



# Software-Enabled Control (SEC)

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# Current State of Control Technology

- Conservative, limited in capability.
- Human operators “close the loop” for extreme disturbances and high performance.
- Old computational assumptions
  - Limited Resources
  - Fixed, static designs and schedules
  - Loose integration of supervisory and “inner loop” control
  - Limited prediction

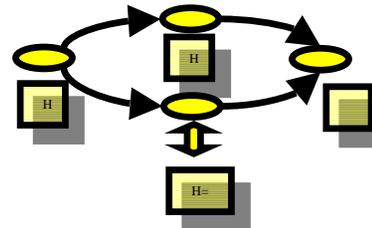
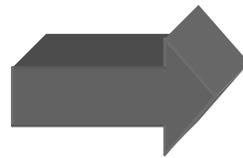


# Program Objectives

Software  
Enabled  
Control

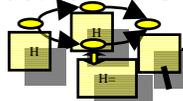
## Individual Systems

Software-  
Based  
Prediction

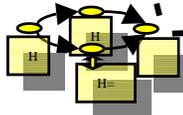


## Coordinated Subsystems

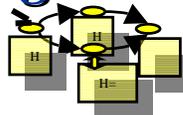
*Radar control*



*Fire control*



*Flight control*



## Cooperating Systems



ITC



# Program Approach *“Superhuman” Control*



- Expand operational envelopes of vehicles through improved control systems.
- Leverage rapid increases in processing power and storage capacity.
- Use dynamic information to dramatically improve control and coordination.



