CORNERSTONE: Foundational Models and Services for Integrated Battle Planning

Paper ID # 78

Topic 4: Collaboration, Shared Awareness, & Decision Making

17th ICCRTS Operationalizing C2 Agility

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Introduction

- Adversary decision cycles are fast, complex and chaotic

➔C2 Agility

- **Synchronized Operations Program:** AFRL exploring ways of improving **coordination** and **synchronization** among its mission domains
  - Air
  - Space
  - Cyber

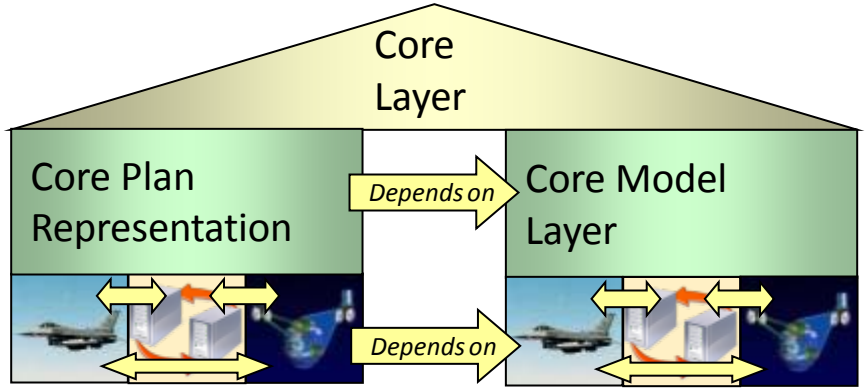
- Experiments revealed need for
  - A common language across domains
  - Persisting collaboration across domains
  - A coherent structure to guide workflow and communication

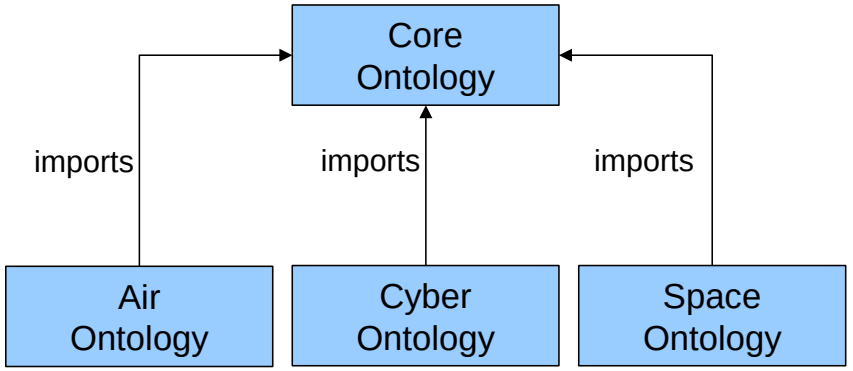
R&D Project

- Cornerstone
  - Foundational data representation and suite of services
- Phase 1 (Mar-Nov 2010)
  - AFRL, BAE Systems, and supporting contractor Metatech
    - Conducted knowledge acquisition workshops
    - Collected existing schemas and Community of Interest (COI) docs
    - Synthesized salient schemas & standards into a shared set of ontologies
- Phase 2 (Aug 2010- Sep 2011)
  - Prototyped services
  - Limited Technology Experiment

