Agent Learning as A Control Problem

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Advanced Technology Laboratories

- **150 employees**
- **Innovate technologies for ready insertion into Lockheed Martin and other industry products**
- **4 Laboratories**
  - Advanced Concepts,Distributed Processing,Embedded Processing
  - Artificial Intelligence
    - **Department of Defense**
      - Basic and applied research
    - **Autonomy, Human Centered Interfaces, Situation Understanding**
    - **Net-Centric Operations Technology**
      - Contracts
      - Internal Research and Development
        - Agent Learning

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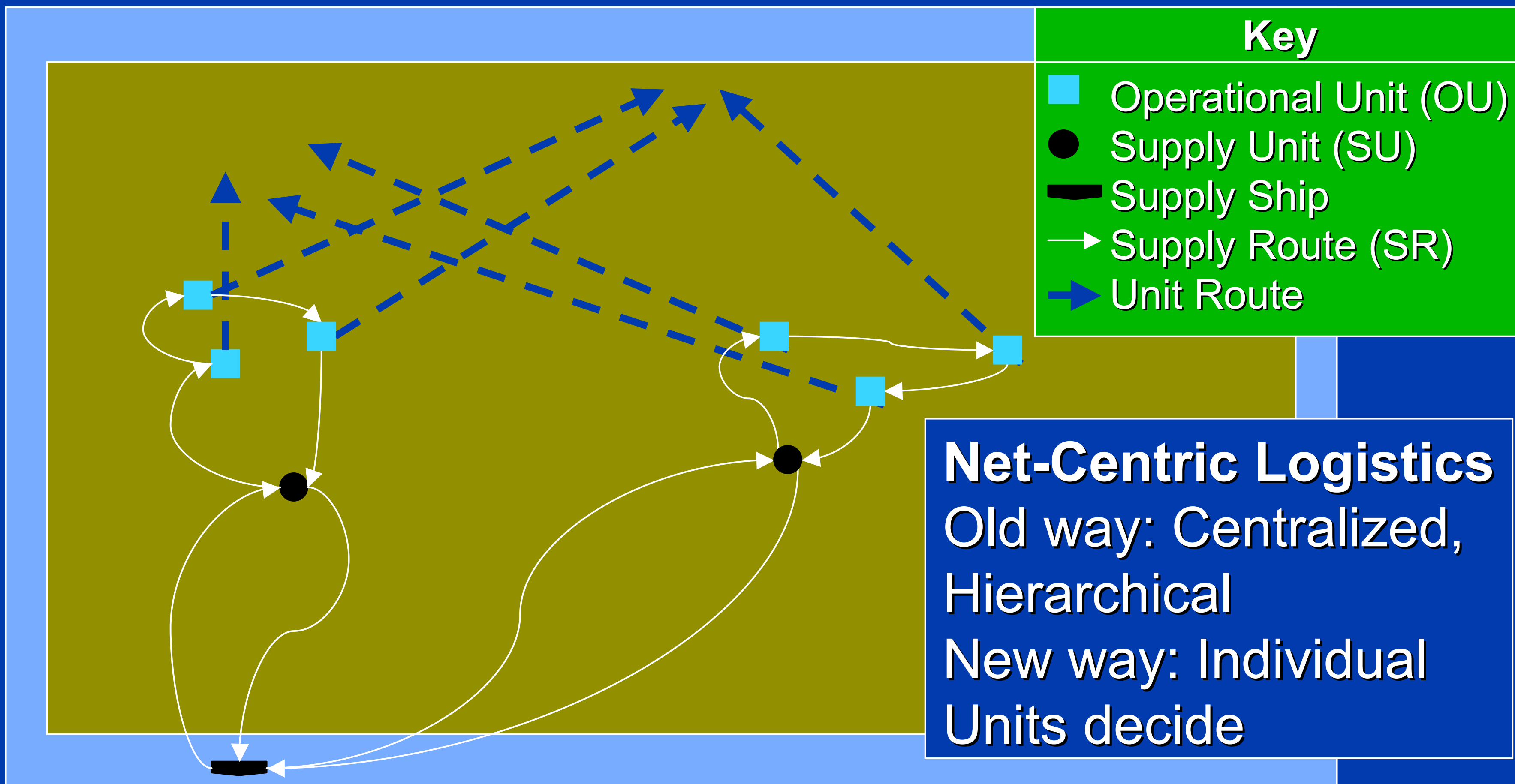
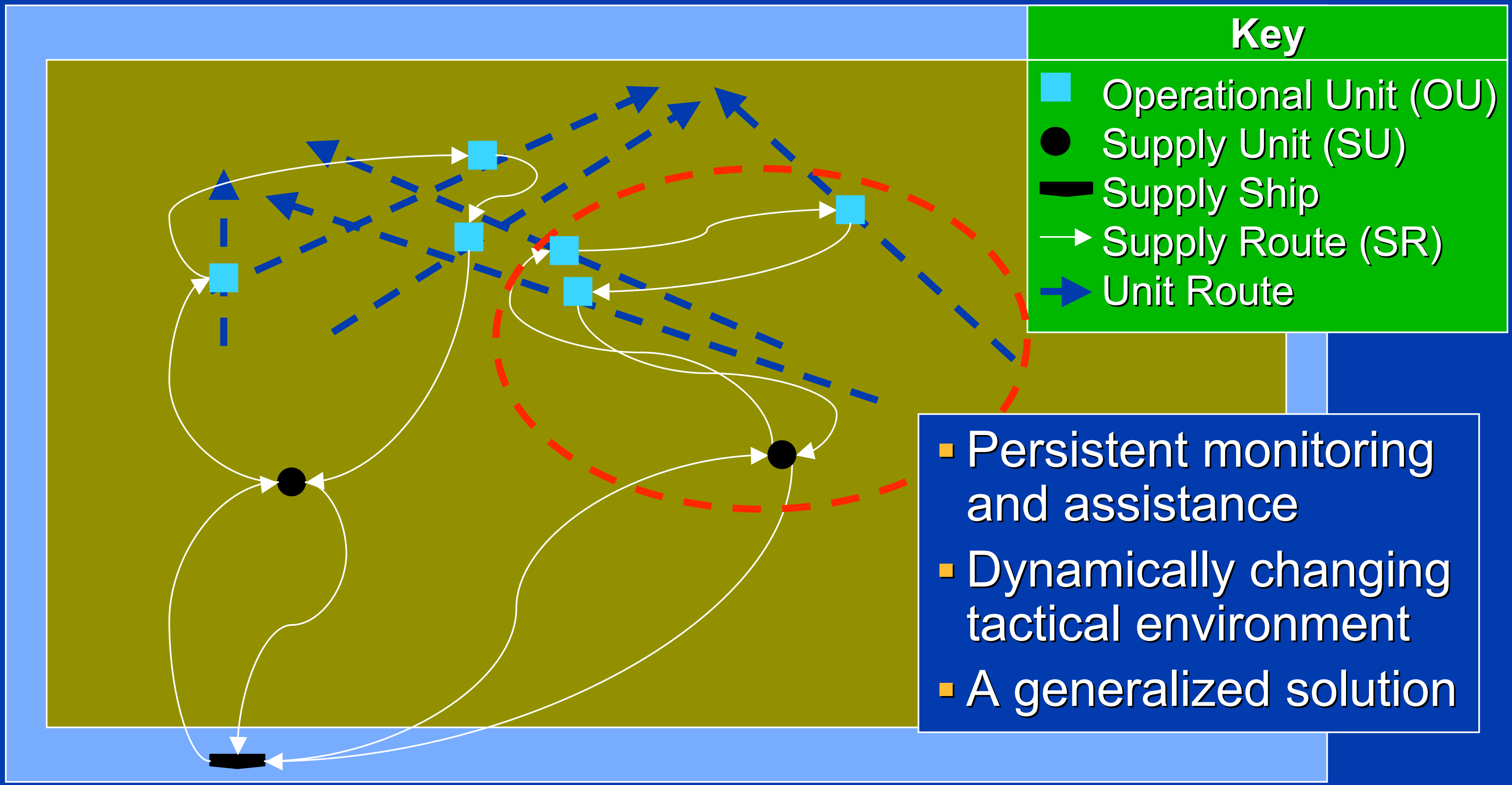
Operational Problem



Net-Centric Logistics
Old way: Centralized, Hierarchical
New way: Individual Units decide

Coordinated logistics among lower echelons form a complex system

Technical Challenges



- Persistent monitoring and assistance
- Dynamically changing tactical environment
- A generalized solution

