

# CAMERA

A world map with a blue ocean and green landmasses, serving as a background for the text.

## Coordination and Management Environments for Responsive Agents

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# Background

## ■ Information Sciences Institute of USC

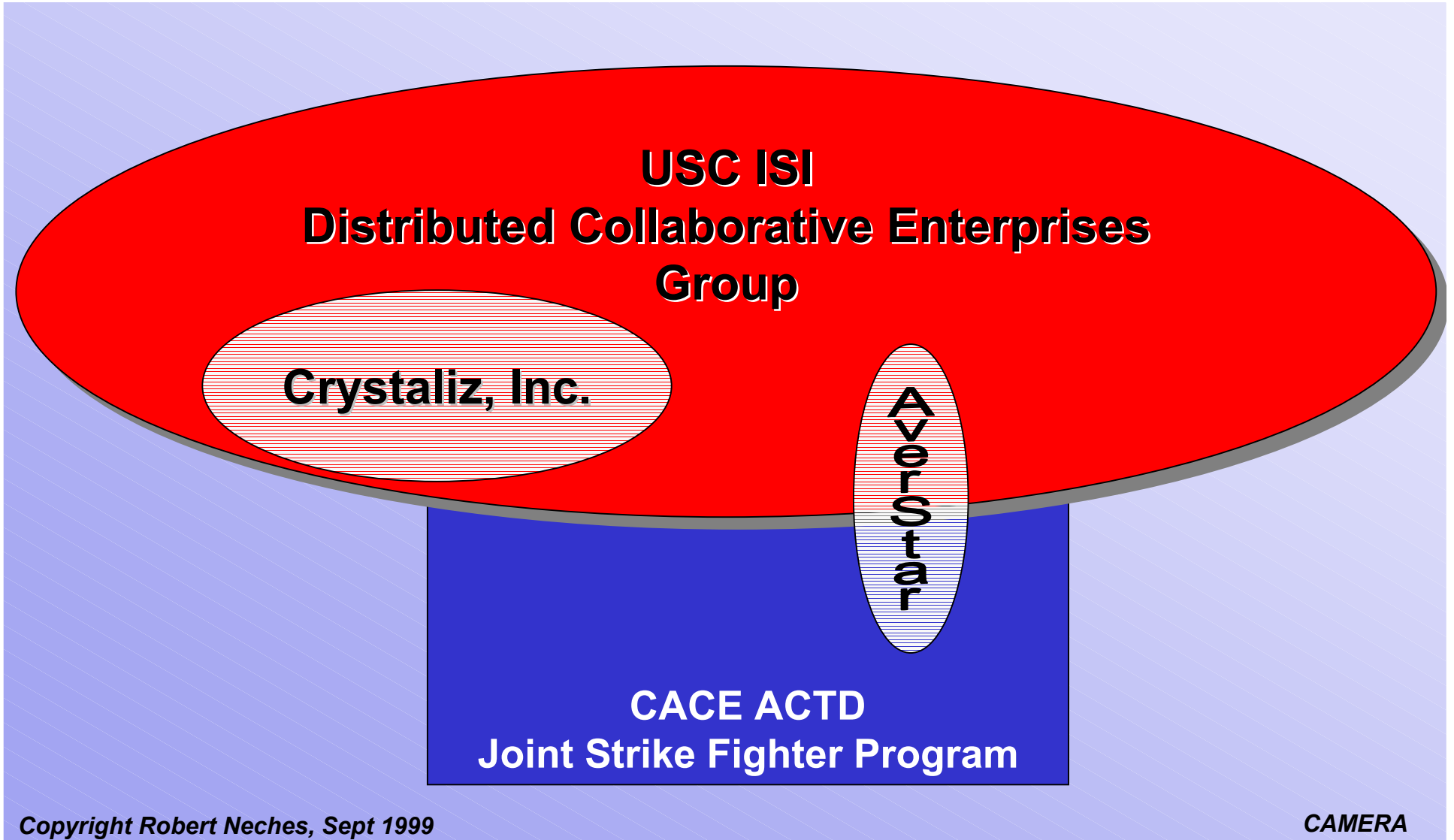
- Mission: make new technologies usable
- Example: lead role in developing the Internet

## ■ Distributed Collaborative Enterprises Group

- Complex, mixed-initiative systems
- Shared situation assessment
- Response coordination



# Current Participants



# Relationship of CAMERA to ANTs

## DARPA

### Autonomous Negotiating Teamware Program

#### ■ The goal of the ANTs program

- create real-time resource management systems
- that operate in highly decentralized environments,
- making maximum use of local information, providing solutions that are both good enough, and soon enough.

Form/reform agent collections for logistics tasks

Fine-grained entities: e.g., pilots, aircraft parts, maint. ops, ...

Priorities in negotiation/renegotiation, controlled by *topic-specific* protocols

#### ■ Distinguishing characteristics of the ANT approach is the explicit time-bounds on calculation of actions.

## CAMERA

*What are the hard problems CAMERA wants to solve?*

# Essential Elements Provided by DARPA Negotiation Technology

Issues uniquely enabled by DARPA's ANT program approach:

## ■ Handling incomplete knowledge, context-sensitive decisions

- Preferences can't be determined until possibilities are known
- Desired tradeoffs change with situation
- E.g., decision to cannibalize an aircraft depends on likely missions

## ■ Exploring tradeoffs between values

- Arrow's Theorem from mathematical economics shows impossibility of analytic approach to satisfying requirements of a group w/o negotiation
- Negotiation systematically generates alternatives for consideration, allows for participating units to uncover issues and refine preferences

## ■ Assuring user confidence

- Acceptance of results fostered by understandable decision process
- Replanning via negotiation tends to produce minimally disruptive changes

# Critical Implications of the CAMERA Approach

If we succeed, the collective system can:

- **Proactively adapt both to problems *and* opportunities...**  
because potentially interested agents can monitor report processes, defined when commitments are negotiated
- **Systematically reevaluate priorities in face of conflicts...**  
because agents responding to issues use records of negotiations to determine who to renegotiate with
- **Robustly handle system changes, communication breaks...**  
because services are linked by request/offer structure and commitment records that facilitate resynchronization

# What Is Our Approach?

- Agents communicate by *content-based addressing*
- *Negotiation management protocols* govern interaction
  - Soft policies, heterogeneous within system
- Formation of *agent collections* dependent on
  - Problem characteristics
  - Contextual constraints
- Agent collection: *active participants*, plus *hangers-on*
- *Commitment based negotiation* to enable localized and distributed decision making
- *Monitoring* of commitments, *renegotiation triggers*
  - Proactively address problems
  - Take advantage of opportunities for better solutions

# CAMERA:

## Software Framework and Substantive Applications



*Candidate Demonstrations:  
Coordination of Actions to Promote Harrier Aircraft Safety*



### Key Ideas:

#### Collection formation, Renegotiation

- *Negotiation management protocols*
  - Establish "rules of the game"
  - Permits alternative, *task-specific* variants
  - Ensure convergence on taking action
  - Closure through *commitments*
- *Commitment-based group control*
  - Resynchronization after separations
  - Problem / Opportunity Monitoring
- *Renegotiation revisits priorities*

**CAMERA**

# Negotiation Management Protocols: Constraints on the Process

- RFPs are requests for services annotated by constraints
  - Differing, task-specific constraints allowed within same system
- Negotiation is based on submitting *counterproposals*
  - Constraints may affect whether to respond, form of response
  - Response offers commitments
  - Response need not be compliant
- Want to treat constraints as a preference hierarchy
  - Non-compliant responses are not rejected
  - Processed if compliant responses fail to satisfy a service request
- Motivation:
  - Favor efficiency whenever possible
  - Let the system degrade gracefully if constraints cannot be met

