Semantic SOA: Key Technologies for DoD Net-Centric Computing

"Sense, Share, Discover, Understand"

NASA Earth Science Sensor Web Meeting
February 14, 2007

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Agenda

- Net-Centricity: The Promise vs. the Reality, and the Emerging Role of Semantics
- The Emerging Role of Web Services/Agents in DoD "Sensor Webs"
- WebAgents – a Semantic Agent Framework for Geospatial Intelligence
- Near Term Application – Time Critical Operations
- Future Vision – Achieving the Promise via the "Semantic Wave"

The DoD Sensor Web Evolution

- “Sneaker-nets”
- “Machine-to-Machine”
- Semantic Interoperability

Net-Centricity: Promise vs. Reality

- The growth and nature of “time critical” threats is driving the DoD towards Network-Centric Warfare and “upstream” Multi-Sensor (“Multi-INT”) Fusion

- The promise of these ideas is that “horizontal integration” can shorten decision timelines by leveraging the dynamic relationships among:
  - Multi-INT ISR Sensors regardless of platform/platform “owners”
  - Decision Makers (strategic/tactical) regardless of their location
  - Effectors (warfighters and operators) regardless of service

- SOAs enable interoperability and dynamic compositions of services across diverse tactical network architectures; intelligent agents can autonomously infer and execute actions to provide “smart push” services

Net-Centricity: Promise vs. Reality (cont.)

- However most existing DoD ISR sensor data systems lack semantics
- As a result, although Global Net-Centricity can make disparate data available anywhere at any time, *people*, not machines are still used to "connect the dots"
- Efforts are underway to change this picture:
  - W3C/DAML Programs
  - DoD XML Registry; Intelligence Community Markup Language (ICML); DoD Discovery Metadata Specification
  - Horizontal Fusion Portfolio/Net-Centric Enterprise Services (NCES) Initiatives
  - FEA Data Reference Models (DRM)-Semantic Interoperability Community of Practice (SICoP)

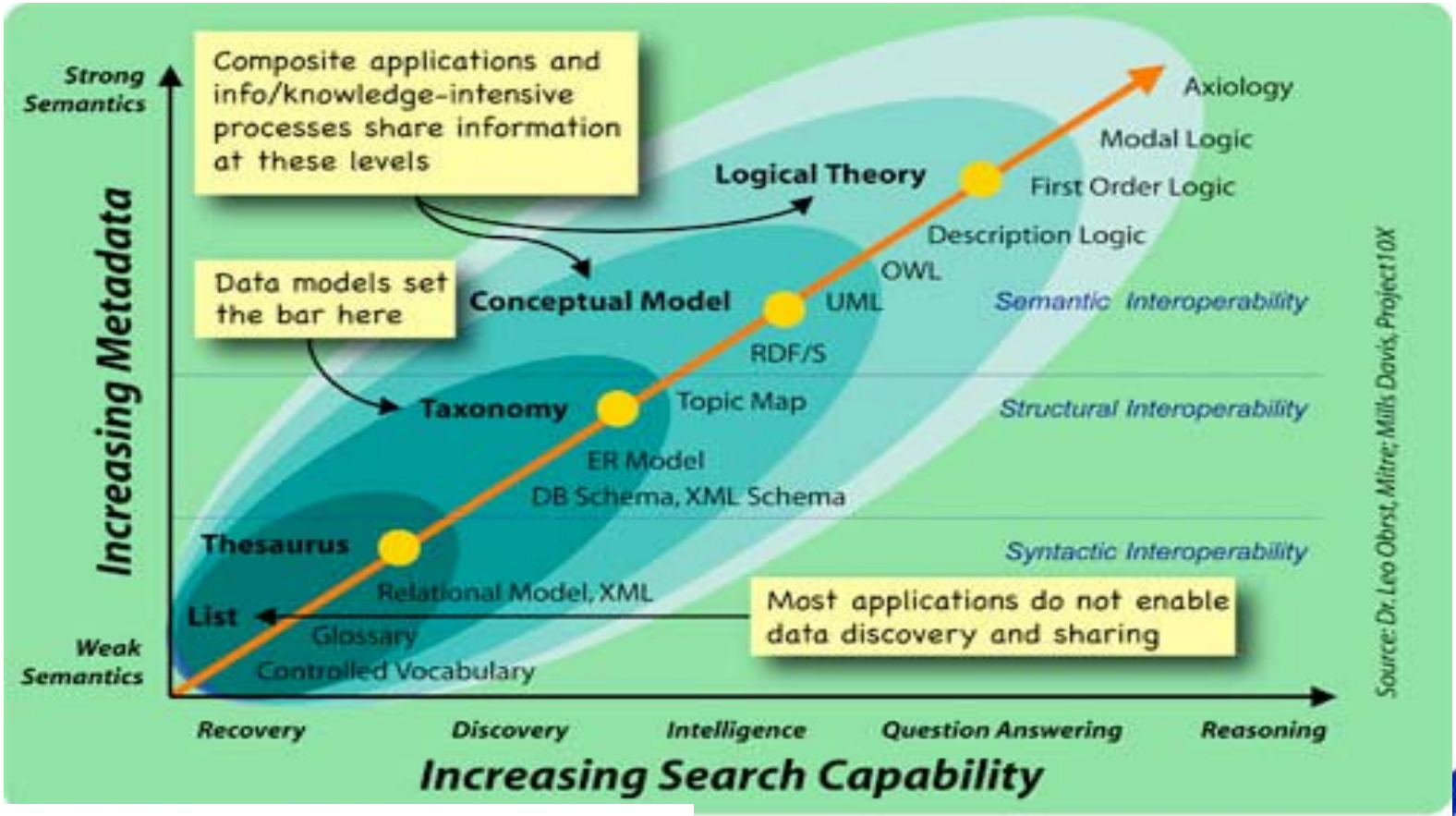
Semantics: Making "Sense" of the Data

The real race will be won by those who create the most valuable configuration of knowledge in the shortest time….

- Semantic technologies make the meaning of data explicit by representing meanings, associations, and know-how (e.g. rules) about the uses of things separately from data and program code.
- This knowledge representation is called an ontology — a run-time semantic model of information, defined using constructs for:
  - Concepts Relevant to the Domain of Interest
  - Properties and Attributes of Concepts
  - Constraints on properties and attributes
  - Instances of concepts – individuals, threats, places (data, facts)
- Ontologies can make digital content (any form of digital media such as imagery, video, text, etc.) "smart" when annotated with metadata based on an ontology

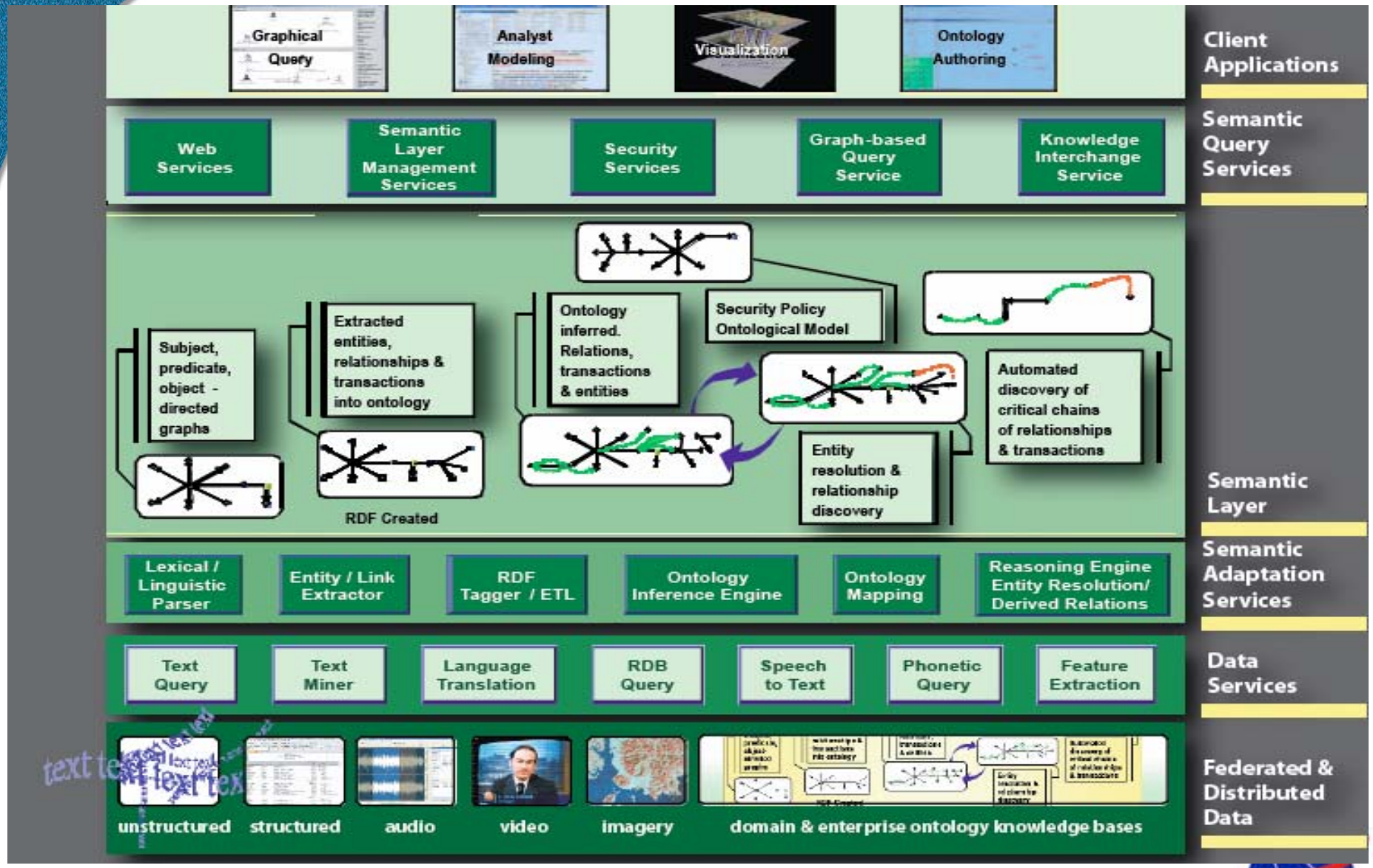
More Metadata/Knowledge Modeling → More Reasoning Capability*

