

# Early Conceptual Design of Future Manned and Unmanned Aerial Vehicles

Elias Johnson

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# Perceived Challenges in Developing Conceptual Architecture

Complexity caused by ambiguity and **lack of information** surrounding system architecture and mission

Complexity caused by **overwhelming amount of information** surrounding system architecture and complex mission applications

Early Concept Development

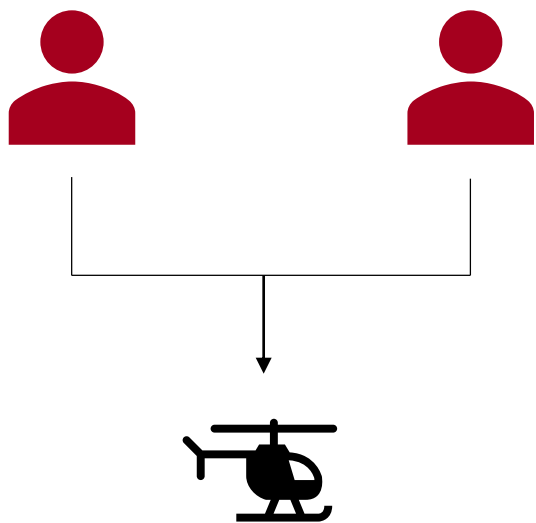
Concept Exploration

Concept of Operations

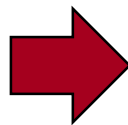
Requirements and Architecture

# Paradigm Shift in Military Aviation - (Evident in U.S. Army Future Vertical Lift Program)

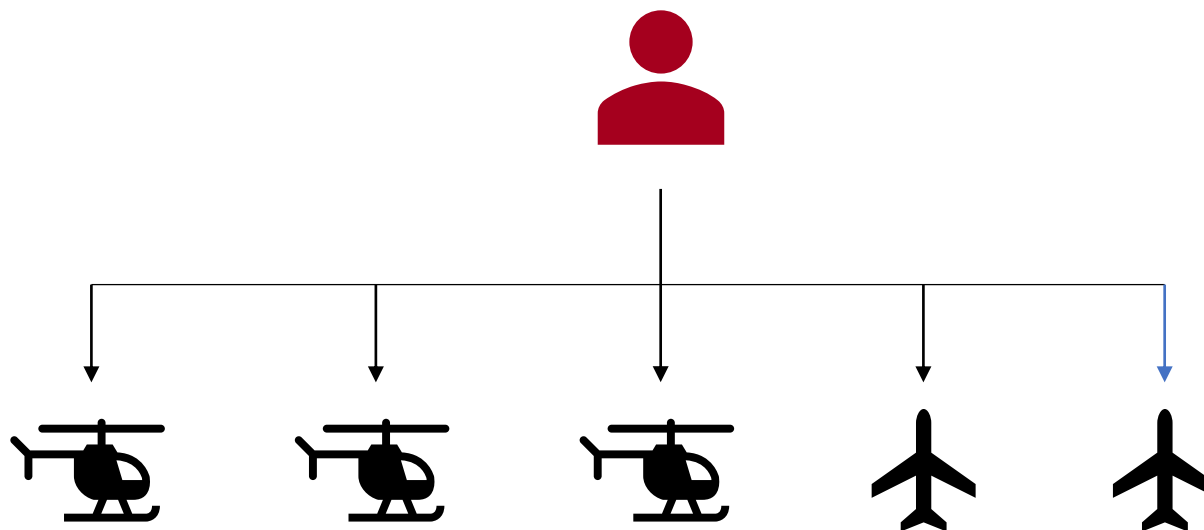
Many, Controlling One



Lower level of aircraft and mission autonomy



One, Controlling Many

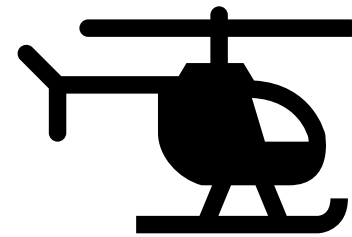


Higher level of aircraft and mission autonomy

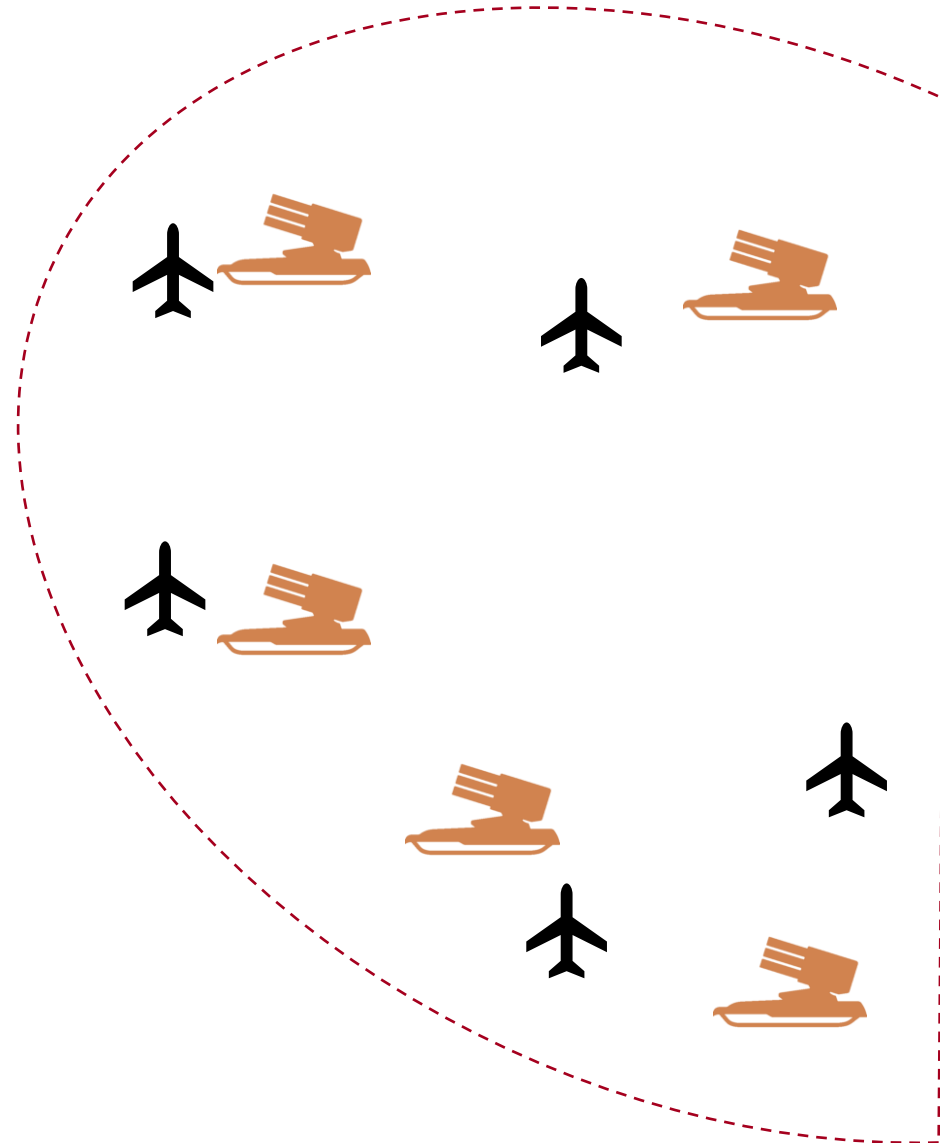
