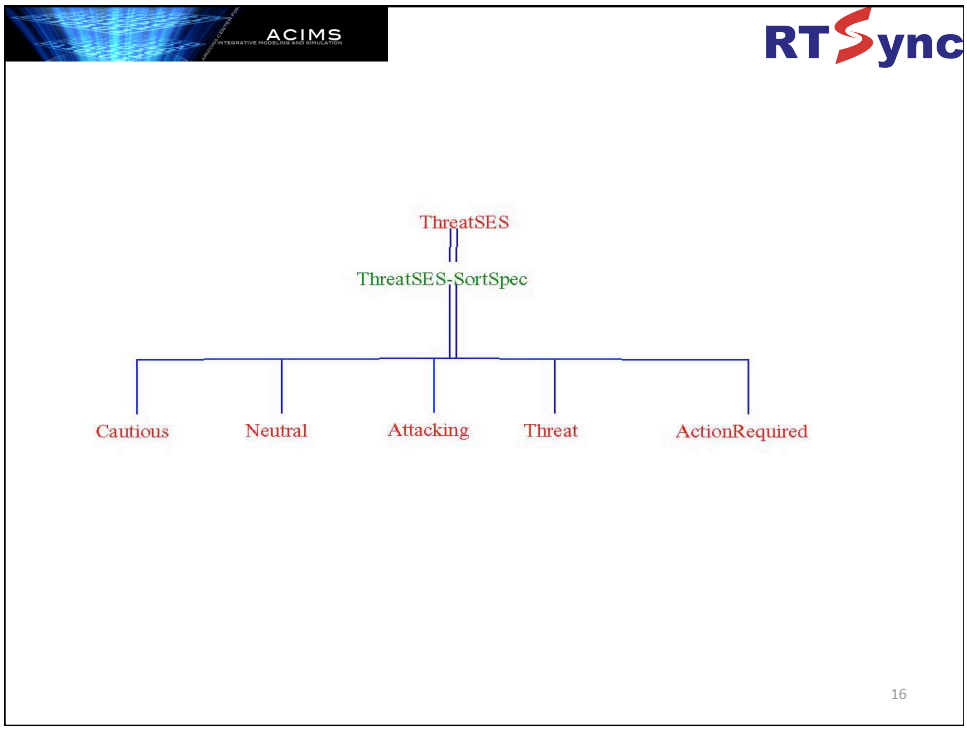
RelationSES
RelationSES-contentDec
Affiliation
Speed
Aggressiveness
Distance
Direction
Affiliation-SortSpec
Speed-SortSpec
Aggressiveness-SortSpec
Direction-SortSpec
Unknown
Hostile
Friend
Fast
Halt
Slow
Neutral
FiringAt
Closing
Away
Traversing
Distance-actionDec
AR
WR
AR-RangeSpec
WR-RangeSpec
InARange
OutARange
InWRange
OutWRange
15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ThreatSES
ThreatSES-SortSpec
Cautious
Neutral
Attacking
Threat
ActionRequired
16

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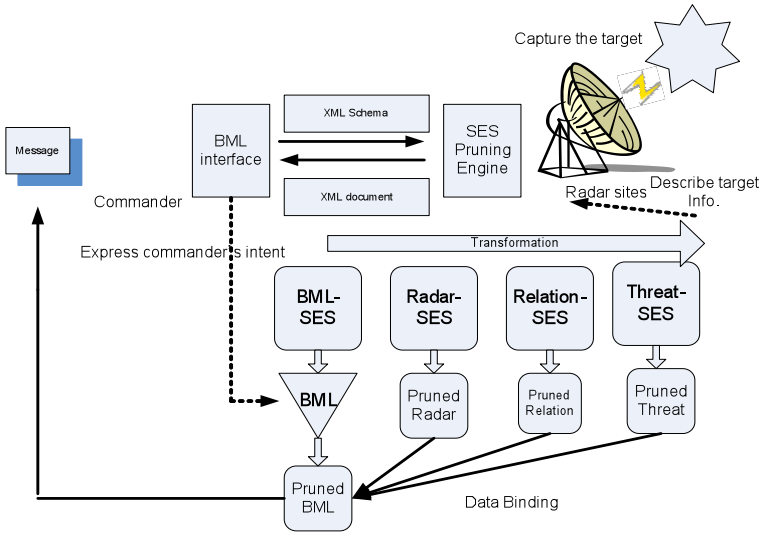
Resulting Data Fusion System Architecture



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Conclusions

- We proposed an information exchange framework for data fusion in sensor networks
- Extended BML to express pragmatic frames in a unambiguous way
- BML requests invoke ontological operations in SES to provide threat level report schemata
- The approach casts the data fusion process development within an ontological framework that is amenable to modeling and simulation