Ontology Spectrum



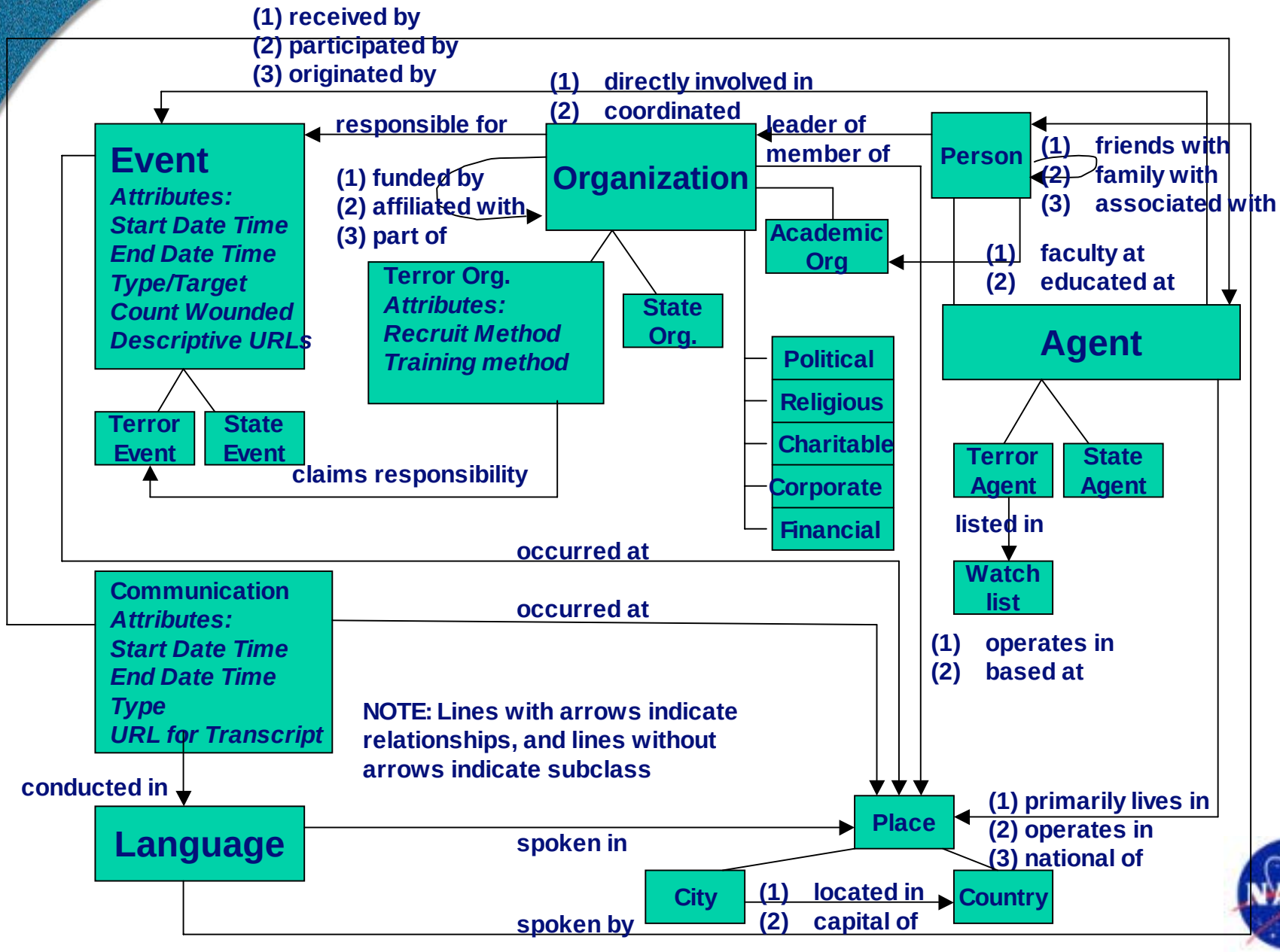
*Source: DRM 2.0 Implementation Guide

The IC Establishes “Virtual Sensor Webs” Through Semantics



*Source: Joel Gladding, SAIC

Sample Terrorist Ontology Schema



Strategic Semantic Challenge: Linking Ontologies*

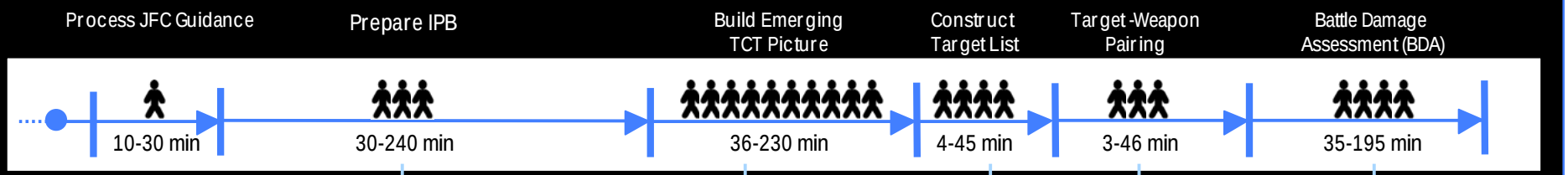
* Source: Mills Davis “Semantic Wave 2006” Keynote Presentation

Illustrative DoD Net-Centric Efforts: The Emerging Role of SOA/Agents in DoD "Sensor Webs"

U.S. AIR FORCE

A Driving Net-Centric Challenge: Time Critical Targeting (TCT)

Best to Worst Case: 83-591 min (prosecute only); 118-786 min (with BDA)



Issues
- Manual read of a large text plan; manual deconfliction for coalition ops

Clients
- A2IPB

Issues
- On Target Detection, Trafficability, Target History Analysis, EBO considerations

Subtasks
- Task ISR Sensors, *5-30min*
- Redeploy Sensors, *15-120min*
- Fuse Multisource INT, *15-45min*
- Additional Analysis, *0-15min*
- Mensuration, *1-20min*

Clients
- TCTA
- JSWS
- JTAT

Issues
- Extensive check for Collateral damage considerations

Subtasks
- Nominate Targets, *1-1min*
- Target Deconfliction, *0-20min*
- Prioritize Targets, *1-3min*
- Select Targets, *0-1min*
- Coordination, *1-20min*

Issues
- Range of available weapons

Subtasks
- Weather Effects, *0-1min*
- Weapon Selection, *1-10min*
- Route Analysis, *0-5min*
- Package Construction, *1-10min*
- Coordination, *1-20min*

Clients
- JEES
- AODA

Subtasks
- Task ISR Sensors, *5-30min*
- Redeploy Sensors, *15-120min*
- Fuse Multisource INT, *15-45min*

Key DoD Transformational Themes

- **TCT Operations from hours ⟹ < 10 minutes**
- **Fixed Targets ⟹ Time-Sensitive Targets "On the Move"**
- **Stovepipes ⟹ Synchronized Effects-Based Ops**
- **Deliberate Planning ⟹ Dynamic Plan/Re-Plan "On the Fly"**
- **Theater ⟹ Global Focus**

Global Net-Centric Surveillance and Targeting

To deliver decision quality intelligence information to the Warfighter by leveraging automated NRT correlation/fusion of airborne and national Multi-Int data to detect, locate, identify, and assess previously undetected/unlocated mobile targets ***(initially SAMs, SSMs)***

Integrated Picture

Application of Technology

- Agent-based data access
- Model-based upstream fusion
- Collaborative visualization

Enables Critical Process Improvements

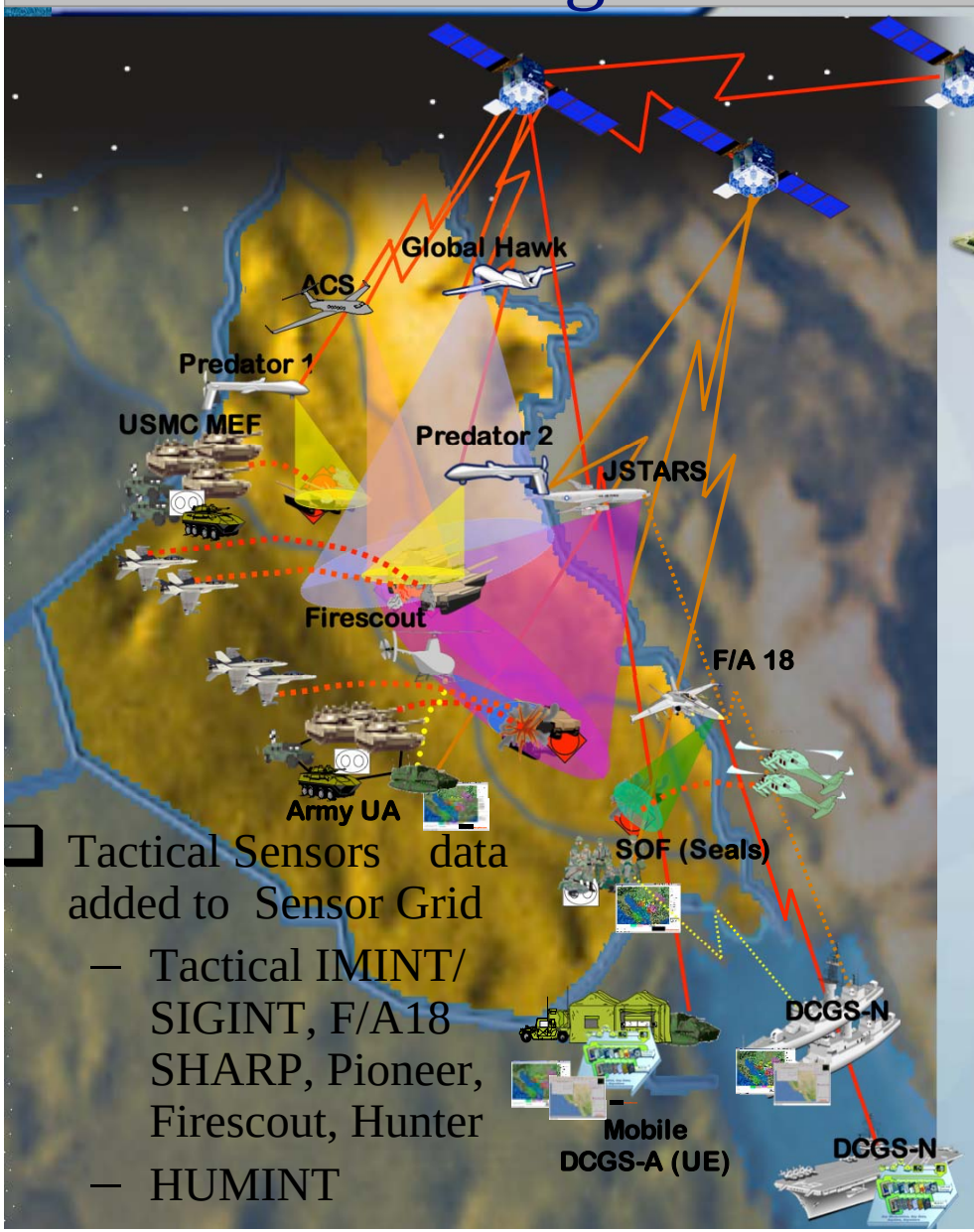
- Navigation of Stovepipes
- Upstream Fusion
- Specific Target ID
- Dynamic Re-tasking Nominations

Producing

- Reduced decision cycles
- Ambiguity reduced and precision increased

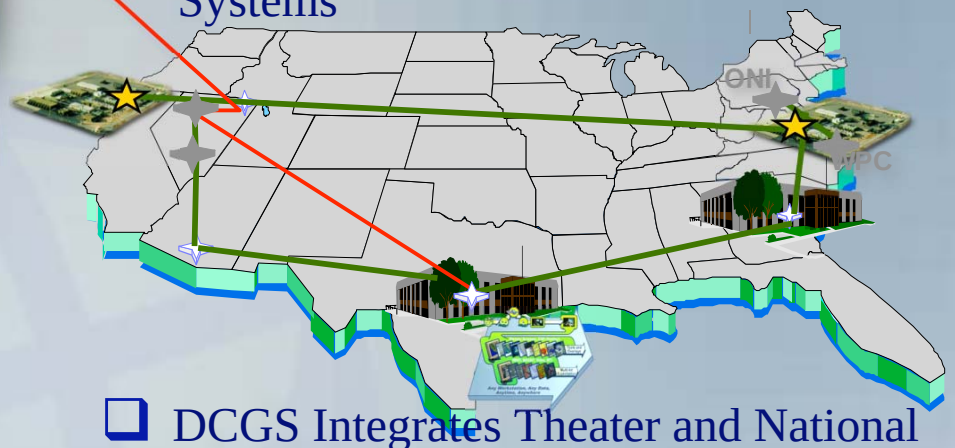
Unclassified / For Official Use Only

Distributed Common Ground System (DCGS) "Google"-like Intelligence Sharing



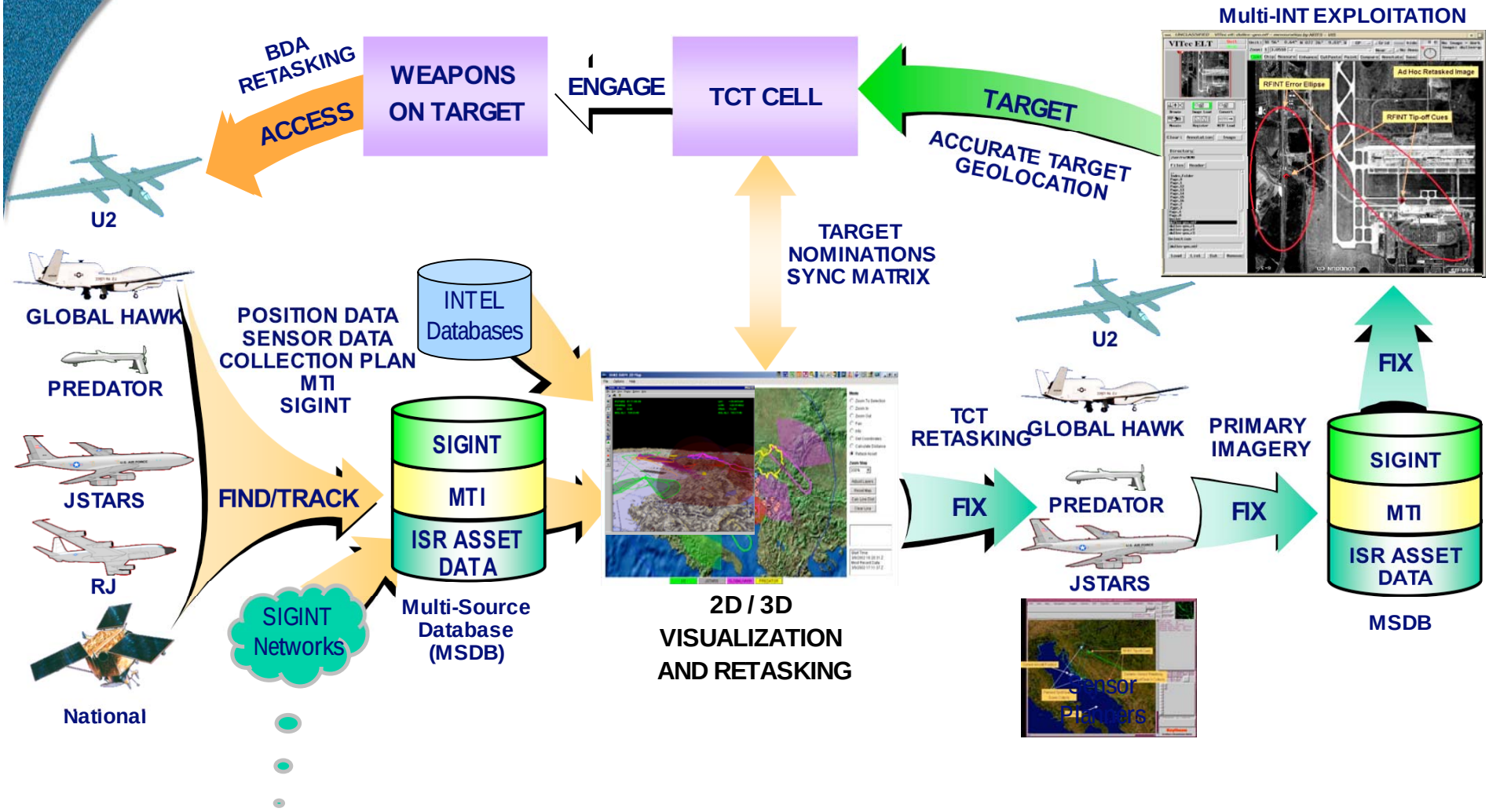
- Tactical Sensors data added to Sensor Grid
  - Tactical IMINT/ SIGINT, F/A18 SHARP, Pioneer, Firescout, Hunter
  - HUMINT

