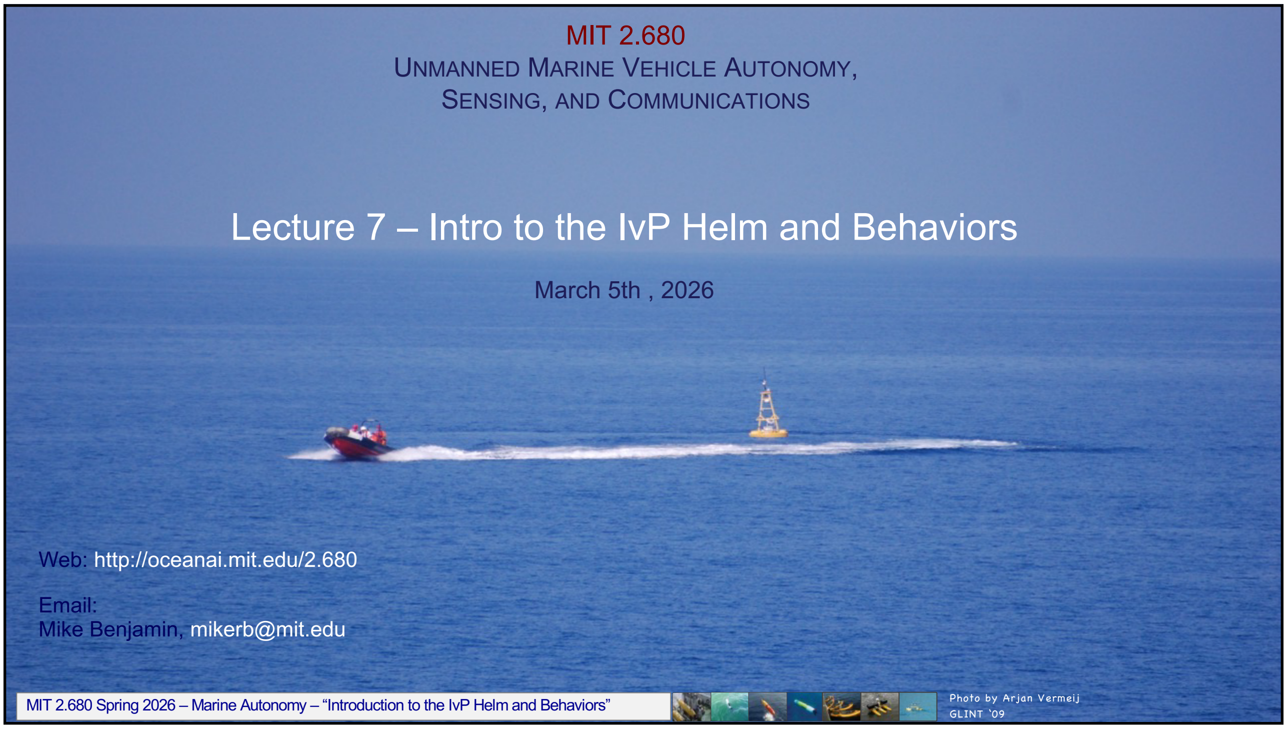

MIT 2.680

UNMANNED MARINE VEHICLE AUTONOMY,
SENSING, AND COMMUNICATIONS

Lecture 7 – Intro to the IvP Helm and Behaviors

March 5th , 2026

Web: http://oceanai.mit.edu/2.680

Email:
Mike Benjamin, mikerb@mit.edu

MIT 2.680 Spring 2026 – Marine Autonomy – "Introduction to the IvP Helm and Behaviors"

Photo by Arjan Vermeij
GLINT '09

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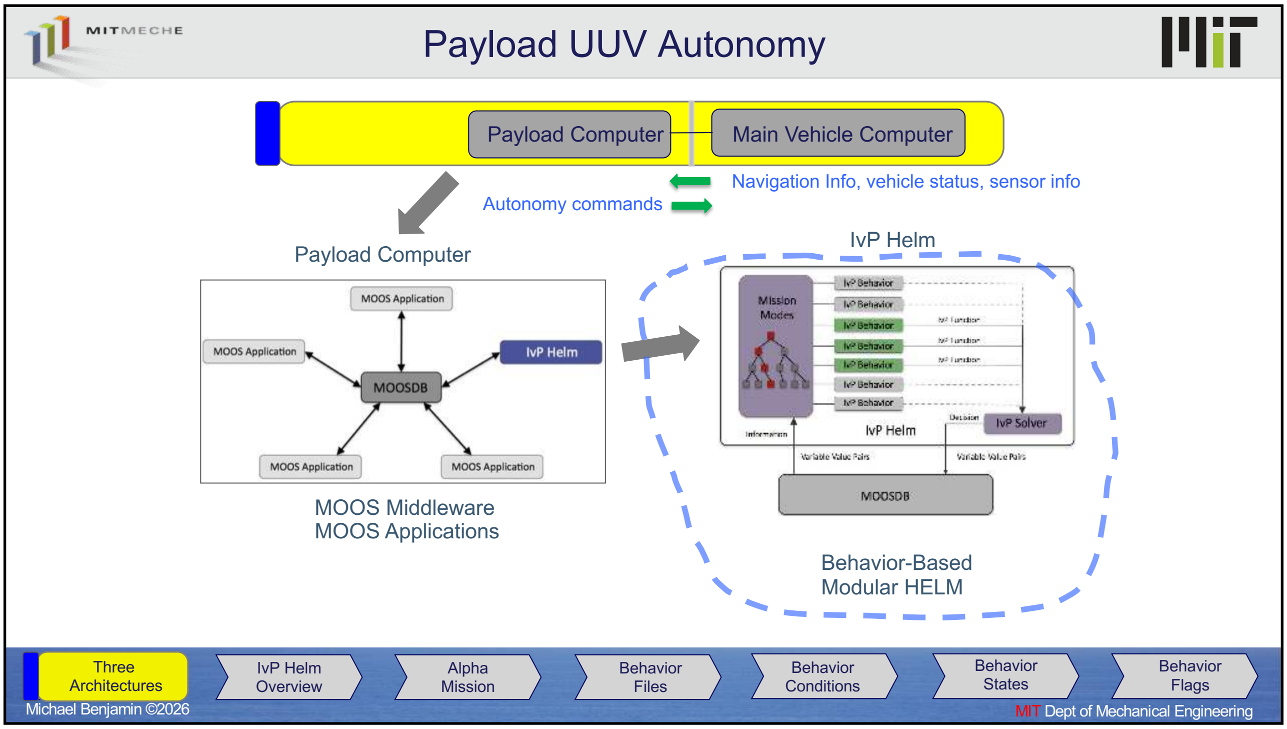

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Payload UUV Autonomy

Payload Computer

Main Vehicle Computer

Navigation Info, vehicle status, sensor info

Autonomy commands

Payload Computer

MOOS Middleware
MOOS Applications

IvP Helm

Behavior-Based
Modular HELM

Three Architectures | IvP Helm Overview | Alpha Mission | Behavior Files | Behavior Conditions | Behavior States | Behavior Flags

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IvP Helm Overview

- Behavior Files
- Behavior Conditions
- Behavior States
- Behavior Flags

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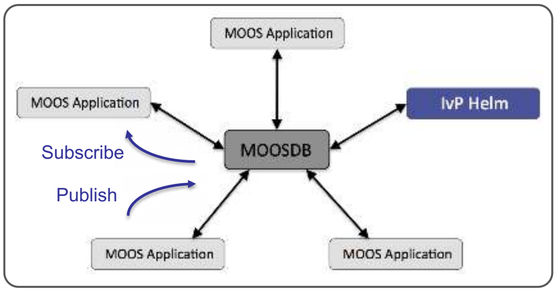
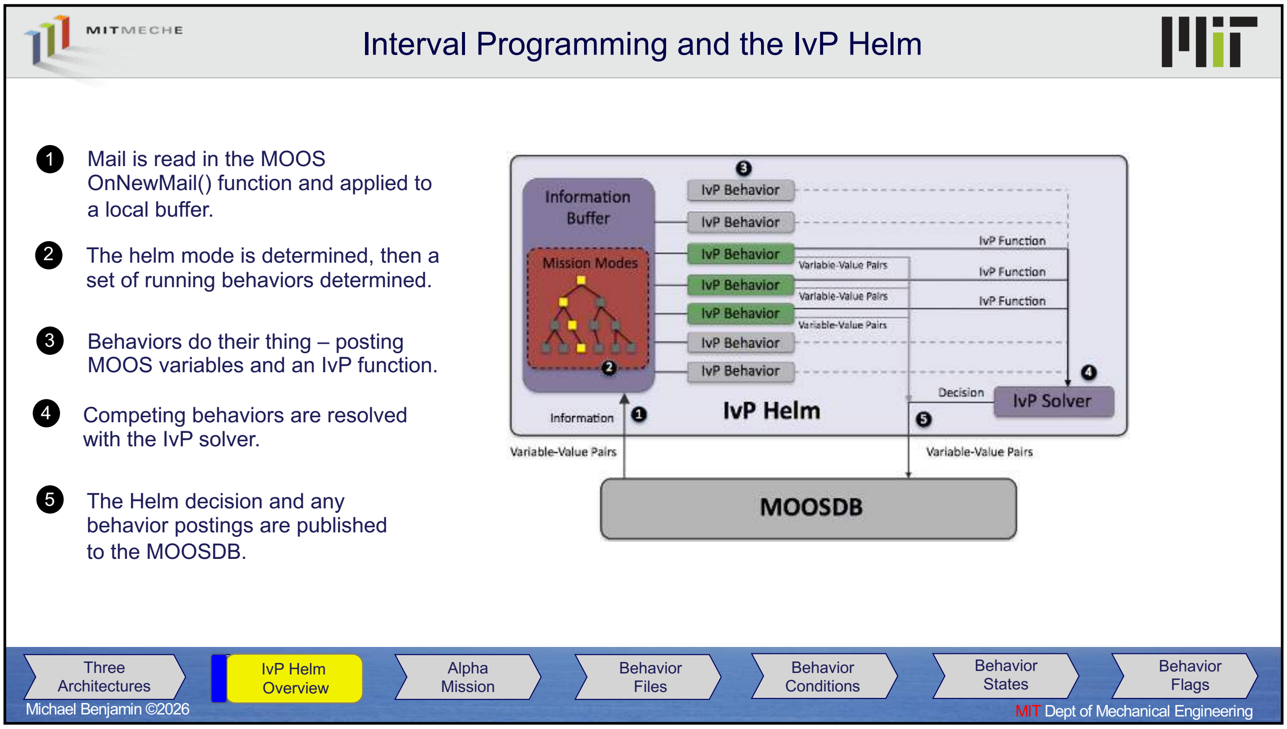
The IvP Helm

- The IvP Helm is a MOOS App, known as pHelmIvP
- The IvP Helm works with other MOOS Apps, performing sensor-processing, planning, communications.