Many factors to consider when changing plans

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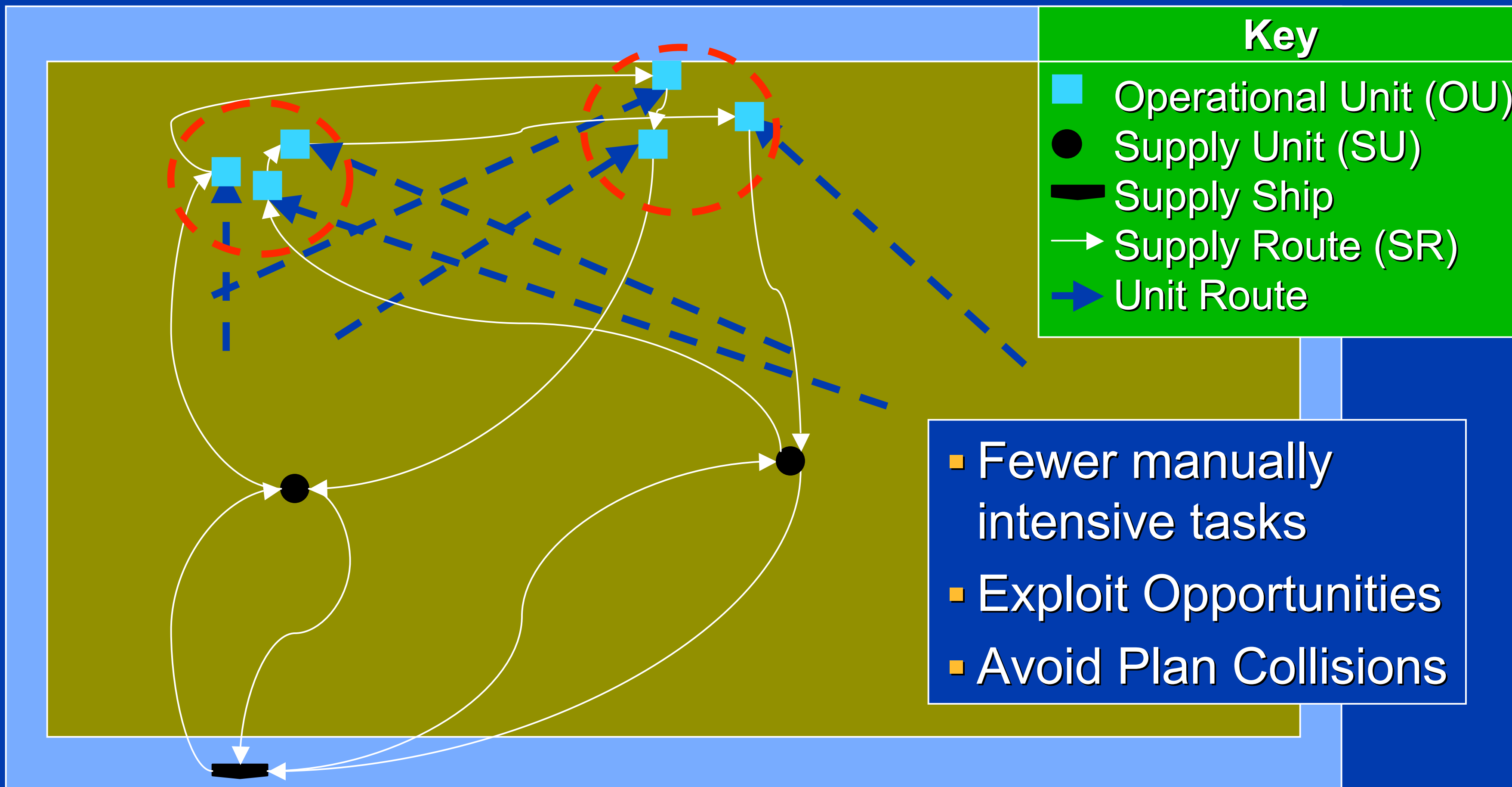
Benefits of Solving Technical Challenges