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Future Work

- Study compatibility of our approach with existing BML system.
- Extend framework to fabricate the whole battle-field picture including ground picture.
- Study interoperability issues with another message format such as Cursor on Target (CoT).
- Further development for GIG/SOA Web Services context
  - Network Centric Enterprise Services (NCES) and Net Enabled C2 (NECC) may benefit from the BML enhanced Information Exchange Framework

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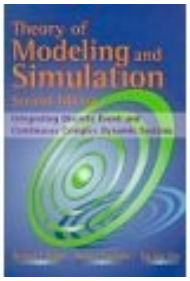
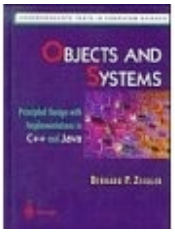
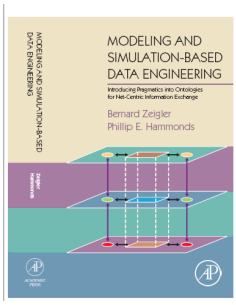
Books and Web Links







devsworld.org

www.acims.arizona.edu

Rtsync.com

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More Demos and Links

http://www.acims.arizona.edu/demos/demos.shtml

- NTAC_DEMO (Marketplace_demo, MarketplaceObserver_demo)
- **Integrated Development and Testing Methodology:**
- **AutoDEVS (ppt) & DEMO**
  - **Natural language-based Automated DEVS model generation**
  - **BPMN/BPEL-based Automated DEVS model generation**
  - **Net-centric SOA Execution of DEVS models**
  - **DEVS Unified Process for Integrated Development and Testing of SOA**
- **Intrusion Detection System on DEVS/SOA**

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BACKUP

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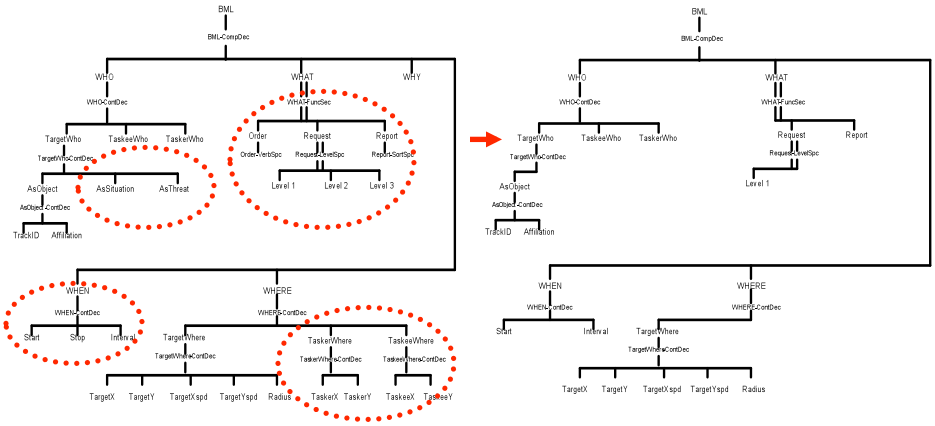
BML for IEF

How BML invokes ontological operations in SES

– Pruning BML-SES in Schema format



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BML for IEF

- Pruned BML-SES extracts data from pruned Radar-SES (mapping relations from BML-SES to Radar-SES)
  - Radar-SES is a SES ontology to deal with radar data
- For Level 1
  - Bind pruned BML-SES with extracted data
  - Send back to user

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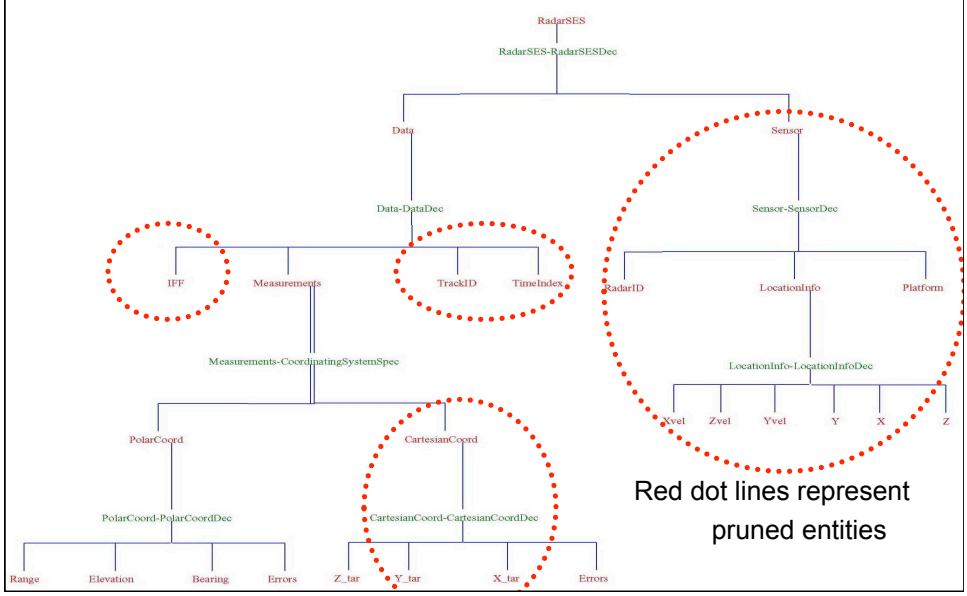
Radar SES