Cross-Domain Knowledge Representation

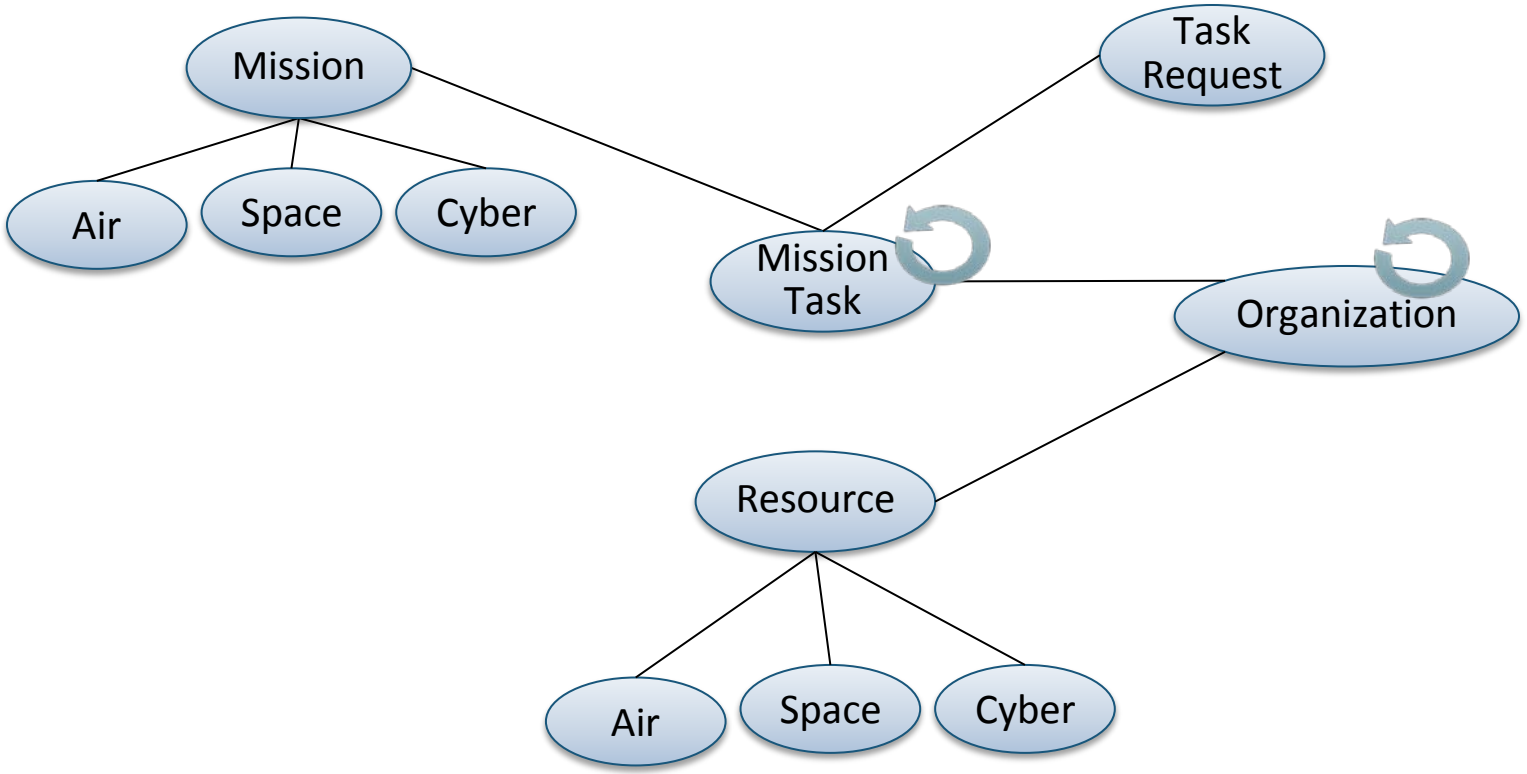
- Cornerstone Core "upper ontology," core model layer
- Domain Ontologies
  - Air Ontology, Cyber Ontology, Space Ontology
  - Extend general concepts into each domain
    - Mission -> AirMission -> AirAttackMission
    - Planner -> CyberPlanner
    - Request -> SpaceRequest
  - Define properties and classes specific to a domain
    - Air: Sorties and Route Points, Cyber: ComputerNetworkNode