A MOOS Community

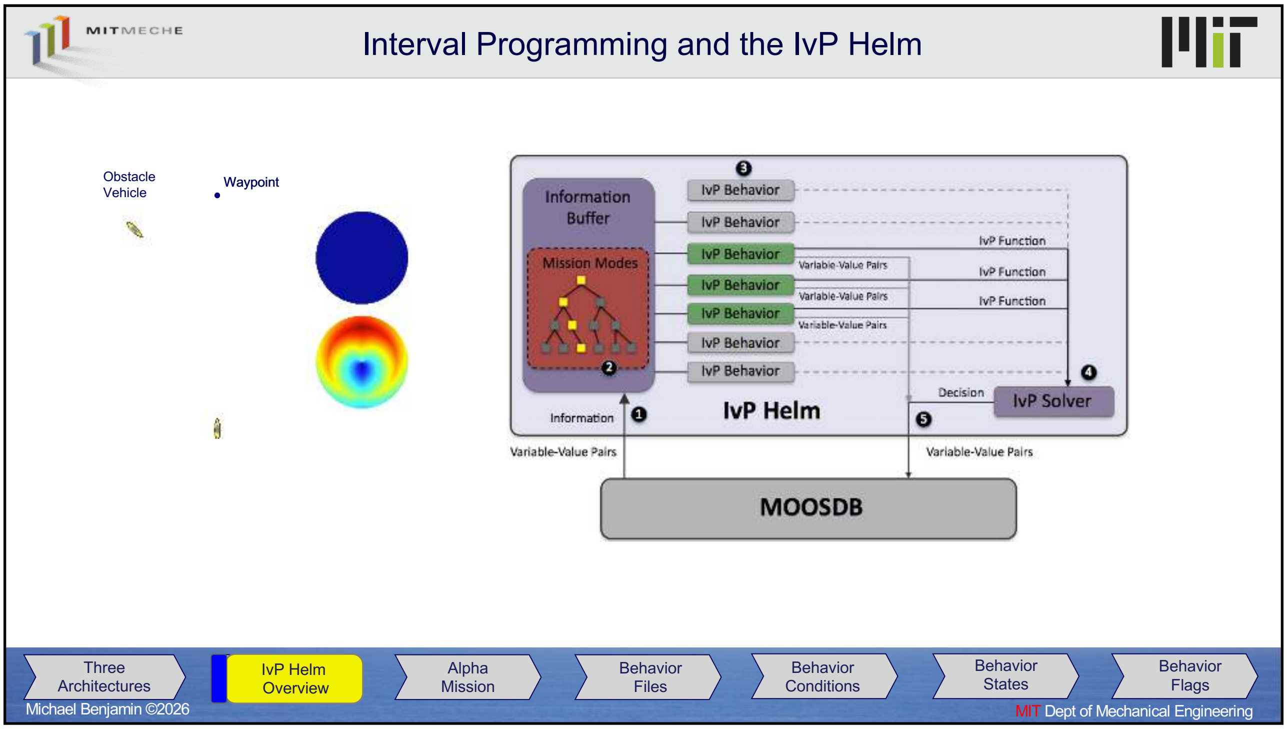
4



Interval Programming and the IvP Helm

1. Mail is read in the MOOS OnNewMail() function and applied to a local buffer.
2. The helm mode is determined, then a set of running behaviors determined.
3. Behaviors do their thing – posting MOOS variables and an IvP function.
4. Competing behaviors are resolved with the IvP solver.
5. The Helm decision and any behavior postings are published to the MOOSDB.

5



Interval Programming and the IvP Helm

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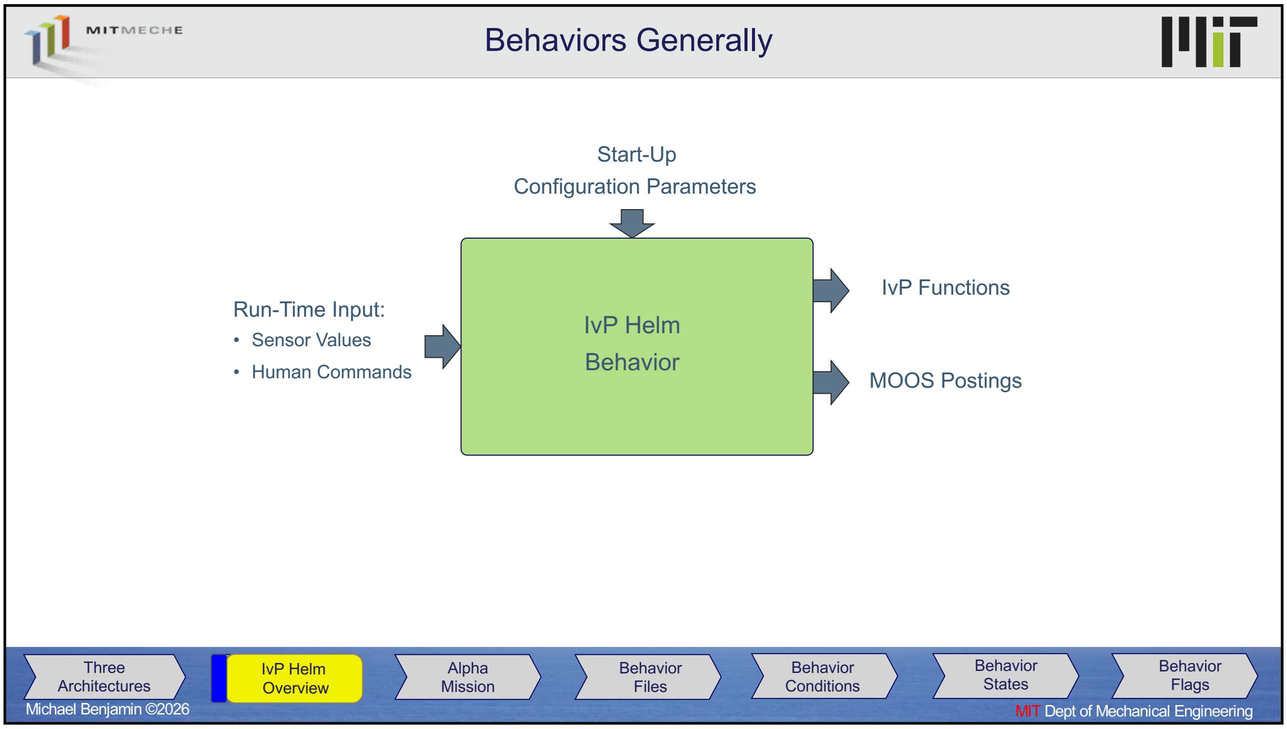

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Behaviors Generally

Start-Up
Configuration Parameters

Run-Time Input:
- Sensor Values
- Human Commands

IvP Helm
Behavior

IvP Functions

MOOS Postings

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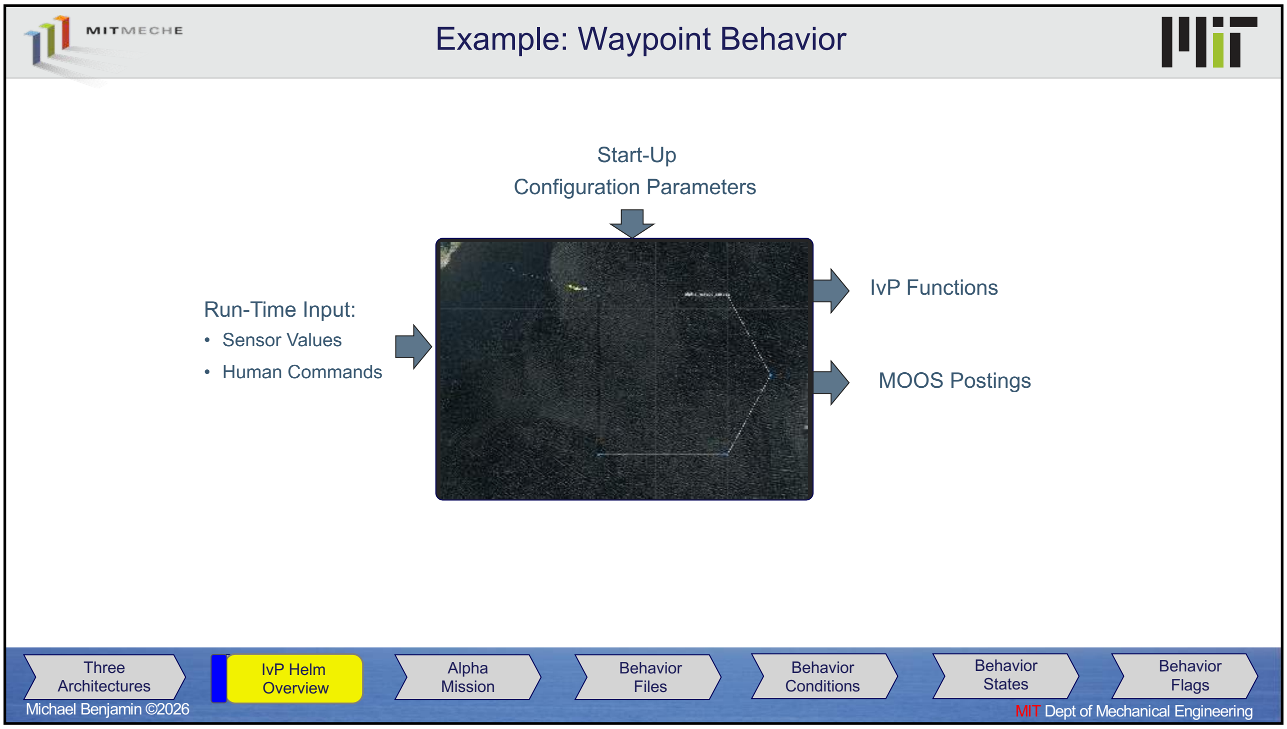