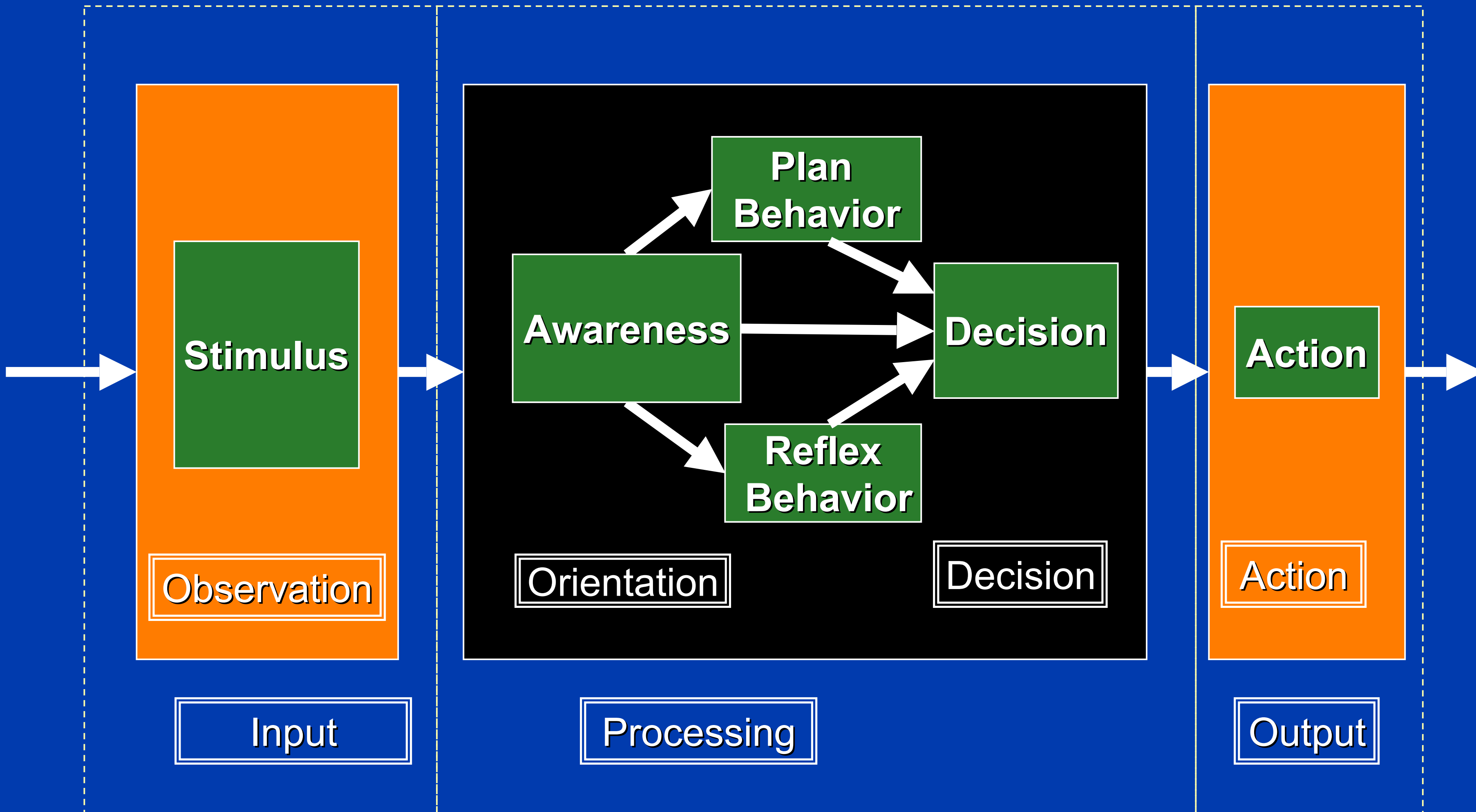
- Fewer manually intensive tasks
- Exploit Opportunities
- Avoid Plan Collisions

Software Agents can be used for decision support

Technical Approach to Achieve Adaptation

- **People are good at adapting to change**
- **Apply three elements from cognitive research**
  - A system that interacts with its environment
  - Mechanisms for adaptation
  - Mechanisms for stability

Technical Approach: Element 1



Put modules for interaction into a software paradigm.

Technical Approach: Element 2 Adaptation Mechanisms (Jean Piaget)

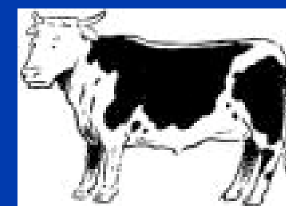
- **Assimilation**
  - Adapting the environment to world model
- **Accommodation**
  - Adapting self to environment
- **Equilibration**
  - The stability mechanism
  - Finding balance between assimilation and accommodation

Technical Approach: Element 2
Example: Children and Animals

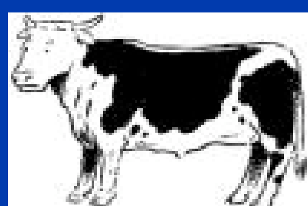
- **Known**

Dog: 