- Sensor-to-Shooter Support with Full Integration of Fire Control/C2 Systems



- DCGS Integrates Theater and National Intelligence
  - National IMINT and SIGINT
  - U-2, GH, Predator, ACS, RJ, JSTARS, etc.
- Multi-INT Visualization provides COP to all forces
  - ISR Sensors (National, U-2, GH, Predator, ACS, RJ, UGS,etc)
  - Blue Force Tracking
  - GCCS-M, ASAS Red/Blue OB

DCGS- CONOPS

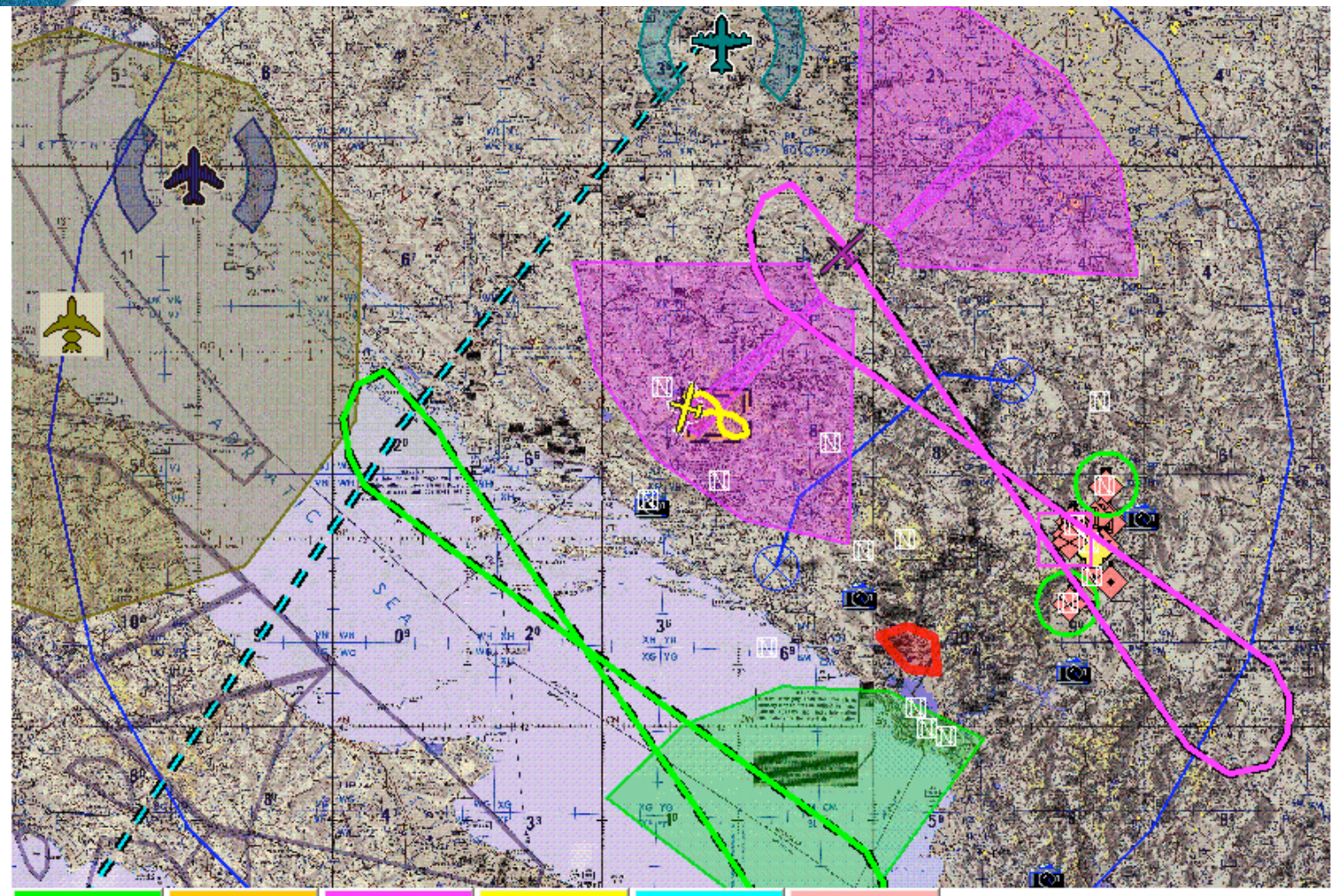

BDA
RETASKING
ACCESS
WEAPONS
ON TARGET
ENGAGE
TCT CELL
TARGET
ACCURATE TARGET
GEOLOCATION
Multi-INT EXPLOITATION
U2
GLOBAL HAWK
PREDATOR
JSTARS
RJ
National
POSITION DATA
SENSOR DATA
COLLECTION PLAN
MTI
SIGINT
FIND/TRACK
INTEL
Databases
SIGINT
MTI
ISR ASSET
DATA
SIGINT
Networks
Multi-Source
Database
(MSDB)
TARGET
NOMINATIONS
SYNC MATRIX
2D / 3D
VISUALIZATION
AND RETASKING
TCT
RETASKING
FIX
U2
GLOBAL HAWK
PREDATOR
JSTARS
PRIMARY
IMAGERY
FIX
FIX
SIGINT
MTI
ISR ASSET
DATA
MSDB
RFINT Error Ellipse
Ad Hoc Retasked Image
RFINT Tip-off Cues

DCGS Metadata Catalog

- The DCGS Metadata Service capabilities include
  - Search catalog
  - Catalog data
  - Subscribe and Unsubscribe
  - Agent-Based Alert Notification service (sentries, alert types, etc.)
- The Metadata Catalog Query capabilities include
  - Geospatial search
    - point radius, polygon, spatial operators
  - Temporal search
    - start and end times
  - Contextual search
    - exact match, and, or, either or, wild cards, etc.
  - Compound search
    - combinations of the above queries

DCGS Metadata Catalog Contents

- Air Tasking Order (including Special Instructions)
- Airspace Control Order
- Named Areas of Interest
- Prospective Enemy Courses of Action
- Target Areas of Interest
- Suspected Time Critical Target (TCT) Infrastructure Areas
- Suspected Launch Basket Infrastructure Areas
- High Value Target locations
- Lines of Communication
- Restricted Areas, No-Strike Zones, No-Fly Zones
- Forward Line of Troops
- Fire Support Coordination Line
- Imagery (IMINT), Multiple All Source Intelligence (MASINT), Signals Intelligence (SIGINT)



Mode

- Zoom To Selection
- Zoom In
- Zoom Out
- Pan
- Info
- Get Coordinates
- Calculate Distance
- Retask Asset