# Topics Covered in Negotiation Management Protocols

## ■ *Negotiation response, timing and scheduling constraints*

- Parameter bounds on counterproposals
- Negotiation cut-off limits (time, first acceptable, nth, ...)
- Scheduling and precedence

## ■ *Capability/requirement descriptions and responses*

- Domain-specific descriptions of service requests

## ■ *Commitment, coordination, role and responsibility relations*

## ■ *Reporting mechanisms and formats*

- Form and content of reporting structures

# Anatomy of a CAMERA Agent

## Agent Code:

*Performs jobs,  
Requests jobs*

## Capabilities: functions performed

- Internally
- Via external RFPs

## Job estimator

- Time
- Cost

## Internal State

## RFP issuance policies

- Determine what RFPs to broadcast
- Constrain form, content, scheduling of acceptable responses

## RFP response policies

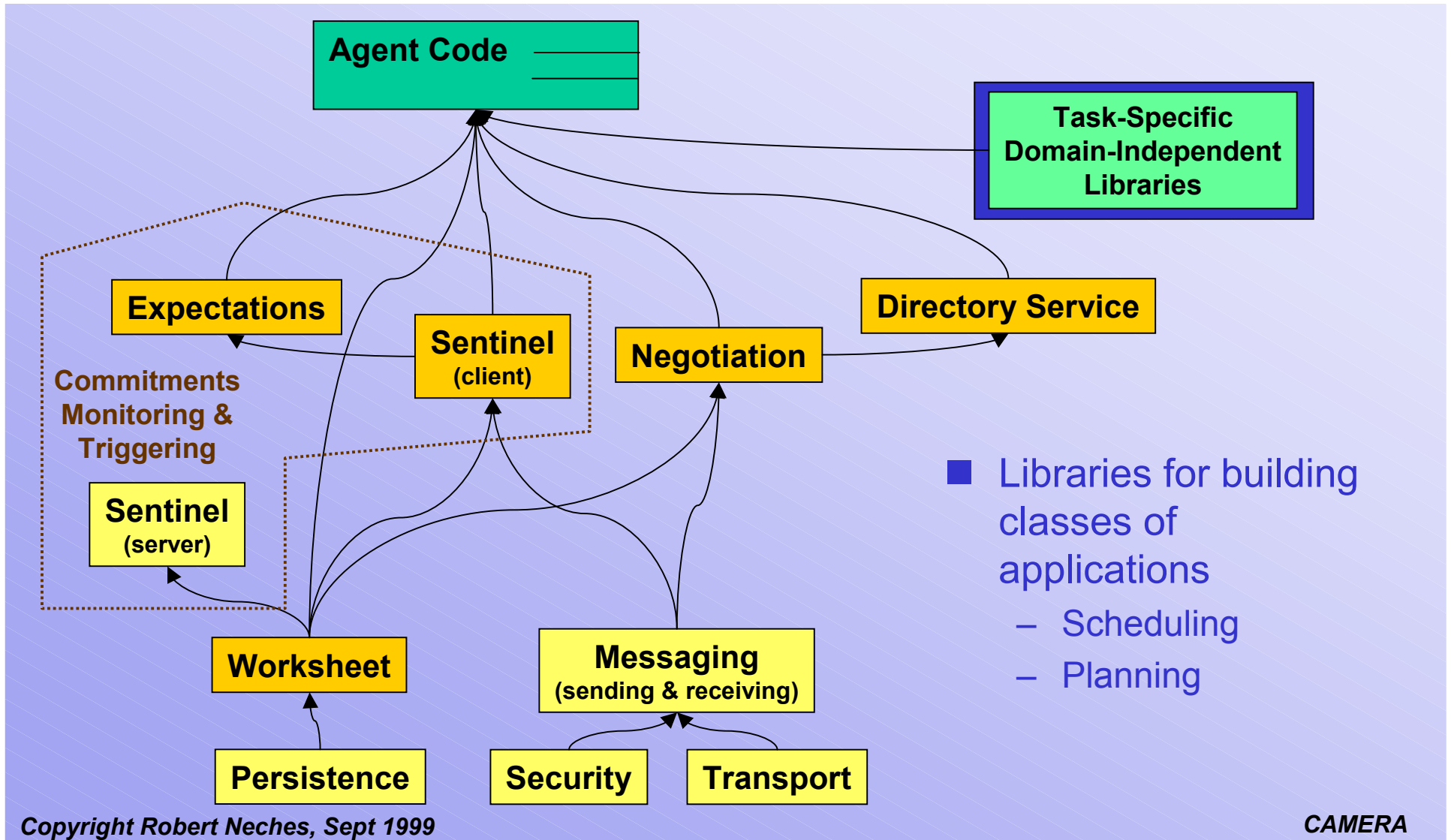
- Assessment of RFP
- Counterproposal generation
- Reporting capabilities

**CAMERA is *not* concerned with the sophistication of these functions**

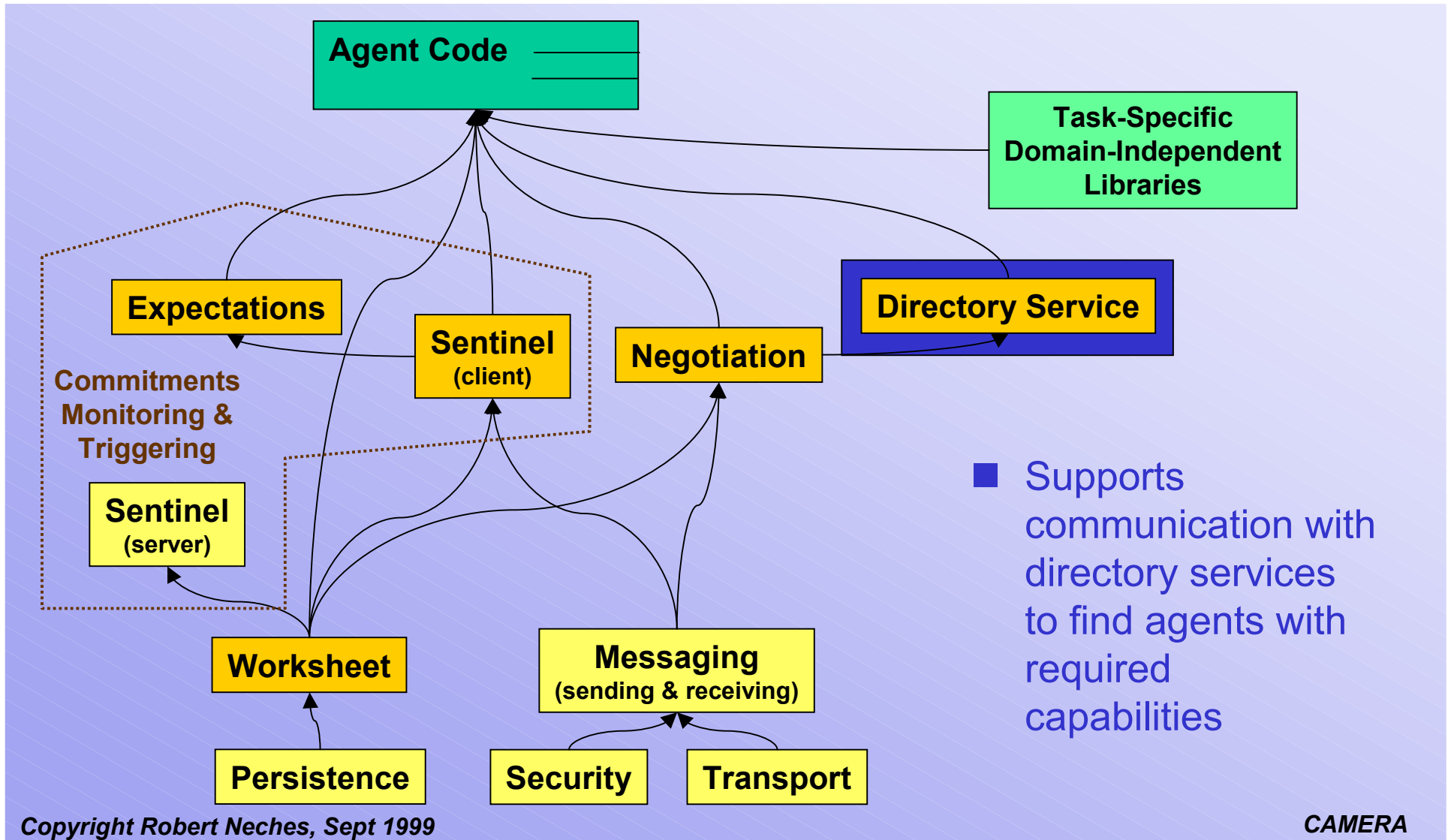
**CAMERA is concerned with how to structure communications between agents with these functions**