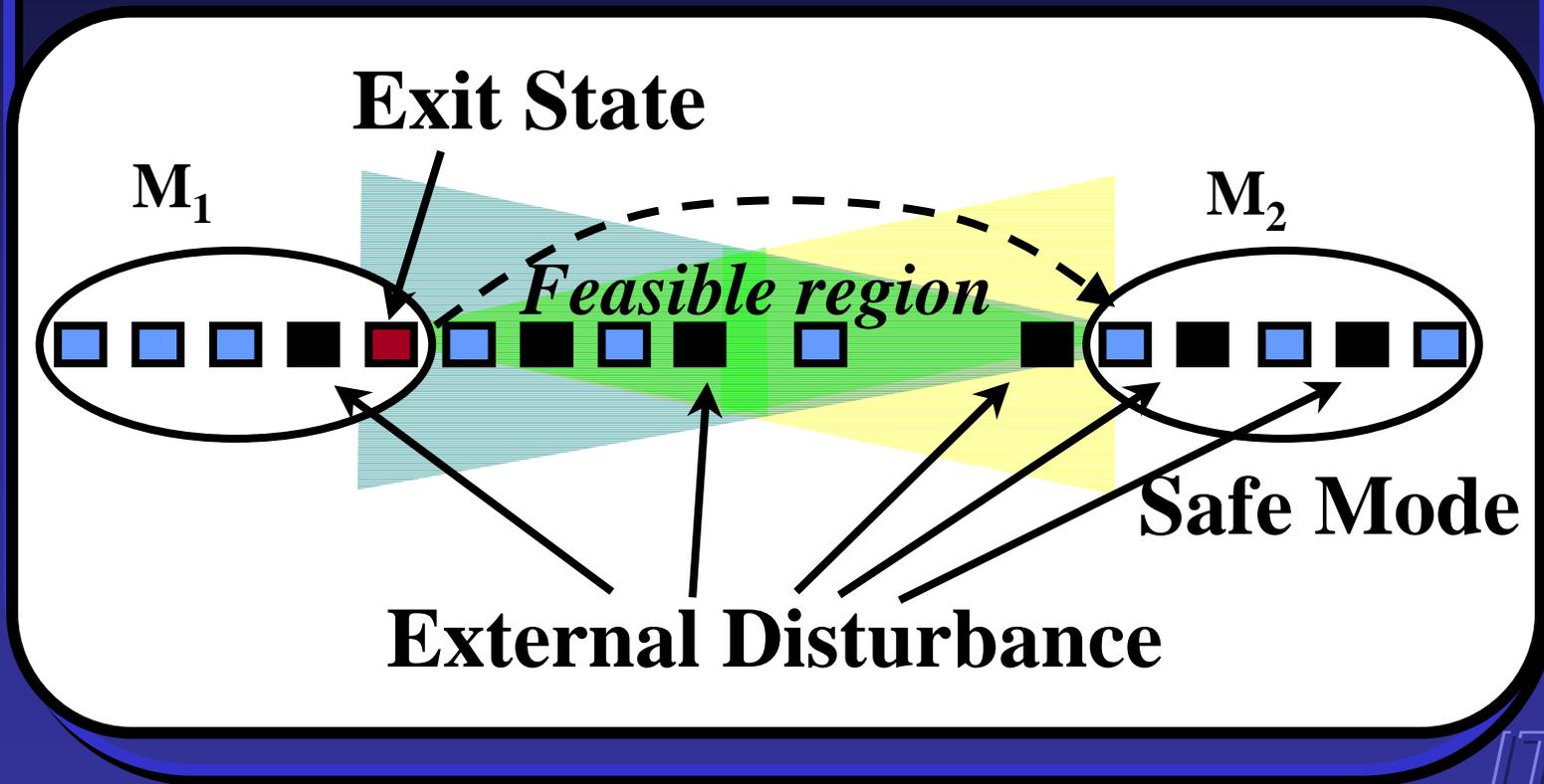
# Technical Tasks

- Active State Models
- Coordinated Multi-Modal Control
- On-Line Control Customization
- Open Control Platform