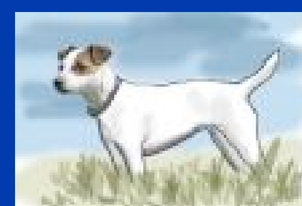
- **Assimilation**

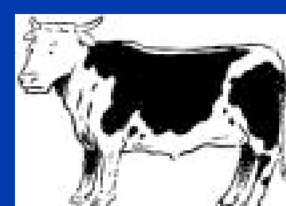
Dog:  

- **Unknown**

???: 

- **Accommodation**

Dog: 

Cow: 

Operational Unit Example

Food is low so order food from SU 1

Lev.	Low	OK	OK		
	Food	Fuel	Ammo	Reliable	Prefer
SU 1	1			No data	
SU 2	2			No data	
SU 3	3			No data	

Operational Unit Example

Failed to receive food; food is still low, so order food from SU 2

Lev.	Low	OK	OK		
	Food	Fuel	Ammo	Reliable	Prefer
SU 1	2			0% (0/1)	
SU 2	2			No data	
SU 3	3			No data	

Accommodate

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Operational Unit Example

Received food from SU 2; Accommodate

Lev.	OK	OK	OK		
	Food	Fuel	Ammo	Reliable	Prefer
SU 1	2			0% (0/1)	
SU 2	1			100% (1/1)	
SU 3	3			No data	

Accommodate

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Operational Unit Example

SU 2 becomes preferred supplier; fuel is low, so try SU 2

Lev.	OK	Low	OK		
	Food	Fuel	Ammo	Reliable	Prefer
SU 1	2			0%(0/1)	
SU 2	1	x		100% (1/1)	X
SU 3	3			No data	

Assimilate

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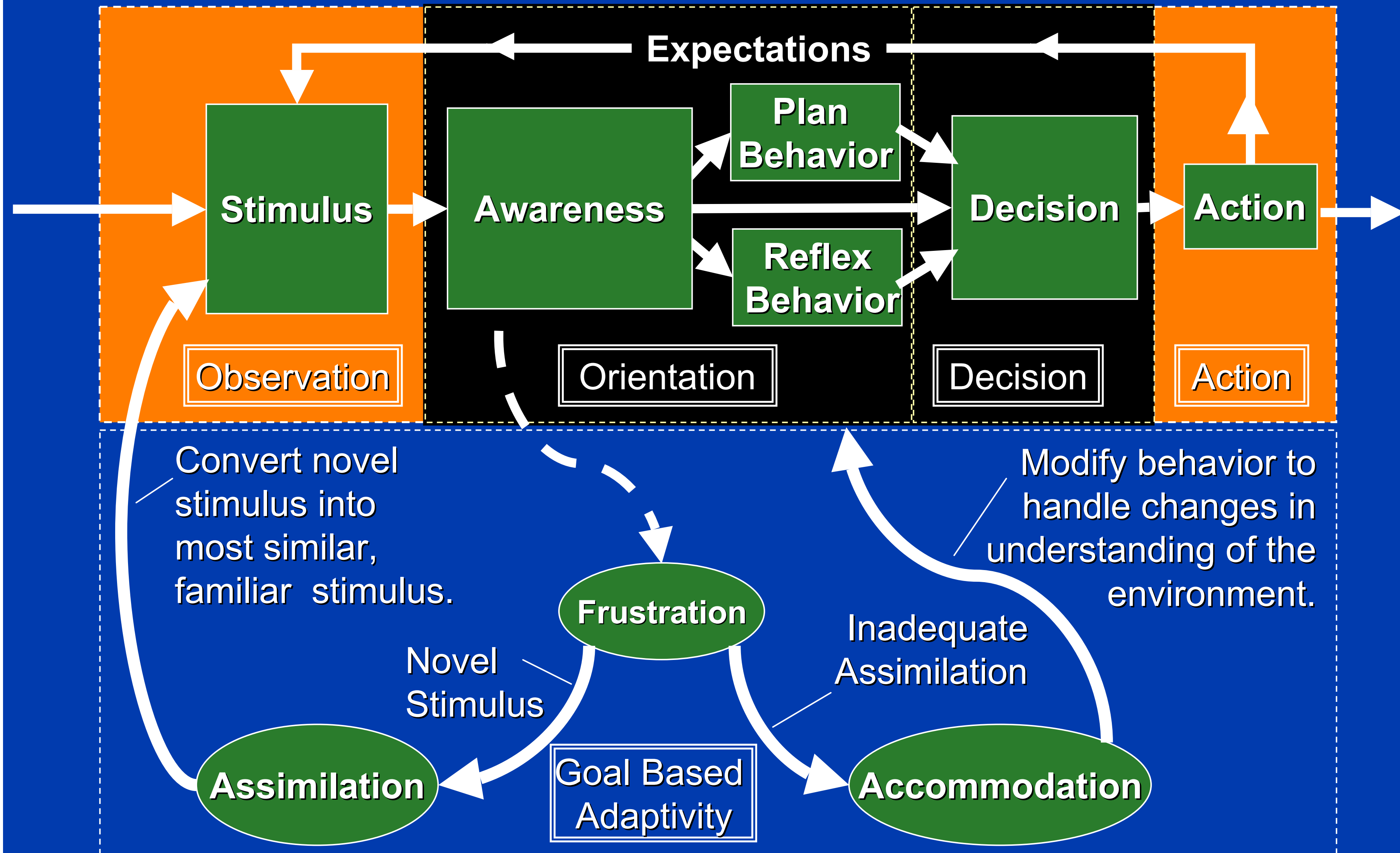
Adding Adaptation to the Decision Model