Zoom Step

150%

Adjust Layers

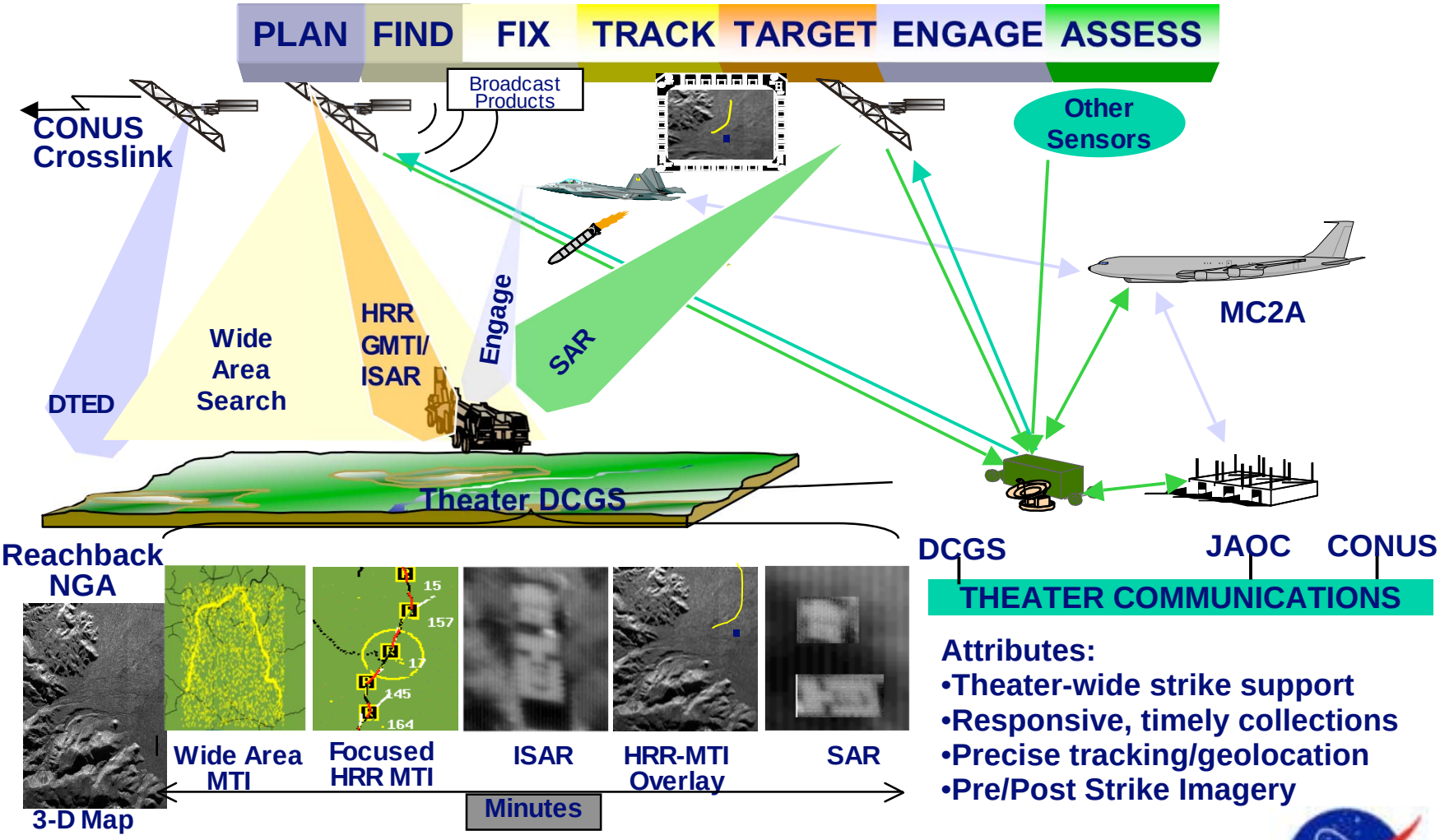
Reset Map

Calc Line Dist

Clear Line

Start Time:
6/13/2003 19:30:39 Z
Most Recent Data:
6/13/2003 21:00:41 Z

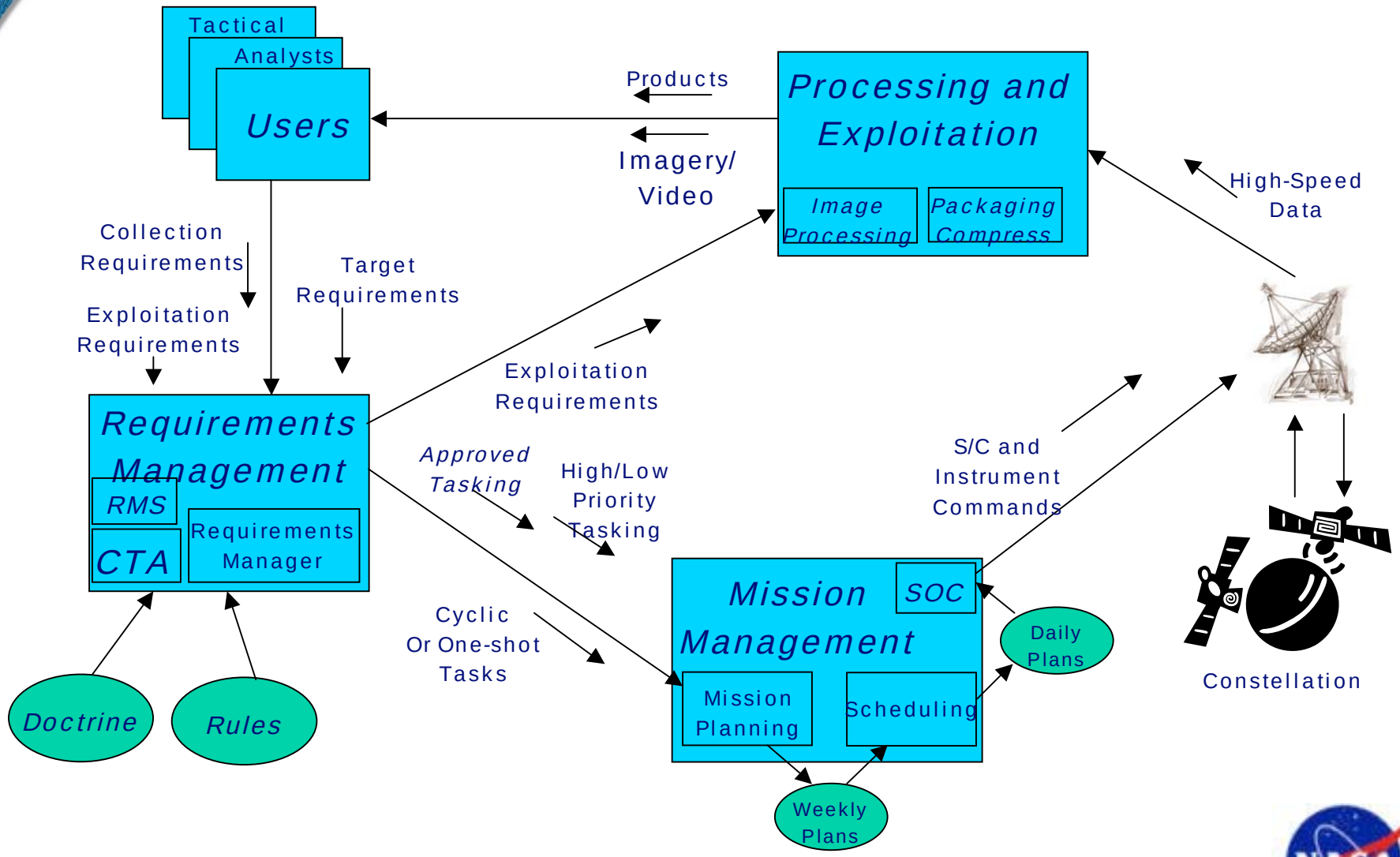
Space-Based Radar (SBR) Constellation



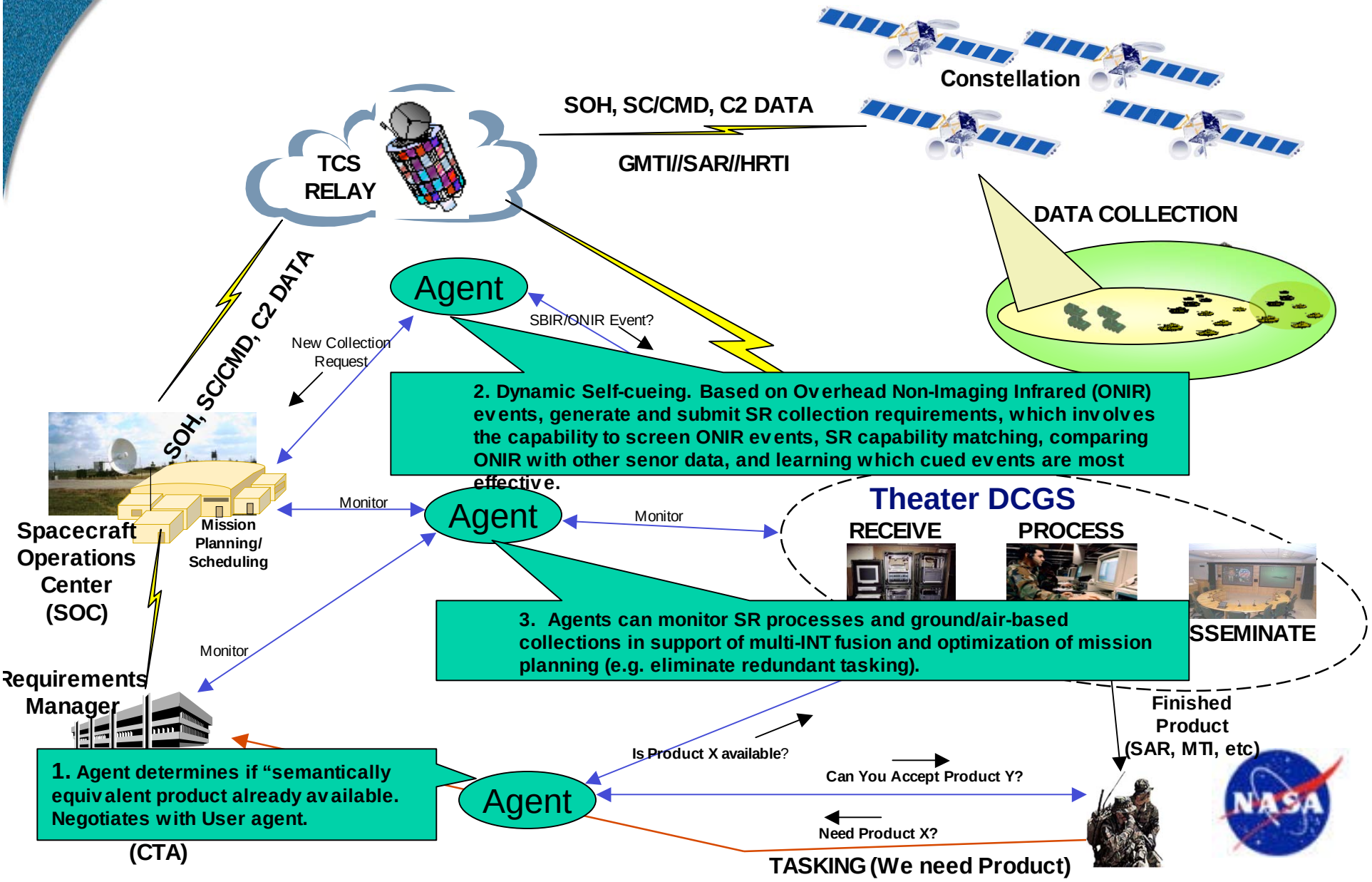
Attributes:

- Theater-wide strike support
- Responsive, timely collections
- Precise tracking/geolocation
- Pre/Post Strike Imagery