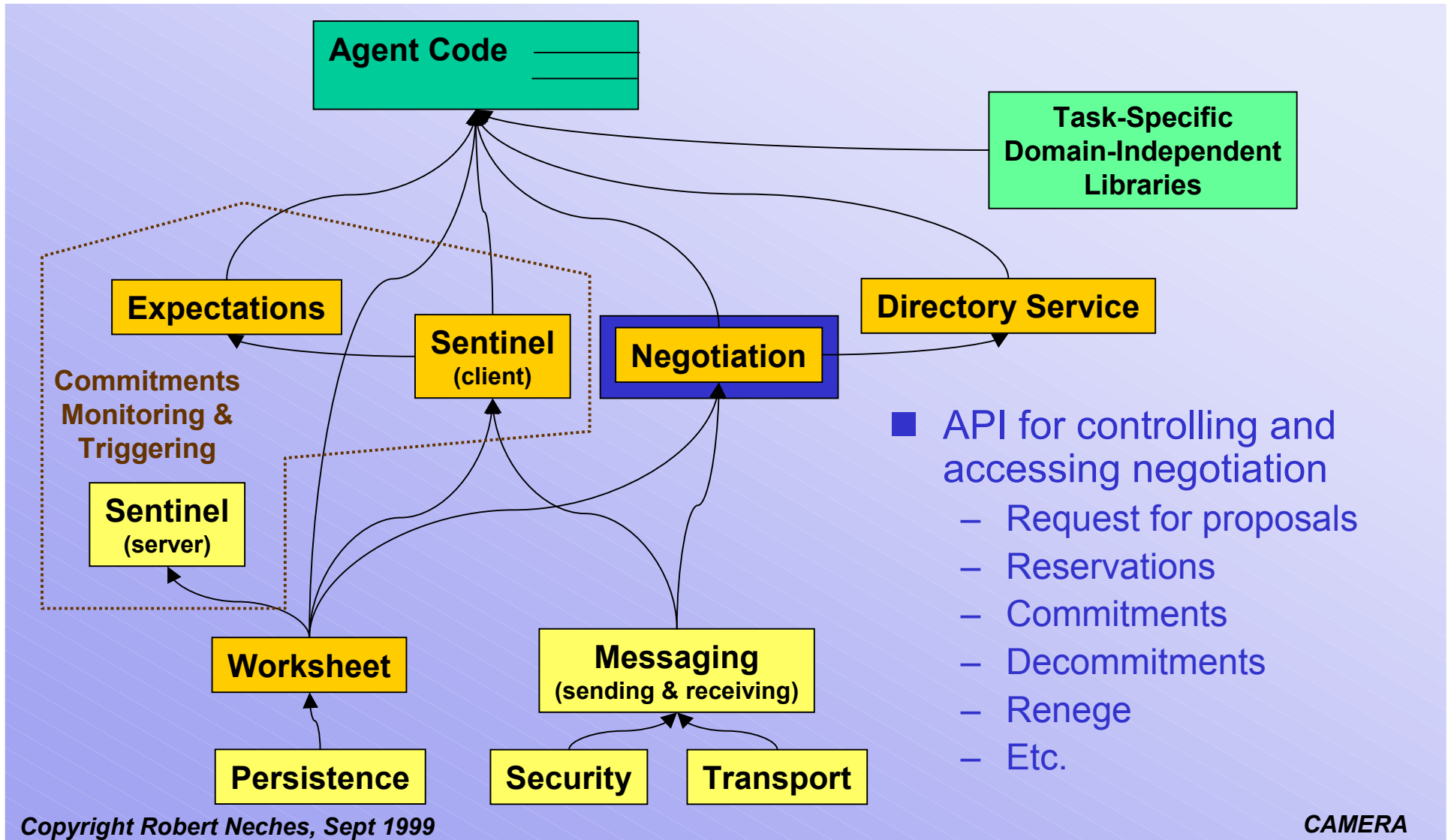
# CAMERA APIs for Building Agents



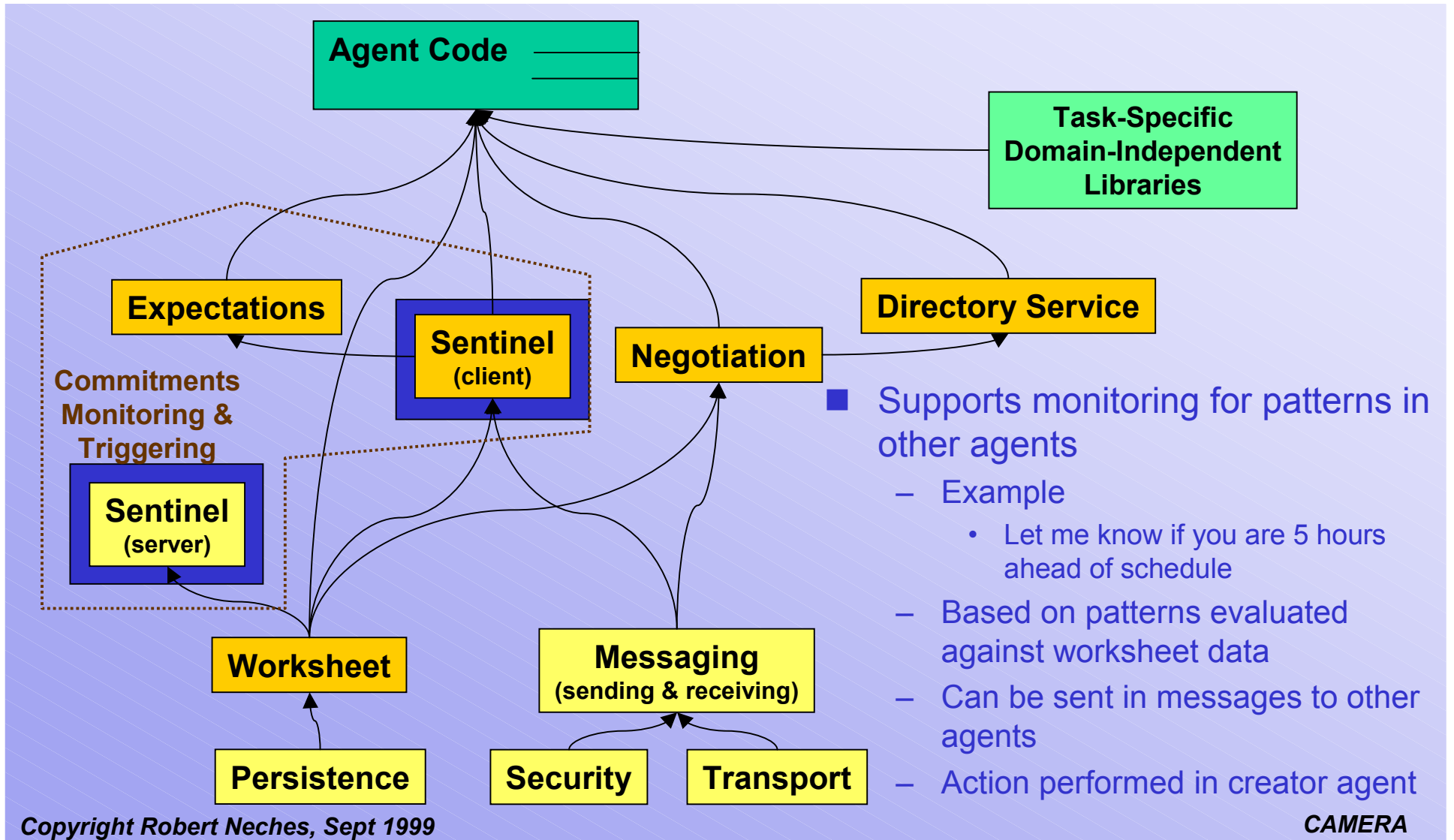
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