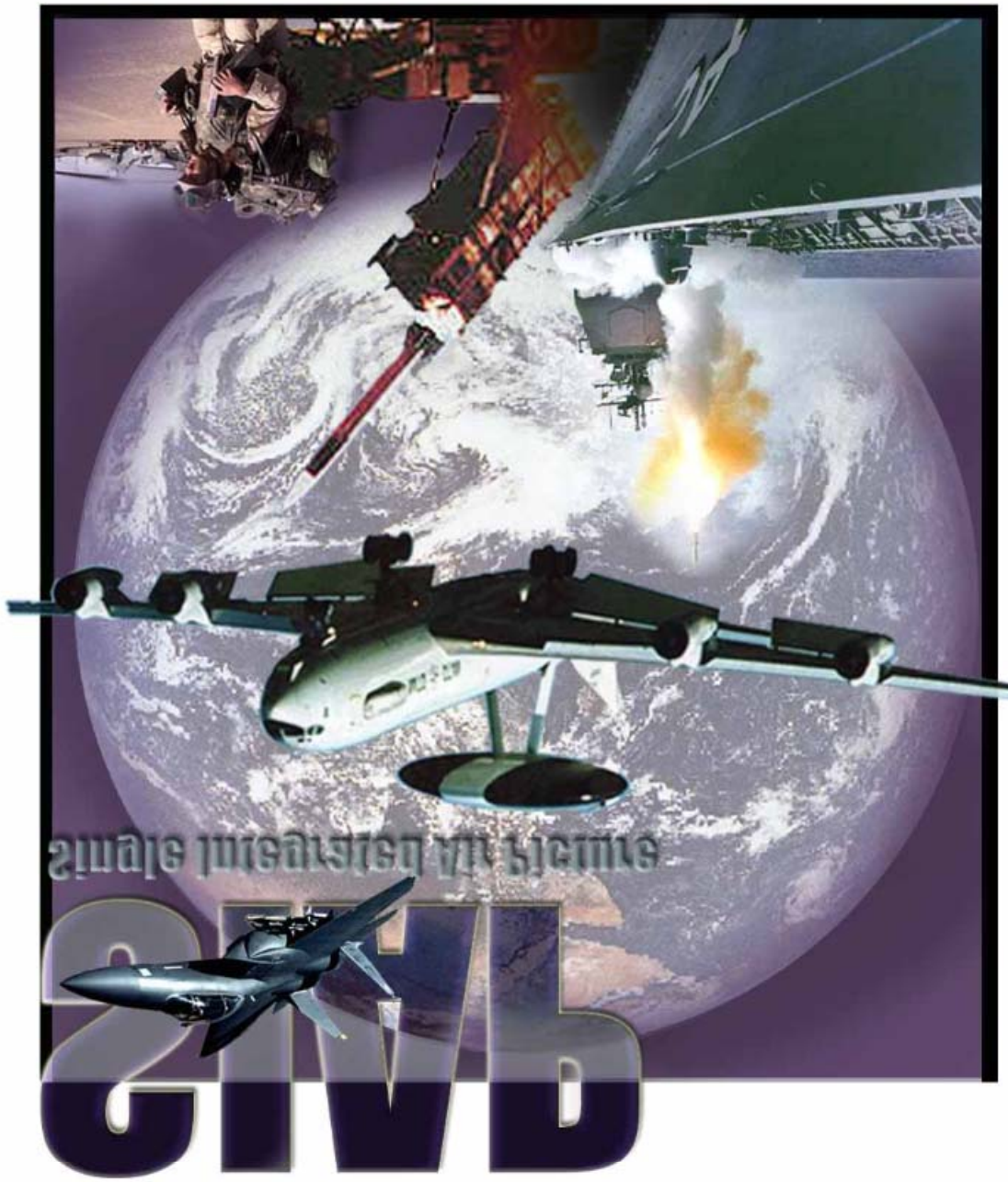


Joint SIAP System Engineering Organization

A C2 System for Future Aerospace Warfare

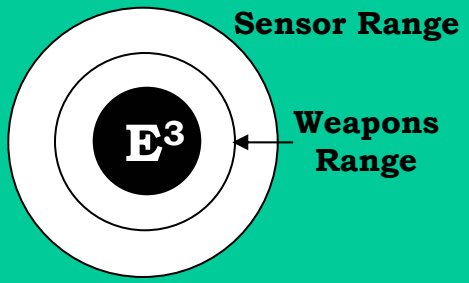
June 2004

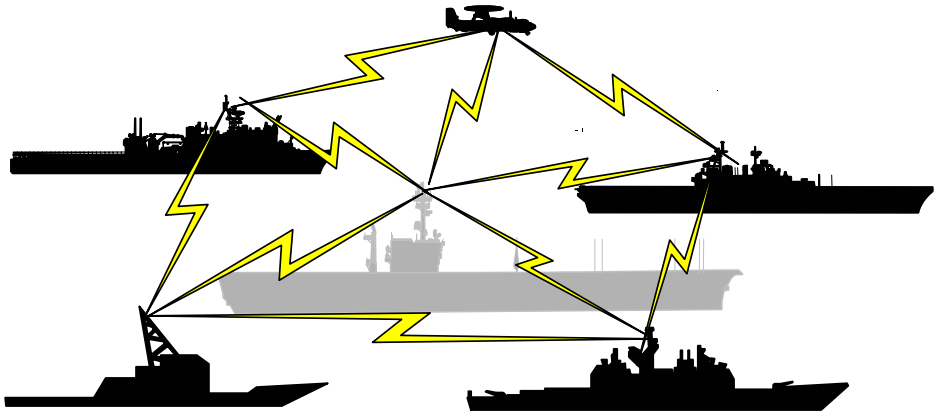
Bonnie W. Young
JSSEO/
Northrop Grumman Mission Systems (NGMS)

The role of C2 in aerospace operations is to optimize the use of offensive and defensive resources to combat aerospace threats.

Shifting to Force Level Thinking

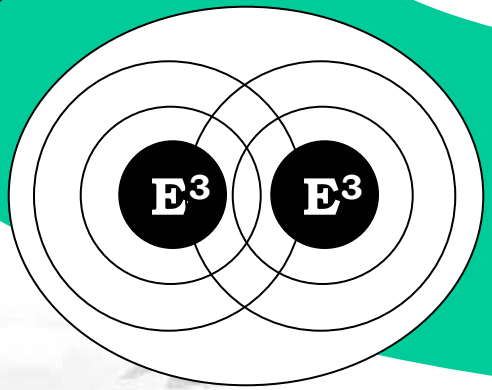
Single Unit



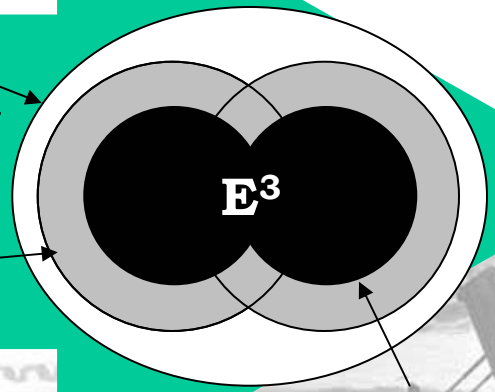


Network Centric Collaboration

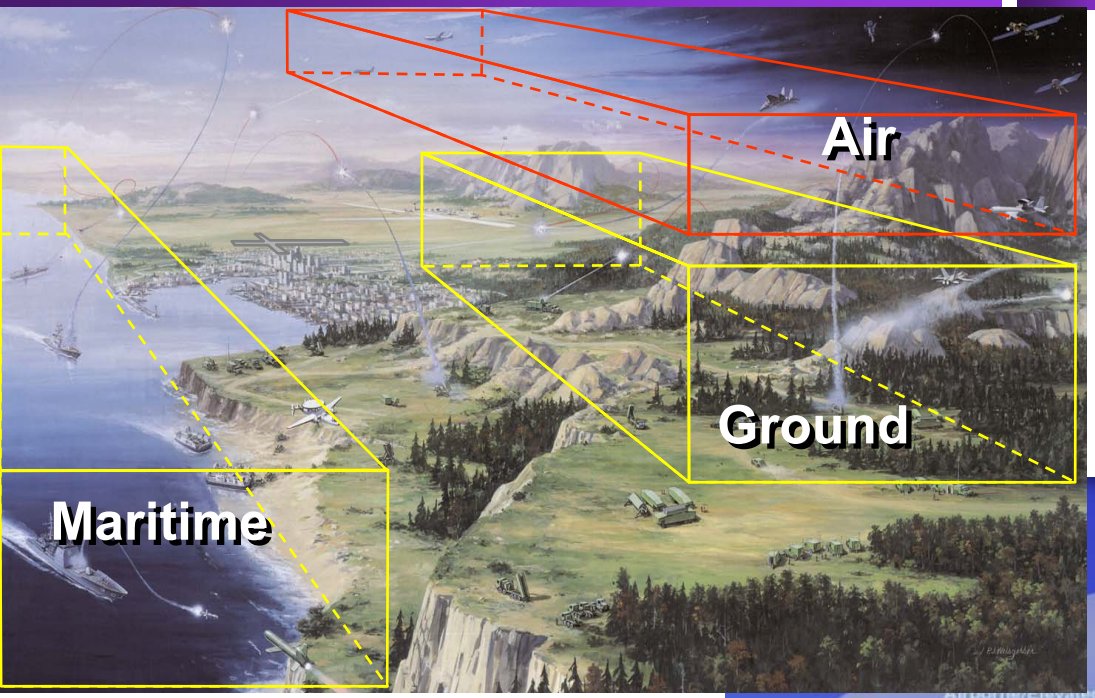
Multiple Units (Non-collaborative)



Multiple Units (Collaborative)