# Case Study – U.S. Army Concept of Operations

## Initial Concept of Operations

A swarm of highly autonomous UAVs deployed in hostile airspace to **detect, locate, identify and destroy enemy anti-aircraft targets** all controlled via supervision by a pilot



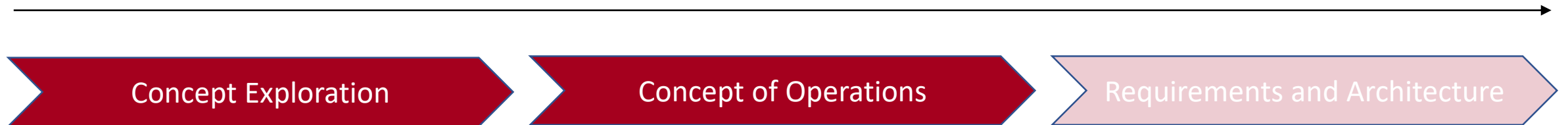
Manned Aircraft



Anti-Aircraft Systems

# Developing Conceptual Architecture given **very little** information

## Early Concept Development



# Sub-Task 1: Identify Elements in Control Structure

*Initial Conceptual Architecture Suggested Steps:*

**Sub-Task 1: Determine Elements from CONOPs**

Sub-Task 2:

Sub-Task 3:

Sub-Task 4:

Sub-Task 5:

## Initial Concept of Operations

A **swarm** of highly **autonomous UAVs** deployed in hostile airspace to detect, locate, identify and destroy enemy anti-aircraft targets all controlled via supervision by a **pilot**

Pilot in Command (PIC)

Pilot Interface

UAV(s)

UAV Decision Making Process

UAV

# Sub-Task 2: Define General Responsibilities for each Element

*Initial Conceptual Architecture Suggested Steps:*

Sub-Task 1: Determine Elements from CONOPs

**Sub-Task 2: Define General Responsibilities for each Element**

Sub-Task 3:

Sub-Task 4:

Sub-Task 5:

## Initial Concept of Operations

A swarm of highly **autonomous UAVs** deployed in hostile airspace to detect, locate, identify and destroy enemy anti-aircraft targets all **controlled via supervision by a pilot**

### Pilot in Command (PIC)

Responsibilities:

R-1: Manage UAV course of action based on mission objectives

### Pilot Interface

Responsibilities:

R-1: Display UAV Course of Action

R-2: Provide mechanism for PIC to provide input

### UAV(s)

#### UAV Decision Making Process

Responsibilities:

R-1: Determine UAV(s) Course of Action

R-2: Send request to Pilot Interface

#### UAV

Responsibilities:

R-1: Execute approved commands

# Sub-Task 3: Add Elements to Address Gaps in Responsibility

*Initial Conceptual Architecture Suggested Steps:*

Sub-Task 1: Determine Elements from CONOPs

Sub-Task 2: Define General Responsibilities for each Element

**Sub-Task 3: Add Elements to Address Gaps in Responsibility**

Sub-Task 4:

Sub-Task 5:

## Initial Concept of Operations

A swarm of highly autonomous UAVs deployed in hostile airspace to detect, locate, identify and destroy enemy anti-aircraft targets all controlled via supervision by a pilot

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### UAV(s)

#### UAV Decision Making Process

Responsibilities:

R-1: Determine UAV(s) Course of Action

R-2: Send request to Pilot Interface

#### UAV

Responsibilities:

R-1: Execute approved commands



# Sub-Task 4: Determine High-Level Control Actions

*Initial Conceptual Architecture Suggested Steps:*

Sub-Task 1: Determine Elements from CONOPs

Sub-Task 2: Define General Responsibilities for each Element

Sub-Task 3: Add Elements to Address Gaps in Responsibility

**Sub-Task 4: Determine High-Level Control Actions**

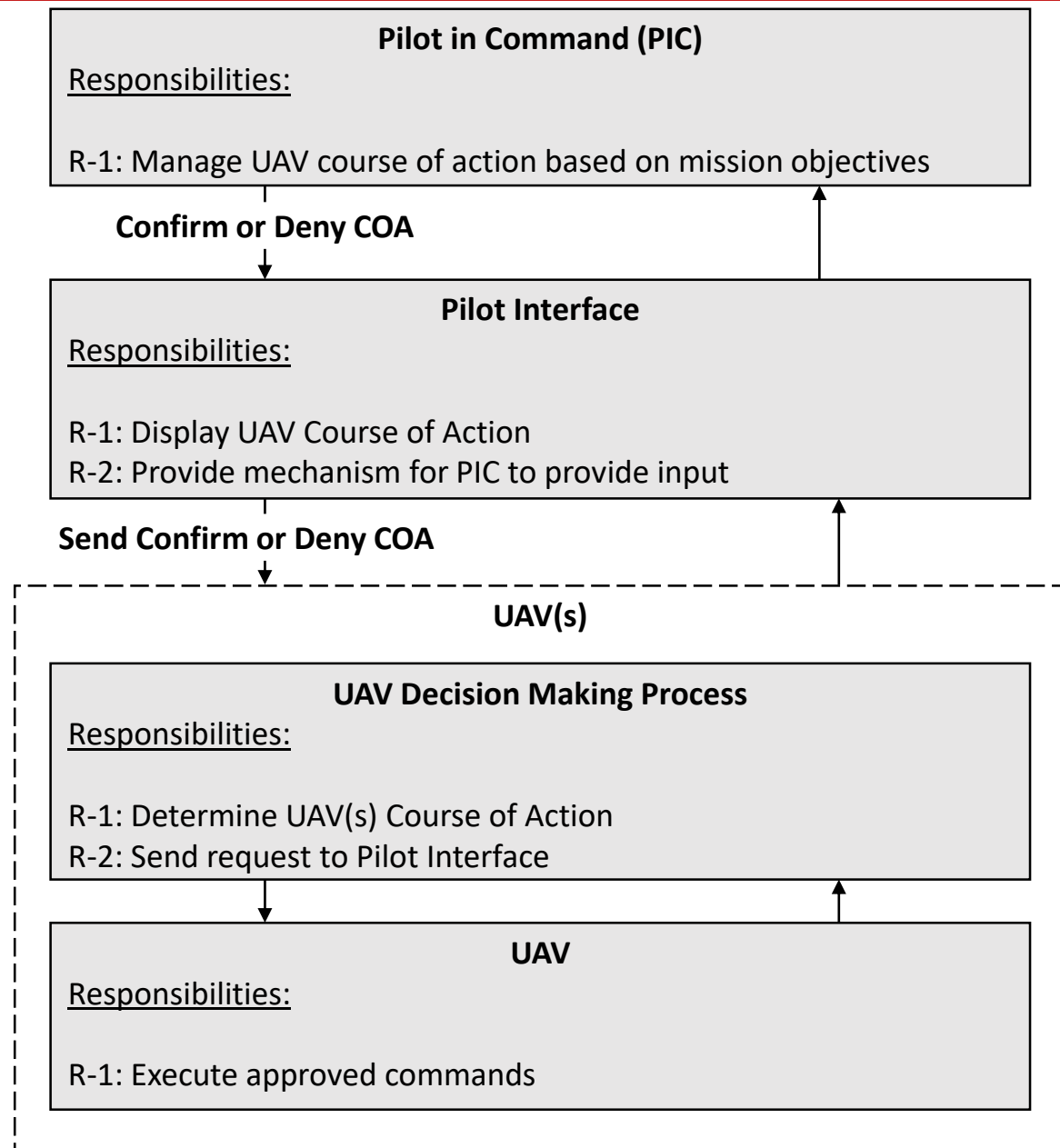
Sub-Task 5:

## Initial Concept of Operations

A swarm of highly autonomous UAVs deployed in hostile airspace to detect, locate, identify and destroy enemy anti-aircraft targets all controlled via **supervision by a pilot.**

## Suggestion

Pick control action(s) that are realistic but not specialized.



## Sub-Task 5: Determine Process Models and Feedback

*Initial* Conceptual Architecture Suggested Steps:

Sub-Task 1: Determine Elements from CONOPs

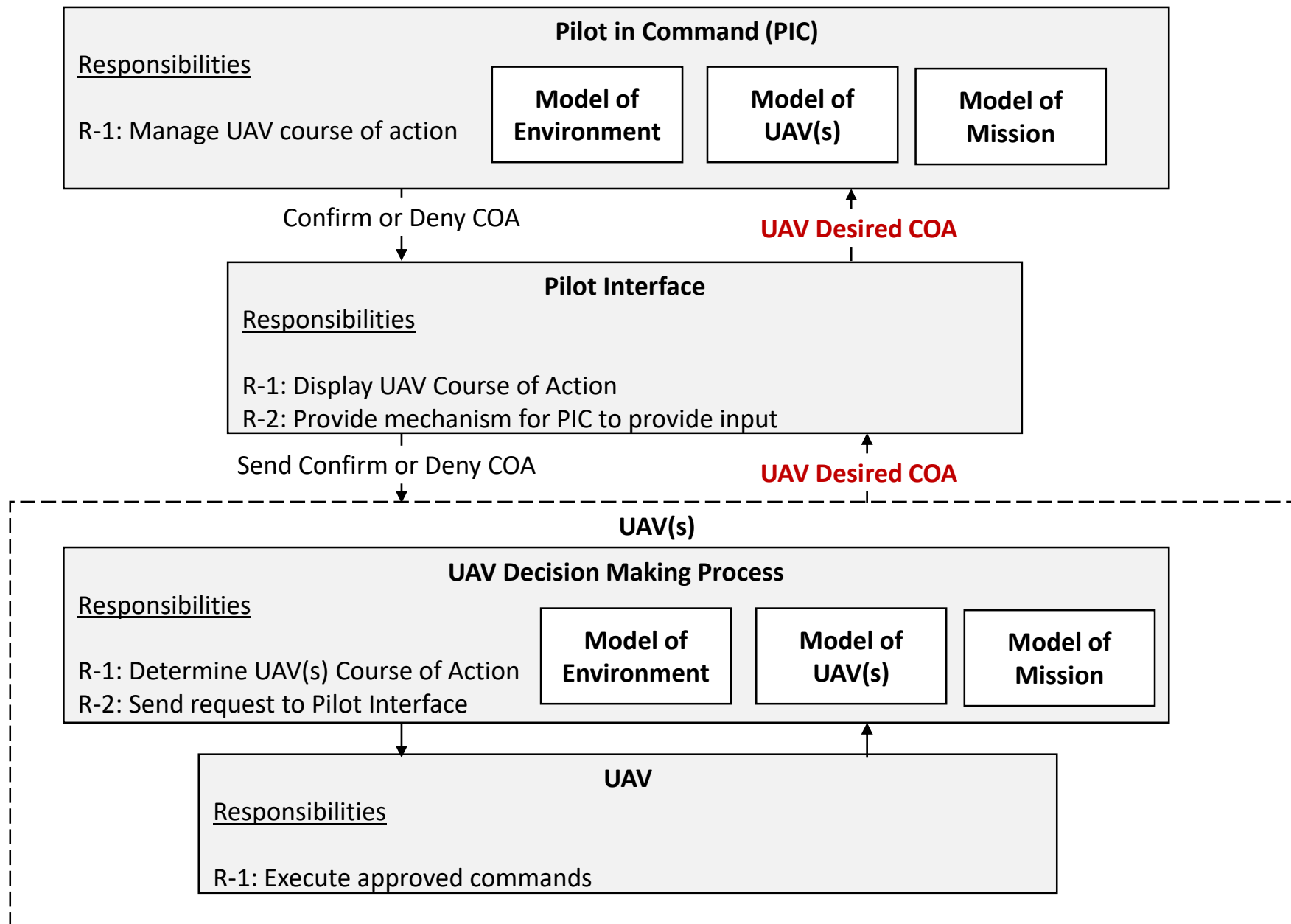
Sub-Task 2: Define General Responsibilities for each Element