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Example: Waypoint Behavior

Start-Up
Configuration Parameters

Run-Time Input:
- Sensor Values
- Human Commands

IvP Functions

MOOS Postings

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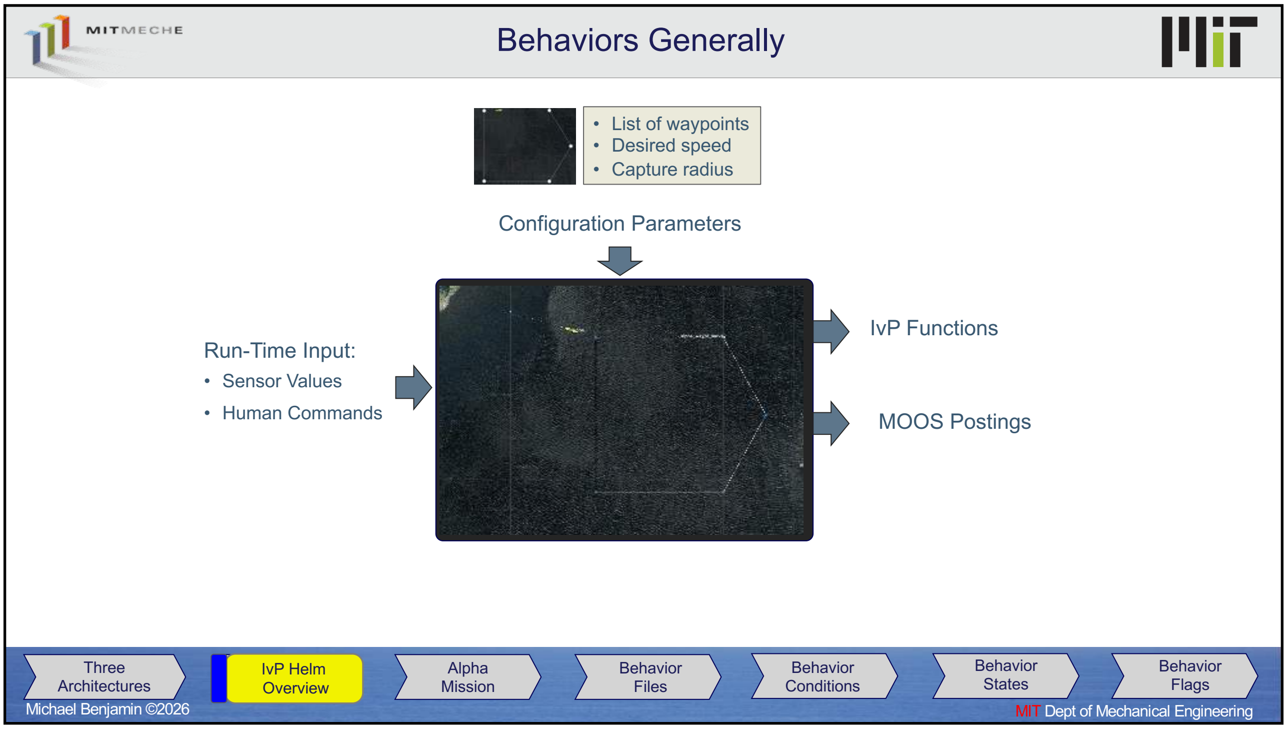

Behaviors Generally

- List of waypoints
- Desired speed
- Capture radius

Configuration Parameters

Run-Time Input:

- Sensor Values
- Human Commands

IvP Functions

MOOS Postings

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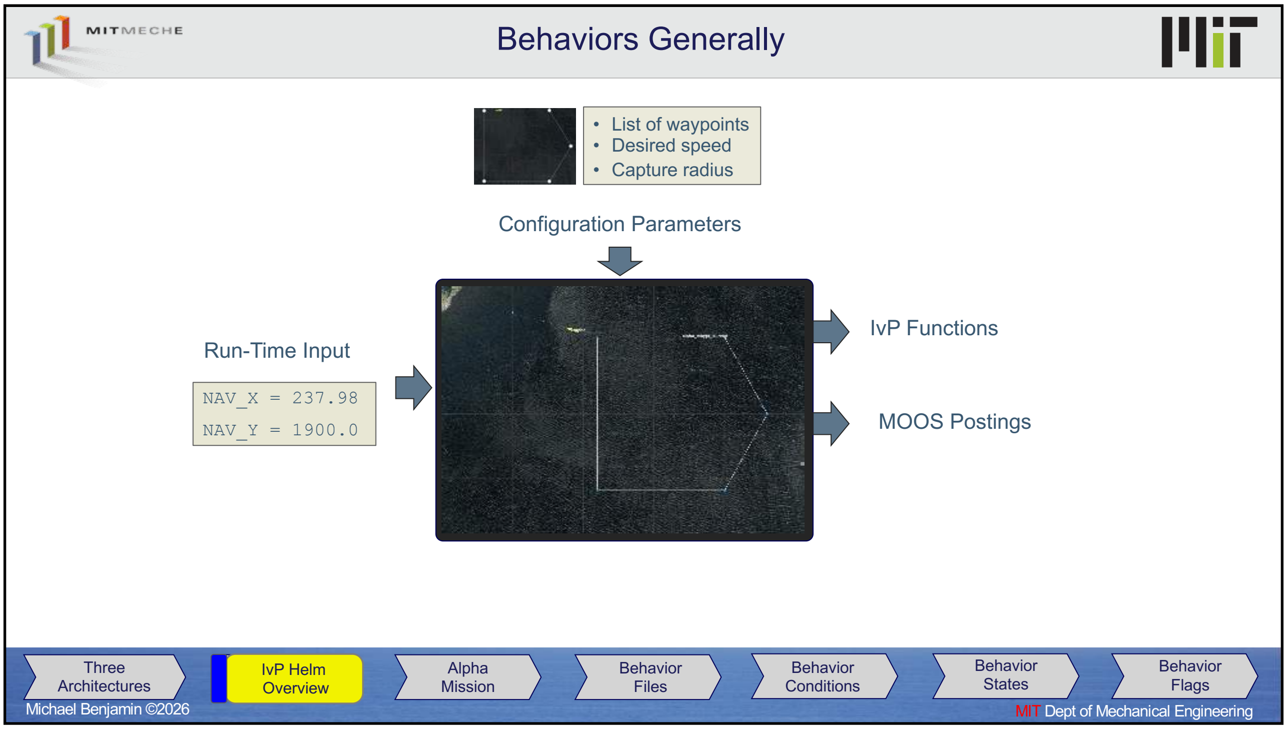

Behaviors Generally

- List of waypoints
- Desired speed
- Capture radius

Configuration Parameters

Run-Time Input

```
NAV_X = 237.98
NAV_Y = 1900.0
```

IvP Functions

MOOS Postings

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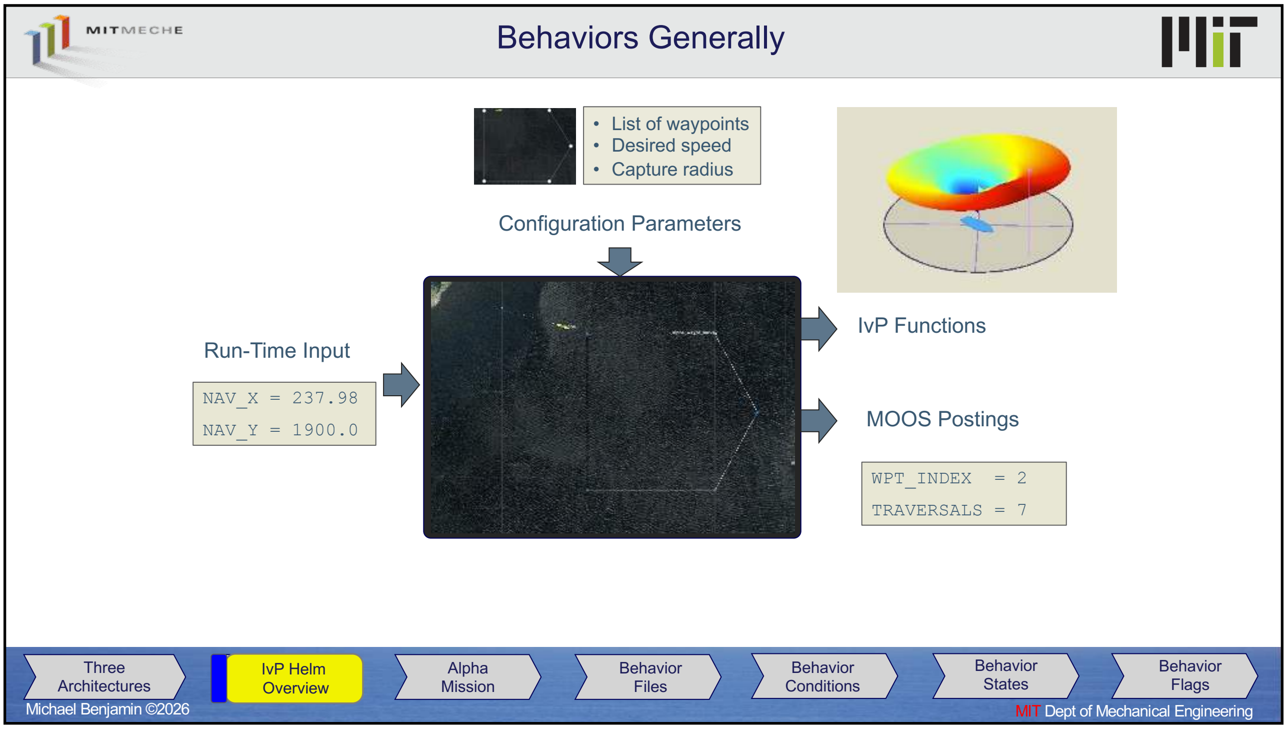

Behaviors Generally

- List of waypoints
- Desired speed
- Capture radius

Configuration Parameters

Run-Time Input

```
NAV_X = 237.98
NAV_Y = 1900.0
```

IvP Functions

MOOS Postings

```
WPT_INDEX  = 2
TRAVERSALS = 7
```

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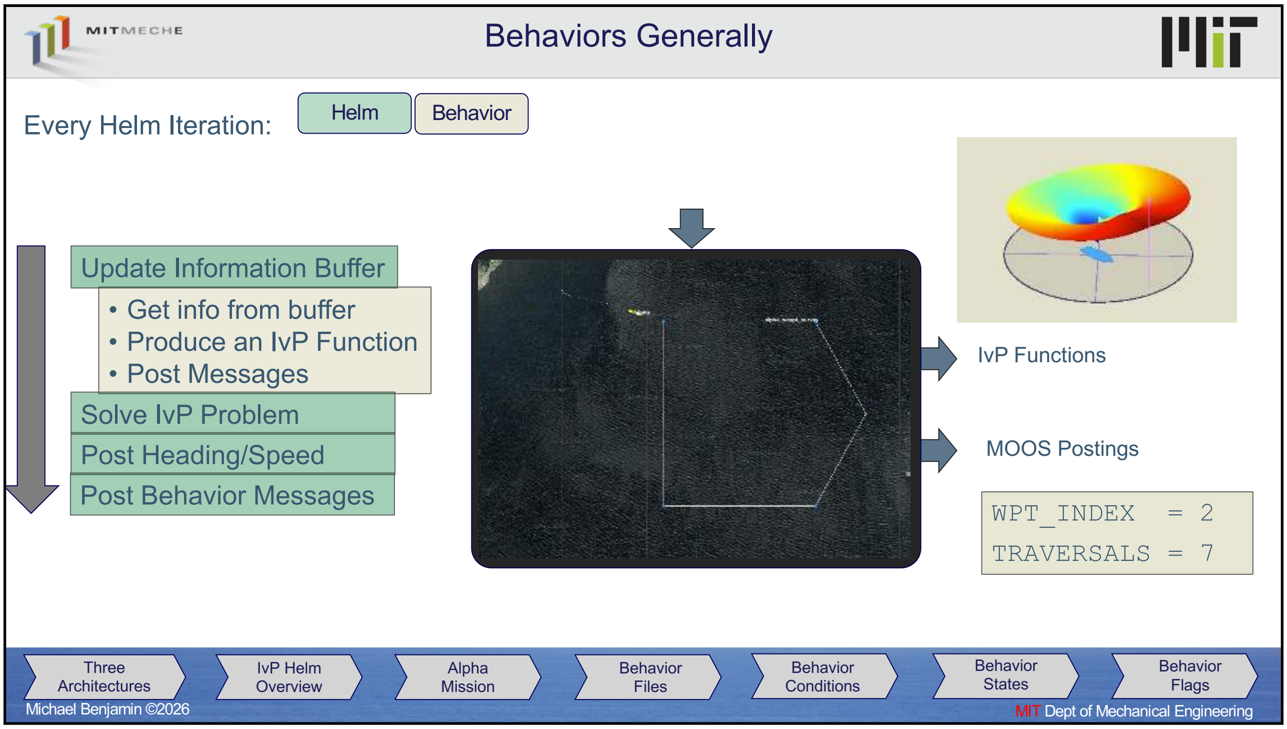