Future C2 Challenges

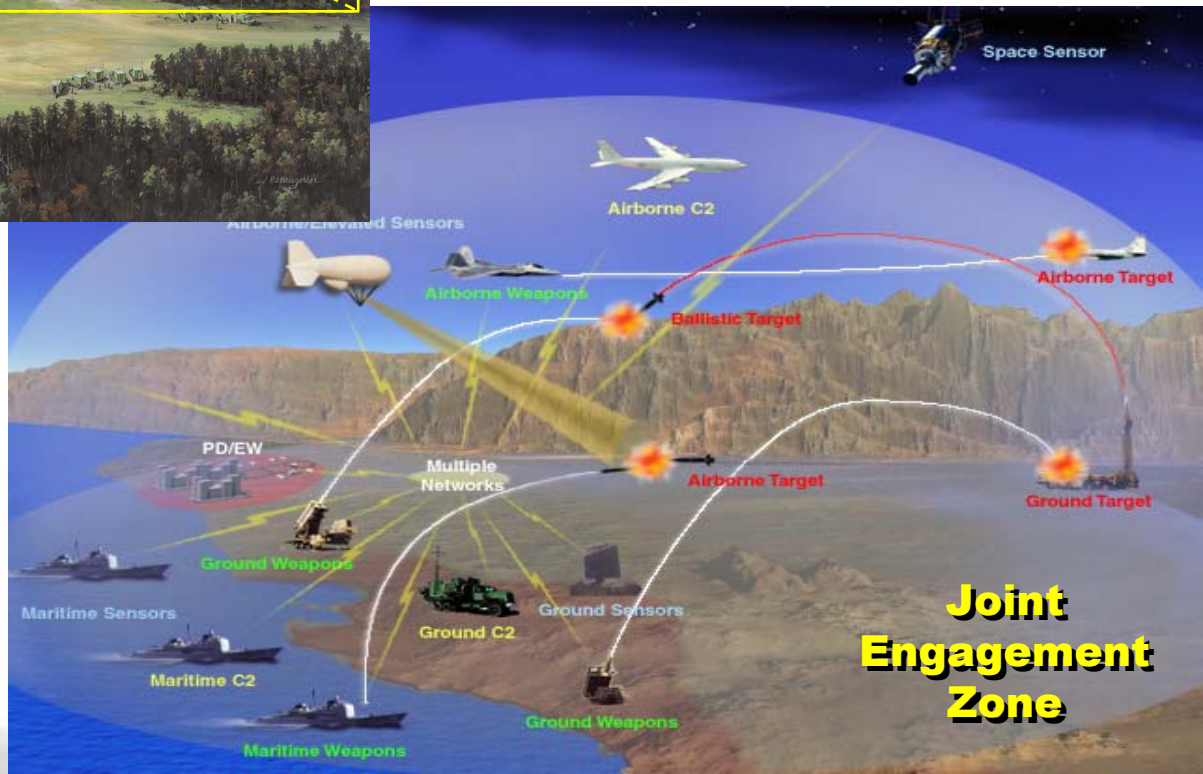


Information Superiority

- Shared Battlespace Awareness
- Single Integrated Air Picture
- Interoperable Air, Ground, & Maritime Pictures
- Picture Accuracy & Completeness
- Fire Control Quality Data

Resource Management

- Integrated Fire Control
- Joint Engagement Zone
- Force-level collaboration
- Collaborative Engagements
- Distributed Weapons & Sensors Coordination



Future C2 Vision

The Vision of Future C2 for Aerospace Warfare is characterized by:

- Force-centric Joint operations
- Collaborative & distributed resource management
- Enhanced situational awareness
- Automated operations
- Decentralized C2

Future C2 Approach

[1] Establish a Network-Centric Warfare (NCW) Foundation:

- Achieve shared battlespace awareness (or SIAP) through enhanced networks and common processing

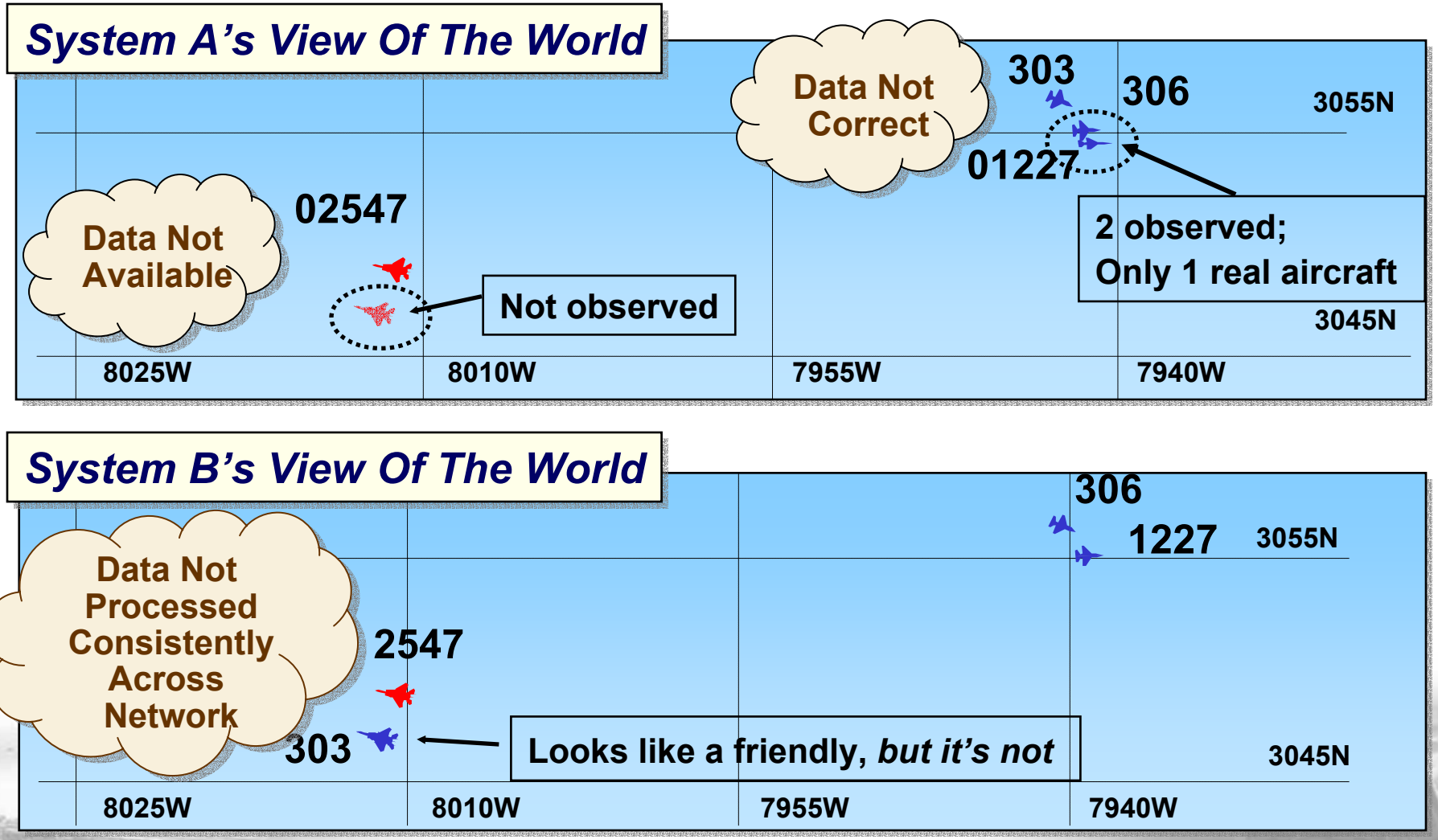
[2] Build advanced data fusion and automated decision aid applications upon NCW foundation:

- Enhance battlespace awareness (information superiority) through advanced assessment and data fusion capabilities
- Manage distributed resources in a collaborative and Force-centric manner using automated decision aids