Sub-Task 3: Add Elements to Address Gaps in Responsibility

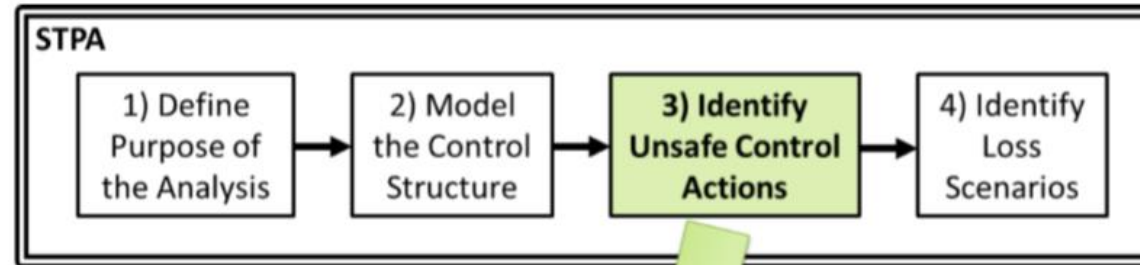
Sub-Task 4: Determine High-Level Control Actions

**Sub-Task 5: Determine Process Models and Feedback**

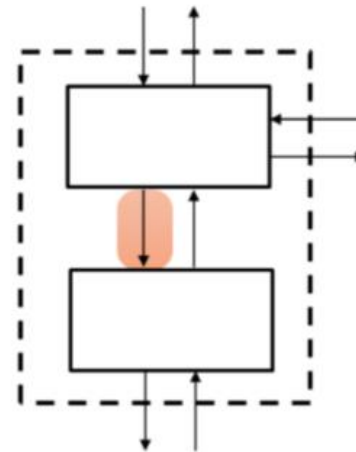
# Sub-Task 5: Determine Required Process Models and Feedback



# Ready for Step 3 of STPA



## 3) Identify Unsafe Control Actions



## Example Scenarios with *Initial* Conceptual Architecture

[UCA-1] : The Pilot in Command (PIC) provides “Confirms Action” **too late** for a time sensitive task and if/when the task is approved it is no longer consistent with the mission objectives [H1, H2, H6].



[UCA-1, Scenario 1] : The Pilot in Command (PIC) may provide a “Confirm Action” too late because they were **unaware the task was time sensitive**. This could occur if:

[UCA-1, Scenario 1-1] - **No tasks were ever identified as time sensitive**. So, the subsequent design and pilot training never equipped pilots to handle time sensitive tasks.

[UCA-1, Scenario 1-2] - A task that was not originally time sensitive when requested by the UAV **becomes time sensitive** because of changes in the environment (e.g., movement of target) or objective of the mission (e.g., change in target)

# Example Questions and Requirements Generated from Scenarios

## Example Questions

[UCA-1, Scenario 1-1, Q-1] What are the time sensitive tasks throughout the mission?

[UCA-1, Scenario 1-2, Q-1] What tasks could start off as non-time sensitive but become time sensitive? Why?

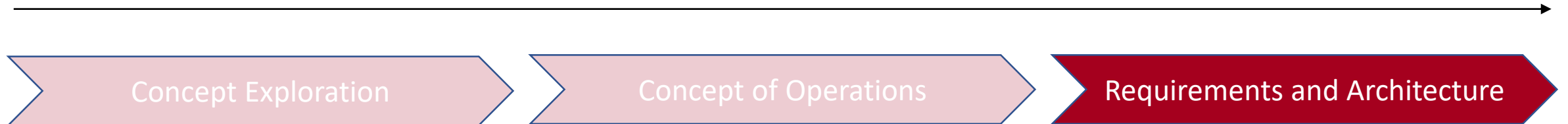
## Example Requirements

[UCA-1, Scenario 1-2, Requirement-1] If there is TBD time gap between the UAV requests and the PIC input, there must be a procedure to ensure that the task is still relevant to the mission.