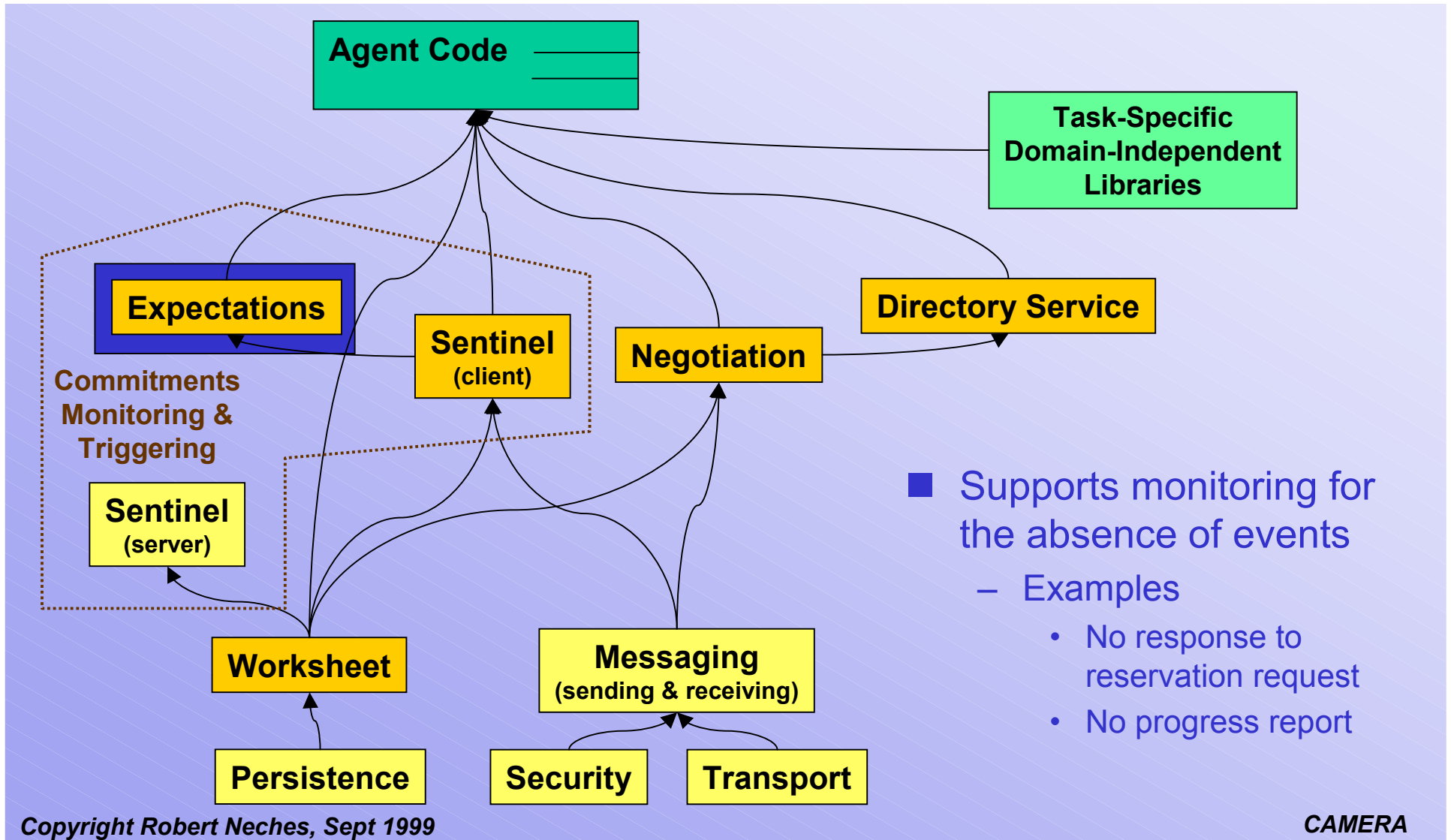
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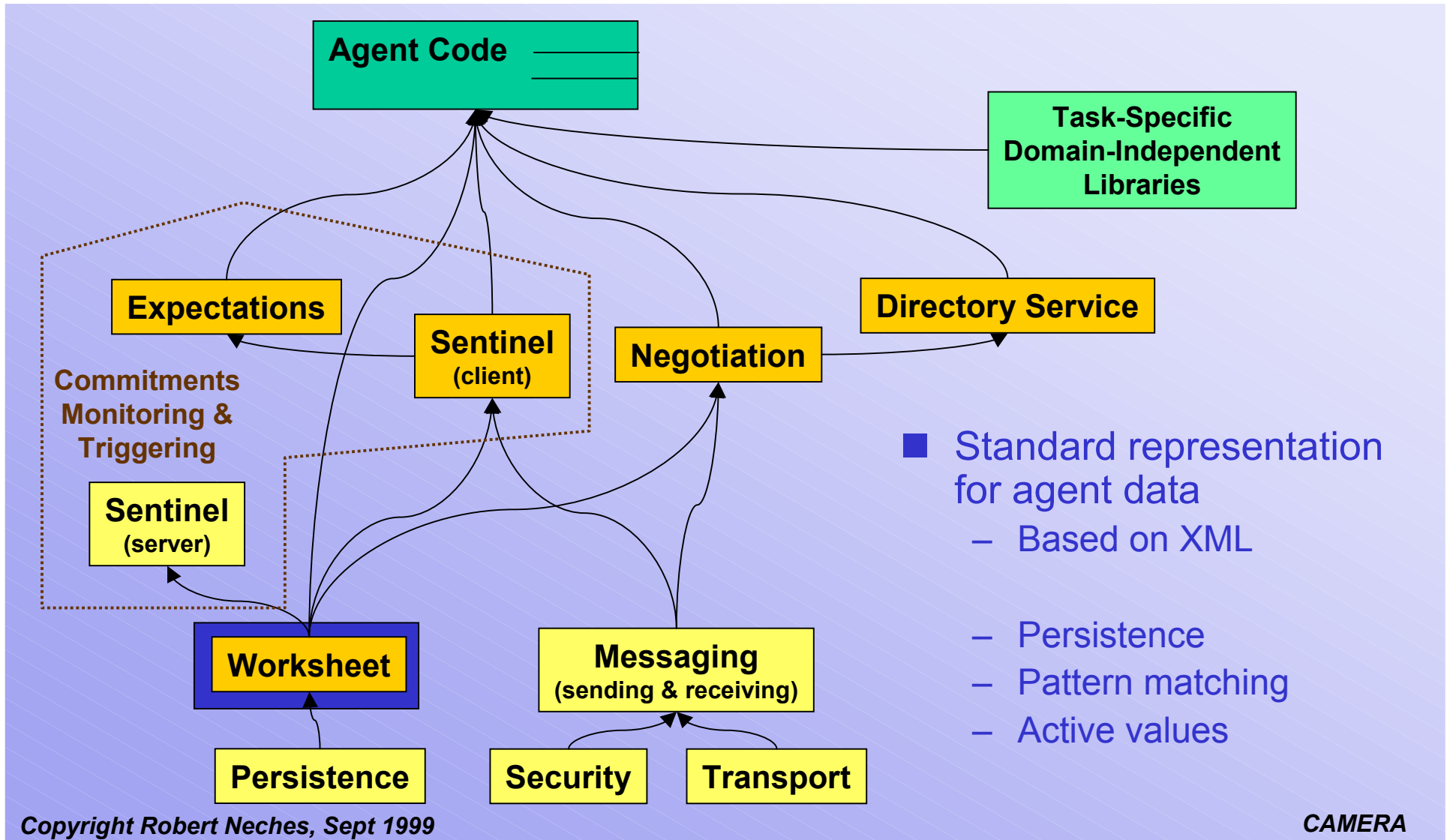
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