# Active State Models

*... With Predictive Transitions*





# Active State Models

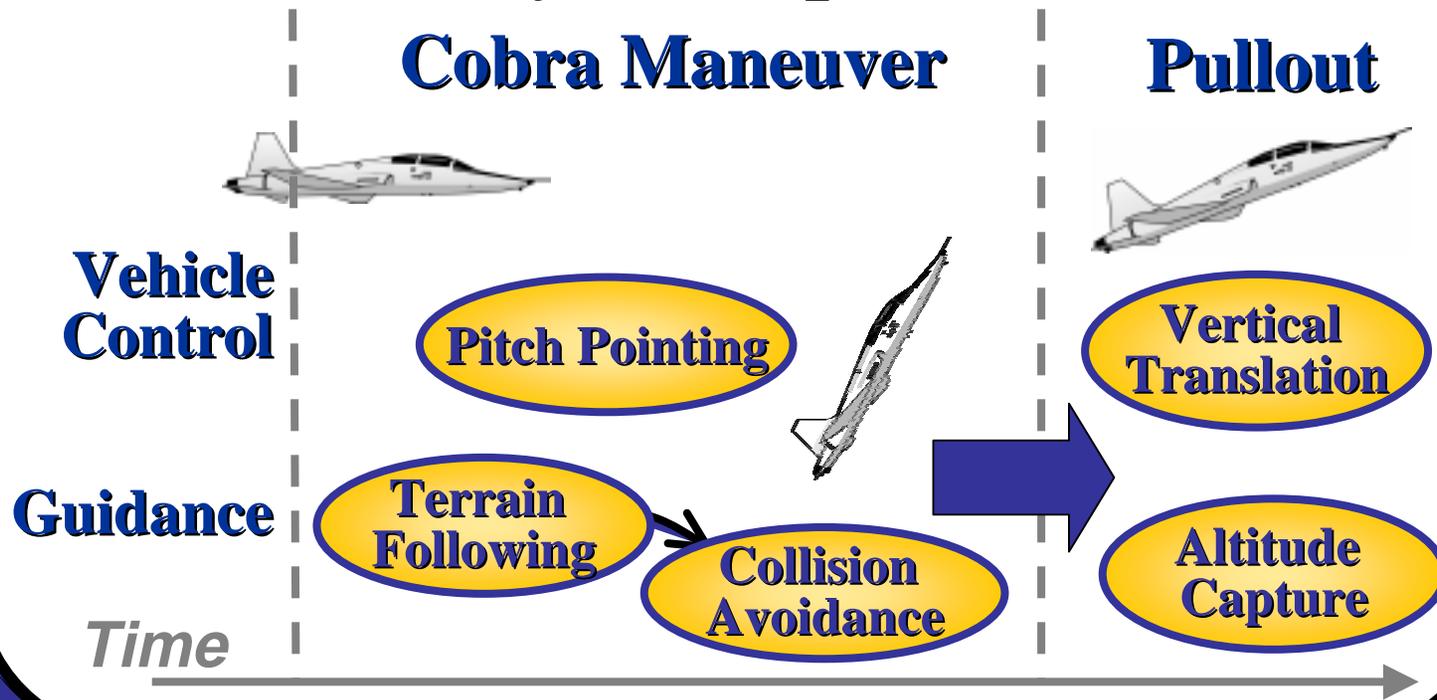
## *Challenges*

- Dynamically exploit first-principles knowledge and on-line data to improve robustness.
- Accommodate multiple system and environmental factors.
- Predict effects over very large state and mode spaces.
- Rapidly assess damage, change.



# Coordinated Multi-Modal Control

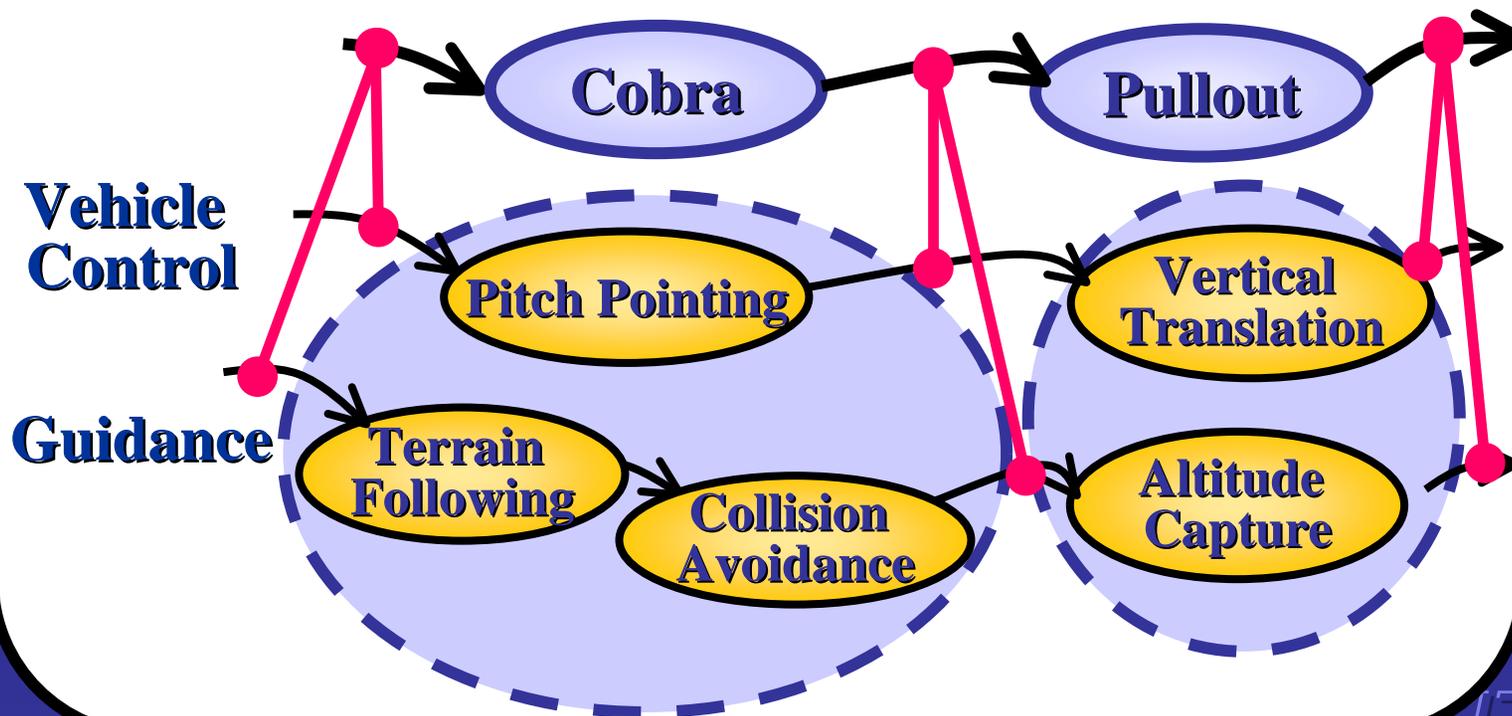
**Problem: Dynamic coordination of subsystem operation**





# Coordinated Multi-Modal Control

## Coordination and Deconfliction of Control





# Coordinated Multi-Modal Control *Challenges*

- Provide coordinated operation.
- Preserve stability of individual systems, as well as global stability and performance.
- Provide efficient control coordination.
- Enable distributed implementation for physically and geographically separated components.