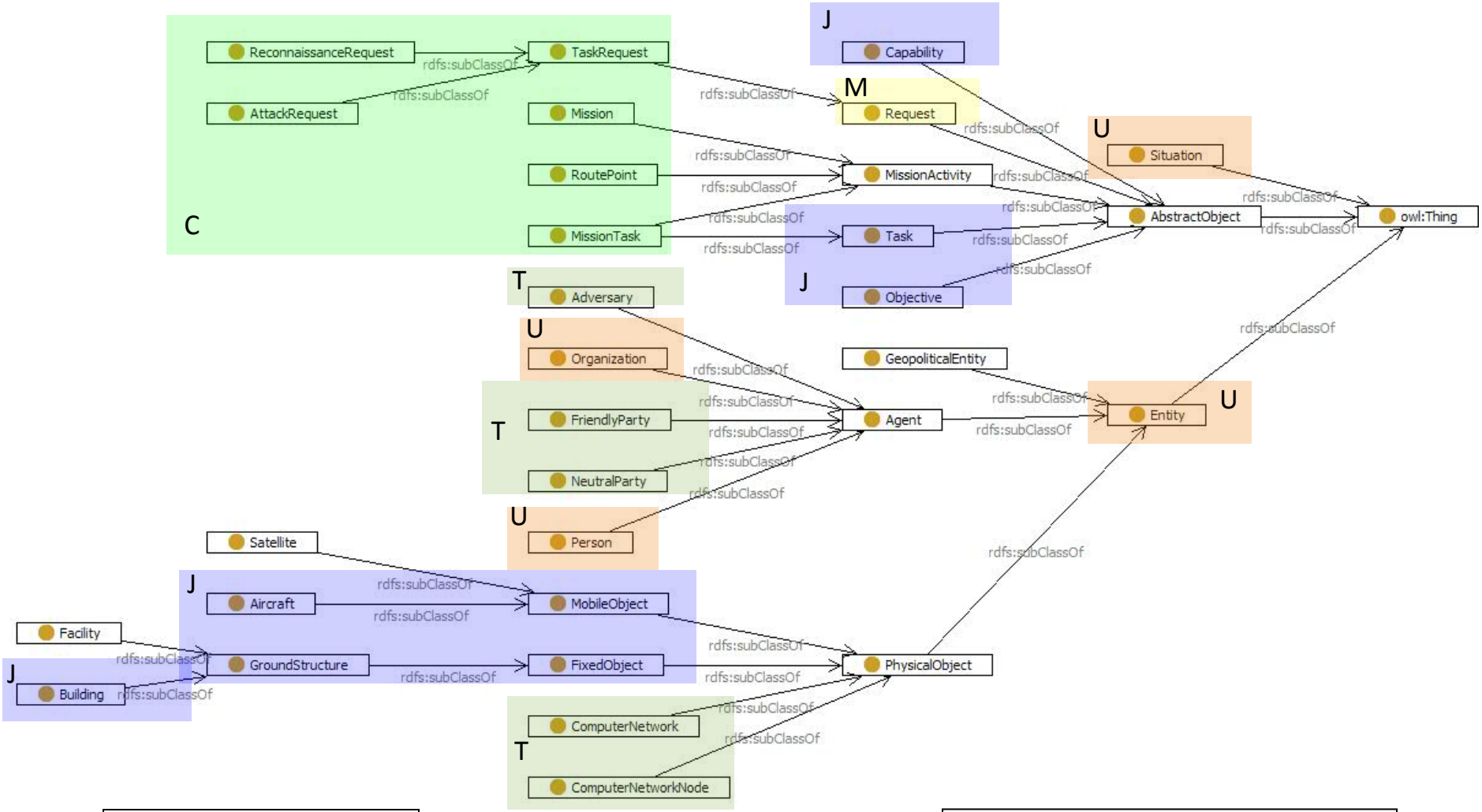
Cornerstone Core Ontology

- Subset of the Core Ontology which illustrates how general classes have sub-classes that open up the domains