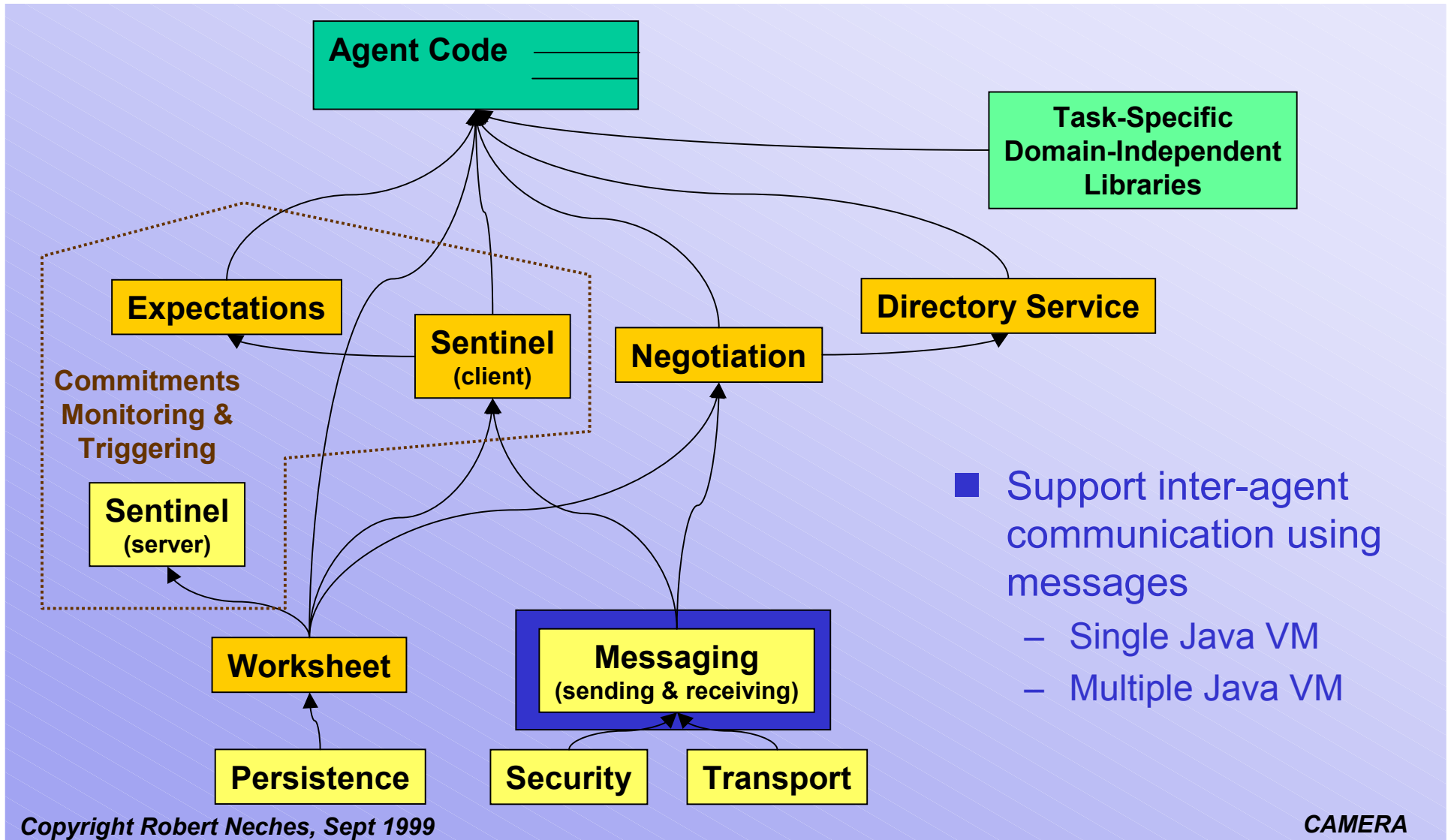
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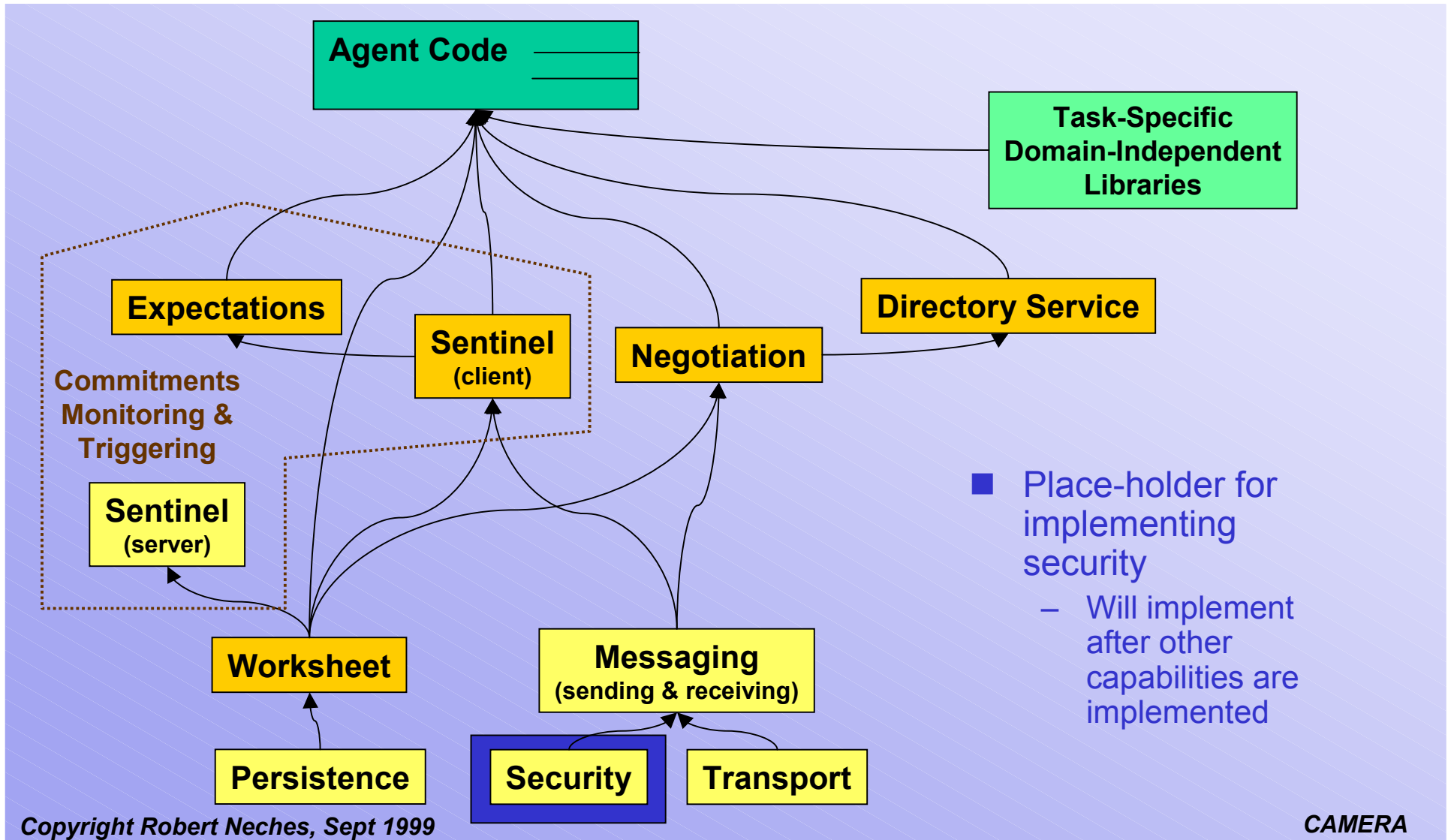