# On-Line Control Customization

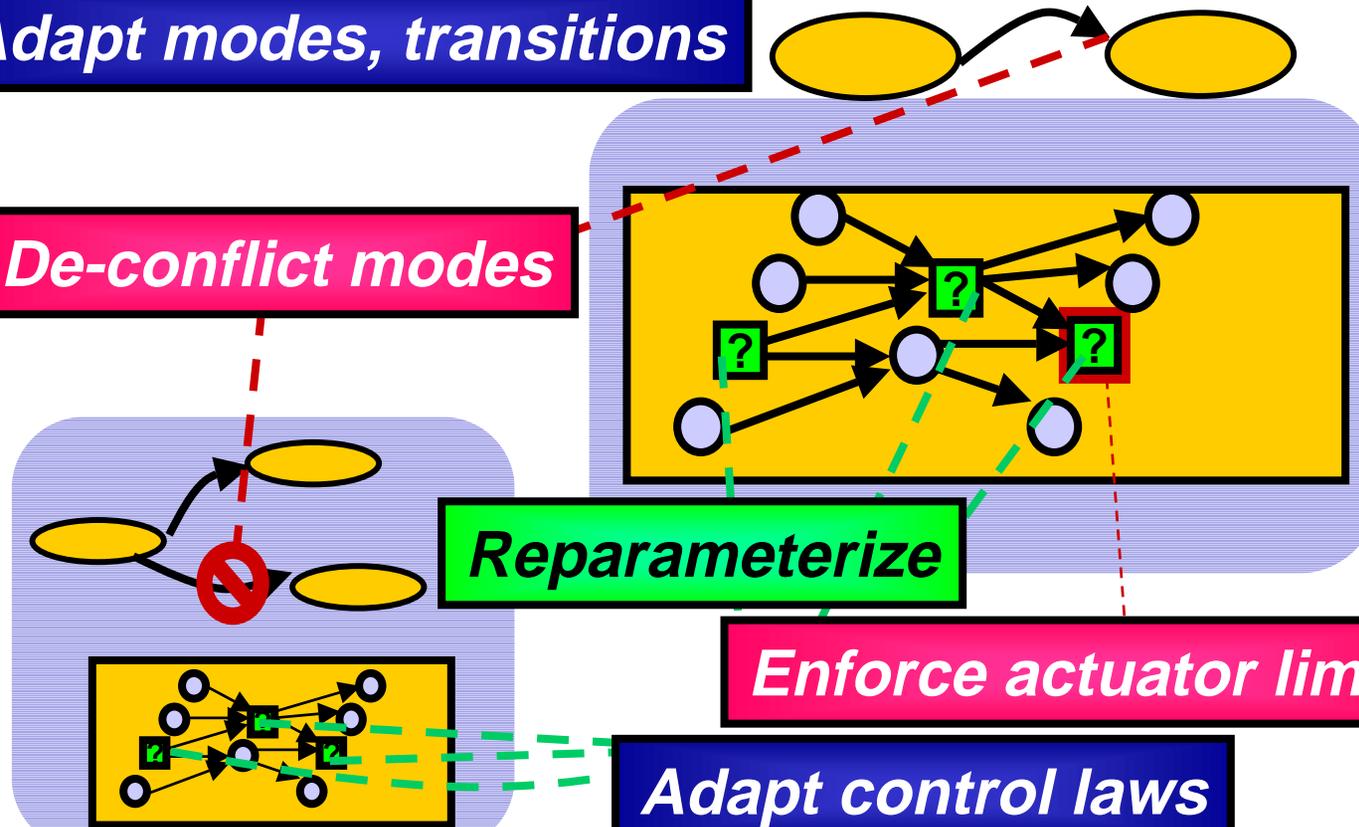
*Adapt modes, transitions*

*De-conflict modes*

*Reparameterize*

*Enforce actuator limits*

*Adapt control laws*



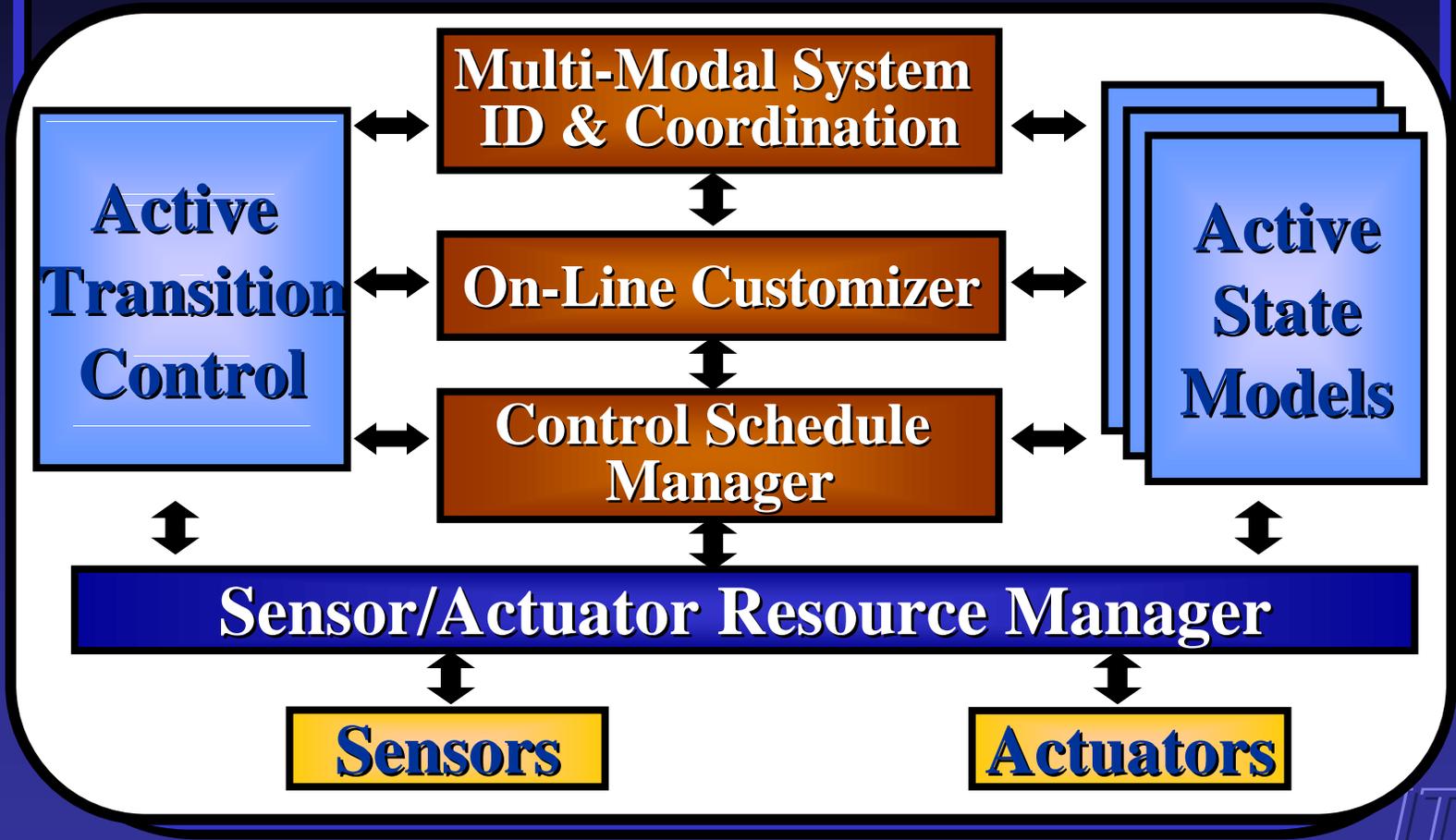


# On-Line Control Customization *Challenges*

- Control re-parameterization and reconfiguration during operation, that:
  - Accommodates dynamically occurring coordination requirements
  - Accommodates environmental disturbances and damage
  - Accommodates sensors and actuators that vary dynamically in effectiveness
  - Preserves stability



# Open Control Platform





# Open Control Platform



- Provide control “middleware” and tool support for building commodity controllers.
- Provide parametric and structural framework to support SEC active-model-based, coordinated, and adaptive multi-modal control technologies.
- Provide flexible experimental platform for SEC control research and demonstration.