Behaviors Generally

Every Helm Iteration: Helm Behavior

Update Information Buffer

- Get info from buffer
- Produce an IvP Function
- Post Messages

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

IvP Functions

MOOS Postings

```
WPT_INDEX  = 2
TRAVERSALS = 7
```

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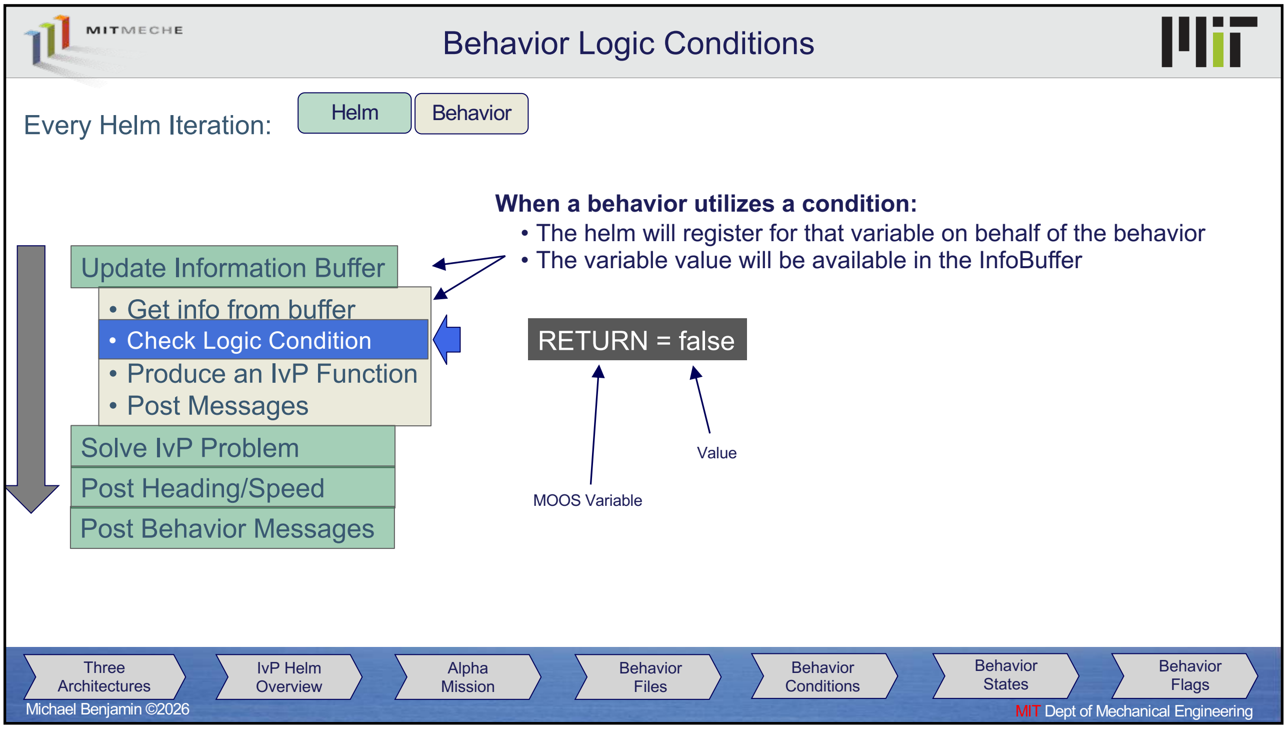

Behavior Logic Conditions

Every Helm Iteration: Helm Behavior

When a behavior utilizes a condition:
- The helm will register for that variable on behalf of the behavior
- The variable value will be available in the InfoBuffer

Update Information Buffer
- Get info from buffer
- Check Logic Condition
- Produce an IvP Function
- Post Messages

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

RETURN = false

MOOS Variable

Value

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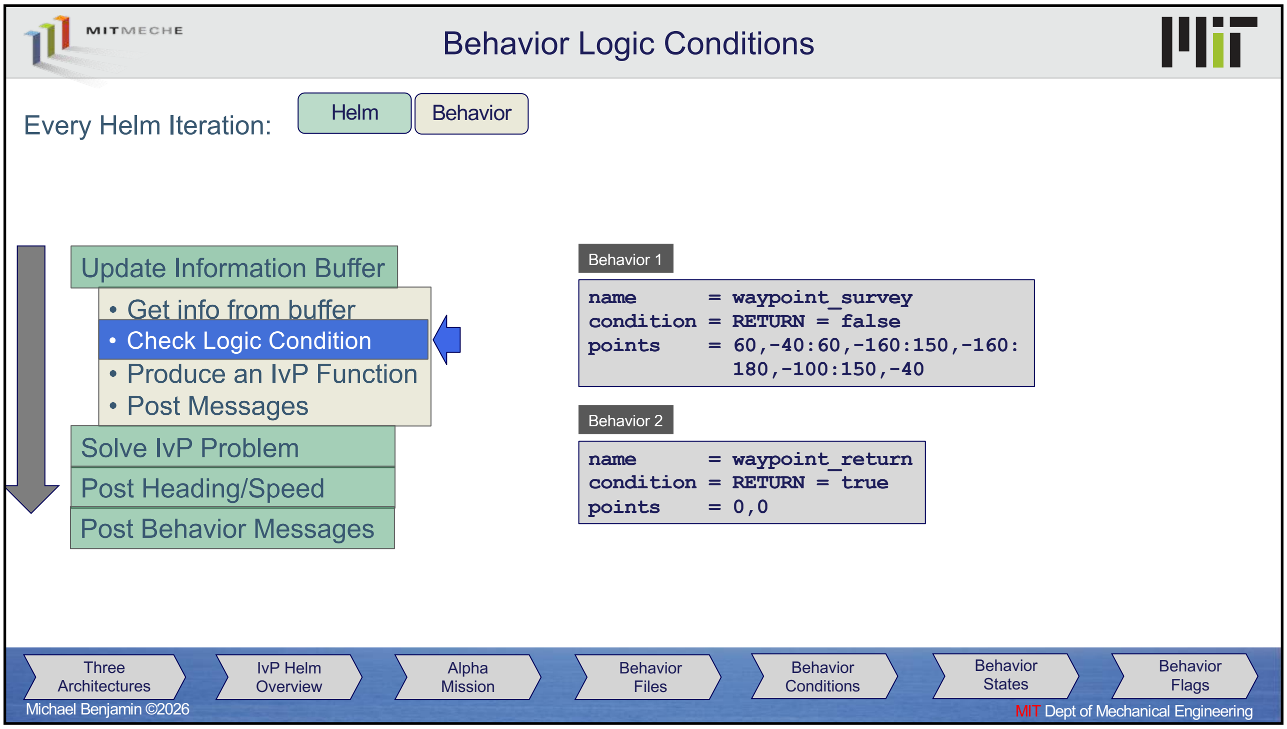

Behavior Logic Conditions

Every Helm Iteration: Helm Behavior

Update Information Buffer
- Get info from buffer
- Check Logic Condition
- Produce an IvP Function
- Post Messages