Cornerstone Ontology Derivation

BAE SYSTEMS Metatech



AO COI

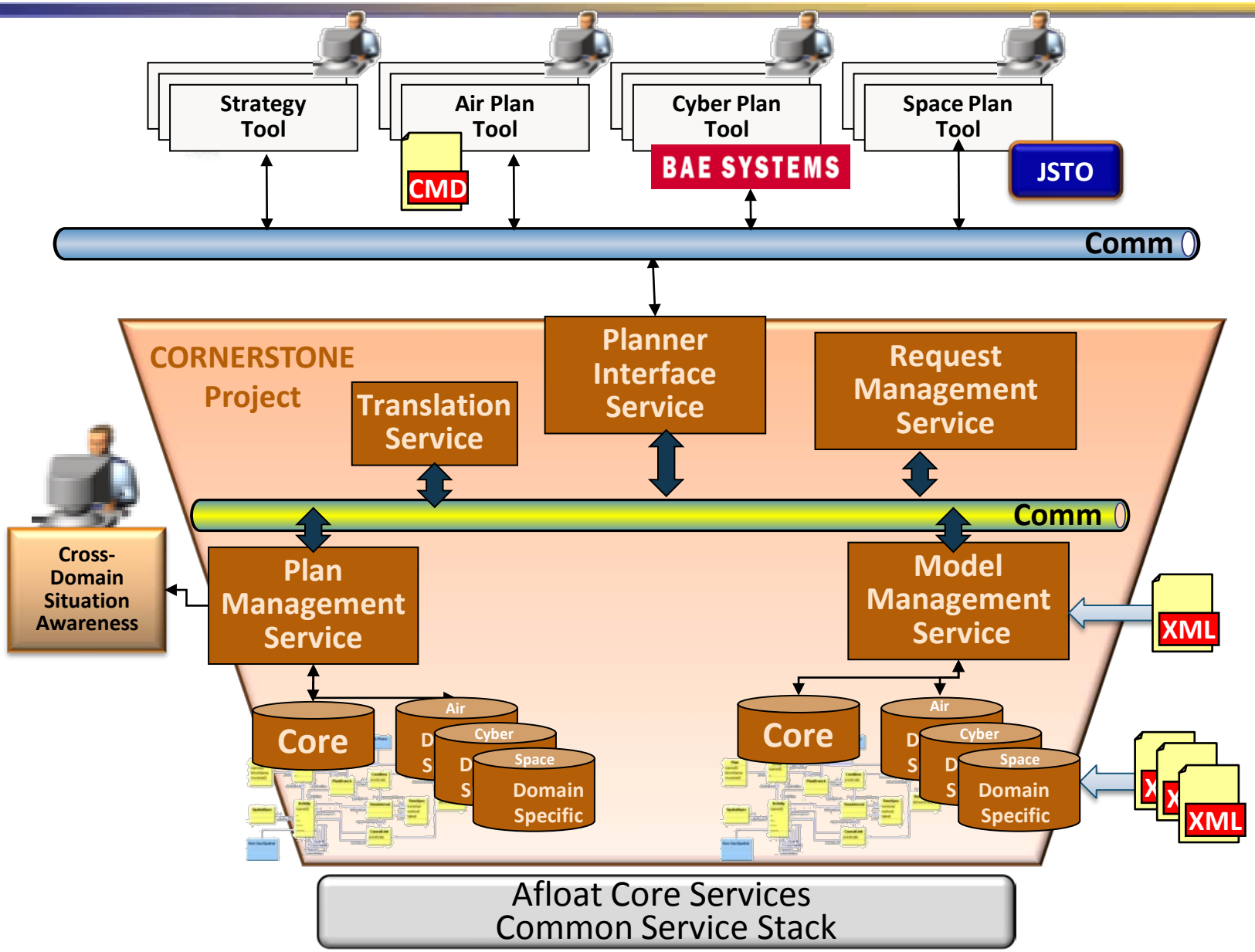
CMD MTR

UCore

BAE

JAGUAR Treadstone

Services


Strategy Tool
Air Plan Tool
CMD
Cyber Plan Tool
BAE SYSTEMS
Space Plan Tool
JSTO
Comm
CORNERSTONE Project
Translation Service
Planner Interface Service
Request Management Service
Comm
Cross-Domain Situation Awareness
Plan Management Service
Model Management Service
XML
Core
Air
Cyber
Space
Domain Specific
Core
Air
Cyber
Space
Domain Specific
XML
Afloat Core Services
Common Service Stack