# Experiment

## *Cooperative airlift*

**Increase controlled envelope**

*Disturbance*

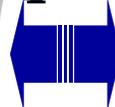


**Increase joint envelope**

*Disturbance*



*Interaction  
Cooperation*





# Demonstration

Goal: Enable high performance autonomous tactical maneuvers for evasion and combat agility.

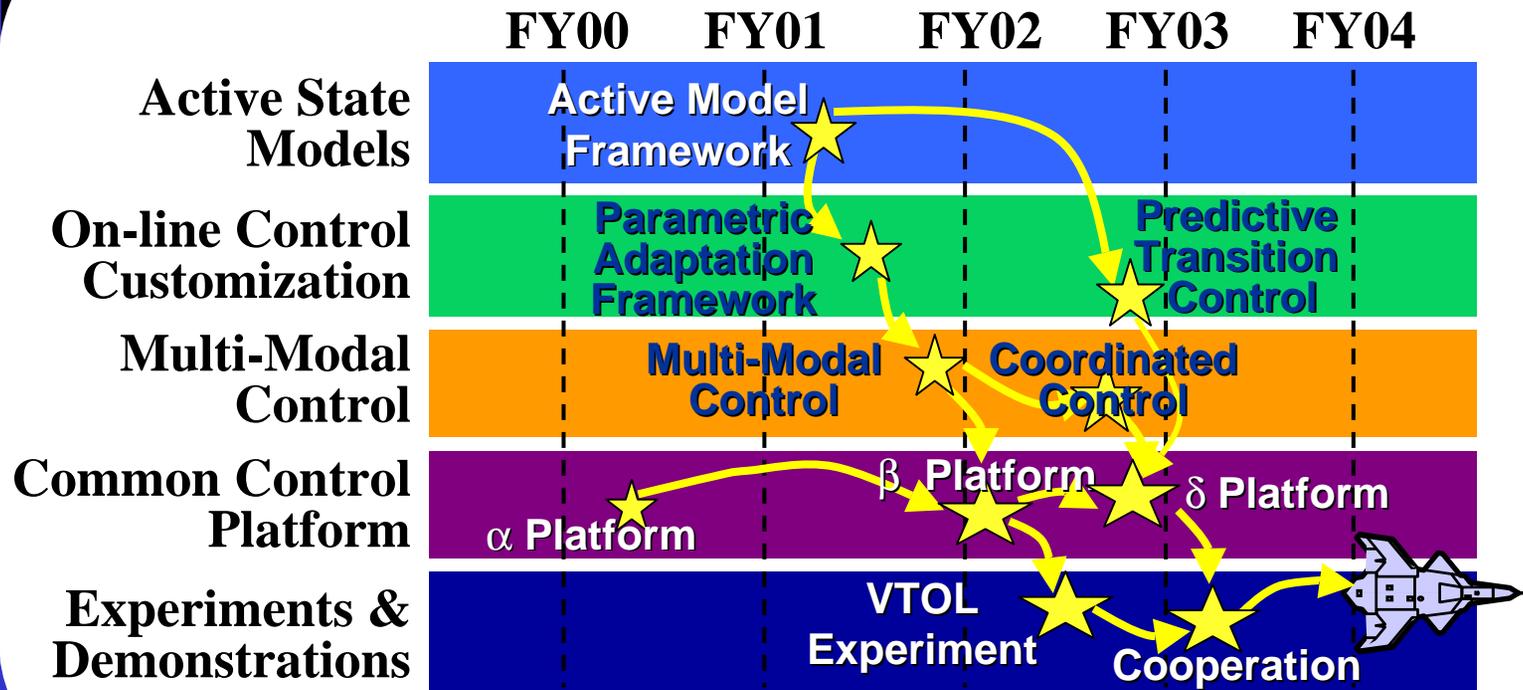


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# Roadmap





# Impact:

- Reinvent Control Systems
- Reusable Control Software
- Open Control Platforms