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

Behavior 1

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
```

Behavior 2

```
name      = waypoint_return
condition = RETURN = true
points    = 0,0
```

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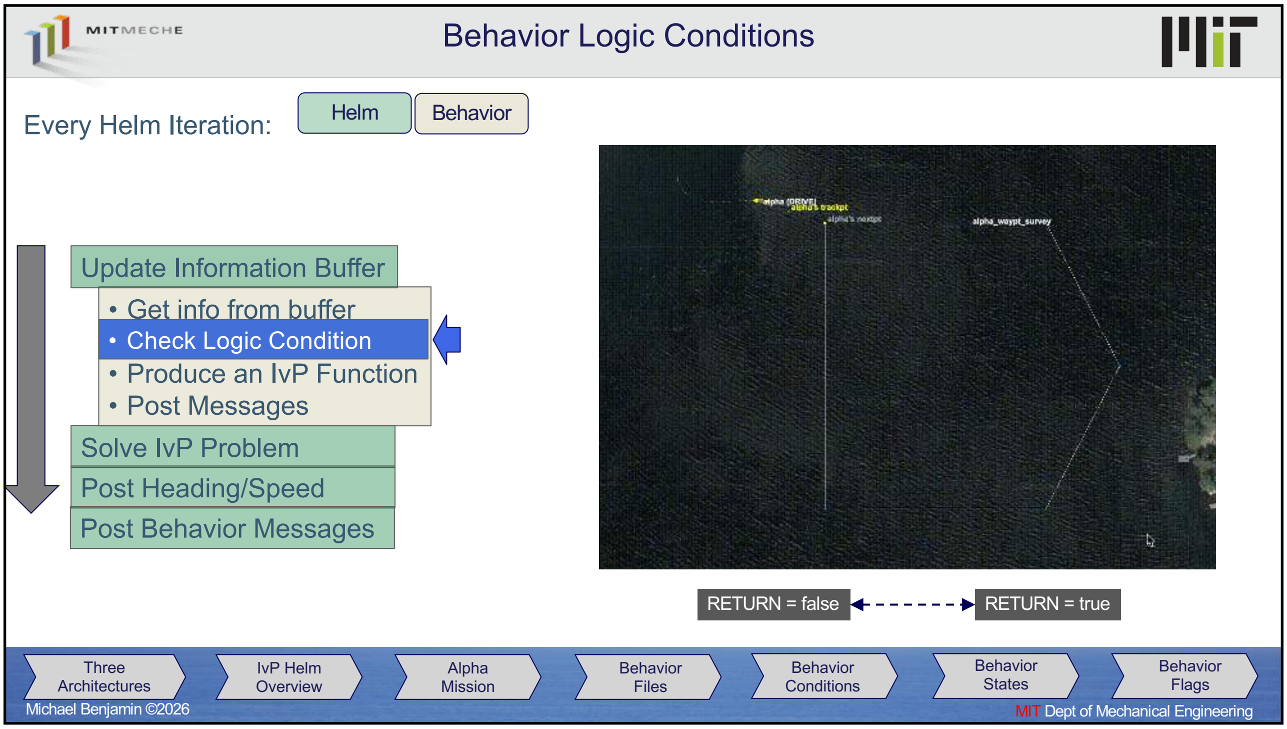

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Behavior Logic Conditions

Every Helm Iteration: Helm Behavior

- Update Information Buffer
  - Get info from buffer
  - Check Logic Condition
  - Produce an IvP Function
  - Post Messages
- Solve IvP Problem
- Post Heading/Speed
- Post Behavior Messages

RETURN = false ◄- - - - - - ► RETURN = true

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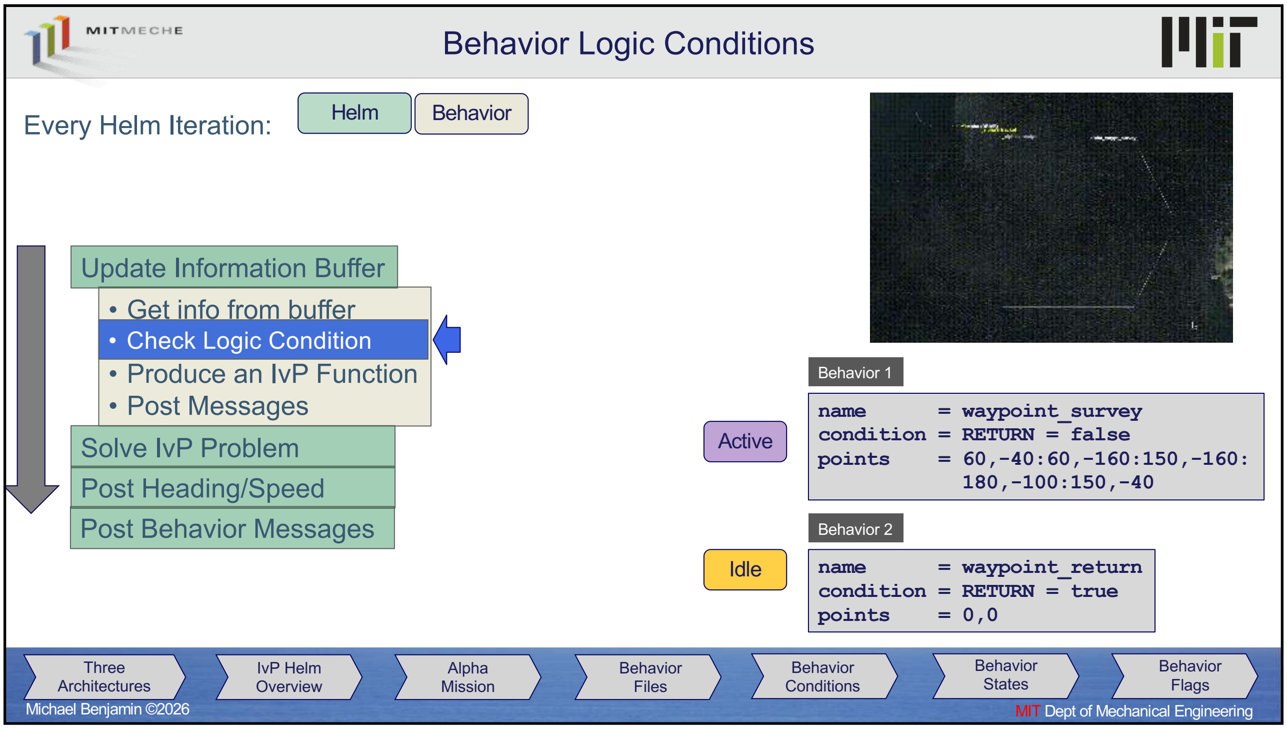

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Behavior Logic Conditions

Every Helm Iteration: Helm Behavior

- Update Information Buffer
  - Get info from buffer
  - Check Logic Condition
  - Produce an IvP Function
  - Post Messages
- Solve IvP Problem
- Post Heading/Speed
- Post Behavior Messages

Behavior 1

Active

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
```

Behavior 2

Idle

```
name      = waypoint_return
condition = RETURN = true
points    = 0,0
```

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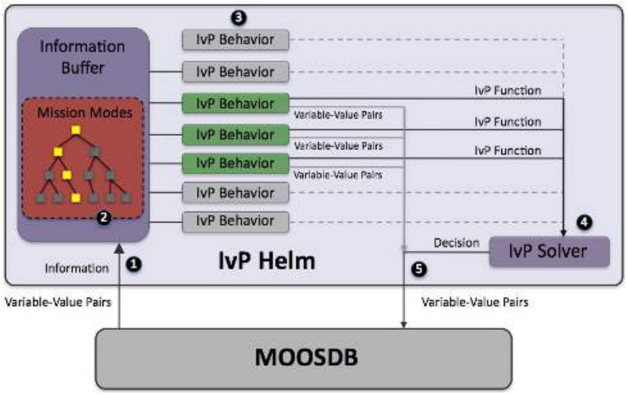
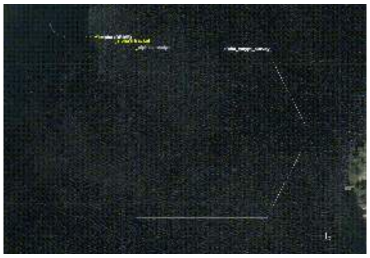
Behavior Logic Conditions





Behavior 1

Active

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
```

Behavior 2

Idle

```
name      = waypoint_return
condition = RETURN = true
points    = 0,0
```

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Behavior Logic Conditions

Every Helm Iteration: Helm Behavior

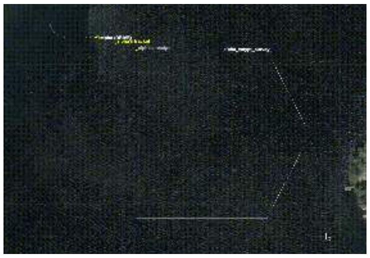
Update Information Buffer

- Get info from buffer
- Check Logic Condition
- Produce an IvP Function
- Post Messages

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages



Behavior 1

Active

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
```

Behavior 2

Idle

```
name      = waypoint_return
condition = RETURN = true
points    = 0,0
```

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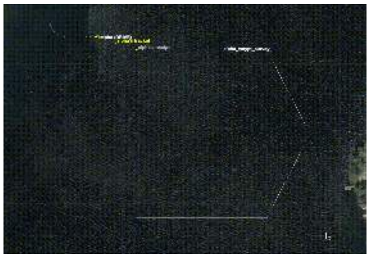
Behavior Logic Conditions

Every Helm Iteration: Helm | Behavior

- Update Information Buffer
  - Get info from buffer
  - Check Logic Condition
  - Produce an IvP Function
  - Post Messages
- Solve IvP Problem
- Post Heading/Speed
- Post Behavior Messages

RETURN	
true	false
Idle	Active
Active	Idle



Behavior 1

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name      = waypoint_survey
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points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
```

Behavior 2

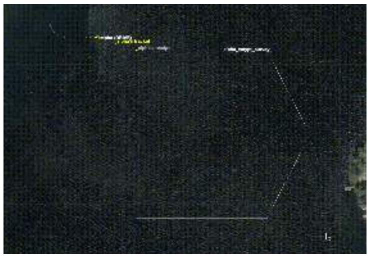
```
name      = waypoint_return
condition = RETURN = true
points    = 0,0
```

Behavior Logic Conditions

Every Helm Iteration: Helm | Behavior

- Update Information Buffer
  - Get info from buffer
  - Check Logic Condition
  - Produce an IvP Function
  - Post Messages
- Solve IvP Problem
- Post Heading/Speed
- Post Behavior Messages

MODE	
returning	surveying
Idle	Active
Active	Idle

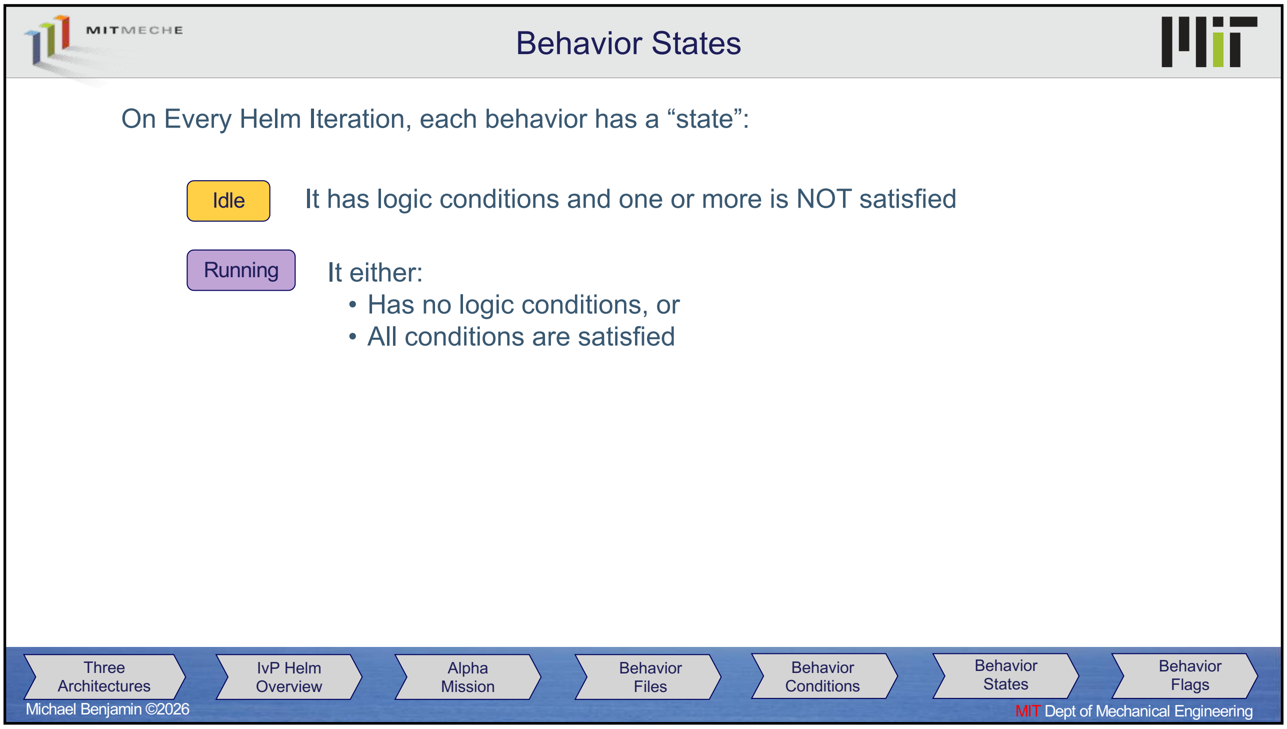


Behavior 1

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
```