Plan Management Service

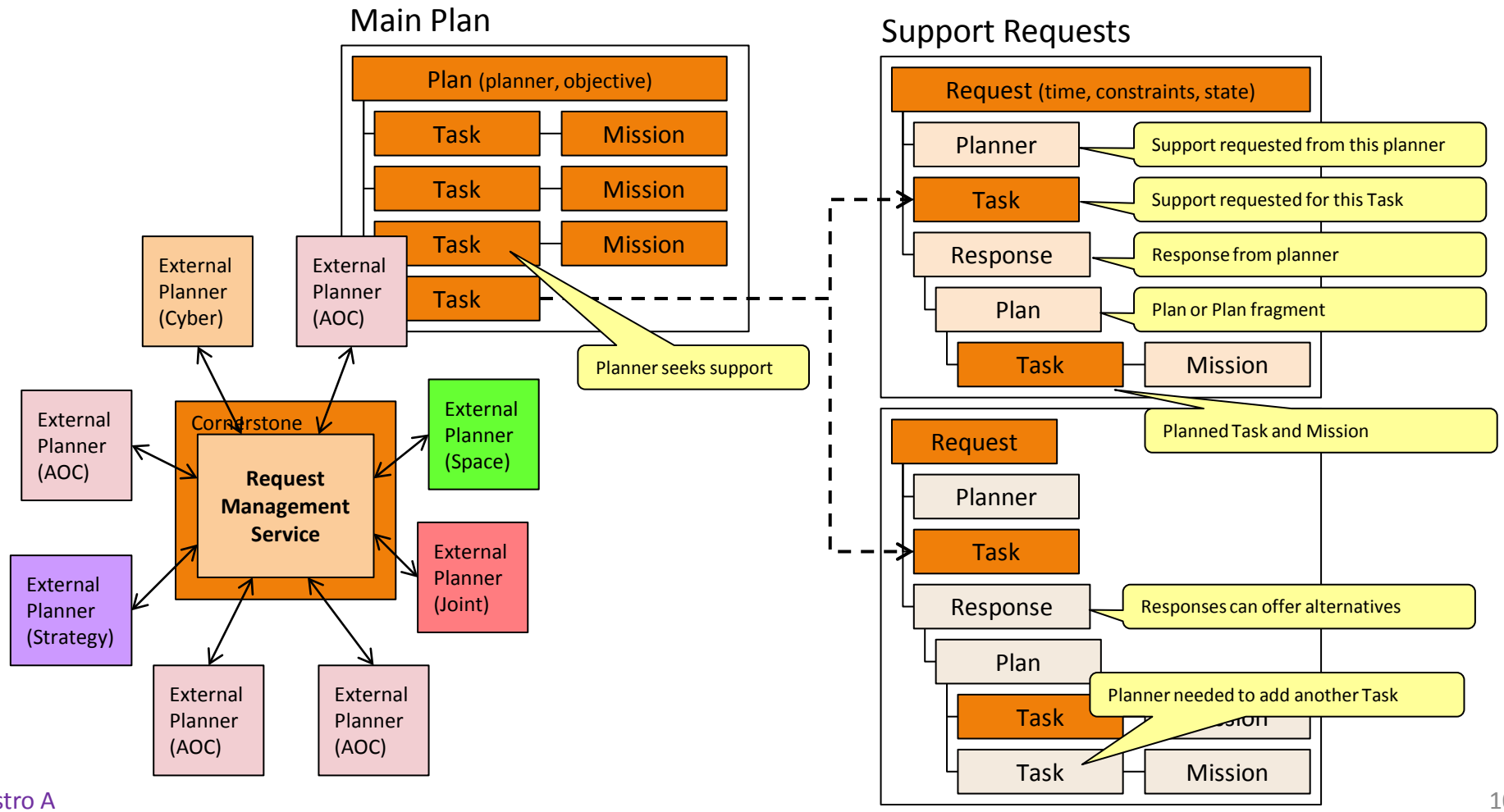
- Provides actively changing battle plans across mission and security domains
  - Create, Read, Update, Delete, Find (CRUDF)
- Managed Objects
  - Request – Plan
  - Task – Query
  - Mission – Ontology
- Repository
  - Underlying storage is OWL RDF triples stored in a SQL database
    - PostgreSQL, MySQL, etc.
  - Multiple stored representations
    - OWL representation
    - External representations are always available
- Pub/Sub notifications for Managed Object lifecycle events

Model Management Service

- Similar to Plan Management Service, but stores “World State”:
  - Current Domain Ontologies (Air, Cyber, Space)
  - Planner instances and capabilities
    - Air Operations Centers (regional and global)
    - Joint Space Operations Center
    - Cyber Operations Center
  - Targets
  - Geography
- Publishes change notifications or reports on-demand updates/differences
- Generic ModelDataSource interface