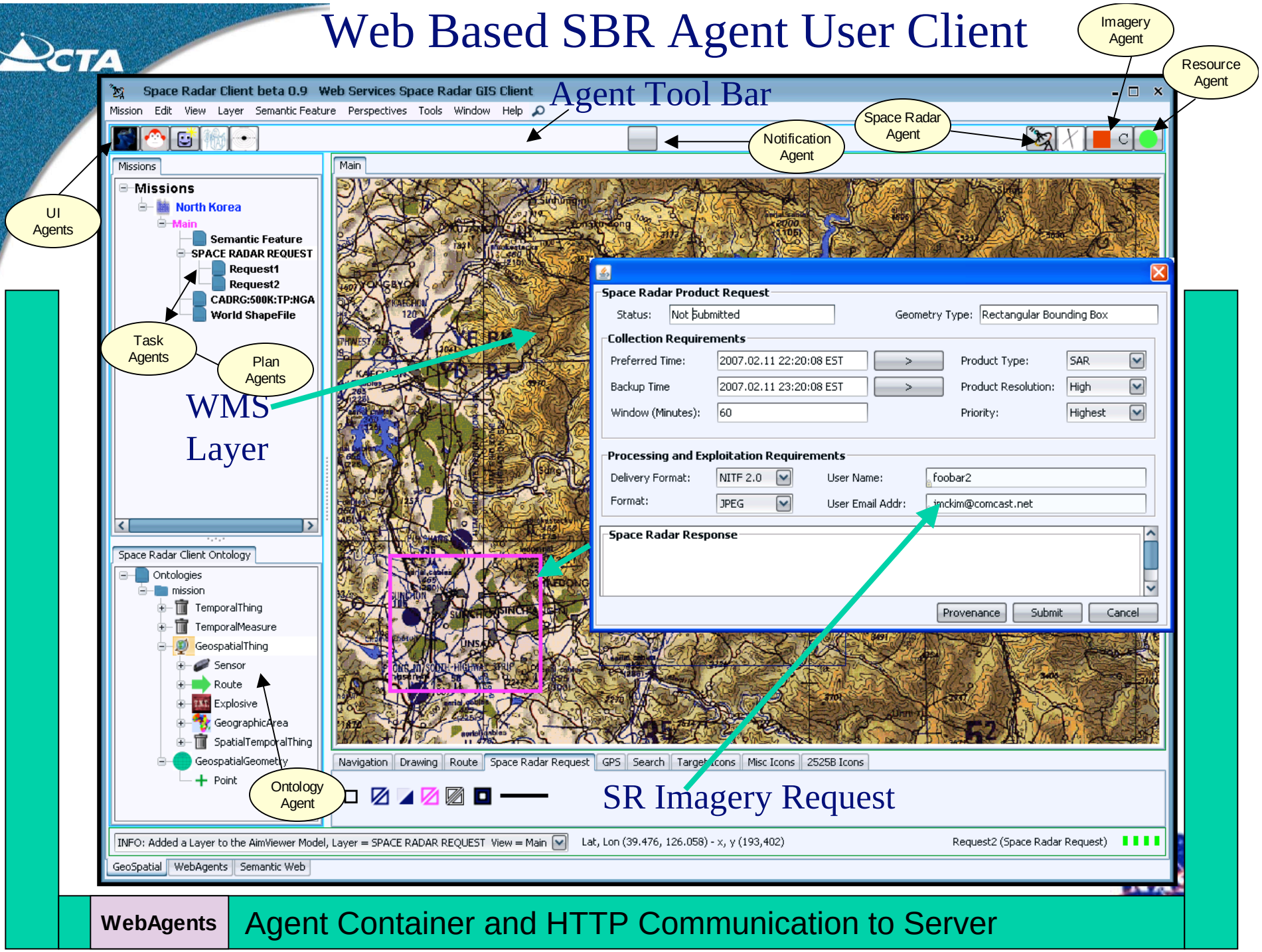
Space Radar C2 Environment



Experimental Agents for SBR C2

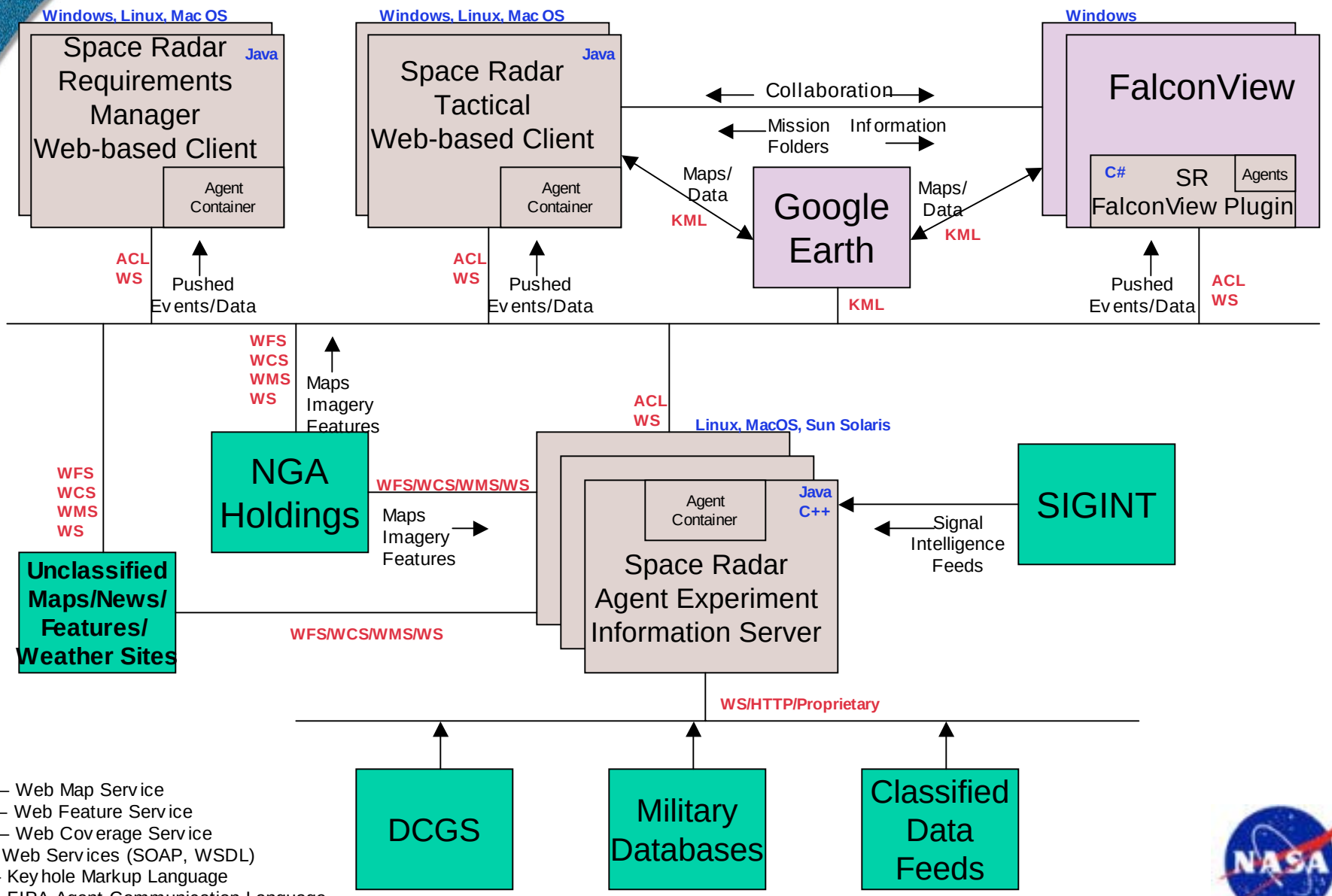


Web Based SBR Agent User Client



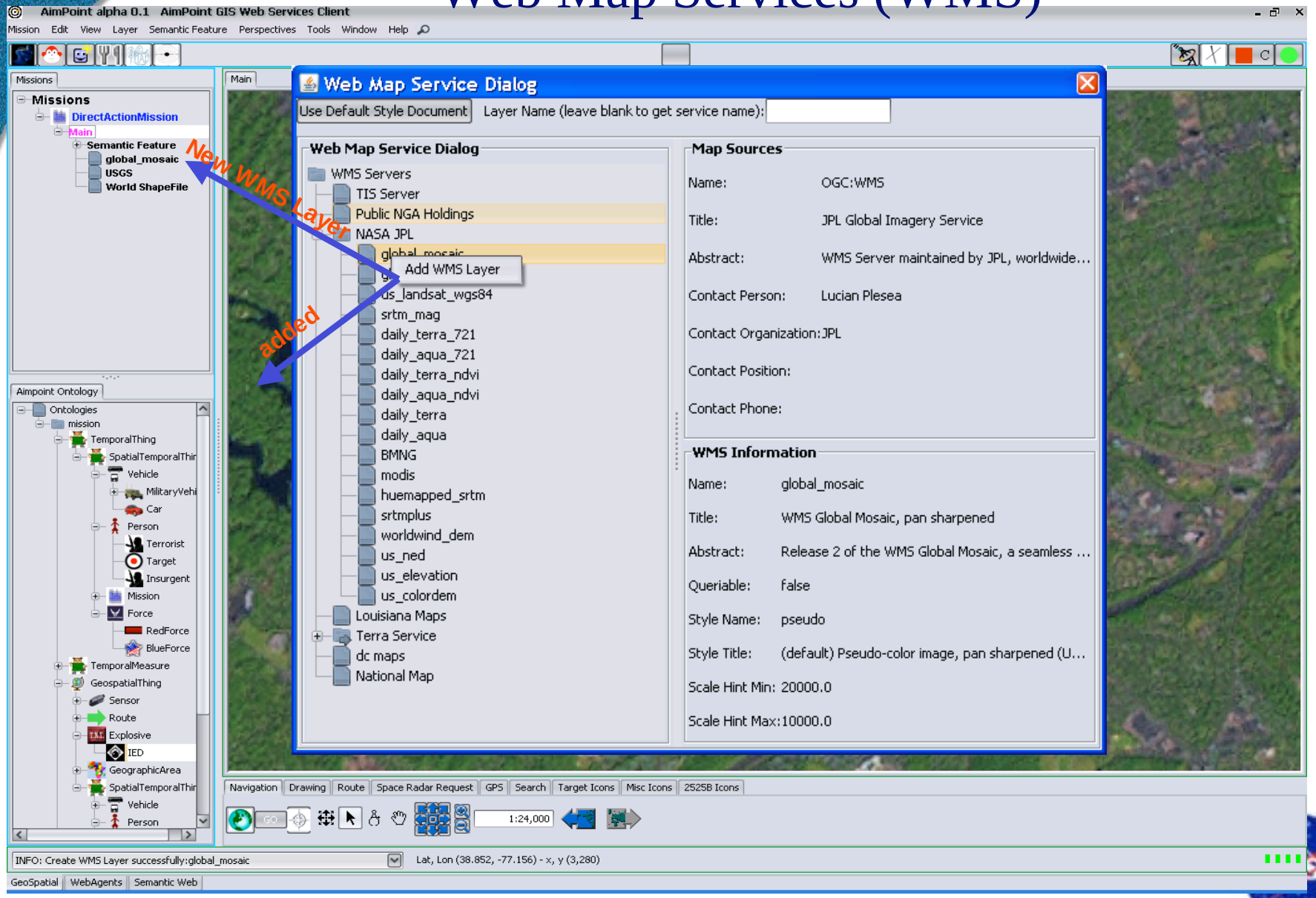
WebAgents Agent Container and HTTP Communication to Server

Experimental Architecture: SBR C2



WMS – Web Map Service
WFS – Web Feature Service
WCS – Web Coverage Service
WS – Web Services (SOAP, WSDL)
KML – Keyhole Markup Language
ACL – FIPA Agent Communication Language
FIPA – Foundations for Intelligent Physical Agents

Dynamically Discover and Add OGC compliant Web Map Services (WMS)