Behavior 2

```
name      = waypoint_return
condition = RETURN = true
points    = 0,0
```



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Behavior States

On Every Helm Iteration, each behavior has a “state”:

Idle — It has logic conditions and one or more is NOT satisfied

Running — It either:

- Has no logic conditions, or
- All conditions are satisfied

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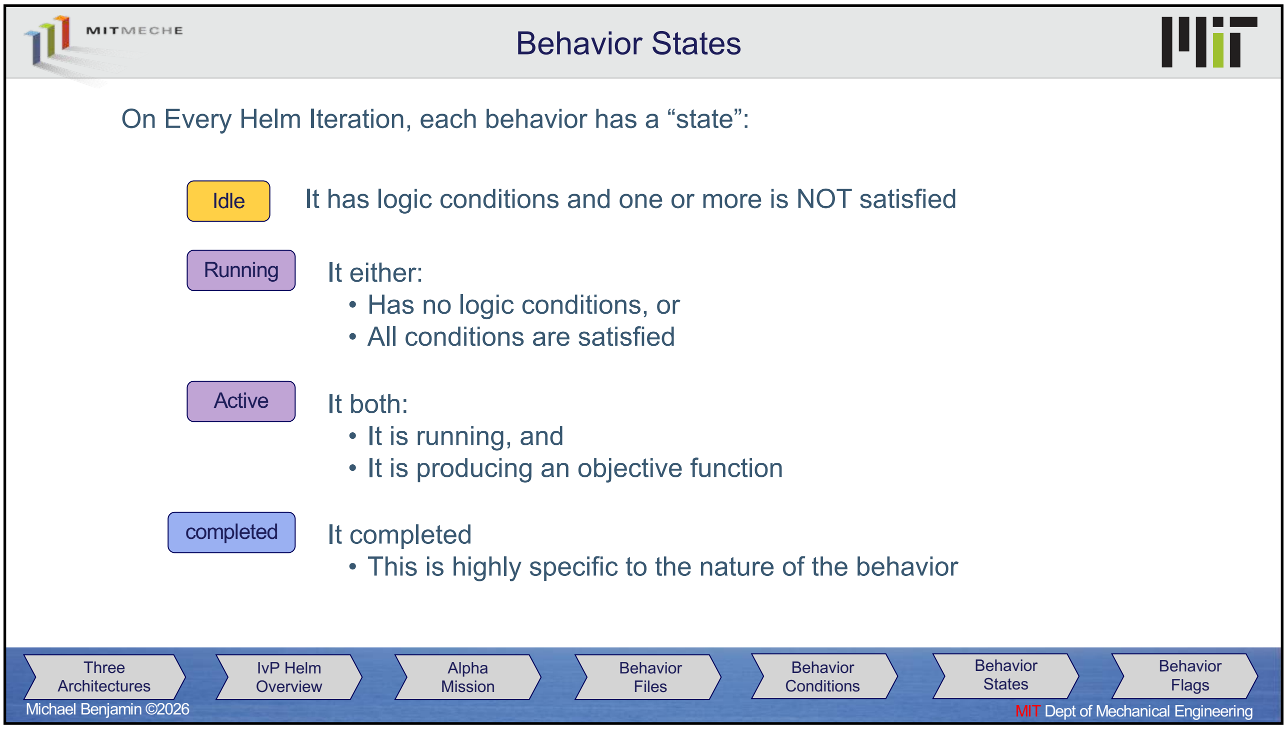

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Behavior States

On Every Helm Iteration, each behavior has a “state”:

Idle — It has logic conditions and one or more is NOT satisfied

Running — It either:

- Has no logic conditions, or
- All conditions are satisfied

Active — It both:

- It is running, and
- It is producing an objective function

completed — It completed

- This is highly specific to the nature of the behavior

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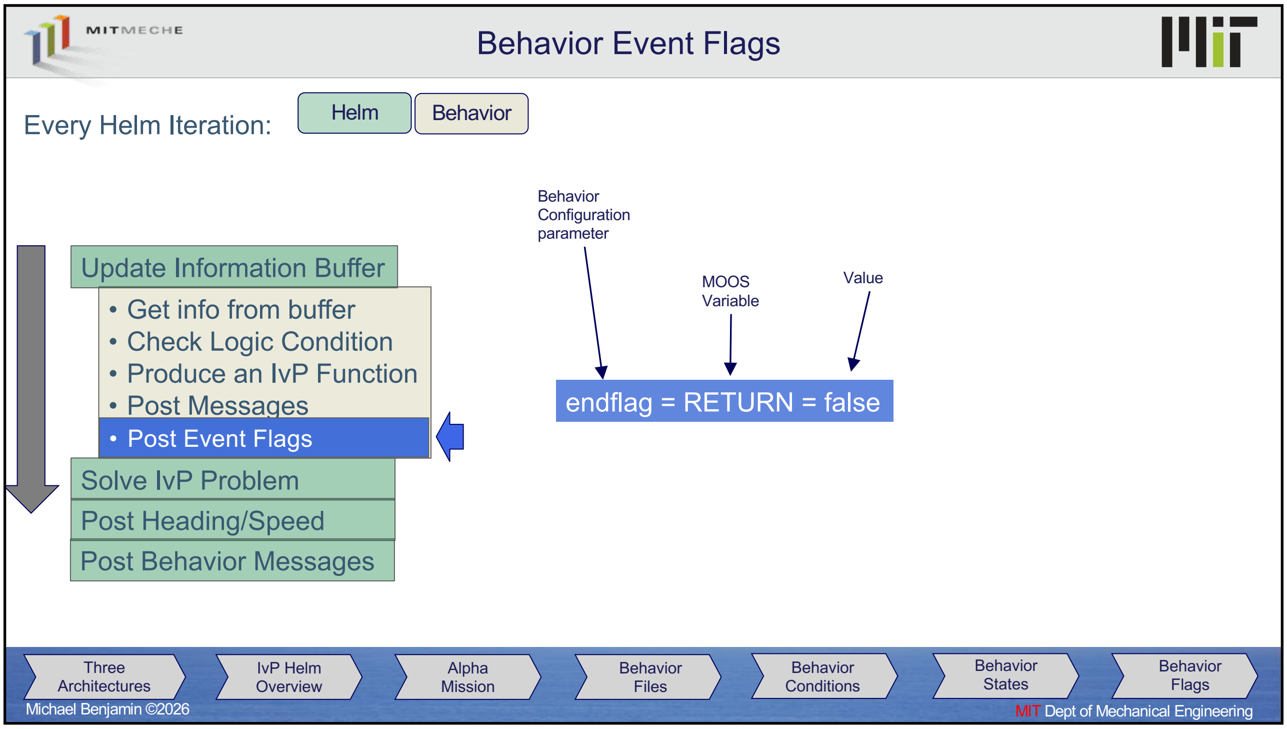

Behavior Event Flags

Every Helm Iteration:

- Update Information Buffer
  - Get info from buffer
  - Check Logic Condition
  - Produce an IvP Function
  - Post Messages
  - Post Event Flags
- Solve IvP Problem
- Post Heading/Speed
- Post Behavior Messages

Behavior Configuration parameter

MOOS Variable

Value

endflag = RETURN = false

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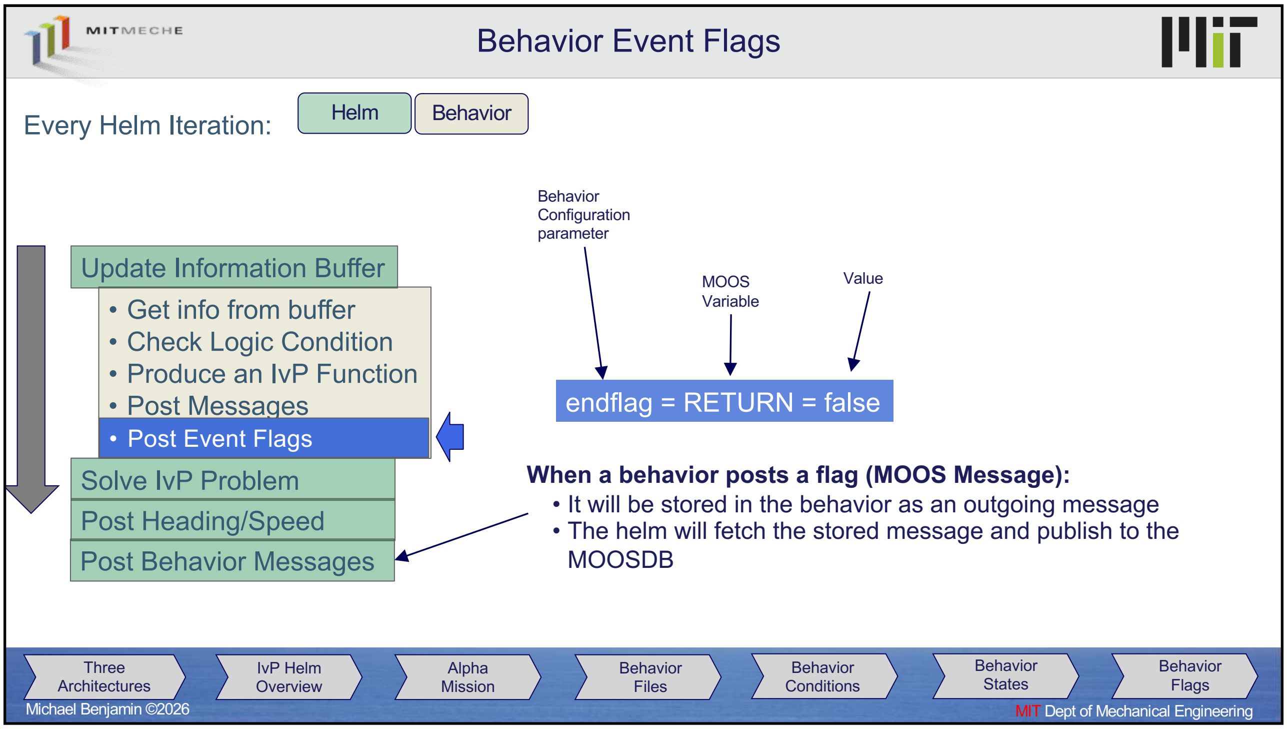

Behavior Event Flags

Every Helm Iteration:

- Update Information Buffer
  - Get info from buffer
  - Check Logic Condition
  - Produce an IvP Function
  - Post Messages
  - Post Event Flags
- Solve IvP Problem
- Post Heading/Speed
- Post Behavior Messages

Behavior Configuration parameter

MOOS Variable

Value

endflag = RETURN = false

When a behavior posts a flag (MOOS Message):

- It will be stored in the behavior as an outgoing message
- The helm will fetch the stored message and publish to the MOOSDB