Establishing a NCW Foundation

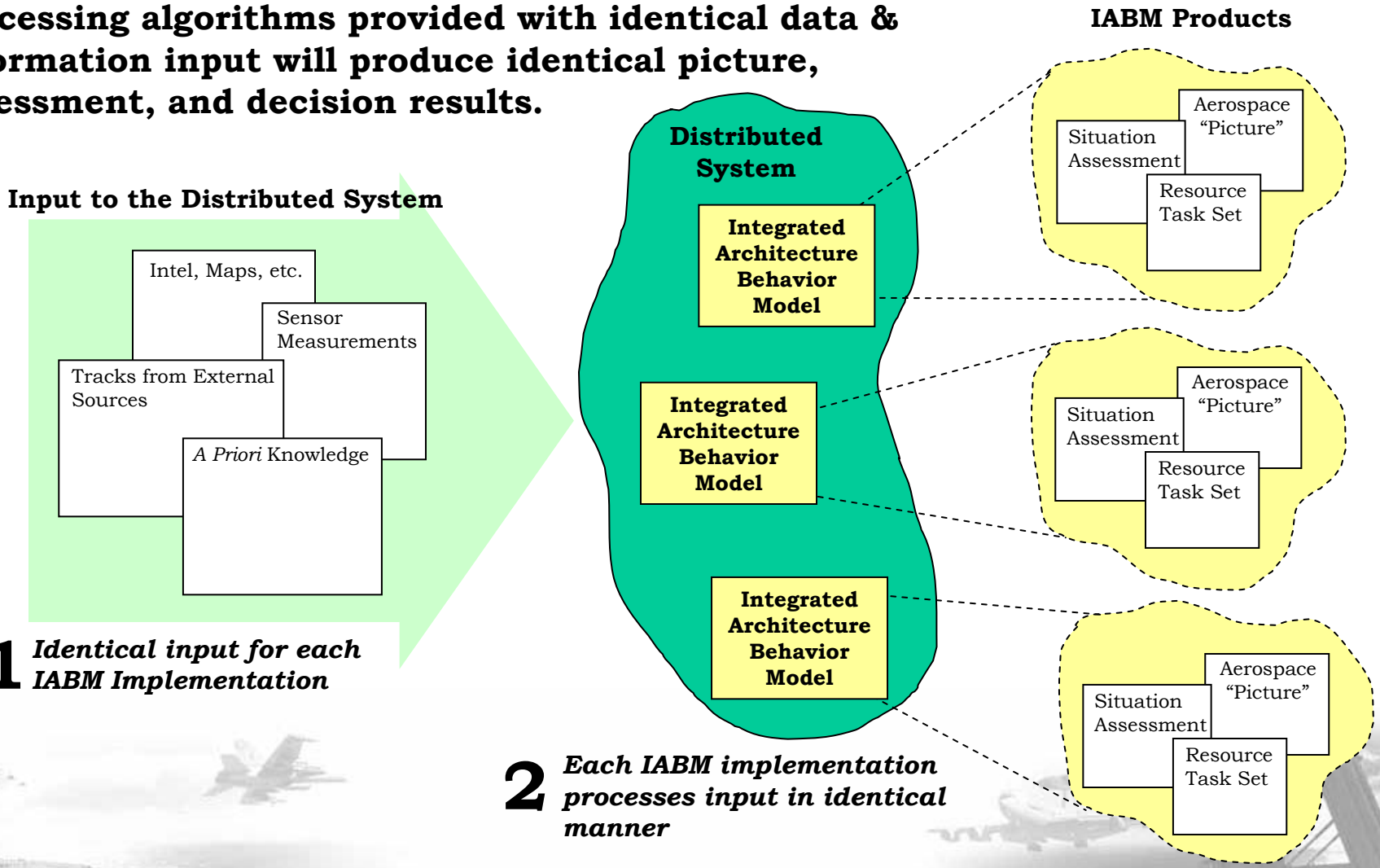
SIAP Challenge

Getting everyone on the same sheet of music



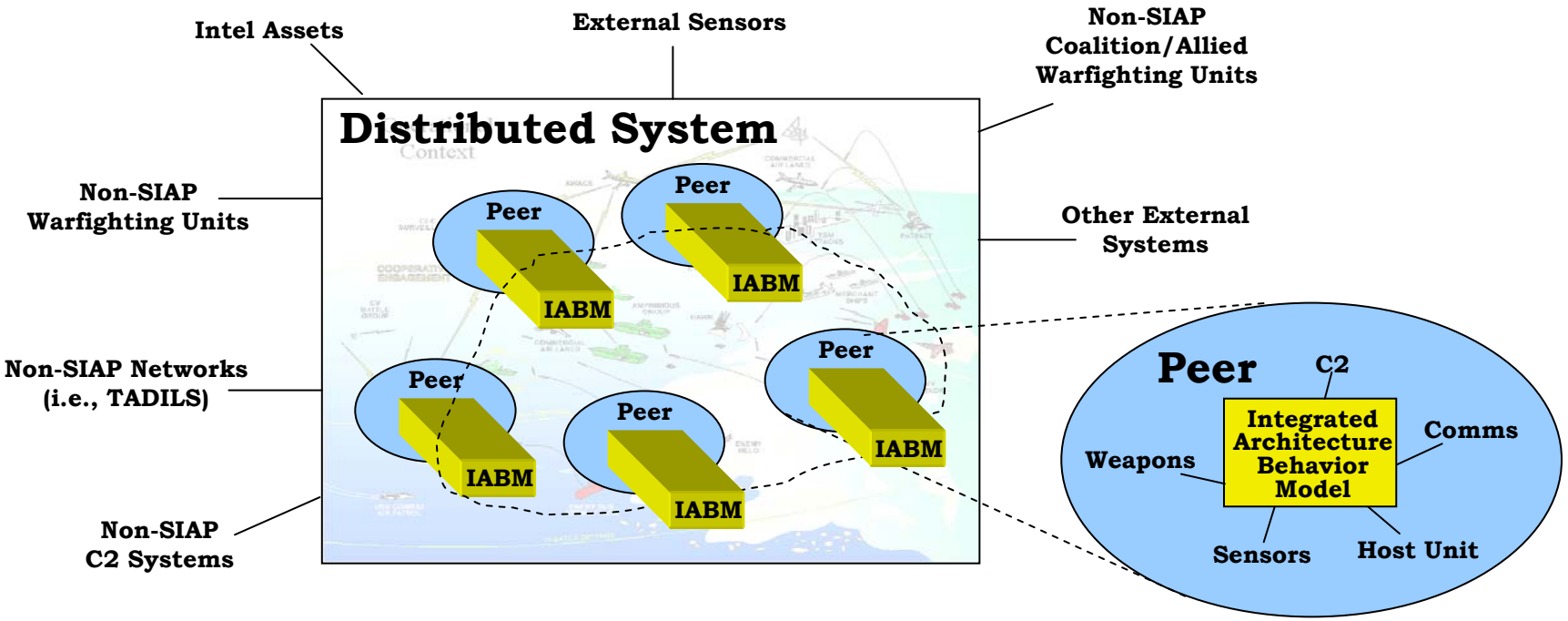
SIAP Common Processing Philosophy

The philosophy, simply stated, is that common processing algorithms provided with identical data & information input will produce identical picture, assessment, and decision results.



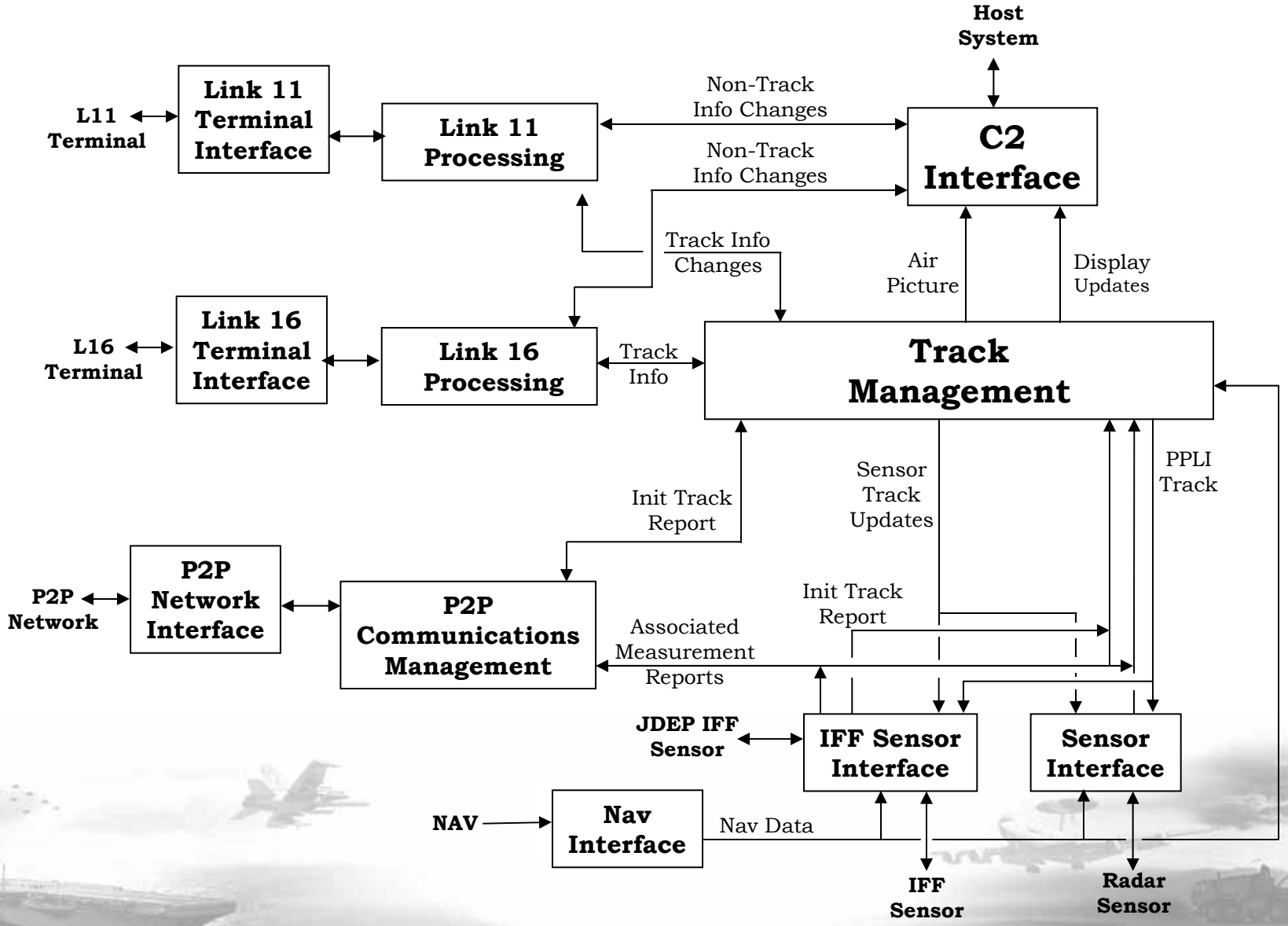
Note: IABM = Integrated Architecture Behavior Model

Distributed System of IABMs

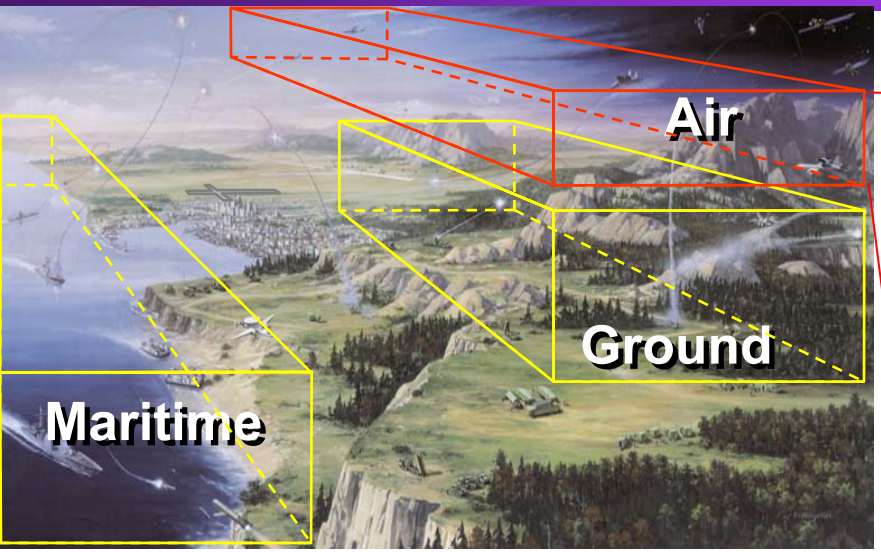


- IABMs will contain common processing algorithms that perform Joint tactical BMC2 functionality.
- IABMs will be integrated into participating Joint warfighting units (ships, aircraft, land-based assets, etc.)
- The SIAP "system" is really a set of distributed IABMs interacting in a collaborative manner over the Peer-to-Peer (P2P) network.