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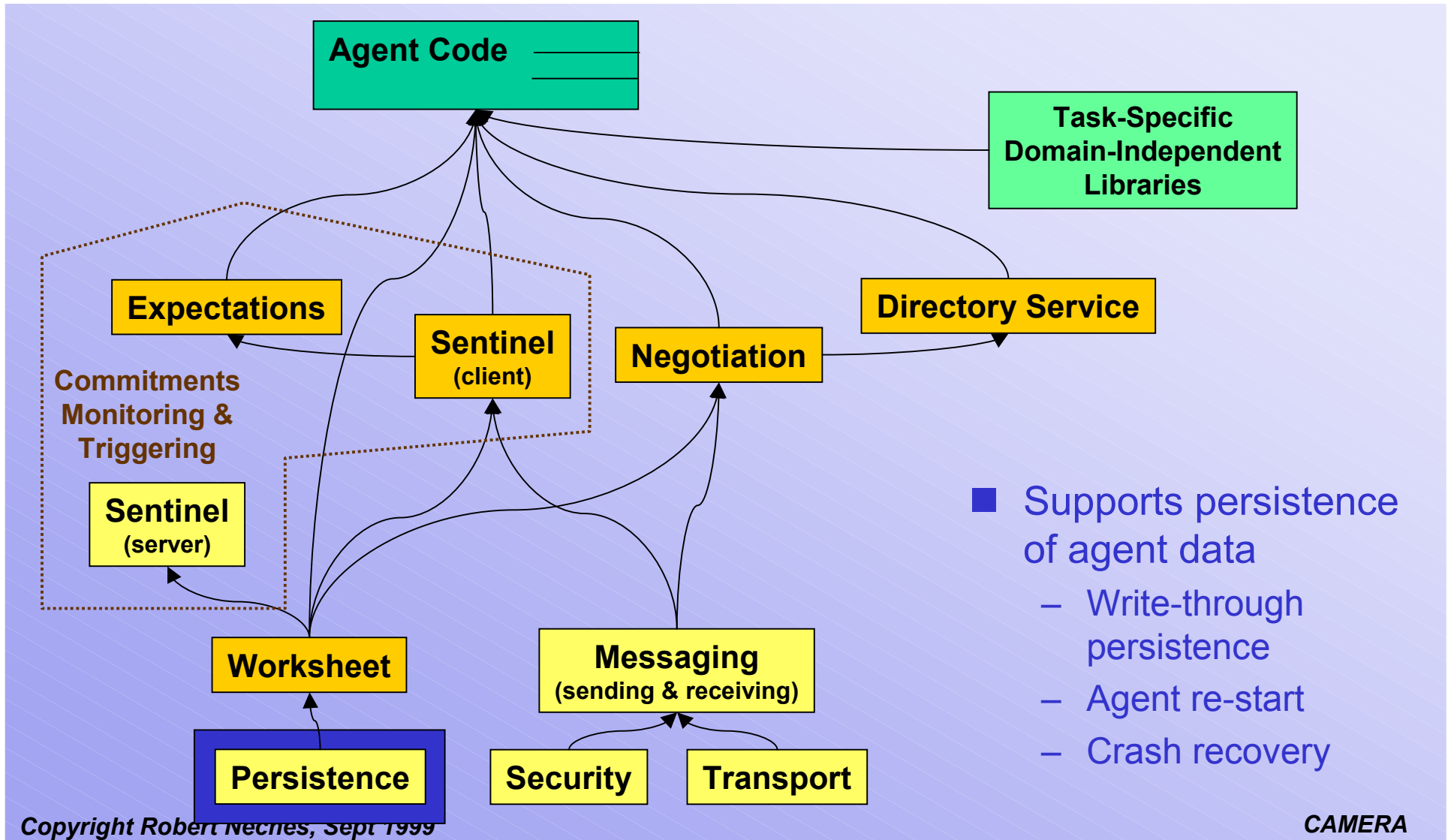
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# How Does CAMERA Differ From Other Approaches?