[UCA-1, Scenario 1-2, Requirement-2] The UAV automation must have a means to update or delete requests if the UAV determines the action is no longer consistent with the mission objectives.

# Developing Conceptual Architecture given an *overwhelming amount* of information

## Early Concept Development



# Sub-Task 1: Determine Elements from Previous Analysis

*Initial Conceptual Architecture Suggested Steps:*

## **Sub-Task 1: Determine Elements (Previous Analysis)**

Sub-Task 2:

Sub-Task 3:

Sub-Task 4:

Sub-Task 5:

Sub-Task 6:

**Pilot in Command (PIC)**

**Pilot Interface**

**UAV(s)**

**UAV Decision Making Process**

**UAV**



## Sub-Task 2: Identify Processes and Functions to Control

*Initial Conceptual Architecture Suggested Steps:*

Sub-Task 1: Determine Elements from Previous Analysis

**Sub-Task 2: Identify Processes and Functions to Control**

Sub-Task 3:

Sub-Task 4:

Sub-Task 5:

Sub-Task 6:

**Concept of Operations**



### List of Controlled Processes and Functions

Resource Allocation  
Mission Risk Tolerance  
Equipment load up  
UAV Maintenance  
Mission Start / End Criteria  
Mission Update Process  
Criteria for Switching Tasks  
UAV Launch  
UAV Flight Controls  
UAV Navigation  
UAV Payload Configuration  
Pilot Control Permissions  
Level of Automation  
UAV Search  
UAV Target Identification  
UAV Target Geo-location  
Weapons Engagement  
Level of Automation  
**UAV Target Prioritization**

# Sub-Task 3: Assign Control Responsibilities from List

*Initial* Conceptual Architecture Suggested Steps:

Sub-Task 1: Determine Elements from Previous Analysis

Sub-Task 2: Identify Processes and Functions to Control

**Sub-Task 3: Assign Control Responsibilities from List**

Sub-Task 4:

Sub-Task 5:

Sub-Task 6:

*Example: UAV Target Prioritization*

## Pilot in Command (PIC)

Responsibilities:

**R-1:** Updates target prioritization to address opportunity and/or mission objective.

## Pilot Interface

Responsibilities:

**R-1:** Displays target prioritization to PIC

**R-2:** Provides mechanism for PIC to change the target prioritization

## UAV(s)

### UAV(s) Decision Making Process

Responsibilities:

**R-1:** Uses prioritization to inform engagement decisions

## UAV(s)

Responsibilities:

**R-1:** Execute commands

# Sub-Task 4: Add Elements Based on Gaps in Responsibility

*Initial* Conceptual Architecture Suggested Steps:

Sub-Task 1: Determine Elements from Previous Analysis

Sub-Task 2: Identify Processes and Functions to Control

Sub-Task 3: Assign Control Responsibilities from List

**Sub-Task 4: Add Elements Based on Gaps in Responsibility**

Sub-Task 5:

Sub-Task 6:

Missing responsibility to  
**Determine Initial Target  
Priorities**

Missing responsibility to **Load  
UAV with Initial Target  
Priorities**

## Pilot in Command (PIC)

Responsibilities:

**R-1:** Updates target prioritization to address opportunity and/or mission objective.

## Pilot Interface

Responsibilities:

**R-1:** Displays target prioritization to PIC

**R-2:** Provides mechanism for PIC to change the target prioritization

## UAV(s)

### UAV(s) Decision Making Process

Responsibilities:

**R-1:** Uses prioritization to inform engagement decisions

## UAV(s)

Responsibilities:

**R-1:** Execute commands

## Sub-Task 4: Add Elements Based on Gaps in Responsibility

*Initial* Conceptual Architecture Suggested Steps:

Sub-Task 1: Determine Elements from Previous Analysis

Sub-Task 2: Identify Processes and Functions to Control

Sub-Task 3: Assign Control Responsibilities from List

**Sub-Task 4: Add Elements Based on Gaps in Responsibility**

Sub-Task 5:

Sub-Task 6:

Missing responsibility to  
**Determine Initial Target  
Priorities**



**Command Authority**  
Responsibilities  
R-1: Establishes target prioritization for the mission

Missing responsibility to **Load  
UAV with Initial Target  
Priorities**



**Pre-Mission Planner**  
Responsibilities  
R-1: Load UAV with initial target prioritization parameters  
R-2: Ensures PIC is informed of prioritization

## Sub-Task 4: Add Elements Based on Gaps in Responsibility

### Command Authority

Responsibilities:

**R-1:** Establishes target prioritization for the mission

### Pre-Mission Planner

Responsibilities:

**R-1:** Load UAV with target prioritization parameters

**R-2:** Ensures PIC is informed of prioritization

### Pilot in Command (PIC)

Responsibilities:

**R-1:** Updates target prioritization throughout the mission to address changes in opportunity and/or mission objective.