Core IABM Configuration



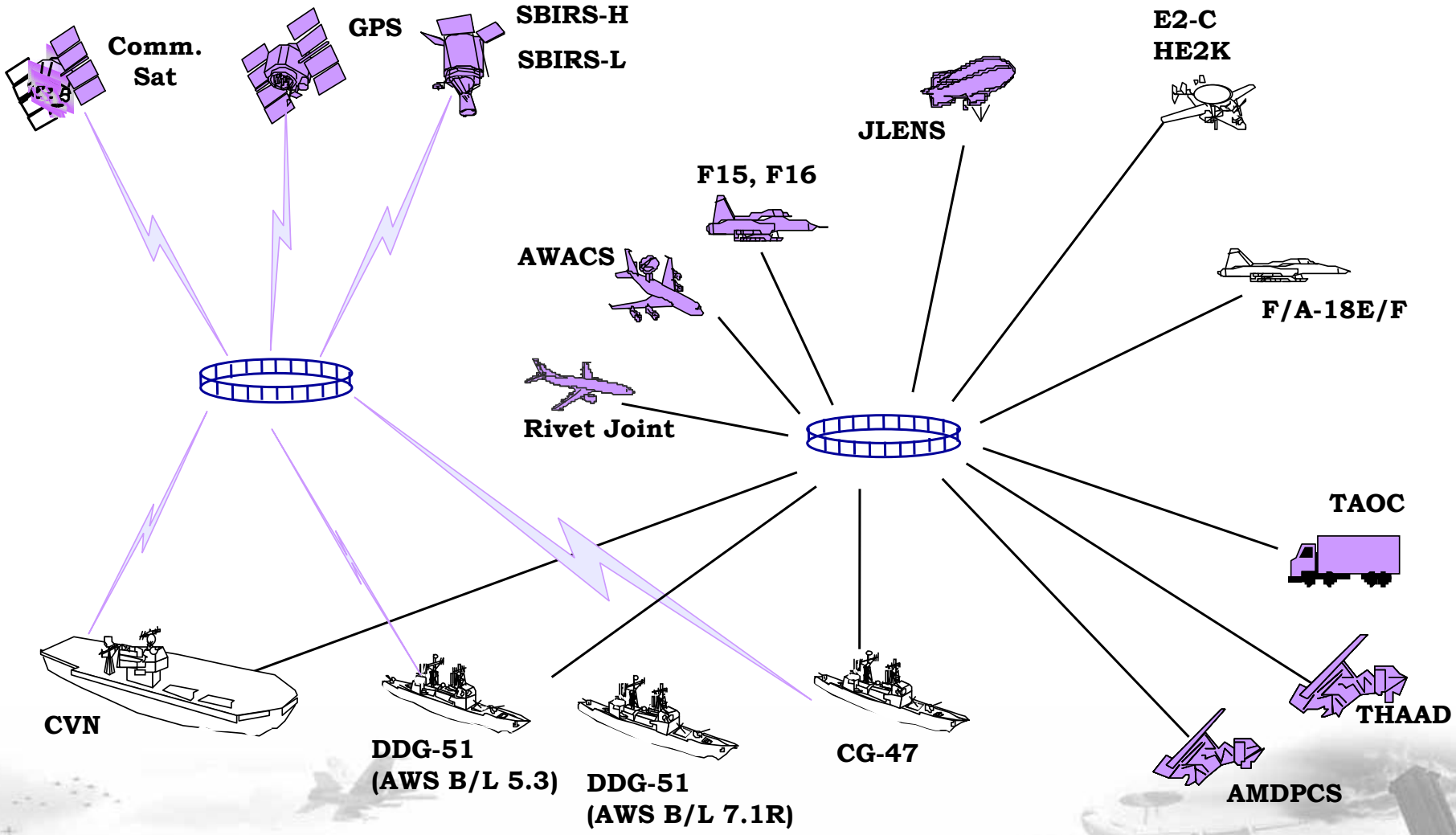
Core IABM Product: SIAP



The **SIAP** consists of common, continual, and unambiguous tracks of airborne objects of interest in the surveillance area. The picture is derived from real time and near real time data, and consists of correlated air object tracks and associated information (such as Combat Identification (CID) information).

- The fundamental solution for achieving tactical information superiority is predicated on common processing at network nodes and adequate information sharing or data dissemination
- The SIAP state is one of mutual data consistency
- Achieving the SIAP is the objective of the NCW foundation

Potential NCW Foundation Nodes



SIAP Data Exchange

Core Data Exchange Characteristics:

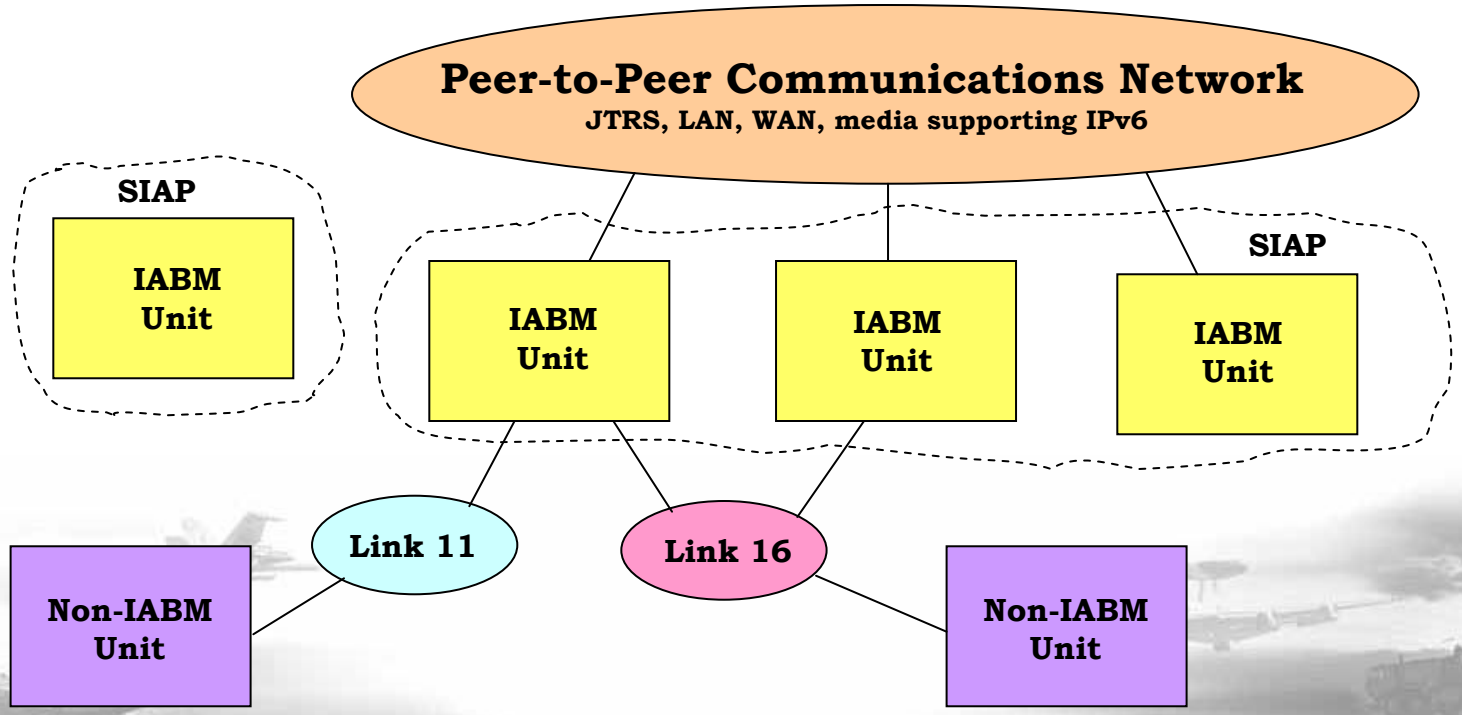
- Support real-time P2P exchange of sensor measurement data
- Broadcast
- Multicast
- Point-to-Point
- Non-real-time traffic for operations control
- Link monitoring
- Quality of Service delivery
- Data integrity and confidentiality
- Bandwidth allocation/monitoring
- Data dissemination prioritization (for time-sensitive data or bandwidth constraints)
- Ad hoc nodal topology (nodes can easily join or leave network)
- Interface with Tactical Data Links (TDLs)

SIAP Info Architecture Example

- Two separate "SIAPs" (air pictures resulting from IABM processes) exist in this scenario:

[1] The stand-alone IABM generates its air picture with data from organic sensors.
[2] The three IABMs collaborating over the P2P network generate a common SIAP.

- The non-IABM units may generate air pictures using their resident tracking processes; however, commonality between their pictures and the SIAP of the three IABMs is not guaranteed.



NCW Foundation

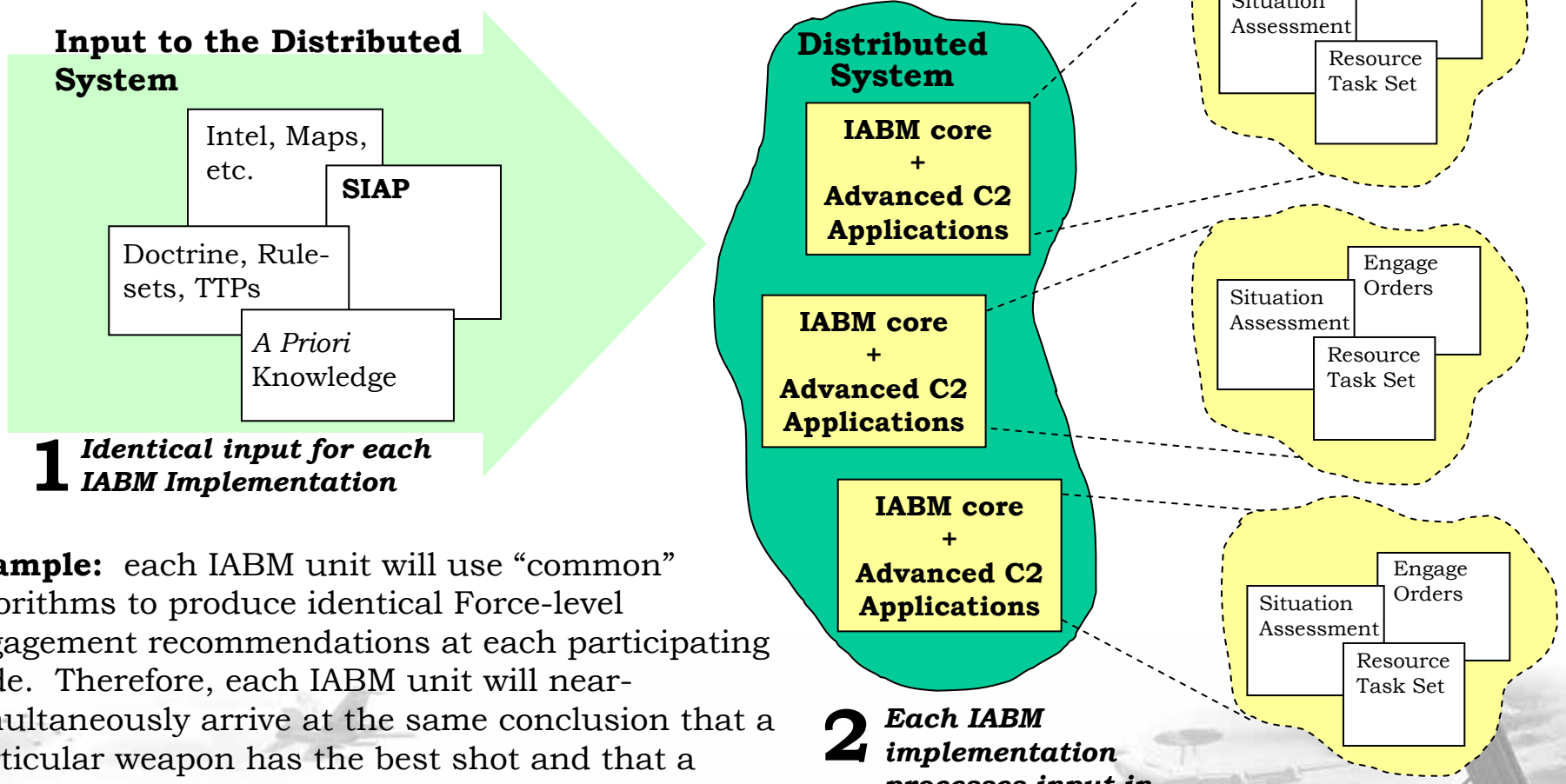
The NCW foundation provides:

- A fundamental level of shared battle space awareness – the single integrated air picture
- An architecture of common processing at distributed units
- An architecture of distributed nodes operating according to centralized guidance and common objectives to modulate individual self-interest
- Units the ability to function collaboratively or as independent stand-alone entities
- A basis for heterogeneous distributed C2 systems to function in an integrated manner that appears to the warfighter as a virtual system of systems (SoS)
- Collaborative SoS characteristics of dynamic complexity to support the complex and unpredictable nature of Joint tactical aerospace warfare.

Building Future Joint C2 Applications upon the NCW Foundation

Future Joint C2 Philosophy

Take the SIAP "Common Processing" Philosophy One Step Further: Equip each IABM with common decision-making and advanced data fusion algorithms, which when fed identical track pictures (or data sets), allows each to produce identical resource tasking recommendations.



Example: each IABM unit will use "common" algorithms to produce identical Force-level engagement recommendations at each participating node. Therefore, each IABM unit will near-simultaneously arrive at the same conclusion that a particular weapon has the best shot and that a particular sensor (not necessarily collocated with the weapon) can best track and/or illuminate the target.

Advanced C2 Applications

Future aerospace C2 relies on incorporating common automated decision aids into each IABM and implementing an architecture that enables the sharing of common data sets and information among IABM units.

The **two key IABM capabilities** that support future Joint C2 concepts are:
(1) **Advanced situational assessment** based on data fusion
(2) **Distributed Force-centric resource management** based on automated decision-aids

Future advances in Joint aerospace C2 rely on:

- Automated Decision-Making
- Advanced Data Fusion
- Enhanced Situational Awareness
- Distributed Resource Management
- Collaborative Time-critical Missions
- Collaborative Planning & Dynamic Re-planning
- Force-wide Resource Optimization

Key Questions

- Can the IABM be designed to enable launch decisions to be made locally while also selecting the best shooter(s) from the Force?

- Can the IABM be designed to enable non-organic sensors to support engagements (before, during, and after launch)?

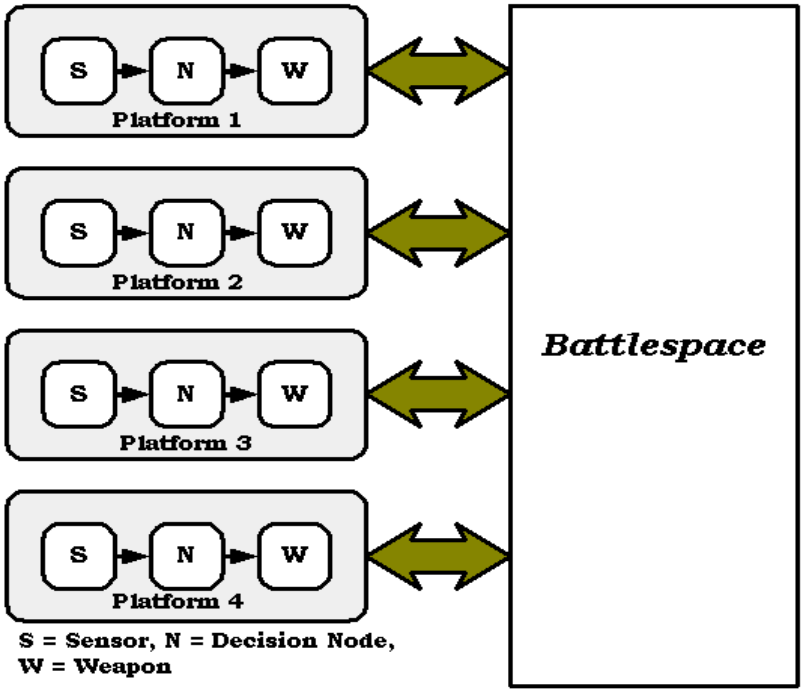
- Can the IABM be designed to enable engagement control to be shared or passed among distributed peers after launch?

Or restated…

Can the IABM be designed to permit local control of warfare assets and maintain organic command authority while enabling Force-level optimized asset utilization, control, and collaboration across distributed warfighting units or hosts?

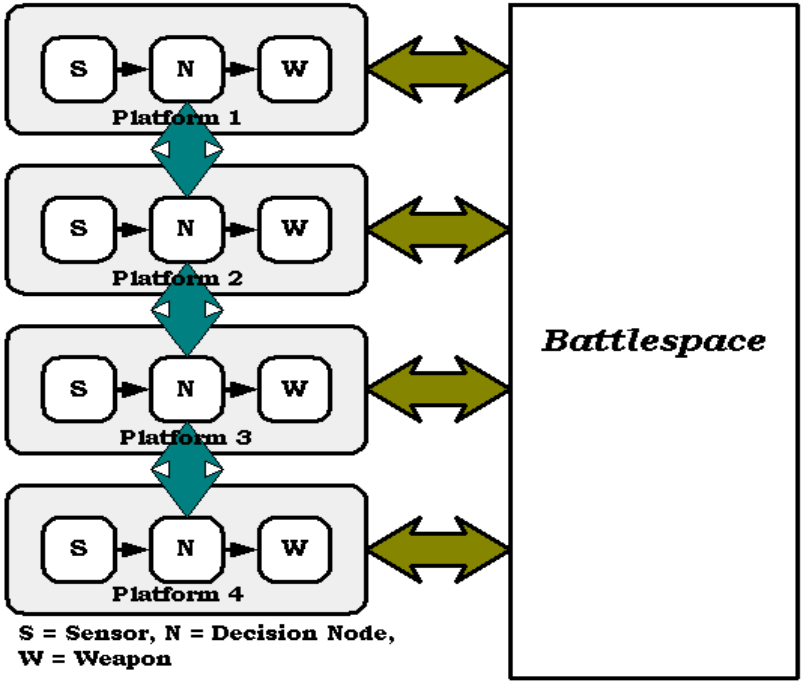
C2 Architectures

Single Unit-Centric



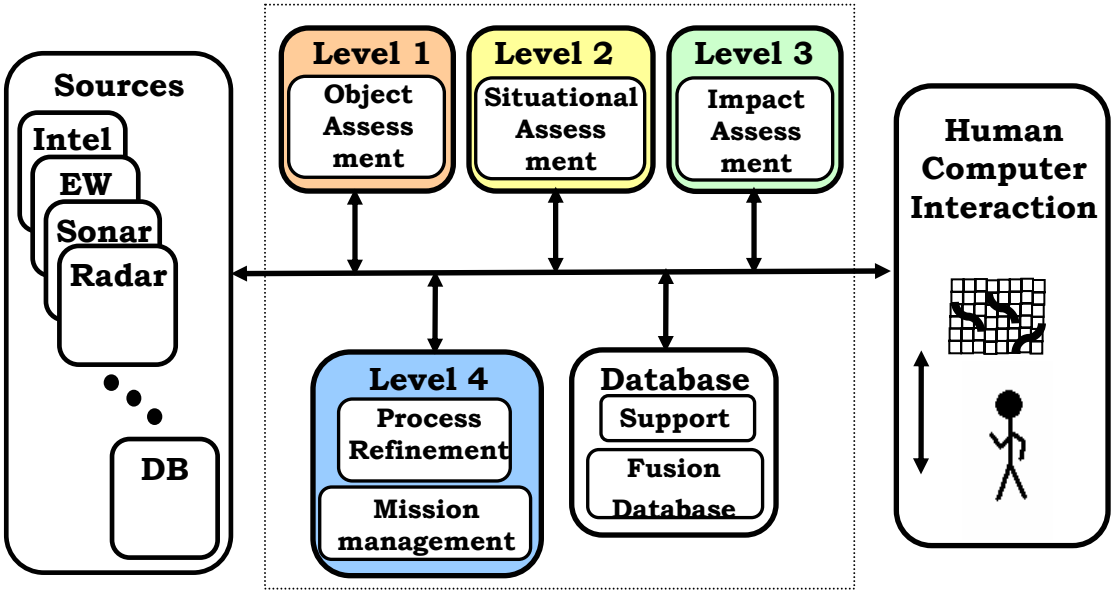
- Non-collaborative, nearly independent units
- Warfare resources managed on a platform by platform basis
- Mission areas addressed on a platform by platform basis

Force-Centric



- Multiple Unit Collaboration Possible
- Warfare resources managed according to Force-wide needs
- Mission areas managed according to Force-wide needs