Element 2 Re-Casts the Stability Problem

- **From**
  - How can a system be both predictable and flexible?
- **To**
  - Stability through equilibration of assimilation and accommodation controlled by "consistent intent?"

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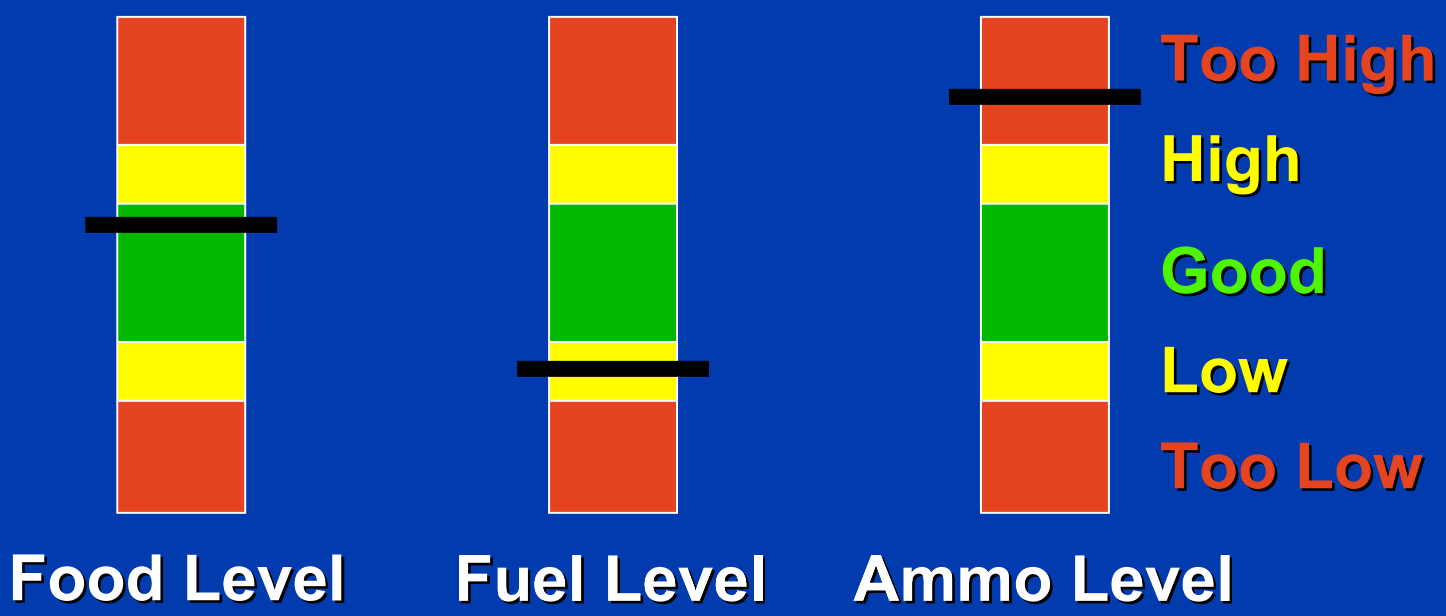
Technical Approach: Element 3 Stability Mechanisms