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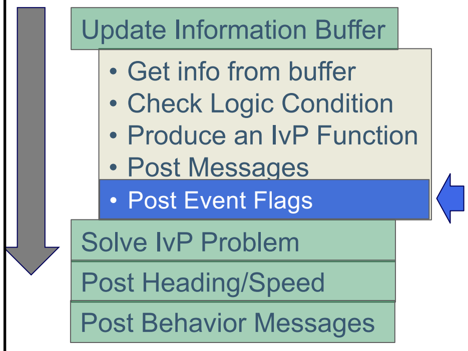
Behavior Event Flags

Every Helm Iteration: Helm Behavior


Update Information Buffer

- Get info from buffer
- Check Logic Condition
- Produce an IvP Function
- Post Messages
- Post Event Flags

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

endflag = RETURN = true

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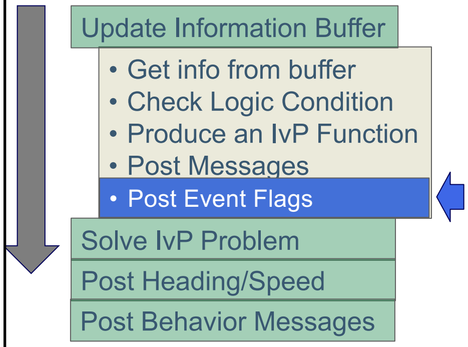
Types of Event Flags

Every Helm Iteration: Helm Behavior


Update Information Buffer

- Get info from buffer
- Check Logic Condition
- Produce an IvP Function
- Post Messages
- Post Event Flags

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

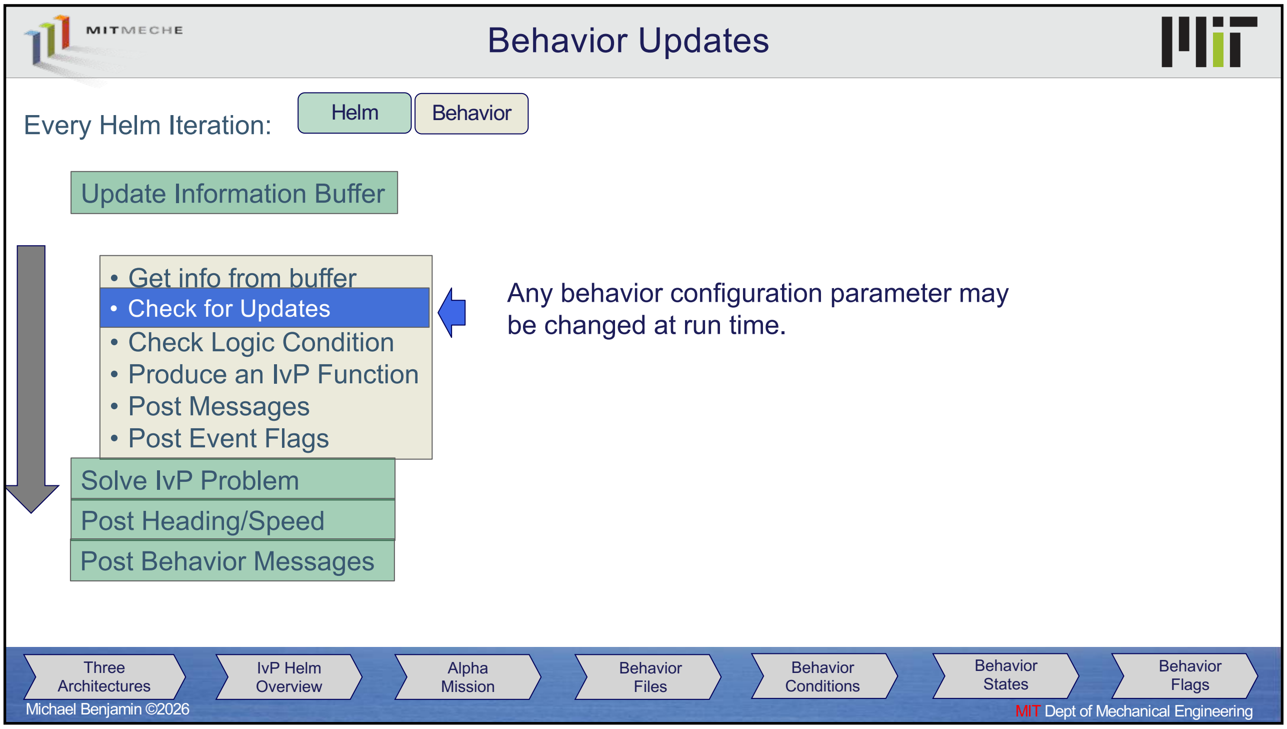
endflag Posted when a behavior completes

idleflag Posted when a behavior enters the idle state

runflag Posted when a behavior enters the running state

runxflag Posted when a behavior on ***every iteration*** when running

activeflag Posted when a behavior enters the active state



Behavior Updates

Every Helm Iteration: Helm Behavior

Update Information Buffer

- Get info from buffer
- Check for Updates
- Check Logic Condition
- Produce an IvP Function
- Post Messages
- Post Event Flags

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

Any behavior configuration parameter may be changed at run time.

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IvP Helm Overview
Alpha Mission
Behavior Files
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Behavior States
Behavior Flags

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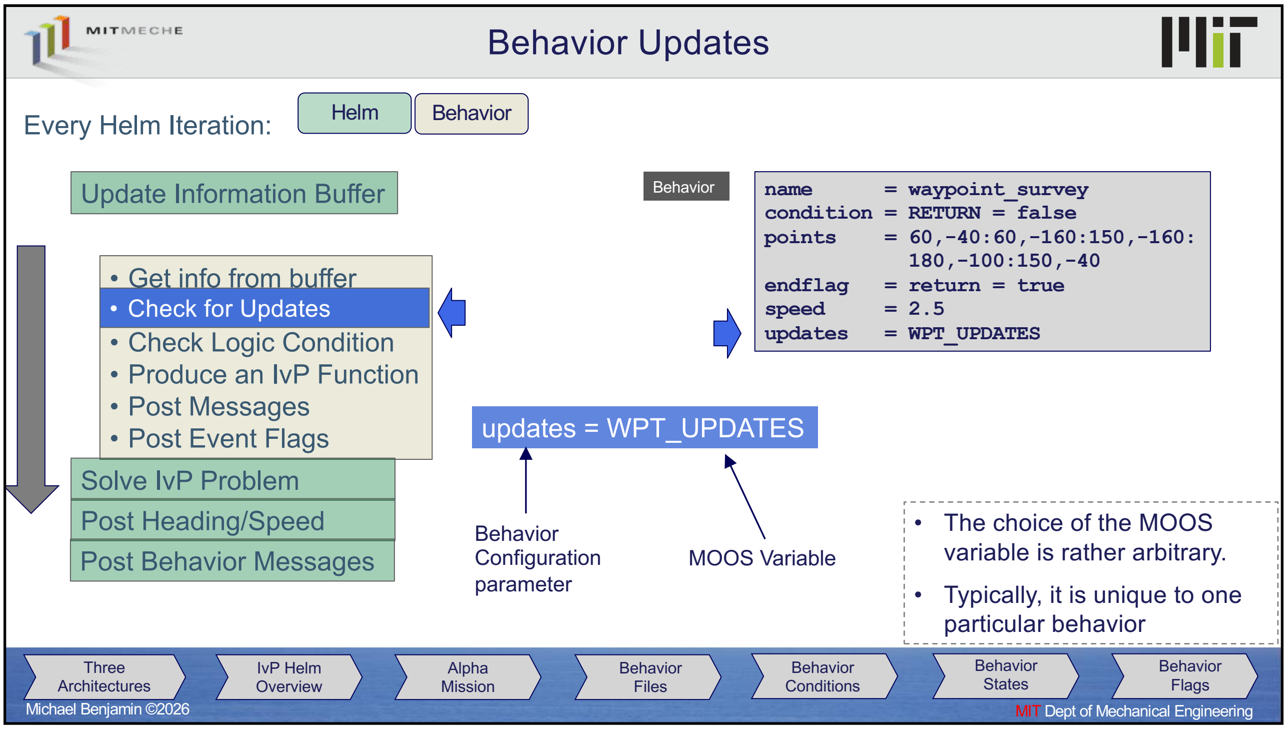

Behavior Updates

Every Helm Iteration: Helm Behavior

Update Information Buffer

- Get info from buffer
- Check for Updates
- Check Logic Condition
- Produce an IvP Function
- Post Messages
- Post Event Flags

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

Behavior

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
endflag   = return = true
speed     = 2.5
updates   = WPT_UPDATES
```

updates = WPT_UPDATES

Behavior Configuration parameter

MOOS Variable

- The choice of the MOOS variable is rather arbitrary.
- Typically, it is unique to one particular behavior

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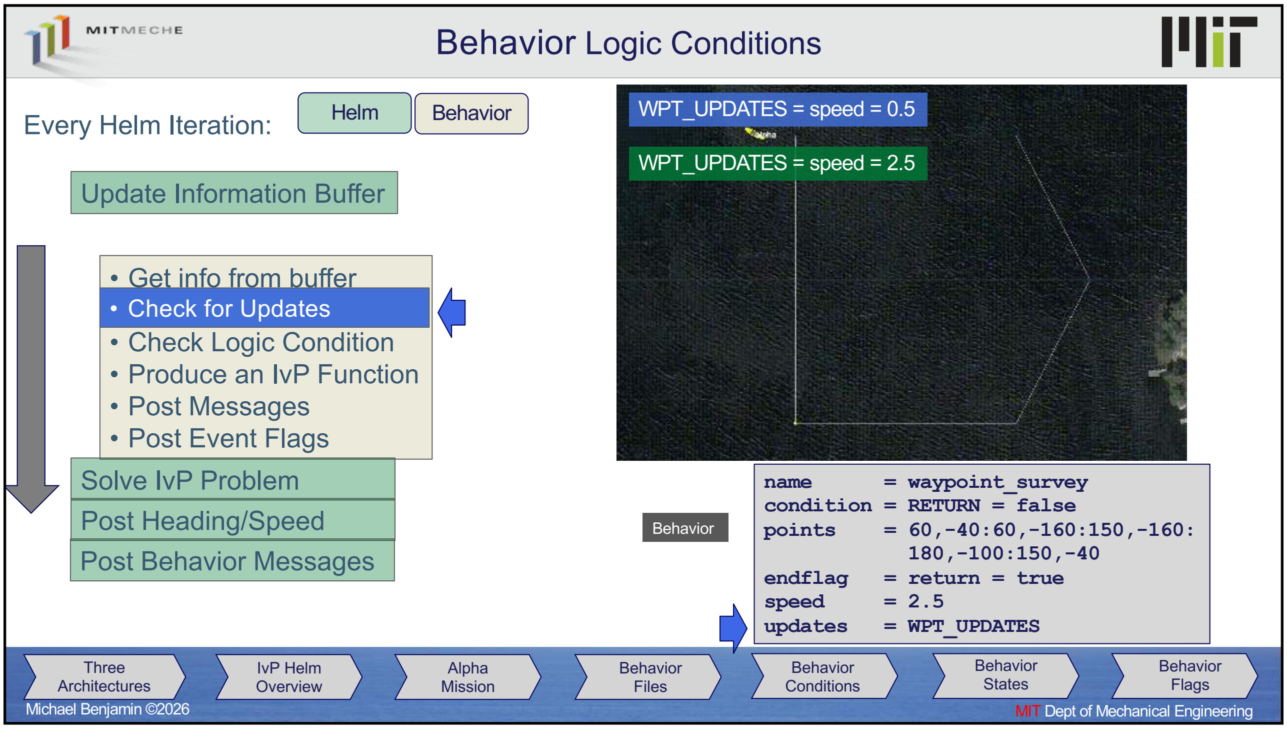

Behavior Logic Conditions

Every Helm Iteration: Helm Behavior

Update Information Buffer

- Get info from buffer
- Check for Updates
- Check Logic Condition
- Produce an IvP Function
- Post Messages
- Post Event Flags

Solve IvP Problem

Post Heading/Speed

Post Behavior Messages

WPT_UPDATES = speed = 0.5

WPT_UPDATES = speed = 2.5