JDL* Levels of Data Fusion



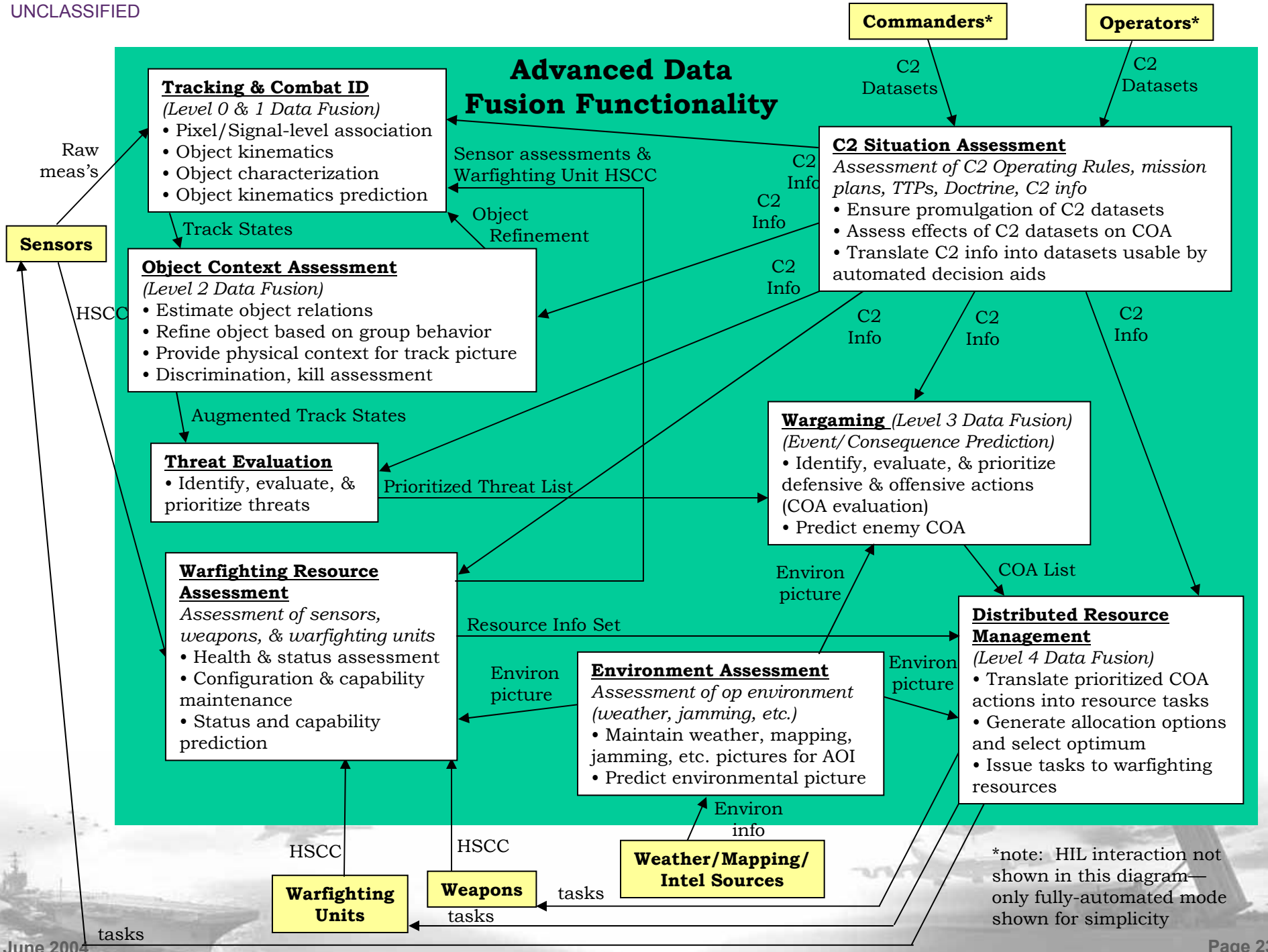
*** JDL = Joint Directors of Laboratories**

Level 1 Data Fusion:
Estimation/prediction of entity states on the basis of observation-to-track association, continuous state estimation (e.g. kinematics) and discrete state estimation (e.g. target type and ID)

Level 2 Data Fusion:
Estimation/prediction of relations among entities, to include force structure and cross force relations, communications & perceptual influences, physical context, etc

Level 3 Data Fusion:
Estimation/prediction of effects on situations of planned or estimated/ predicted actions by the participants; to include interactions between action plans of multiple players (e.g. assessing susceptibilities and vulnerabilities to estimated/predicted threat actions given one's own planned actions)

Level 4 Data Fusion:
Dynamic refinement of fusion process as process occurs; & adaptive data acquisition and processing to support mission objectives


Advanced Data Fusion Functionality
Commanders*
Operators*
C2 Datasets
C2 Datasets
Tracking & Combat ID
(Level 0 & 1 Data Fusion)
• Pixel/Signal-level association
• Object kinematics
• Object characterization
• Object kinematics prediction
C2 Situation Assessment
Assessment of C2 Operating Rules, mission plans, TTPs, Doctrine, C2 info
• Ensure promulgation of C2 datasets
• Assess effects of C2 datasets on COA
• Translate C2 info into datasets usable by automated decision aids
Raw meas's
Sensors
Sensor assessments & Warfighting Unit HSCC
Object Refinement
Track States
C2 Info
C2 Info
C2 Info
C2 Info
C2 Info
C2 Info
HSCC
Object Context Assessment
(Level 2 Data Fusion)
• Estimate object relations
• Refine object based on group behavior
• Provide physical context for track picture
• Discrimination, kill assessment
Augmented Track States
Threat Evaluation
• Identify, evaluate, & prioritize threats
Prioritized Threat List
Wargaming (Level 3 Data Fusion)
(Event/Consequence Prediction)
• Identify, evaluate, & prioritize defensive & offensive actions (COA evaluation)
• Predict enemy COA
Environ picture
COA List
Warfighting Resource Assessment
Assessment of sensors, weapons, & warfighting units
• Health & status assessment
• Configuration & capability maintenance
• Status and capability prediction
Resource Info Set
Distributed Resource Management
(Level 4 Data Fusion)
• Translate prioritized COA actions into resource tasks
• Generate allocation options and select optimum
• Issue tasks to warfighting resources
Environ picture
Environment Assessment
Assessment of op environment (weather, jamming, etc.)
• Maintain weather, mapping, jamming, etc. pictures for AOI
• Predict environmental picture
Environ picture
Environ info
HSCC
HSCC
Weather/Mapping/ Intel Sources
Warfighting Units
Weapons
tasks
tasks
tasks
*note: HIL interaction not shown in this diagram—only fully-automated mode shown for simplicity

Advanced Situational Assessment

Situational Assessment

Level 2 Data Fusion

Object Context Assessment
- Estimate object relations
- Refine object ID & typing based on group behavior
- Provide physical context for track picture
- Discrimination, kill assessment
- Maintain defended assets picture

Threat Evaluation
- Identify, evaluate, & prioritize threats

C2 Situation Assessment
Assessment & Adoption of Blue Force C2 inputs
- Ensure peer promulgation of commands
- Translate C2 inputs into system operating rules, constraints, & parameters

Warfighting Resource Assessment
Assessment of sensors, weapons, & warfighting units
- Health & status assessment
- Configuration & capability maintenance

Environment Assessment
- Develop & maintain environmental picture (weather, mapping, jamming, etc.) for AOI

IABM Evaluation
- Assessment of IABM performance (SIAP state)
- IABM health & status assessment

Force Readiness Assessment
Fusion of assessments
- Determination of overall readiness of warfighting forces

Situational Awareness (SA) is the act of understanding the totality of the tactical situation, including the threat, the defended assets, the readiness of warfighting resources, and command and control constraints within which the systems must operate. SA within the SIAP context is the ability of the collective peers to share a common understanding of the operational situation. In the case of a stand-alone peer, its SA is confined to what it can produce using the information available to it.

Future Joint C2 "Pictures"

Track Picture
Fundamental track & CID data representation of aerospace objects.

Defended Assets Picture
The location, status, & prioritization of all defended assets (ground, maritime, & aerospace; as well as Blue Force, Coalition, & Civilian)). Includes defended aerospace objects and zones as well as points or areas on the ground within an area of interest.

Object Context Picture
Estimates of the group behavior of aerospace objects.

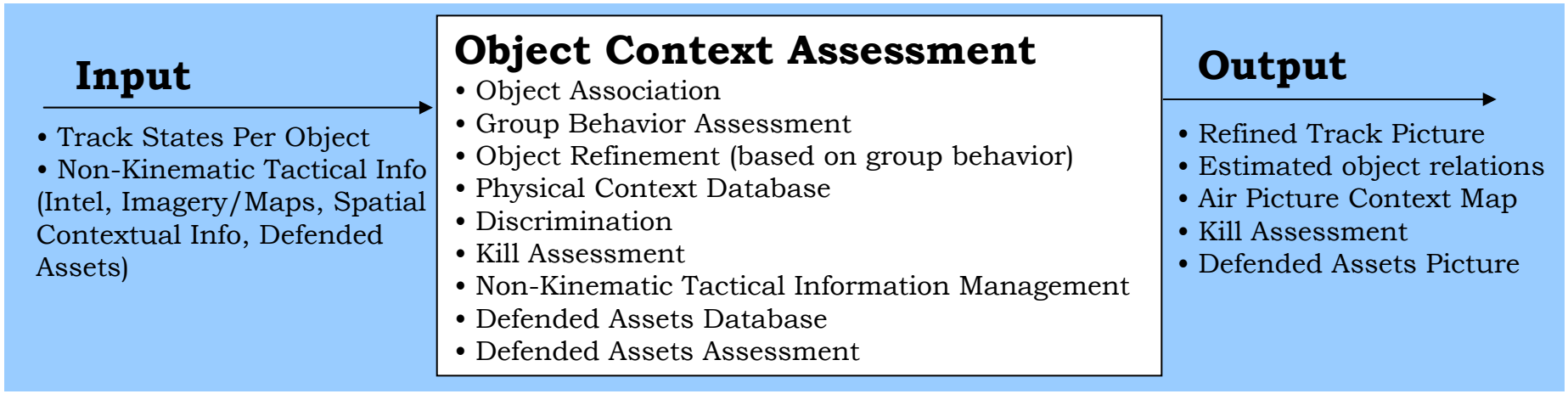
Environmental Picture
Meteorological, electromagnetic jamming, & atmospheric information concerning the battle space area of interest.

C2 Situation Picture
Decision-maker commands, assigned missions of warfighting units, doctrine, Tactics Techniques and Procedures (TTPs), location and status of IABMs, status of P2P network.

Threat Picture
The identification, evaluation, and prioritization of aerospace threat objects

Warfare Resources Picture
The location, Health, Status, Configuration, and Capability (HSCC) information of each warfare resource (sensors, weapons, and warfighting units).

Object Context Assessment



- Examines group behavior of aerospace objects and the operational context of aerospace objects.
- Estimates and predicts relationships among entities (to include force structure, cross-force relations, communications, perpetual influences, and physical context).
- Refines individual object characterizations based on group behavior assessment.
- Develops knowledge of operational environment (battlespace) by maintaining a contextual database of: geography, points of interest, nation borders, no-fly zones, defended assets, etc.