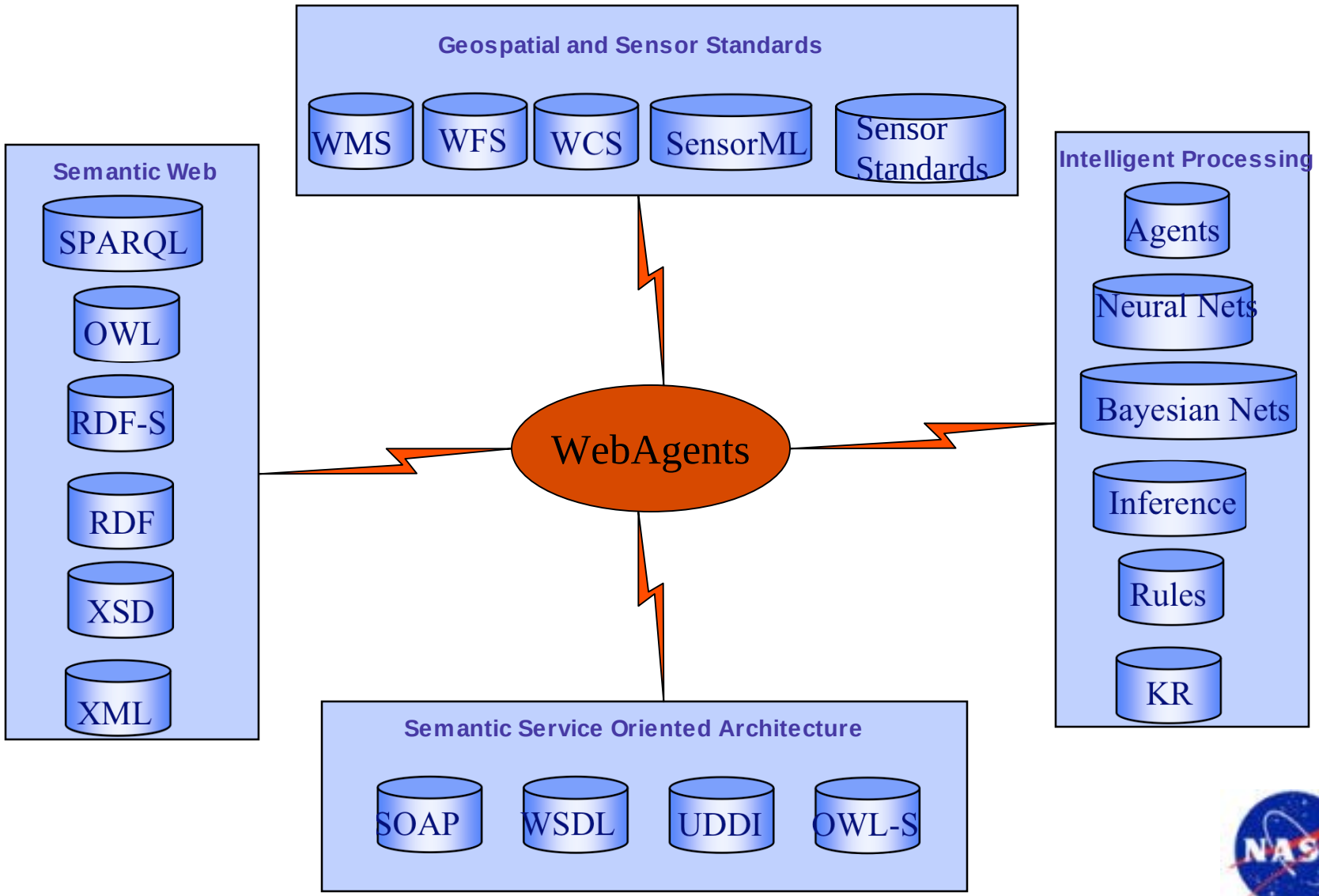


WebAgents: An Agent Framework for Actionable Geospatial Intelligence

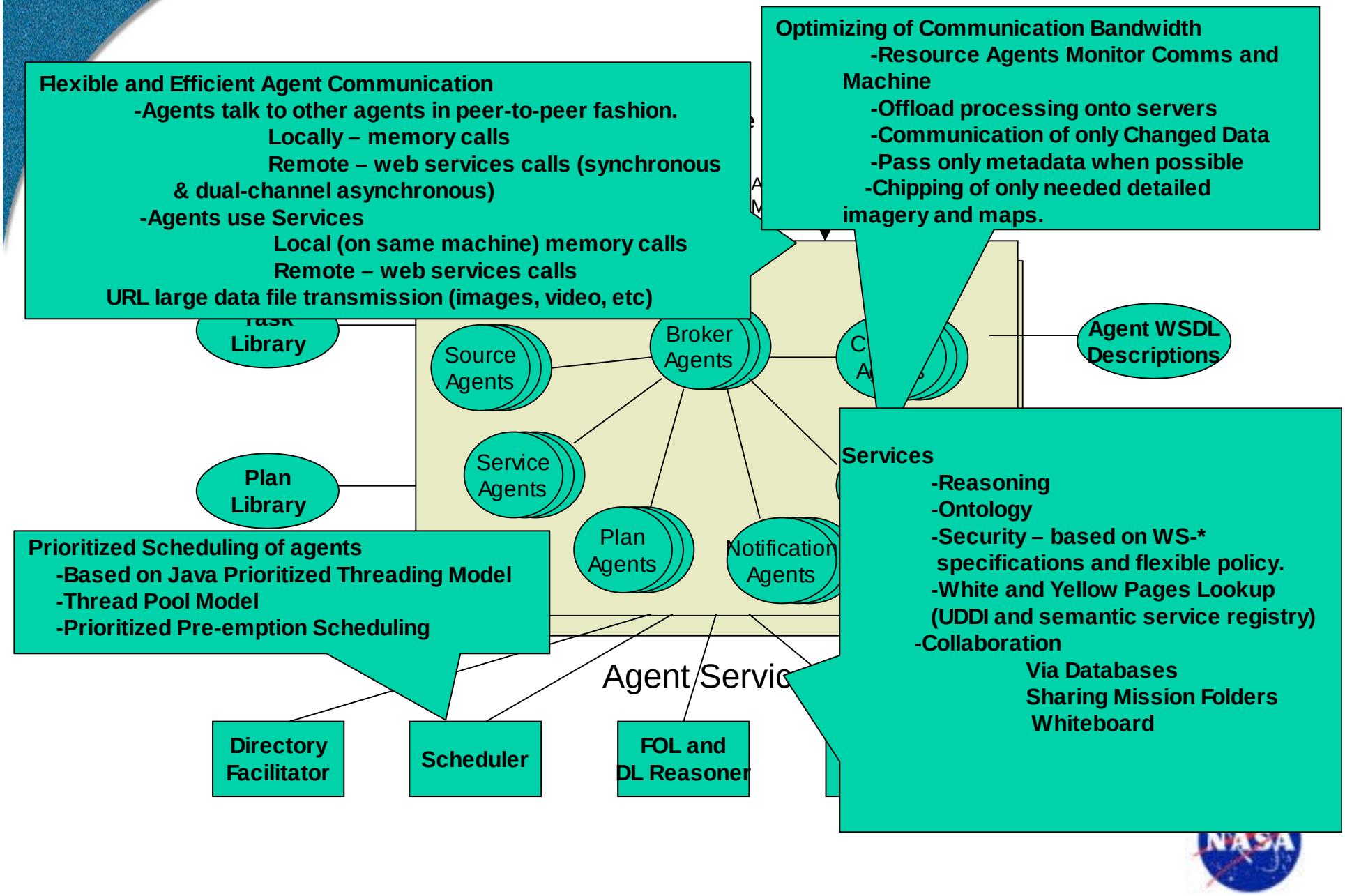
CTA WebAgents Platform

- WebAgents Developed as element of CTA AFRL SBIR
  - Agents Compose Complex Web Services Utilizing OWL-S
  - Agents Provide Intelligence to Net-Centric Sensor Webs
- Addresses issues typically associated with existing agent platforms
  - Communications based on RMI, JINI, and sockets - can't easily go through firewalls.
  - Not integrated with nor based on semantic web technologies
  - Lack of language and machine interoperability
  - Do not leverage Network Transparency benefits of SOA
  - Not designed for performance
- Optimized for distributed performance in bandwidth constrained environments
- Can be readily configured to collect up-to-date SA information from diverse data sources based on the user's goals and mission ontology
- Supports autonomous operations during disconnected periods, anticipating user's information needs
- Supports advanced reasoning/collaboration services

WebAgents: Convergence of Key Processes, Standards and Technologies



WebAgents MAS Architecture

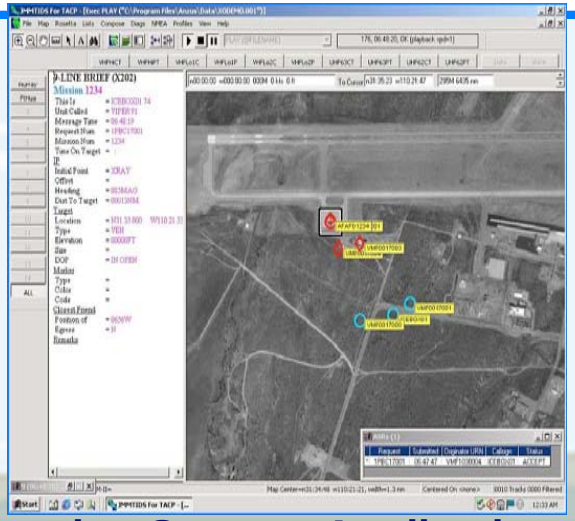


Near Term WebAgents Application: SOF CAS Operations

Current TACP/SOF Elements

Litton MK VII LRF

Direct Digital Link to OFP



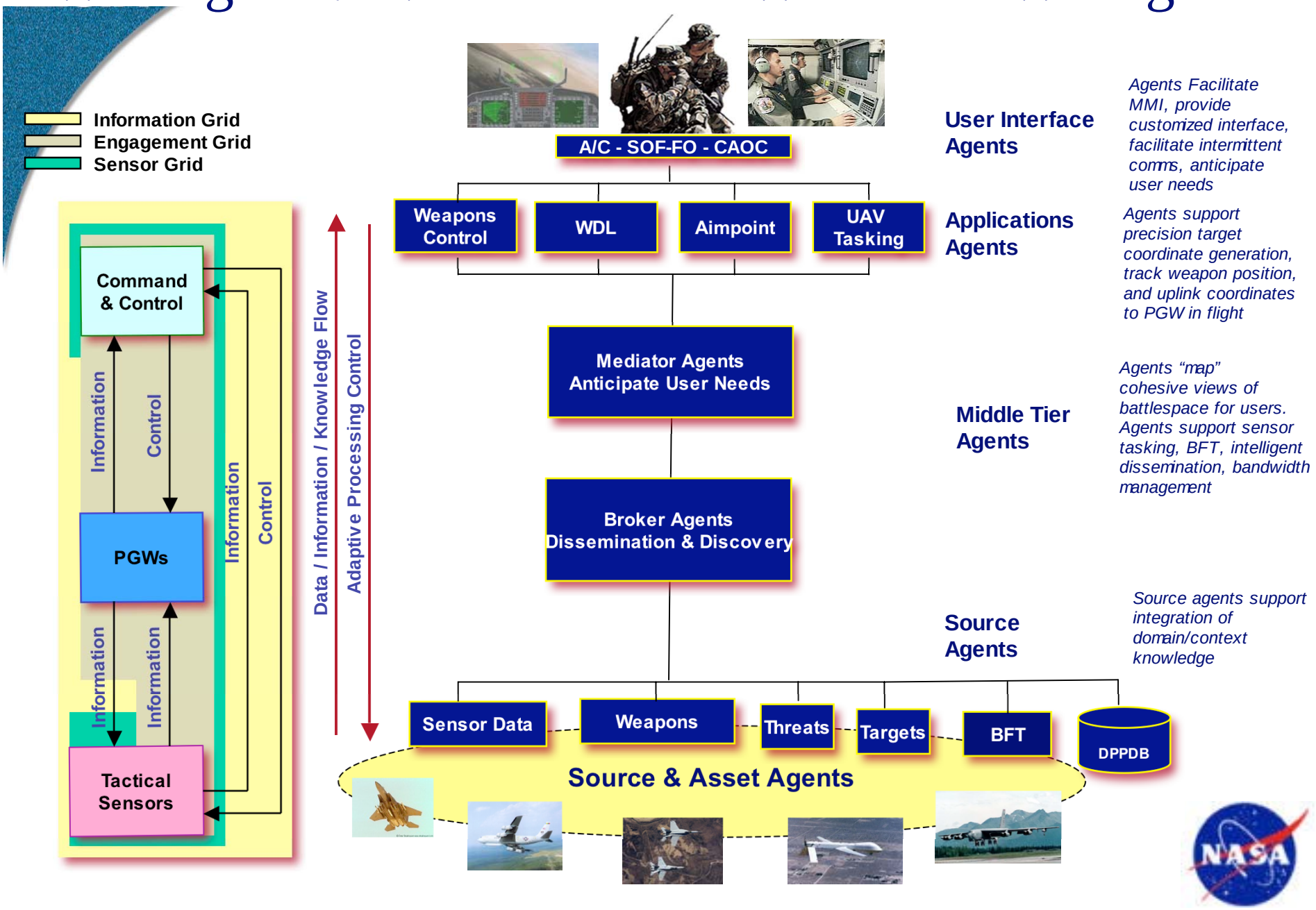
Targeting Support Applications
FalconView/BAO/Maps/Imagery