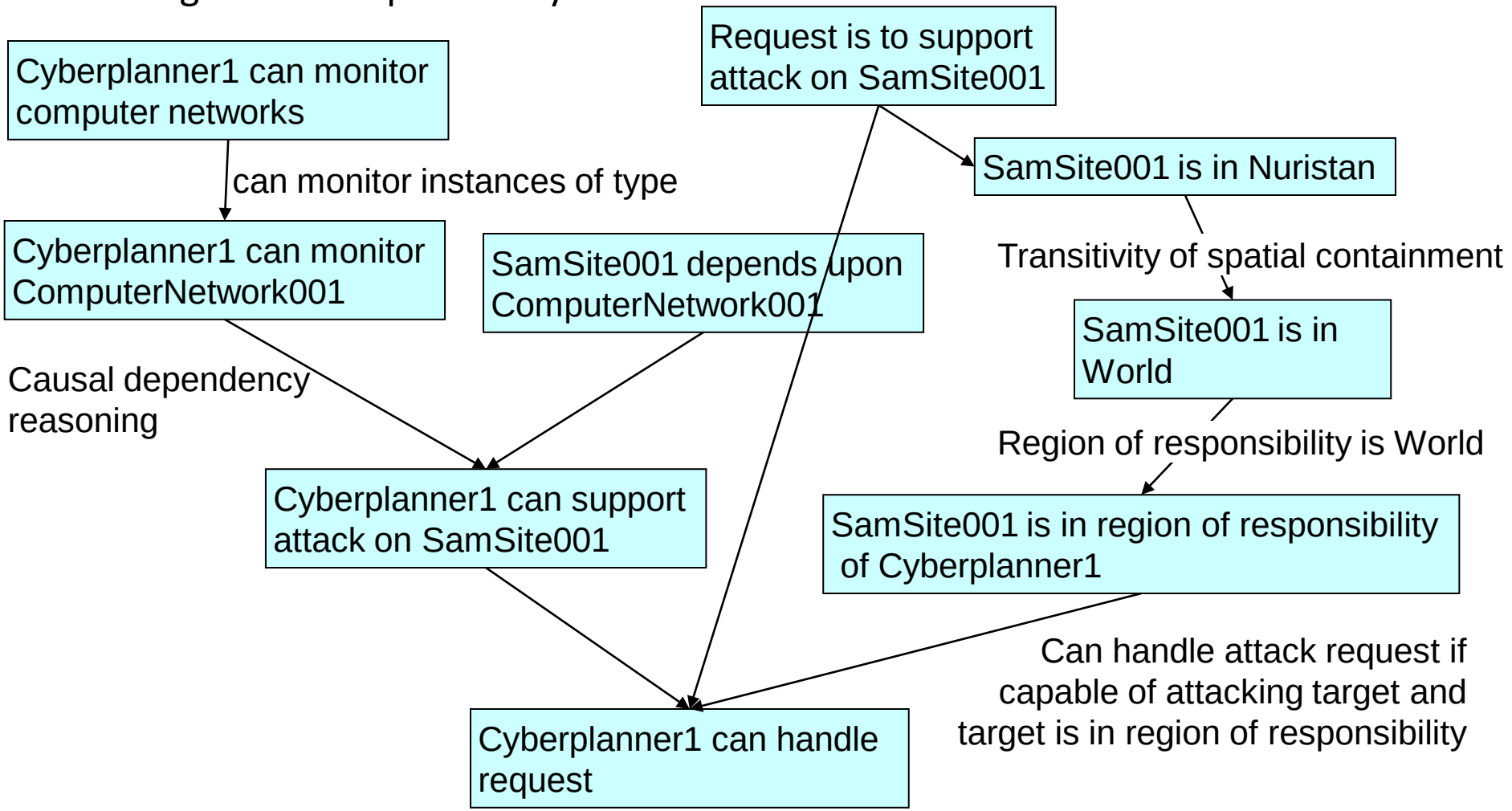
Request Management Service

- Matches request to Planner using Capability models for Planners
- Track request Responses and Options



Planner Chooser Capabilities

- Planner Chooser matches Requests to Planners using Capabilities and Regions of Responsibility