### Pilot Interface

Responsibilities:

**R-1:** Displays target prioritization to PIC

**R-2:** Provides mechanism for PIC to change the target prioritization

### UAV(s) Decision Making Process

Responsibilities:

**R-1:** Uses prioritization to inform engagement decisions.

## Sub-Task 5: Determine Control Actions from Responsibilities

*Initial Conceptual Architecture Suggested Steps:*

Sub-Task 1: Determine Elements from Previous Analysis

Sub-Task 2: Identify Processes and Functions to Control

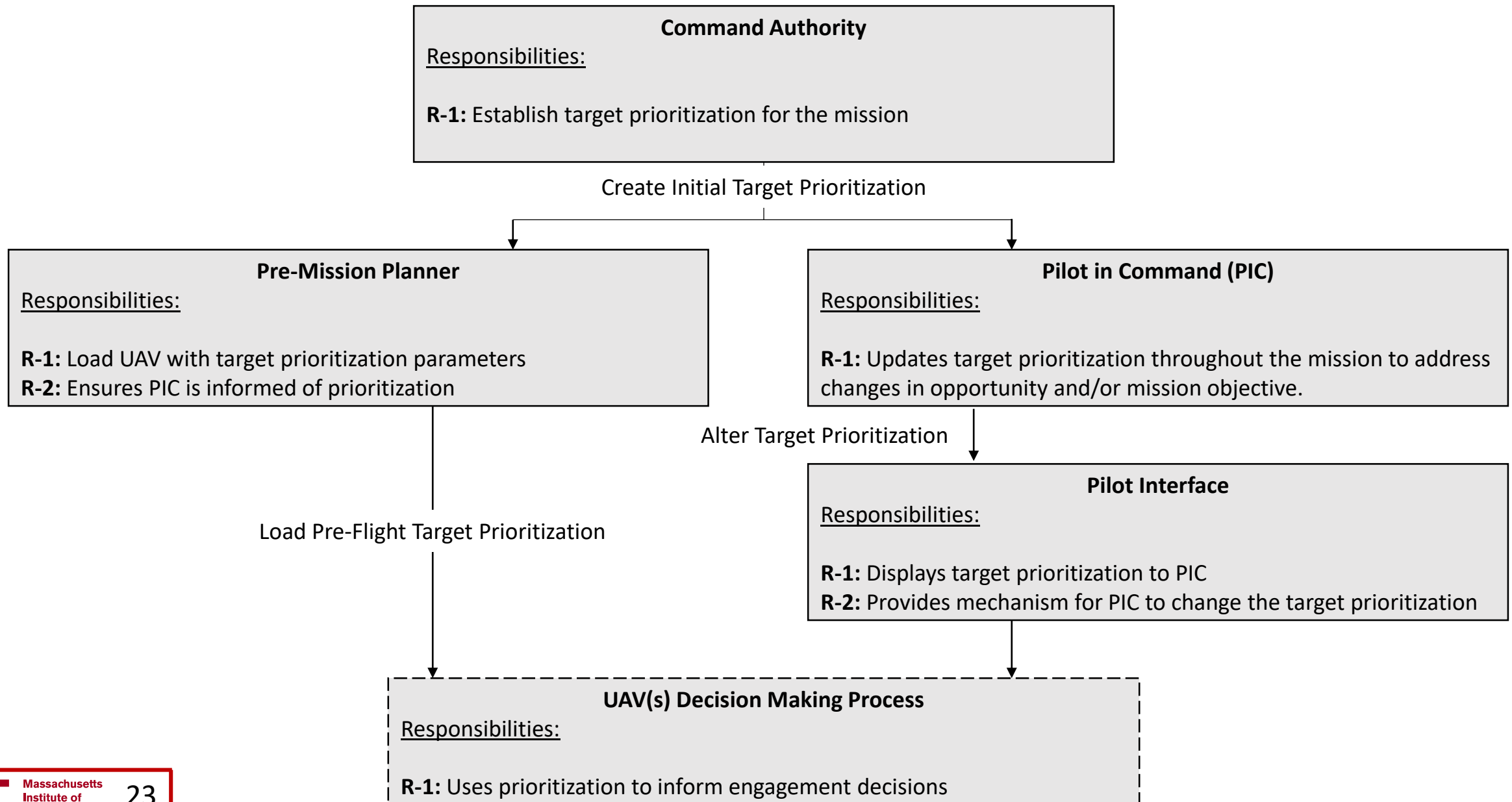
Sub-Task 3: Assign Control Responsibilities from List