Threat Evaluation

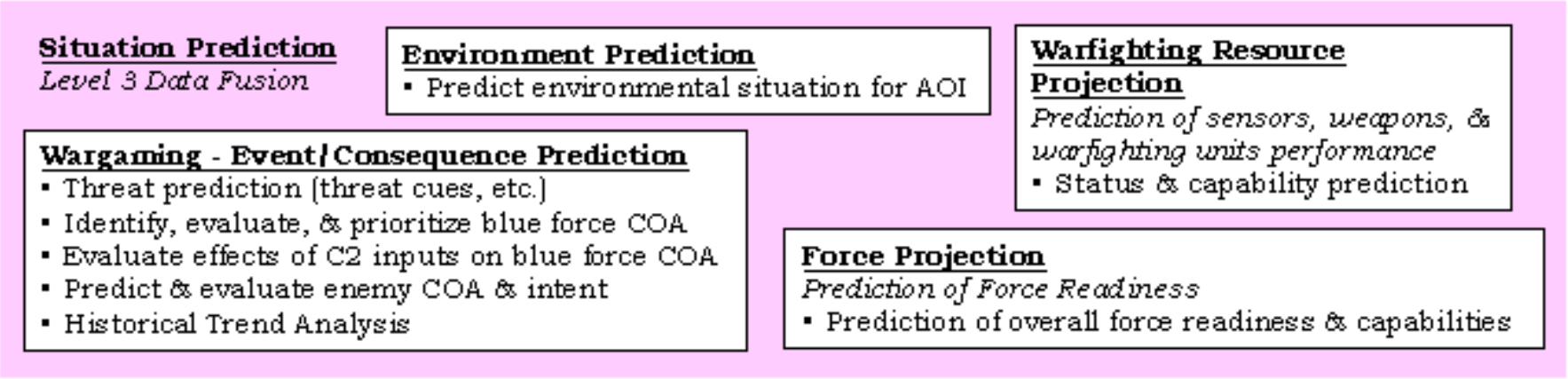
Input
- Augmented Track States
- Defended Assets Picture
- C2 Information (Threat templates, Doctrine, Non-Kinematic Tact Info)

Threat Evaluation
- Threat Assessment
- Threat Prioritization

Output
- Identified/Characterized Threats
- Prioritized Threats

- Determines which aerospace objects are candidates for engagement or defensive action
- Determines whether engagements or actions are allowed
- Assigns relative priorities to those aerospace objects designated as threats.
- Uses track kinematics and track characterization processes to determine track category (e.g., space or air), type (e.g., SCUD-B, M-9, F-16), and identification (e.g., friendly, hostile).
- Provides consistent threat designations and priorities across a distributed system of peers

Situation Prediction



- Projects the current situation into the future to estimate the enemy course of action (COA) and potential impact of the Force's planned actions.
- Uses automated management aids (AMA) to predict real-time, near real-time, and non-real-time operational situations based on blue and red hypothesized COAs.
- Assesses inferences about alternative futures or hypotheses concerning the current situation and possible COAs.
- Assigns quantitative confidence values to potential COAs
- Enables collaborative planning, effective resource management, and dynamic replanning

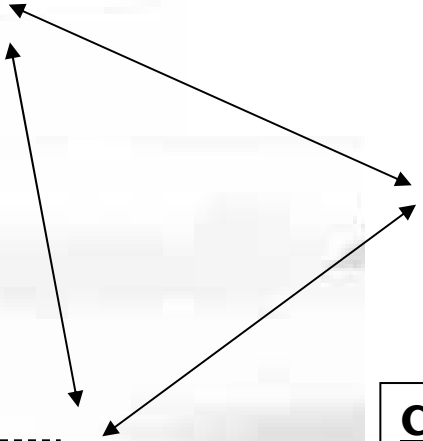
Distributed Resource Management

DRM concept: Each Peer determines optimum Force-level use of each warfare resource in the ensemble & tasks local resources accordingly

Future Peer
Core IABM Capabilities
Situational Awareness
Situation Prediction
DRM

Future Peer
Core IABM Capabilities
Situational Awareness
Situation Prediction
DRM

Future Peer
Core IABM Capabilities
Situational Awareness
Situation Prediction
DRM

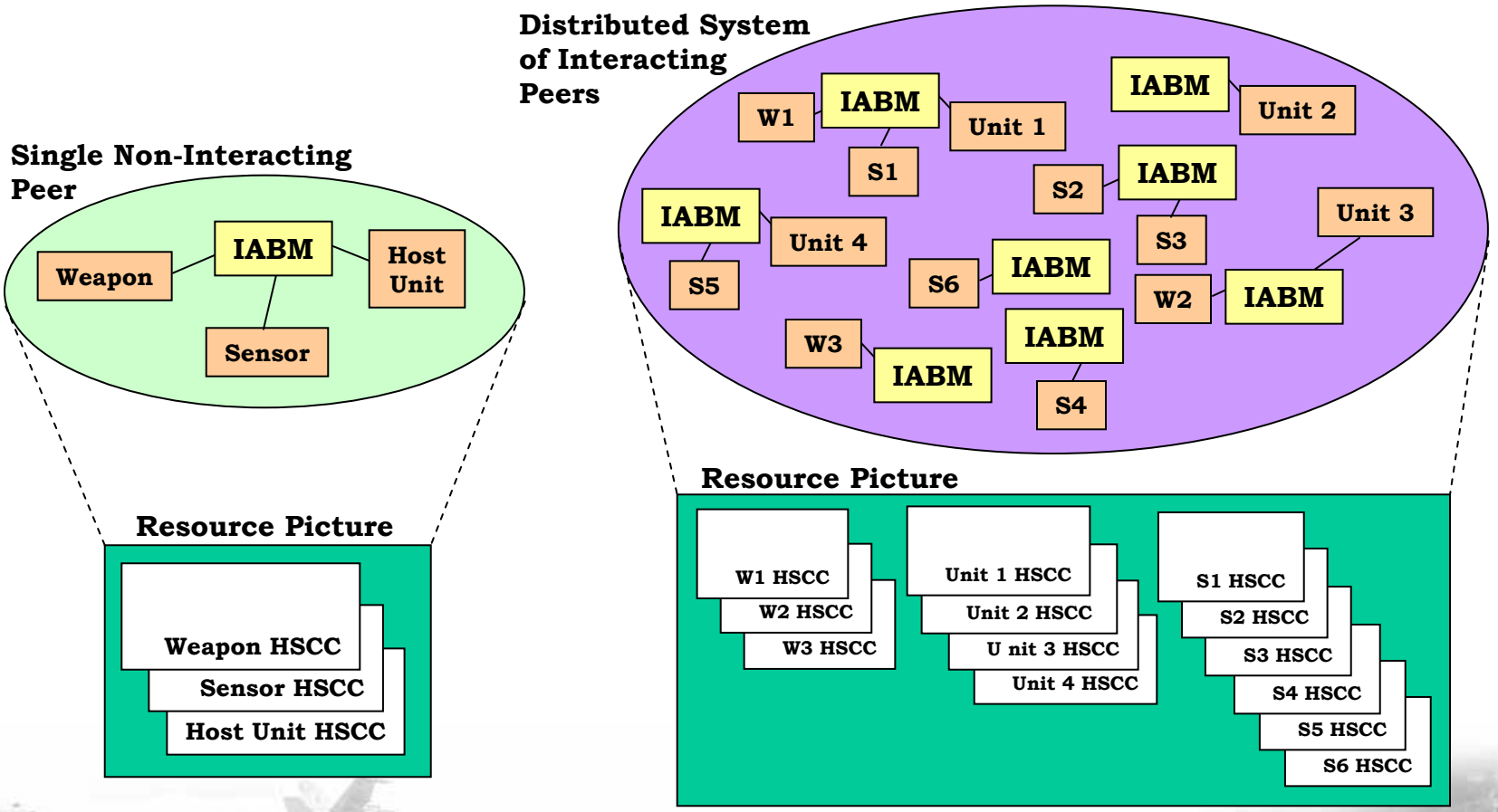


Achieves & Relies on JDL Level 4 Fusion!

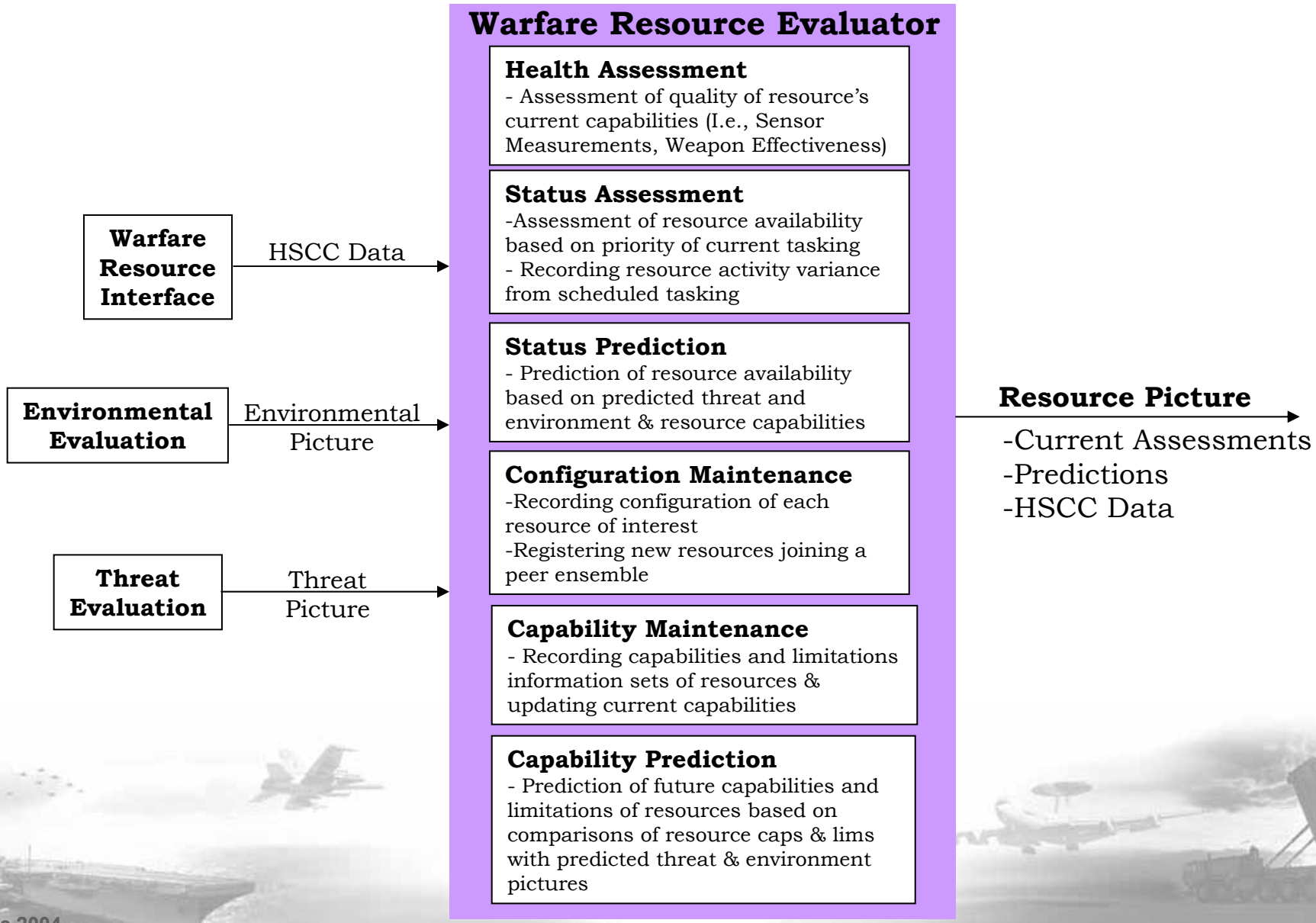
Characteristics:

- Dynamically updateable doctrine
- Decentralized architecture
- Synchronized information, doctrine, decision aids

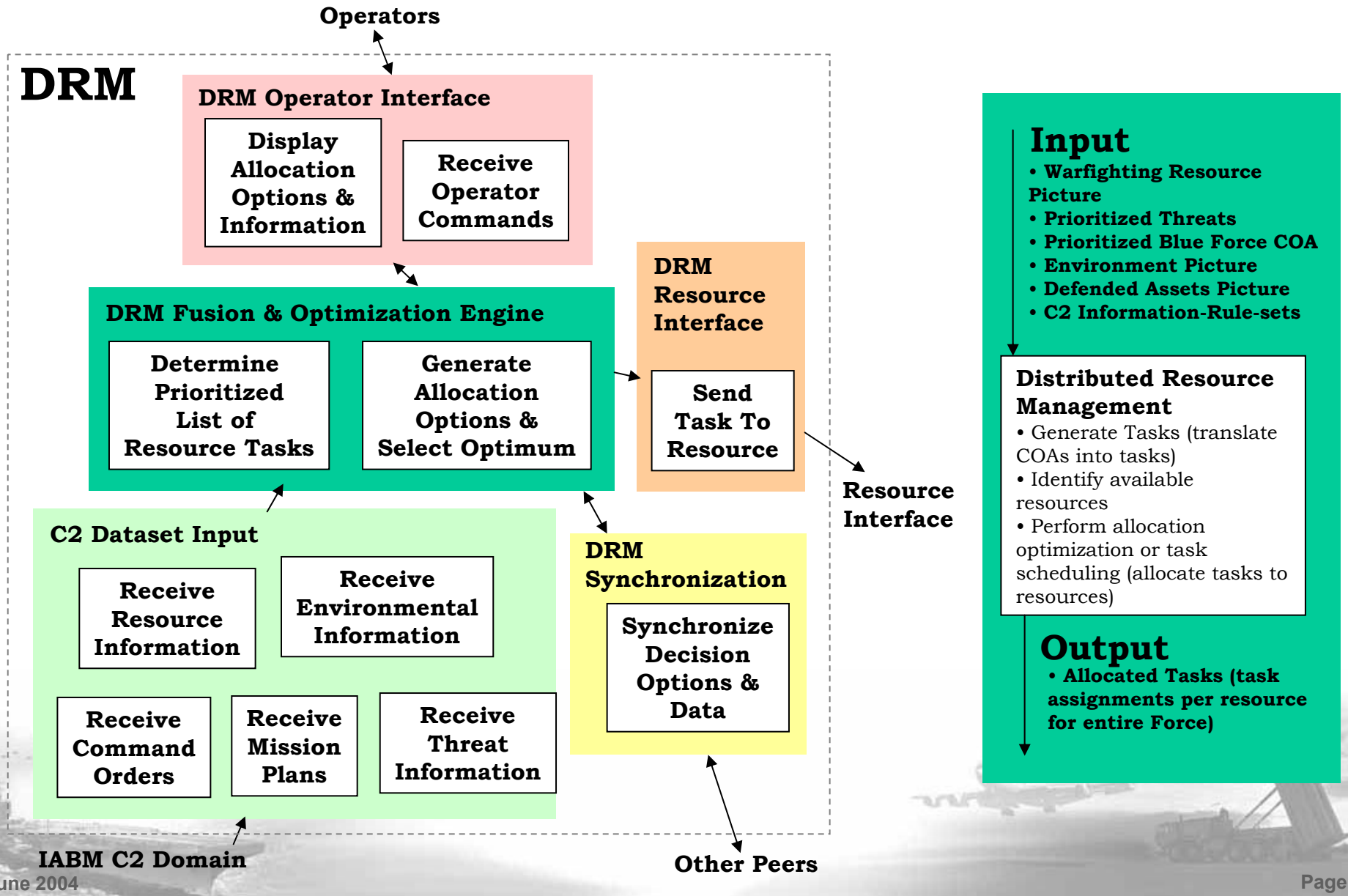
"Resource Picture" Examples



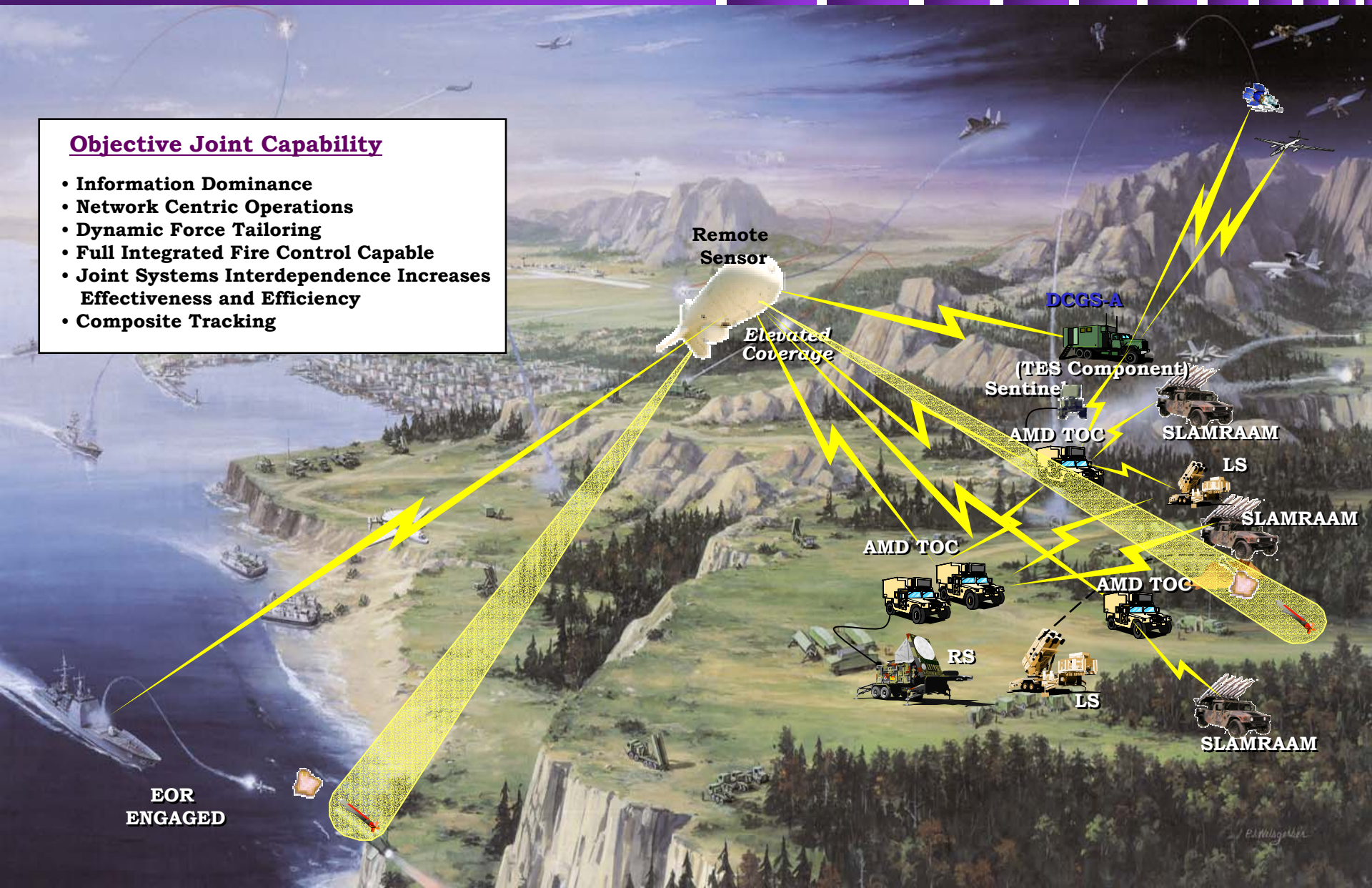
Warfare Resource Evaluation



DRM Capability



Example of Future Joint C2



Future Joint Aerospace C2 Payoffs

- **Integrated Fire Control** - the optimized use of distributed warfare resources for collaborative engagement strategies
- Selection of the **best shooter** and shot opportunities among weapons comprising a Joint Force
- Improved **economy of weapon resources**
- Improved **SIAP accuracy** and coverage (and therefore earlier detection and enhanced surveillance coverage) using feedback control tasking for optimized sensor data acquisition
- Lifted constraint of **organic sensor/weapon pairing** for engagements
- **Improved engagement envelopes** and more varied and flexible engagement strategies.
- Improved airspace management - enabling **Joint Engagement Zones**
- Automated wargaming enabling **dynamic replanning** of tactical resources and **collaborative planning** capabilities
- Enhanced state of **information superiority**; and therefore, **enhanced decision-making** by warfighters

Conclusion

- Establishing a NCW foundation is the basis for future aerospace warfare advancement.

- Future C2 vision is based on extending the SIAP "Common Processing" philosophy to include common advanced data fusion and decision-making algorithms at each Peer

- Future C2 concept enables local control of warfare assets while enabling Force-level optimized use, control, and collaboration of warfare assets across distributed units.