HARRIS
AN/PRC-117F

Provide Terminal Attack Control

TACTER-31A

WebAgents: “Virtual Sensor Webs” for Warfighters

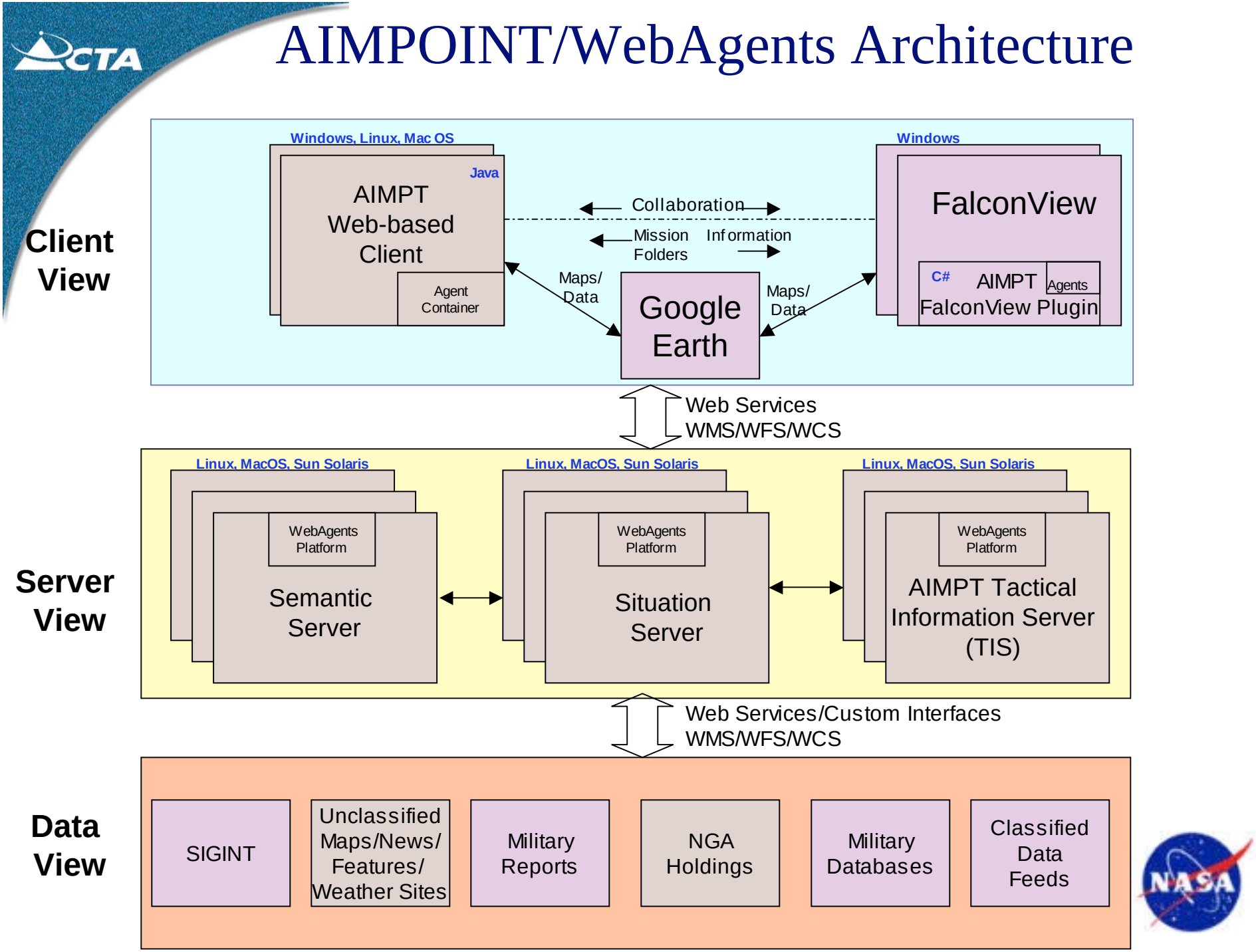


What Warfighters Need from Smart Systems*

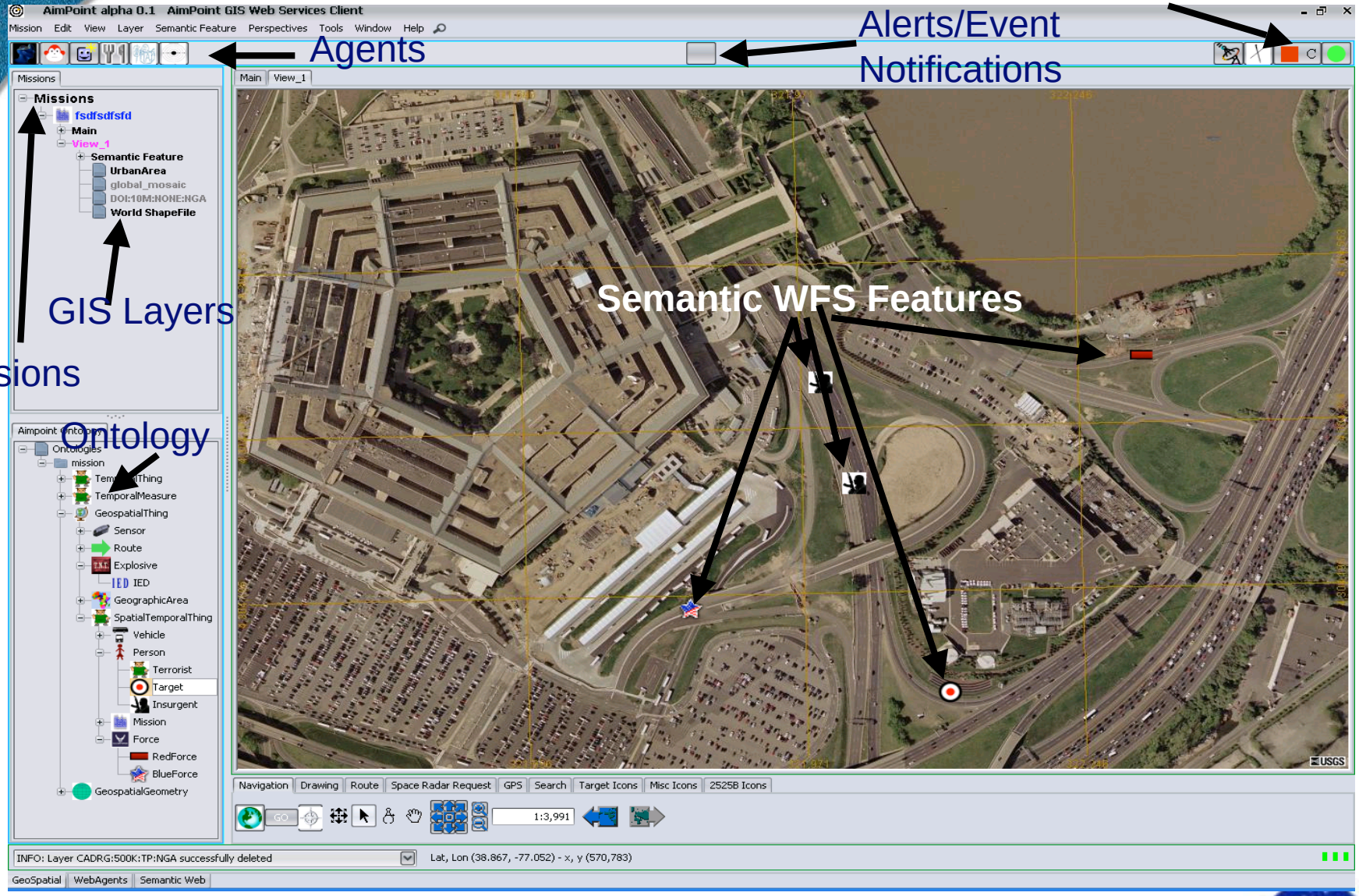
- Information Management – "Help me manage my time, the data I need, the knowledge I'm sent"
- Reach back/Intelligent Push/Chipping – "Handle the ISR requests that go to C2 nodes; help me get most relevant spot area imagery"
- Locations of Interest – "Where are my buddies, where are the threats"
- CoT Events – "Mission ICONS on the map plus , e.g., take picture of a suspect, then send picture and location as a CoT event"
- Ice Fishing – "Wait to see what shows up, then provide me changes that occur…"
- History Channel – What do we know about personalities, patterns of behavior, relationships, of objects I am observing?