- Soft negotiation protocols = meta-model
  - Heterogeneous system:  
moves local knowledge into negotiation process itself
  - Allows experimentation with alternative regimes
- Notion of ranges around requirements in RFPs
  - Puts bounds on topics for renegotiation
  - Balances flexibility and efficiency
- Commitments, *with progress reports*
  - Support monitoring, triggering of renegotiations
  - Renegotiate *before* you're in trouble, not after

# Why Is It Feasible?

- Development philosophy answer:  
We're not building everything
  - Builds on maturing agent “best practices”
  - Uses COTS infrastructure software
  - Combines technologies we've done before
    - Knowledge representation, pattern matching
    - RFPs based on ISI DEALMAKER contract representation
    - Distributed computation technology (Crystaliz)
- Risk management answer
  - Incremental introduction of complexity
  - Maintain matrix of threats, approach, fallbacks

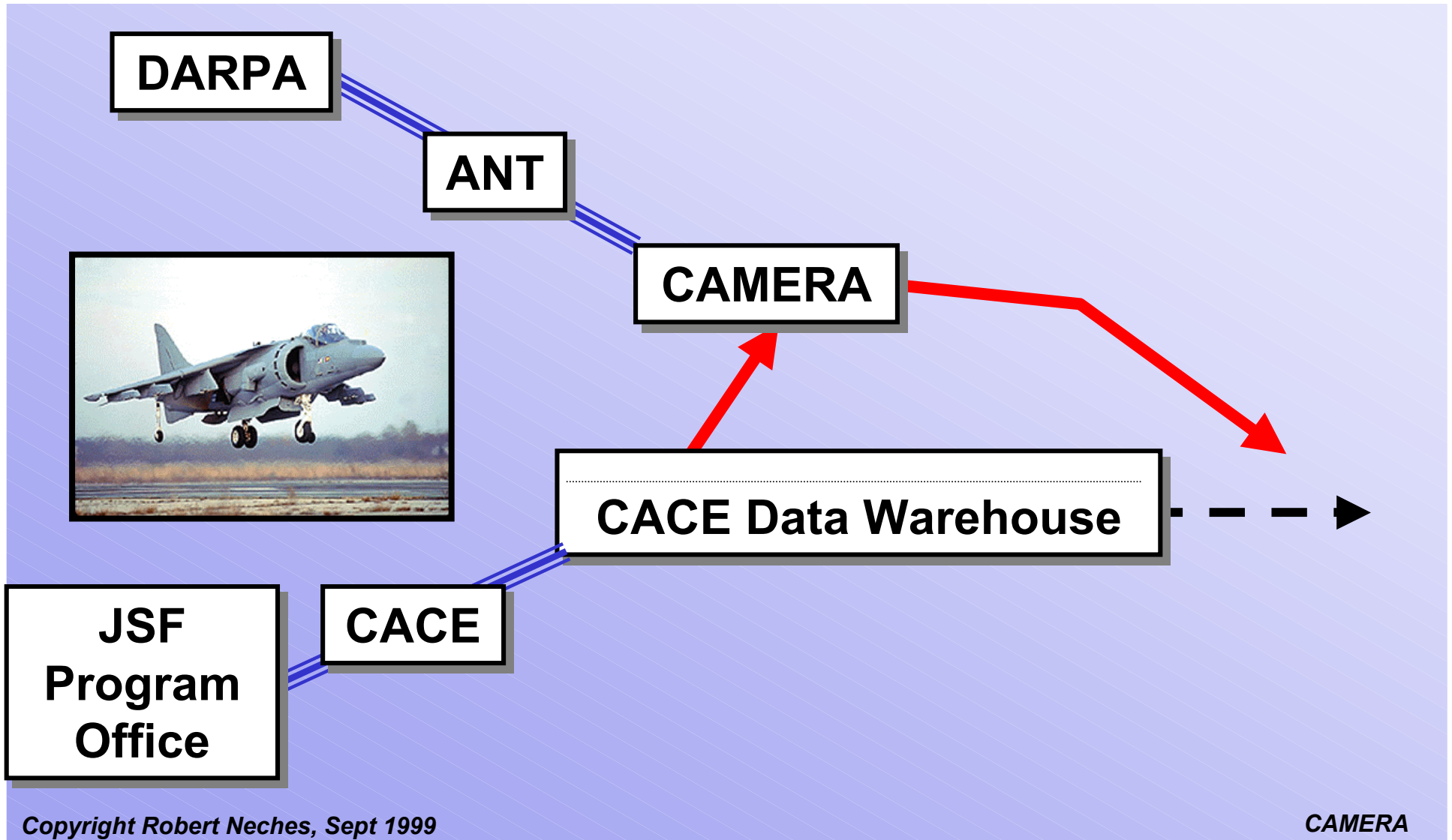
# Risk Management Matrix

Potential Problems	Approach	Fallback
Don't reach closure	Consider compliant responses first	Protocols force closure
Excess traffic	Content-based routing plus credentials	Simplify registration, sequentialize processing
Excess overhead at agents' end	Parallel threads in agent anatomy	Coarser grained agents
Too hard to program	Library of idioms	Well documented APIs
Brittleness	Range of protocols	More complex agent logic, simpler protocols
Hard to scale	Agent grouping	Scale on fewer dimensions, e.g., internet vs many agents

# Expected Tangible Results of The CAMERA Project

- Domain-independent agent negotiation framework to build sophisticated applications
  - Developers use or refine the negotiation protocols offered in the framework
  - Developers program application-specific agent logic
  - Framework conducts the negotiation
  - Framework offers default behavior; developers can override
- 1 - 4 Practical applications
  - Flight scheduling
  - Mission-Sensitive Aircraft Resumes
  - Mission-Sensitive Maintenance Operations
  - Agent-based Service and Parts Exchange Network

# Opportunities to Use CAMERA Results in Distributed, Real-time Resource Management Applications, Transitions



# Flight Scheduling Application

<http://lobster.isi.edu/camera-team>

# Strategy

- Useful to CACE

- Increase safety by lowering task saturation
- Provide more time to respond to changes
- Leverages the data warehouse

- Interesting for the DARPA ANT Program

- Tests and demonstrates agent negotiation technology

- Produce versions incrementally

- First demonstration 6-9 months

# Schedules Negotiated by Agent-based Planners (SNAP)

- Propose weekly and daily schedules
- Allow operators to refine the schedule
- Transmits schedule to SARA
- Repair schedules to respond to unforeseen events

# Agent Negotiation Approach

## Agents

- Represent the objectives and concerns of stake-holders

## Negotiation

- Enables forming groups of agents to perform tasks
- Defines responsibilities of participants & reporting structures for ensuring progress
- Helps investigate trade-offs

## SNAP Agents

- Pilots
- Aircraft
- Missions
- Ranges
- Weather
- Day Schedule
- Week schedule

# Pilots

## Goals

- Fly missions to
  - Achieve training goals
  - Participate in FRAGs

## Inputs

- Snivel Log
- Availability
- Current quals

## Negotiation

- Bid on FRAG missions
  - Bid if quals and schedule allow it
- Propose training missions
  - Propose missions that advance training goals
- Commitments
  - If win bid, commit to fly
  - If can't make it (Snivel Log) break commitment

# Aircraft

## Goals

- Fly missions
- Be mission capable

## Inputs

- Capabilities
- Availability

## Negotiation

- Bid on missions
  - Bid if capabilities, hours of use and schedule allow it
- Commitments
  - If win bid, commit to fly
  - If can't make it (maintenance problem) break commitment

# Missions

## Goals

- Be scheduled to fly

## Inputs

- Mission specs

## Negotiation

- Bid to get on day schedule
  - Ask pilots and aircraft to bid to participate
  - If cannot get bids from pilots and aircraft, don't bid
- Commitments
  - If win bid, commit to schedule
  - If pilots or aircraft decommit find replacements, negotiate new time, or renege

# Day Schedule

## Goals

- Schedule missions for a specific day

## Inputs

- Available times & external resources (range)

## Negotiation

- Ask missions to bid
  - Ask pilots and aircraft to bid to participate
  - If cannot get bids from pilots and aircraft, don't bid
- Commitments
  - Manage increases in commitment levels to create stable schedules