- **Homeostasis according to Ashby**
  - “A form of behavior is adaptive if it maintains the essential variables within physiological limits.”*
- **“Essential variables” or Homeostatic Variables (HVs) represent intent of the system**
- **Goal becomes to maximize the margin from each “physiological limit” of each “essential variable”**

* W. Ross Ashby, Design For a Brain, 2^{nd} ed. pg. 58

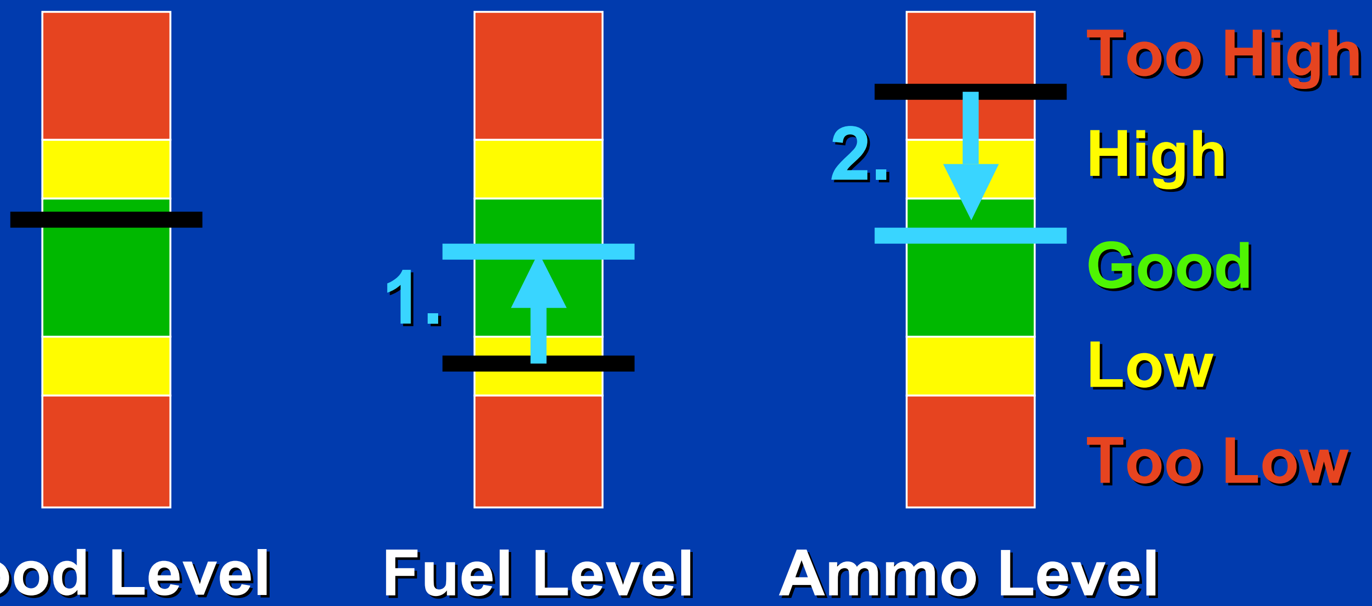
Technical Approach: Element 3
Stability Mechanisms

- **Homeostatic Variables (HVs)**
  - A set of ideal levels
  - Decisions motivated by variables



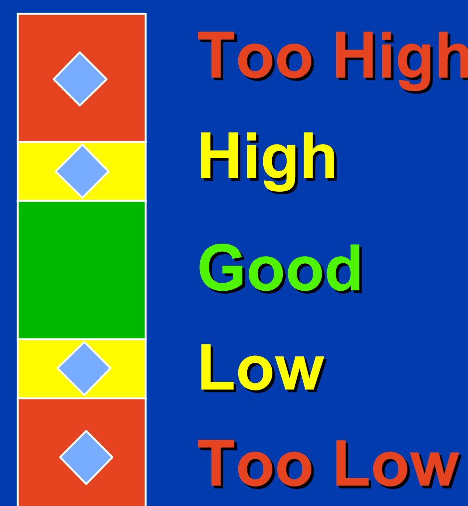
Technical Approach: Element 3
Example: Create Consistent Intent

- **Example behaviors**
  1. Order fuel => increased fuel
  2. Target Practice => decreased ammo