* Mobile users. Source: TSgt A. Yoshida (AFSOC), July 2005

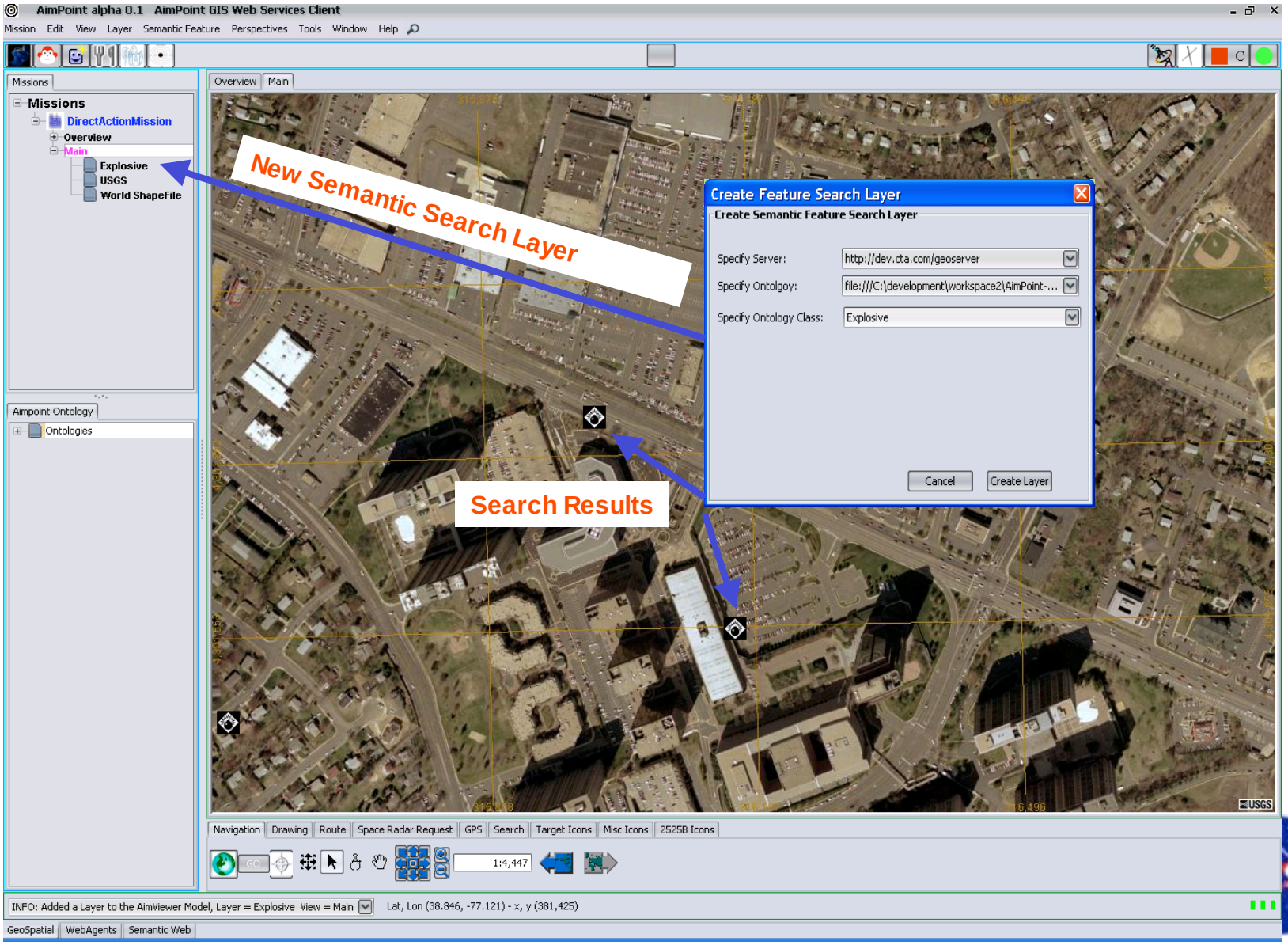
AIMPOINT/WebAgents Architecture

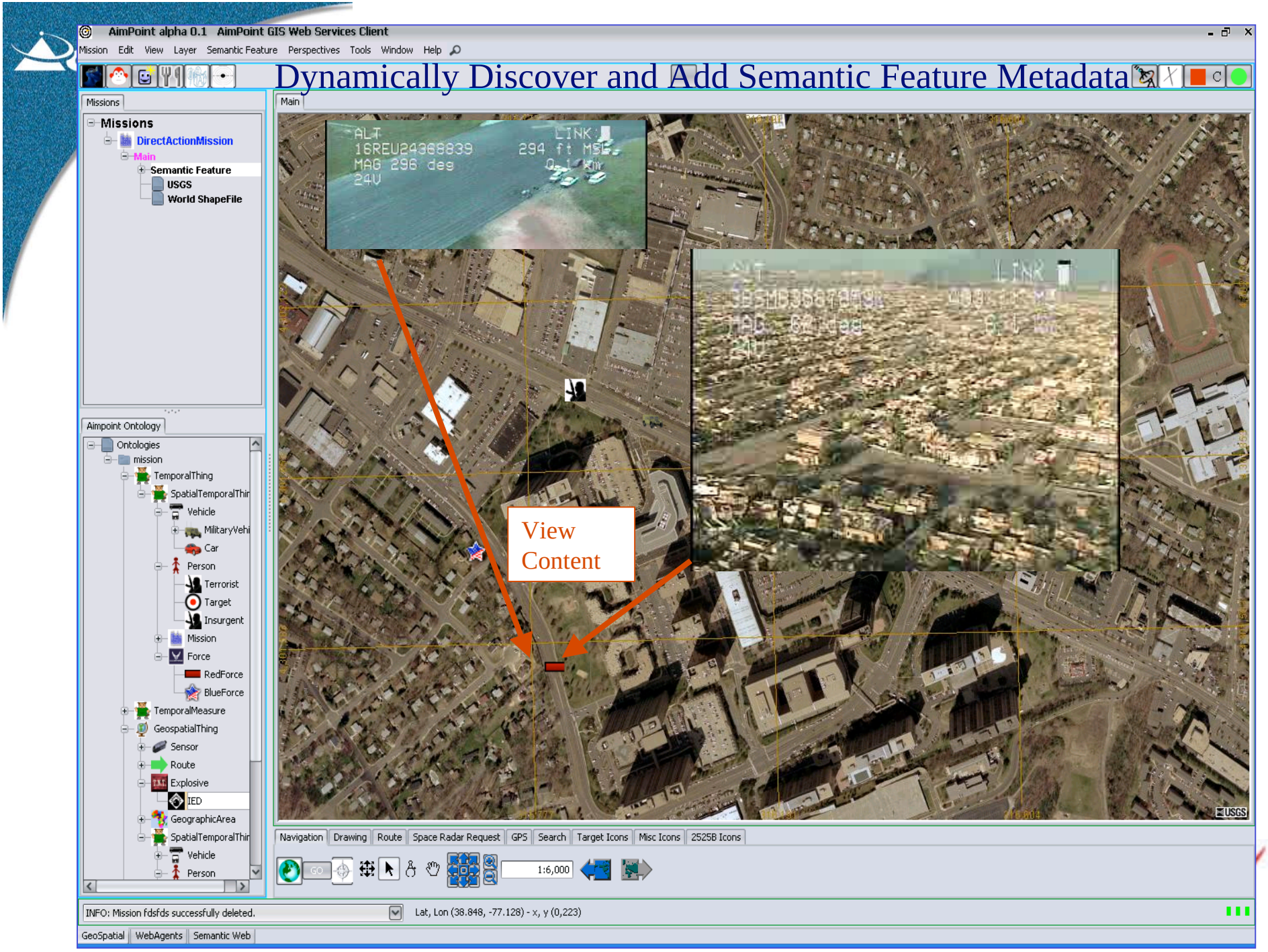


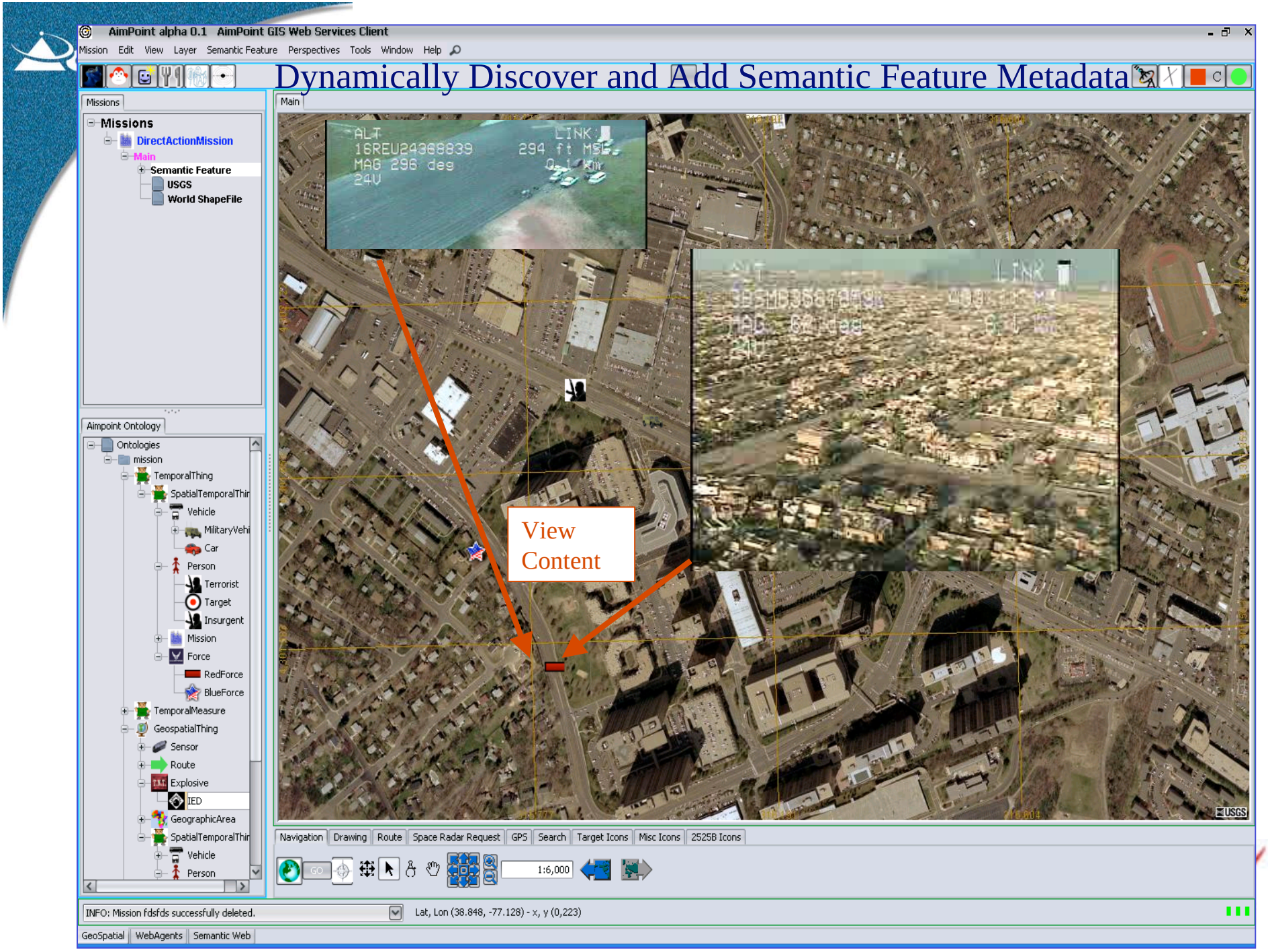
Geospatial Semantics



Dynamically Discover and Add OGC compliant WFS Semantic Features




AimPoint alpha 0.1 AimPoint GIS Web Services Client
Mission Edit View Layer Semantic Feature Perspectives Tools Window Help
Dynamically Discover and Add Semantic Feature Metadata
Missions
Missions
DirectActionMission
Main
Semantic Feature
USGS
World ShapeFile
Aimpoint Ontology
Ontologies
mission
TemporalThing
SpatialTemporalThir
Vehicle
MilitaryVehi
Car
Person
Terrorist
Target
Insurgent
Mission
Force
RedForce
BlueForce
TemporalMeasure
GeospatialThing
Sensor
Route
Explosive
IED
GeographicArea
SpatialTemporalThir
Vehicle
Person
Main
ALT
16REU24388839
MAG 296 deg
24V
LINK
294 ft MSL
View
Content
USGS
Navigation
Drawing
Route
Space Radar Request
GPS
Search
Target Icons
Misc Icons
2525B Icons
1:6,000
INFO: Mission fdsfds successfully deleted.
Lat, Lon (38.848, -77.128) - x, y (0,223)
GeoSpatial
WebAgents
Semantic Web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Ontologies
mission
TemporalThing
SpatialTemporalThir
Vehicle
MilitaryVehi
Car
Person
Terrorist
Target
Insurgent
Mission
Force
RedForce
BlueForce
TemporalMeasure
GeospatialThing
Sensor
Route
Explosive
IED
GeographicArea
SpatialTemporalThir
Vehicle
Person
Main
ALT
16REU24388839
MAG 296 deg
24V
LINK
294 ft MSL
View
Content
USGS
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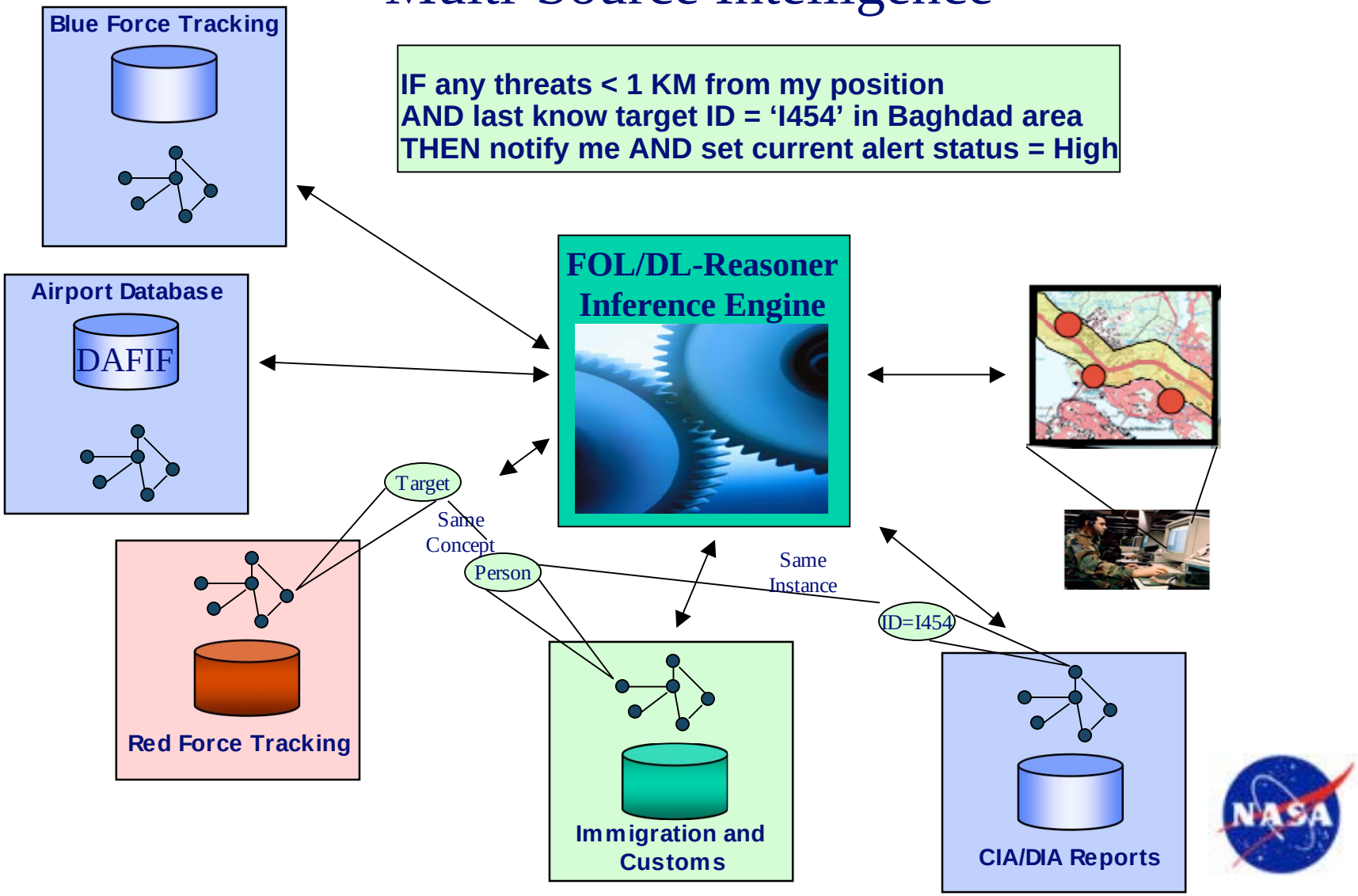
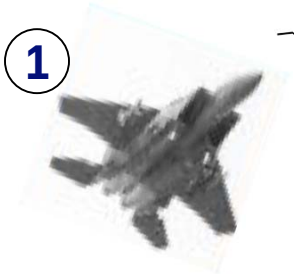
2525B Icons
1:6,000
INFO: Mission fdsfds successfully deleted.
Lat, Lon (38.848, -77.128) - x, y (0,223)
GeoSpatial
WebAgents
Semantic Web

Future Vision:
Achieving the Promise via the "Semantic Wave"

Semantic Interoperability:
Dynamically Discover, Access, Fuse Multi-Source Intelligence



"Real-Time Sensor Webs: Avoid "Friendly Fire" while Accelerating TCT



1

Aircraft releases weapon

Against enemy C2 Node

3

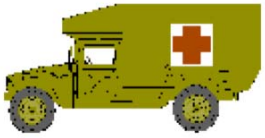
Divert to pre-determined safe areas

Link 16/TTNT

2

JSOTF agents, integrating data from multiple data sources, identify potential conflict and notify observers of coalition noncombatants moving into target zone; observers (or their agents) send wave-off command to weapon in flight

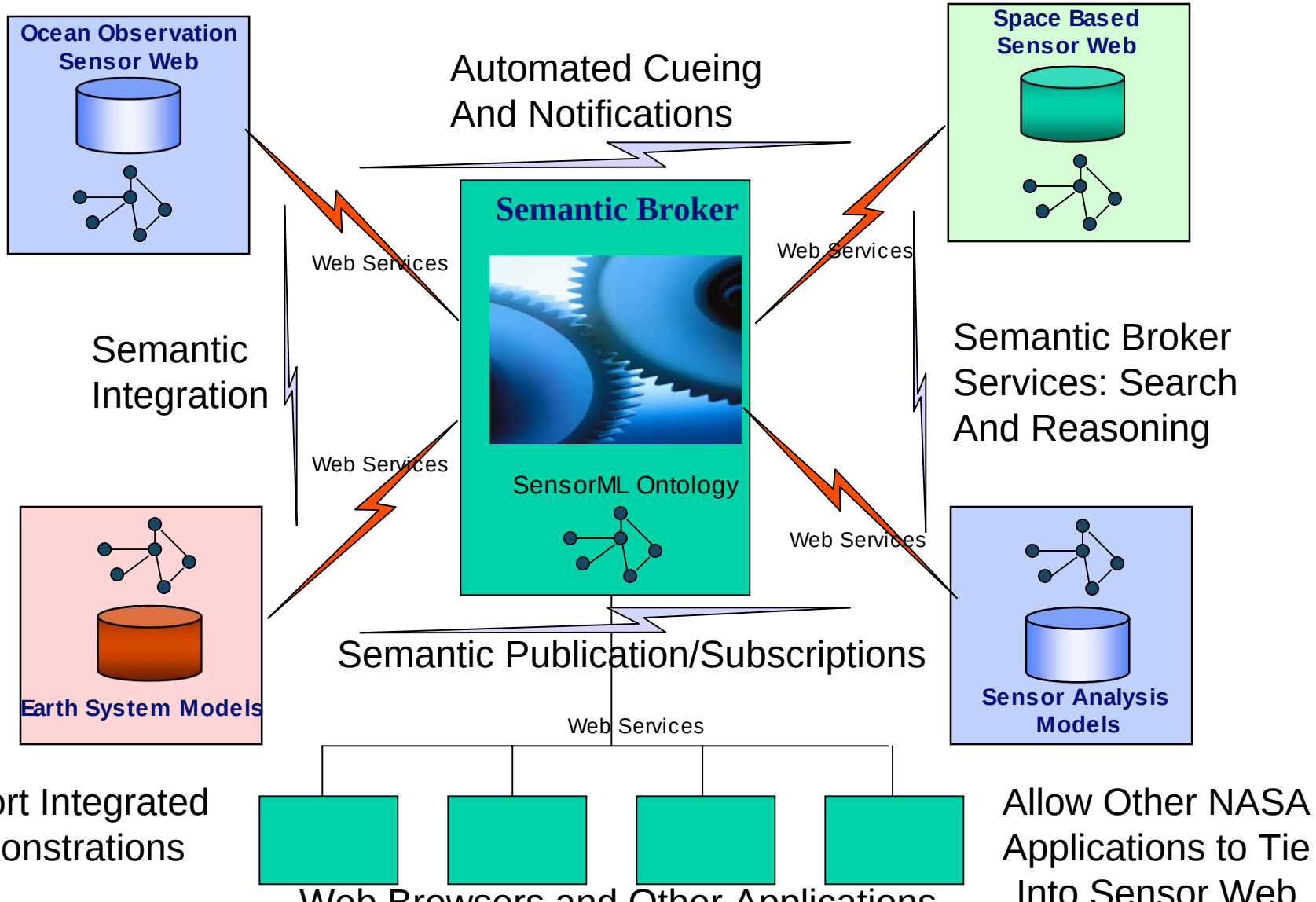
Enemy C2 Node



4 ***Weapons safe area***

Agent-enabled JSOTF C2 Node

Potential NASA Semantic Sensor Web Interoperability Framework



Systems that "know"

Semantic Technology will be key

to Achieving the True Value of Net-Centric Operations…

as well as Future Social Interactions?