Red dot lines represent pruned entities

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BML for IEF

- For Level 2/ 3
  - Proceed to Situation Awareness process in SES ontology
  - Feature based Relation-SES pruning process
  - Relations and Rule based Threat-SES pruning process
  - Bind pruned BML with level2/ 3 data in pruned Relation-SES and pruned Threat-SES.
  - Send back to user

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Examples

- Scenario 1
  - The commander of 01 battalion wants to receive continually updated basic information of air-targets concerning dangerous flying objects in the neighborhood of a point (Xp,Yp) in Cartesian coordinate system with radius of 4 miles, to understand current air space situation.
- BML Request
  - ***request*** AirTargetsInfo 01Bat 001FC

    at Xp, Yp with radius of 4 start at now label-r-001
  - 'Where' could be area, not pinpoint. So it is assumed as a circle.

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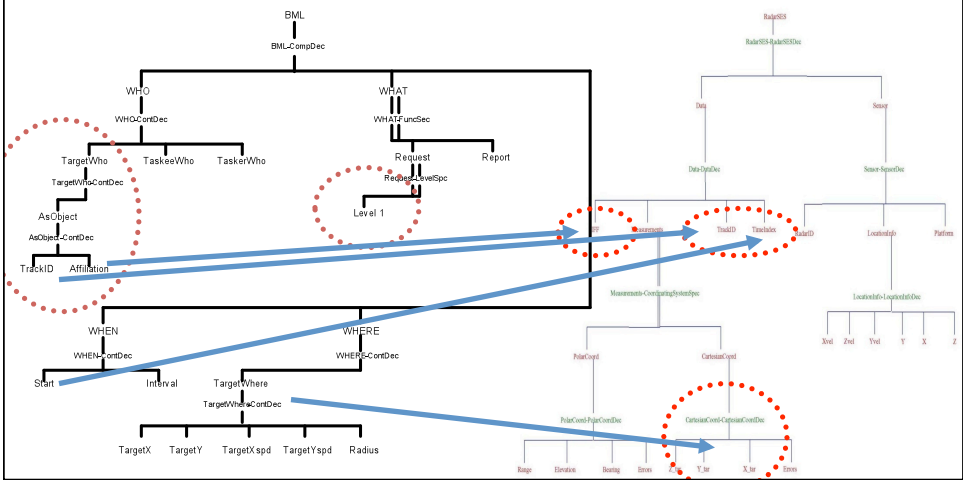
Examples

- 'AirTargetsInfo' requests Level 1 info and perform a pruning process in BML-SES



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Examples

- Data binding with data in pruned Radar-SES
- BML Report at every interval period
  - *status-report* one hostile interceptor

    at 30, 30 at now fact label-sr-001

- Scenario 2
  - The same commander now wants to recognize threatening targets in the same area. He wants to determine whether or not he needs to turn the unit to yellow alert in accordance with the received threat analysis results.

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Examples

- BML Request
  - ***request*** AirThreat 01Bat 001FC at Xp, Yp with radius of 4 at Uxp, Uyp start at now label-r-002
  - Add user location info for level 2, 3 processes.
  - 'AirThreat' invokes level 3 process. Do the same pruning as example 1 except level entities.
- Feature based pruning in Relations-SES
  - Target features: location, velocity, heading, iff
  - User features: location

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Examples

- Determine Relations by features
  - Affiliation by iff
  - Speed by velocity
  - Aggressiveness by other reports
  - Distance by relative distance range between targets and users
  - Direction by relative target heading
- It could be the following relation set:
  - A target is hostile, slow, neutral, away, out of warning range, out of action range from the commander.

- Predefined Rules about the set of relations determines the threat types in Threat-SES
  - The target is cautious.

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Examples

- It comes back to C2 system as a report:
  - ***status-report*** one hostile cautious interceptor at 32, 32 at now fact label-sr-002