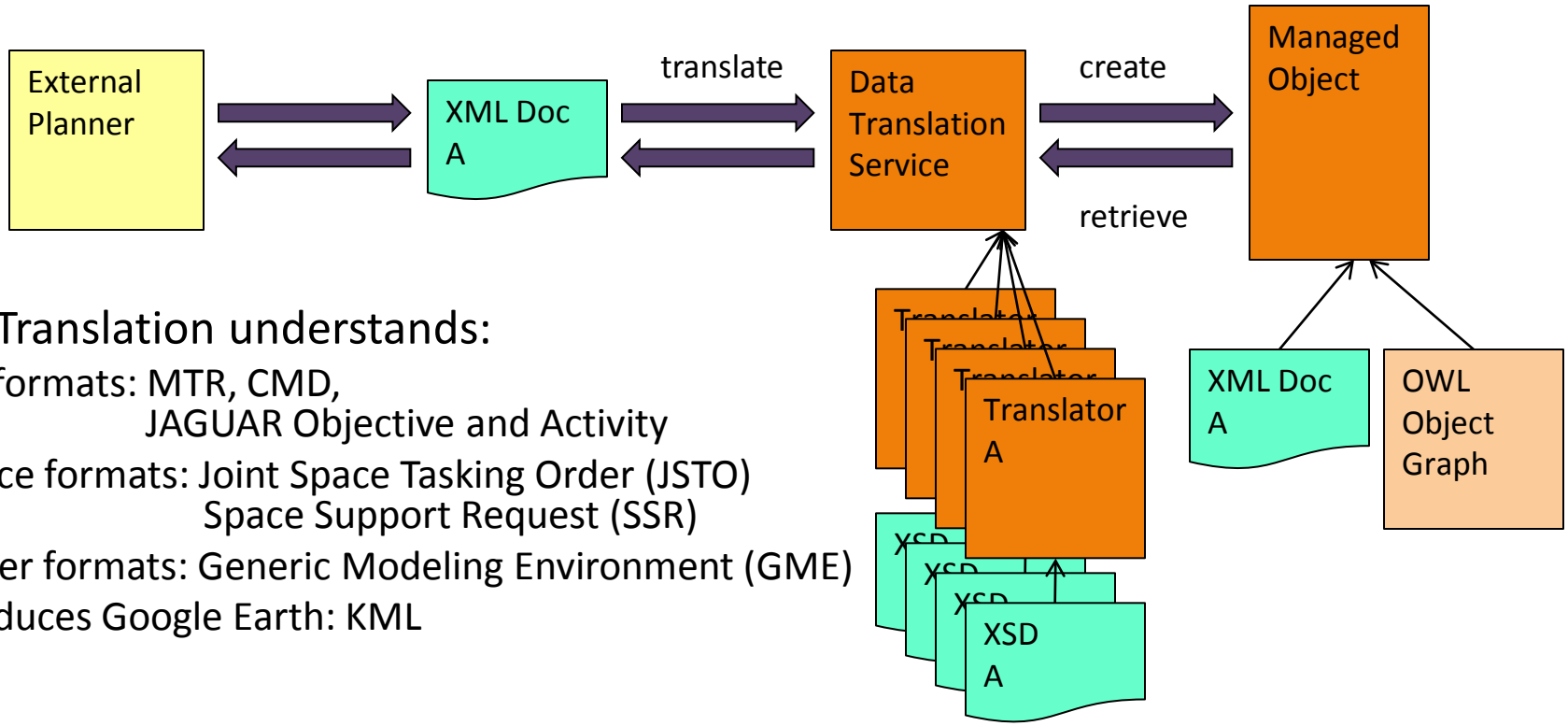


Planner Interface Service

- The Planner Interface Service acts as a central interface point for non-Cornerstone-aware planners
  - Maps external documents to Cornerstone Managed Objects using the Data Translation Service
  - Maps external workflow to Cornerstone's using the Request Management Service
- External Planner Integration
  - Translation
    - JAGUAR (Air)
    - GME (Cyber)
    - ASC2EM (Space)
    - Others to follow
  - Web/SOA connectivity
    - Future