Sub-Task 4: Add Elements Based on Gaps in Responsibility

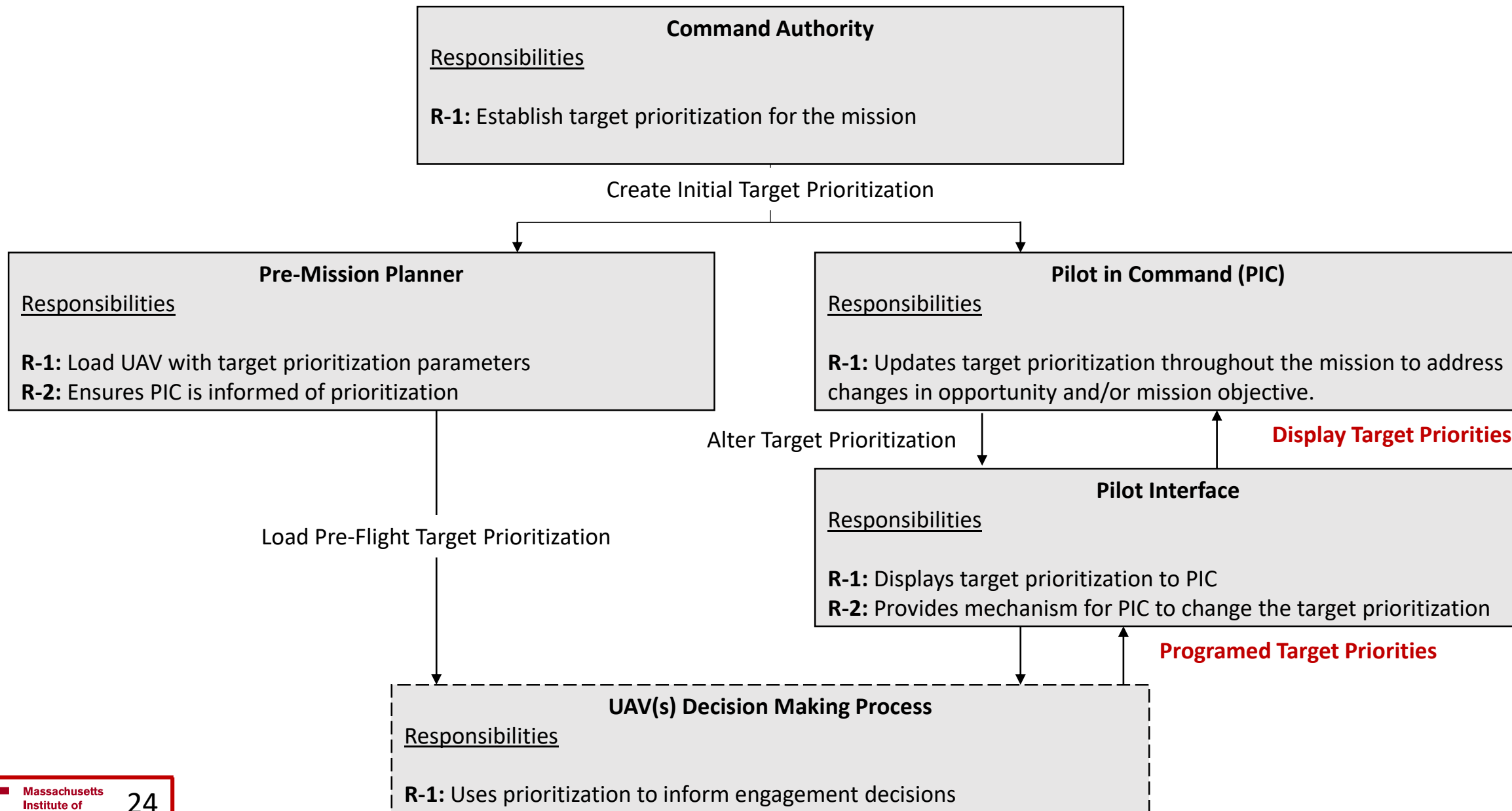
**Sub-Task 5: Determine Control Actions from Responsibilities**

**Sub-Task 6: Determine Process Model and Feedback for List**

# Sub-Task 5: Determine Control Actions from Responsibilities



# Sub-Task 6: Determine Process Model and Feedback for List





## Advantages to Following this Process

Does not require comprehension of detailed Conceptual Architecture (*hundreds* of control actions) at **once**.

Instead, *highlights* a portion of the Conceptual Architecture

Results in detailed Conceptual architecture for each process and function

Possible to combine Conceptual Architectures for each function or process for a detailed model of the system

**END OF PRESENTATION**

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**HAPPY TO ANSWER ANY QUESTIONS**