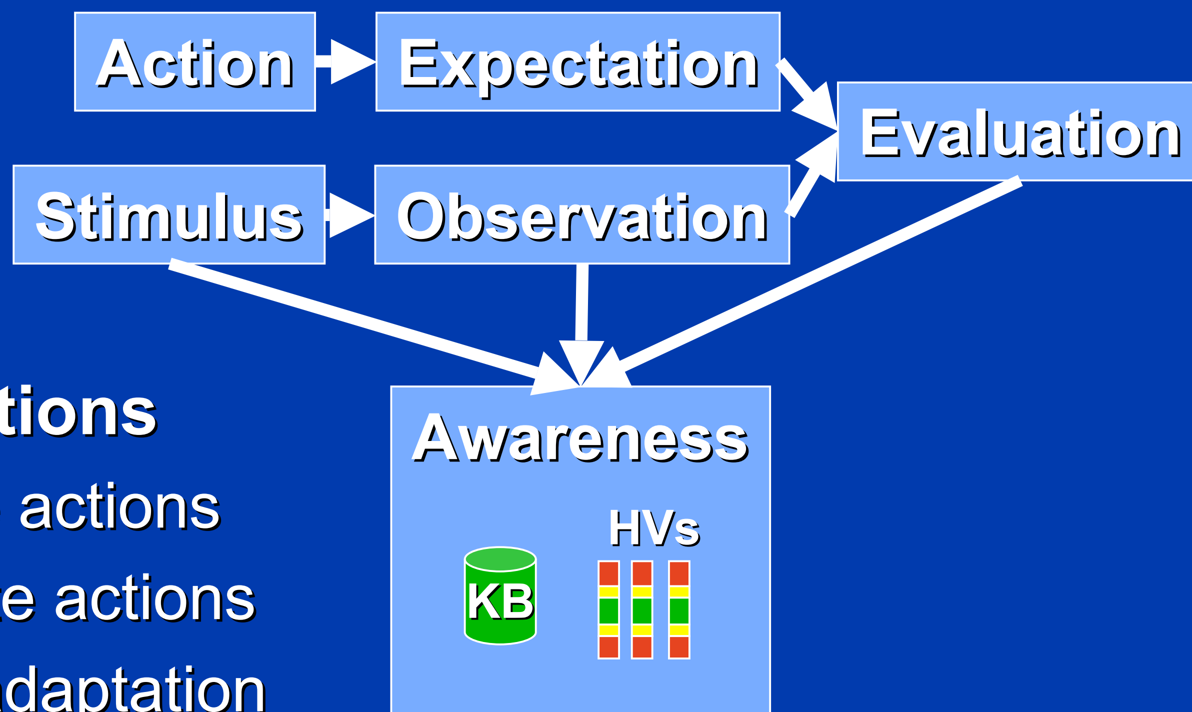
Adding Stability Mechanisms To The Decision Model

- **Damasio's Somatic Markers (◇)**
  - Given an HV level, create a marker that links to a behavior that moves the level towards the "Good" area.
  - Learning is invoked when the behavior fails to move in the intended direction.
  - Behaviors have an expected impact on HVs.



Adding Stability Mechanisms To The Decision Model: Evaluating Actions

- Expectation vs. observation



- Role of Expectations
  - Used to choose actions
  - Used to evaluate actions
  - Used to guide adaptation
  - Can be learned from experience.

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Current Status

- **Adaptive, Cognitive Agent Architecture**
  - Implements Piaget's adaptation model: assimilation, adaptation, equilibration
    - **Applies Reinforcement Learning Technique**
  - Controls Learning with Damasio's Somatic Marker model
    - **Stable in most cases**
    - **May have trouble with large number of HVs**
  - Demonstration/Experimentation on simplified Sense and Response Logistics scenario

Conclusions

- Realization of Piaget's and Damasio's theories provides competent, adaptive behavior
- Achieves general-purpose (not domain or task specific) machine learning and adaptation
- Actual Deployment will require stronger stability results

Future Work

- **Formalize the Stabilization Process**
  - Ashby – Polystable system
    - **Change more than one parameter if the parameters don't interact**
      - Keep track of interactions
      - Keep track of what changes cause

Backup Slides

Evaluation Capability

- **What is Varied**
  - Supply Units(SUs)
    - **Number of assets**
  - Operational Units(OUs)
    - **Rates of supply use**
  - Geographical position
  - Capacity
  - Speed
  - Initial Conditions

- **Two Perspectives**
  - OUs Request Supplies
  - SUs Supply OUs

- **Performance Factors**
  - Operational Availability
  - Well-being of Agents
  - Time to Adapt to a Change

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Environmental Effects

- Food consumption
- Burning fuel
- Theft
- Supplies found by unit