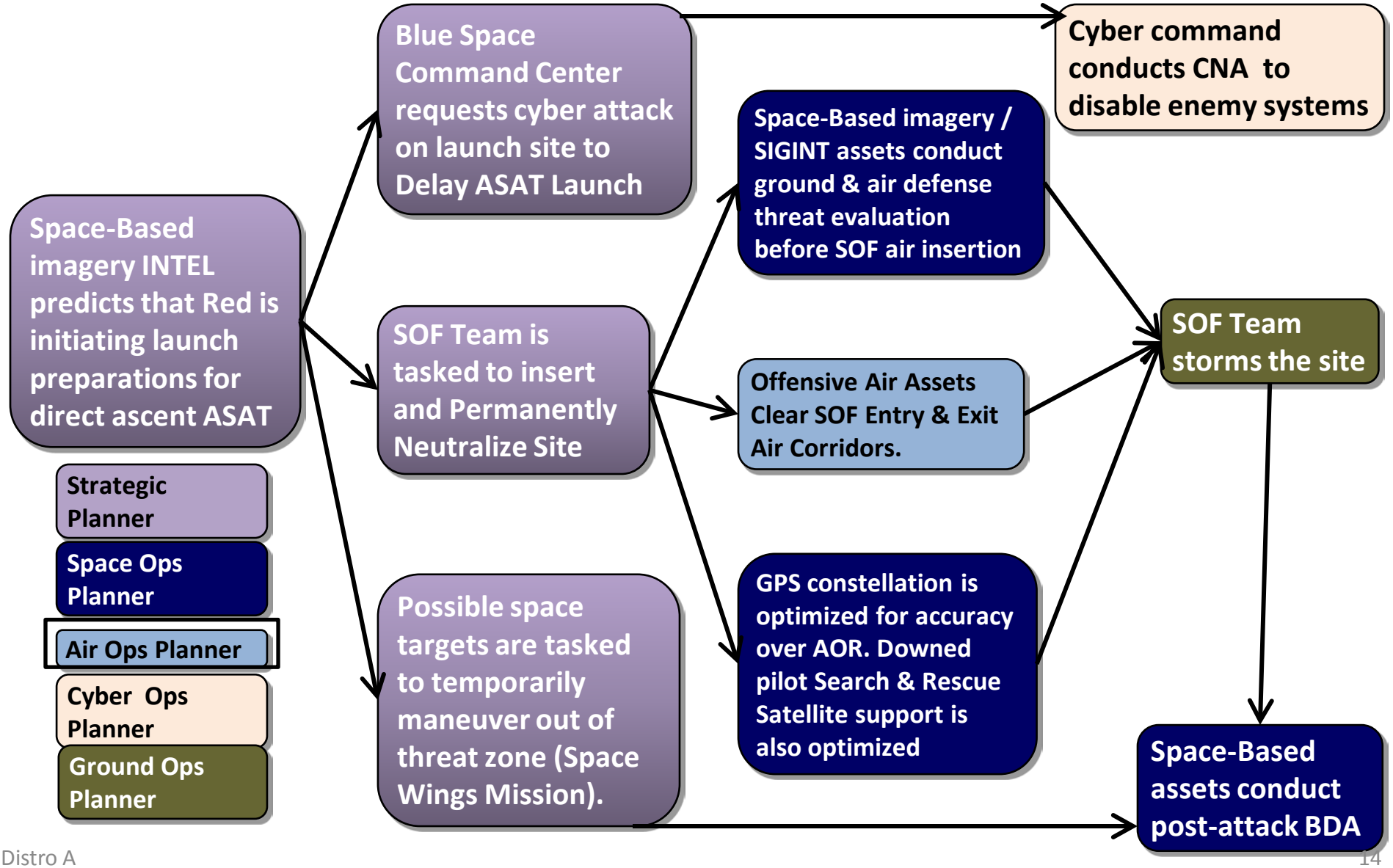
Data Translation Service

- Take in documents in currently used representations such as the Air Operations Community of Interest's MTR (Mission Task Request) and CMD (Common Mission Definition) format, and produce OWL models that are in the common Cornerstone ManagedObject format



- Data Translation understands:
  - Air formats: MTR, CMD,
    JAGUAR Objective and Activity
  - Space formats: Joint Space Tasking Order (JSTO)
    Space Support Request (SSR)
  - Cyber formats: Generic Modeling Environment (GME)
  - Produces Google Earth: KML

Limited Technology Experiment



Limited Technology Experiment

BAE SYSTEMS Metatech

- Air, Cyber and Space planners coordinate response to the threat of an ASAT launch via Cornerstone services
- Air Request with “no-strike” target (a hospital) rejected through constraint checker
- Stress test of cross-domain thread run 50 times (later increased to 1000)
- New Cyber capability added during runtime via ontology update

Thread	Purpose	Metrics	Results
1. Cross-Domain Mission Processing	Verify successful end-to-end processing of mission requests for air, cyber, space.	Recall, Accuracy: % of expected data reported, % correct output	100% recall and accuracy verified by air, cyber, space subject matter experts for four missions (ten trials)
2. Constraint Processing	Verify detection of violation of no-strike target constraint	% correct trials	100% expected violations reported (ten trials)
3. Run-Time Performance	Establish baseline system and service-specific average run-time and memory usage.	Goal: < 30 sec end-to-end runtime	15 sec for initial trials but run-time increased over the course of 50 trials due to memory leak in object cache (fixed after LTE)
4. Dynamic Model Extension	Verify successful run-time extension of planner capability model.	% correct trials, # unexpected errors	100%, 0 errors: no planners found initially, cyber-planner found after model extension (ten trials)

Future Research

- Request Negotiation
- Fully integrate Cornerstone with existing Planners
- Extend the Model Management Service
- Test Harness
  - Allow for generation of large numbers of test artifacts
  - Support producing realistic load levels of requests and missions: hundreds to thousands
- SCORA --BAE Systems has begun work on a related project entitled Synchronized Constraint-based Optimization, Repair, and Assembly (SCORA)
  - Planning automation support via optimal search algorithms
  - Find “best” combination of missions options to fulfill a set of desired effects.
  - Research plan repair techniques to synchronize multiple cross-domain missions
  - Assemble and publish a complete integrated battle plan.

Conclusion

- Experiments
- Unified Plan Representation
- Set of Collaboration Services

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