# Week Schedule

## Goals

- Schedule missions for a specific week

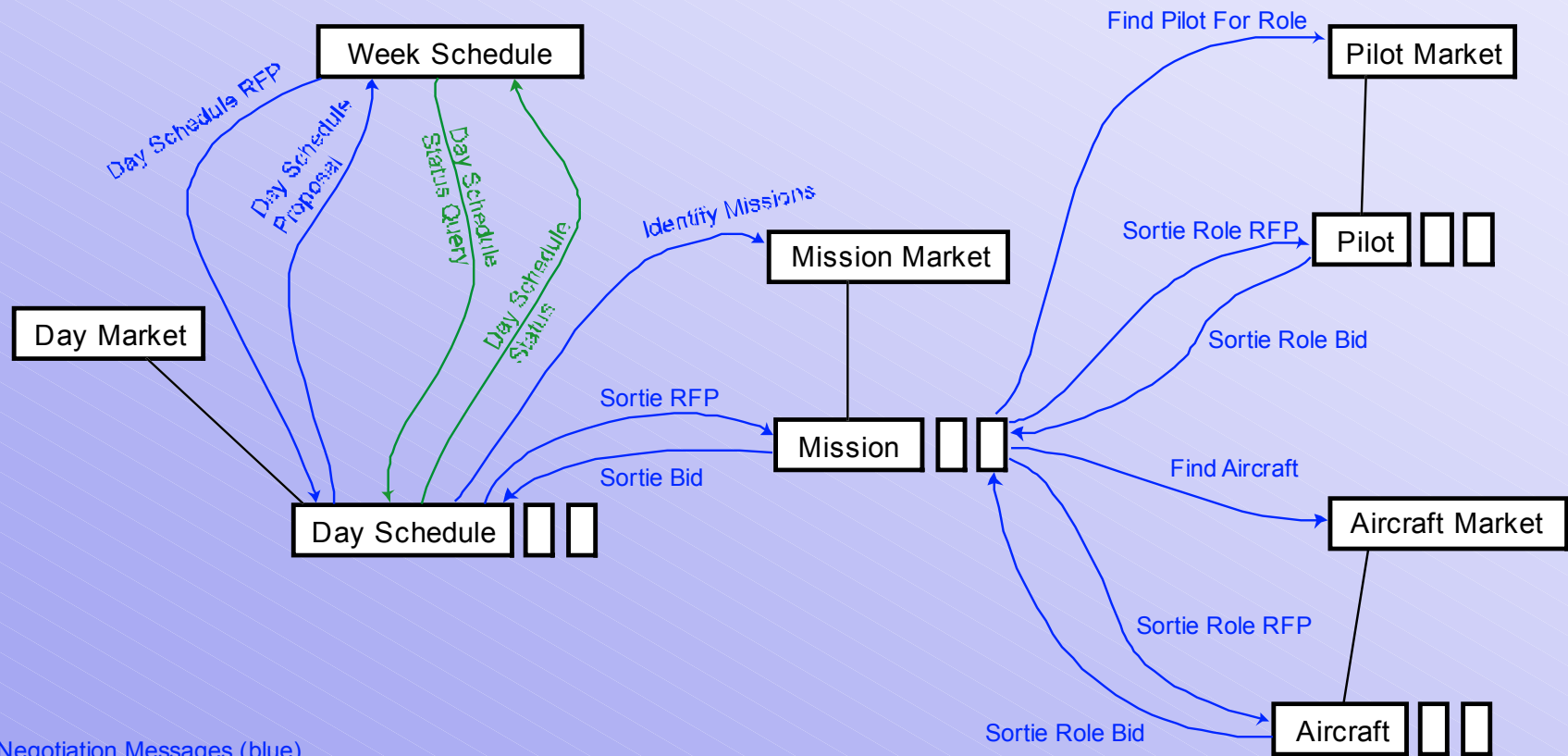
## Inputs

- Available times & external resources (range)

## Negotiation

- Ask Day Schedule agents to propose daily schedules
  - Ask for frag schedules
  - Ask for training schedule
- Commitments
  - Manage day schedules to ensure that global week schedule is satisfactory

# Agent Summary



Negotiation Messages (blue)

Status Messages (green)

Standard Market/Agent Messages -- not detailed (dashed)

# SNAP Schedule

- Incremental capabilities
- Spring 2000 – initial feasibility demonstration
  - Ability to produce weekly and daily schedules
  - Consider critical entities first
- Summer 2000 – increased domain knowledge
  - Rangers, weather, ...
  - Schedule repair

# Scope of the Applications

- Proof of concept demonstrations
- Not engineered for leave-behind
- Transition path if promising:
  - Short-term: hand-off to CACE ACTD
  - Long-term: transition to Joint Strike Fighter

# Evaluation

- User / Advisor feedback on functional capability demos
  - Marine Air Group 13, MCAS Yuma
  - Navy via SPAWAR/NTCSS
  - Joint Strike Fighter Program
- Measure effectiveness wrt:
  - Mission readiness and safety
  - Logistics costs
    - Time, money, warehouse space, etc.
    - Personnel effort; bartering time

# Research Plans: Phased Technical Goals

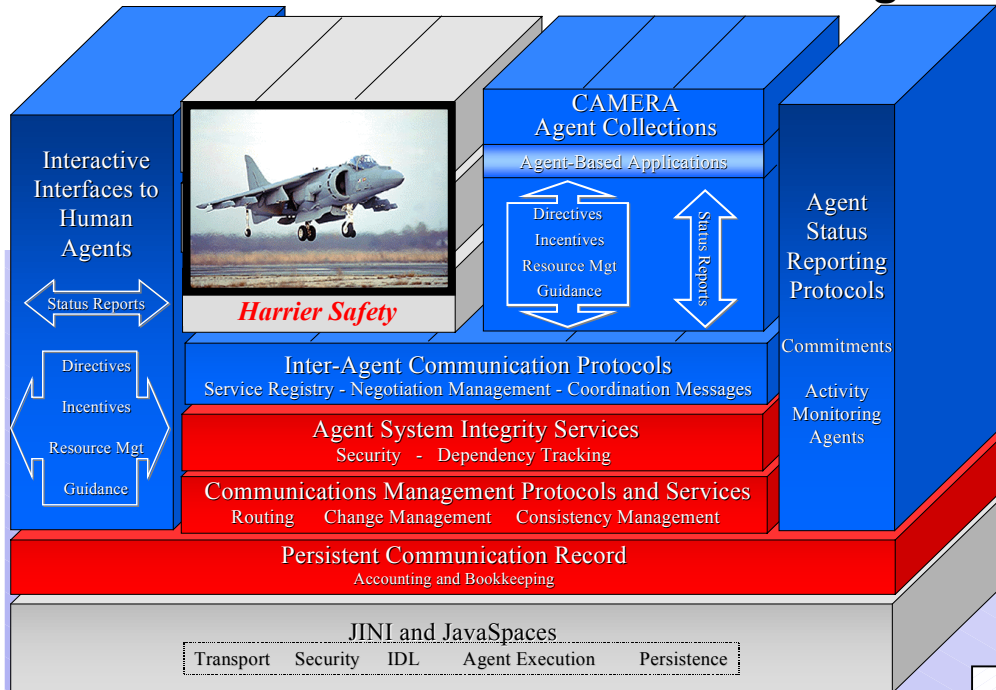
- Year One:  
Initial formation of agent collections
- Year Two:  
Initial regrouping within collections,  
Corrective renegotiation via checkpoints
- Year Three:  
Scaled, efficient monitoring  
Renegotiation as-needed, when needed

# Standard Capabilities

Inter-agent negotiation framework enables agents to:

- *Announce capabilities / availability*
- *Send, receive, process requests*
- *Report status, progress, priorities*
- *Maintain joint commitments*
- *Enforce security restrictions*
- *Form communication/control paths*
- *Negotiate/renege organizations*

# CAMERA: Coordination and Management Environments for Responsive Agents



## New Ideas

### Collection formation, Renegotiation

- **Negotiation management protocols**
  - Establish “rules of the game”
  - Permits alternative, *task-specific* variants
  - Ensure convergence on taking action
  - Closure through *commitments*
- **Commitment-based group control**
  - Resynchronization after separations
  - Problem / Opportunity Monitoring
- **Renegotiation revisits priorities**

## Impact

**Collective systems growing to 1000's of agents, which can**

- **Proactively adapt both to problems and opportunities**
- **Systematically reevaluate priorities in face of conflicts**
- **Robustly handle system changes, communication breaks**