```
name      = waypoint_survey
condition = RETURN = false
points    = 60,-40:60,-160:150,-160:
            180,-100:150,-40
endflag   = return = true
speed     = 2.5
updates   = WPT_UPDATES
```

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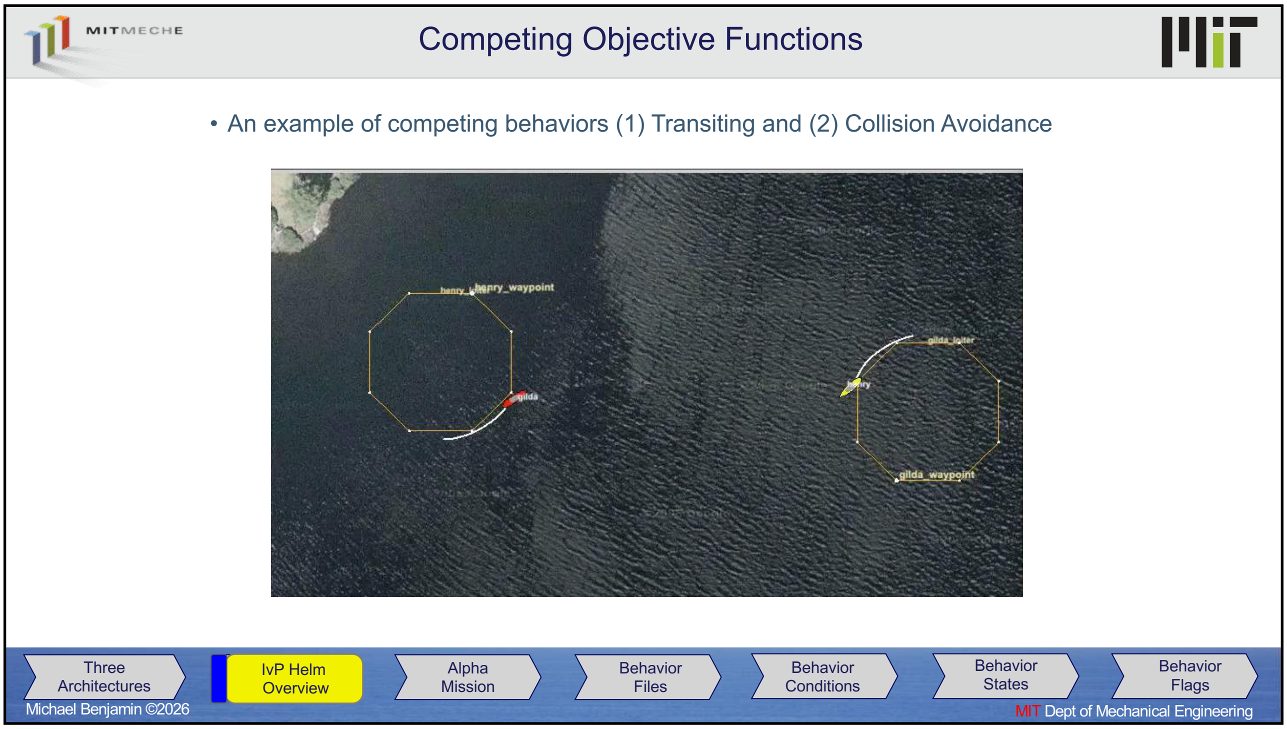

Competing Objective Functions

- An example of competing behaviors (1) Transiting and (2) Collision Avoidance

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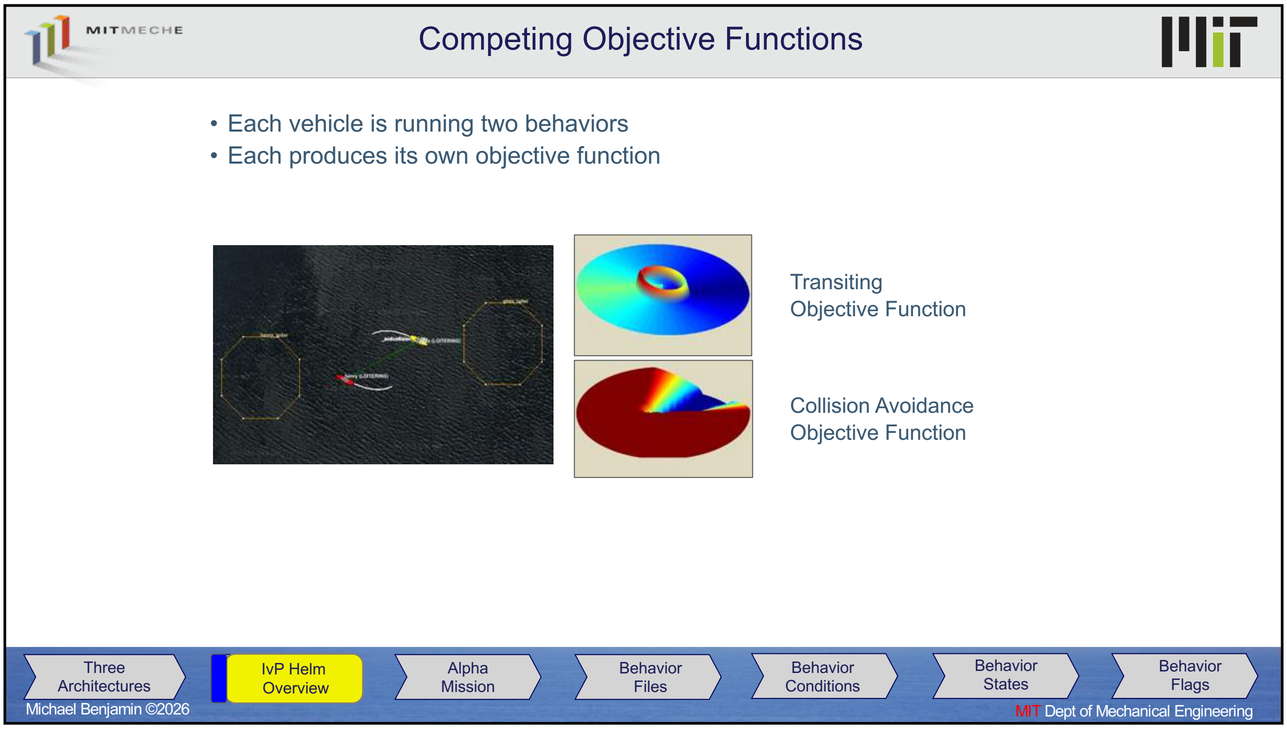

Competing Objective Functions

- Each vehicle is running two behaviors
- Each produces its own objective function

Transiting Objective Function

Collision Avoidance Objective Function

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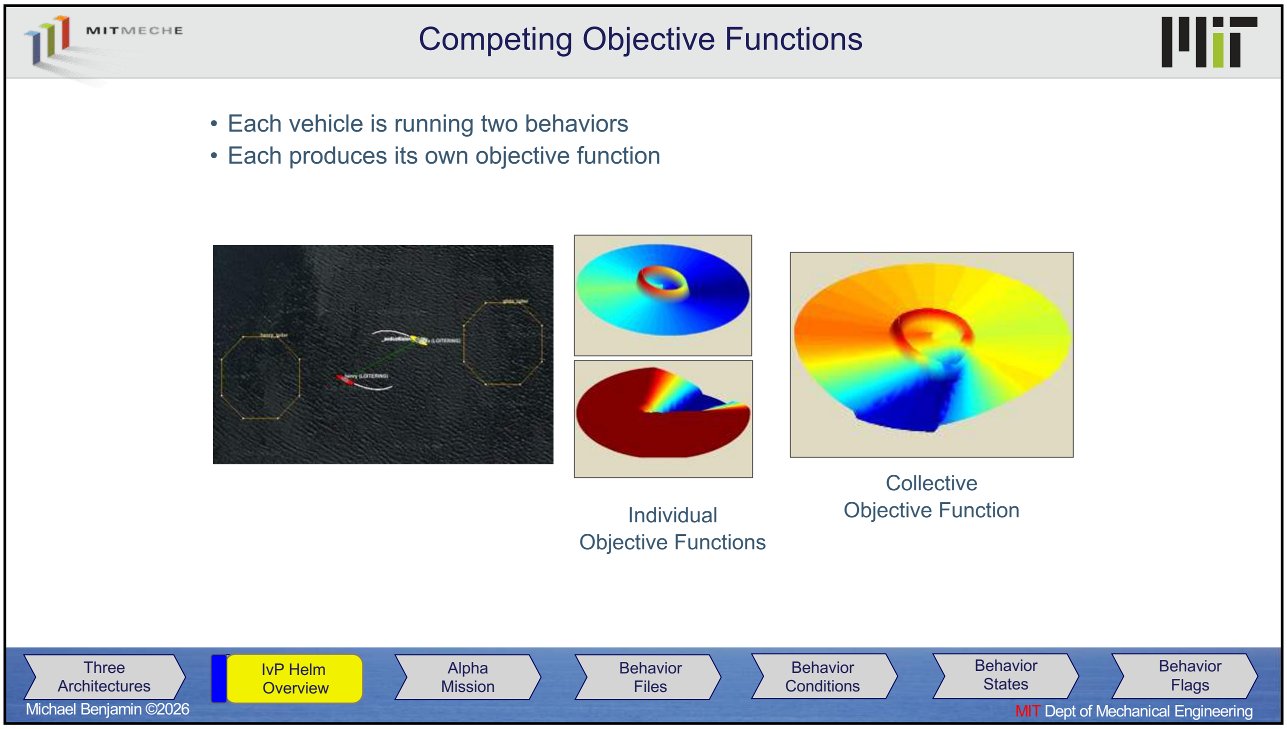

Competing Objective Functions

- Each vehicle is running two behaviors
- Each produces its own objective function

Individual Objective Functions

Collective Objective Function

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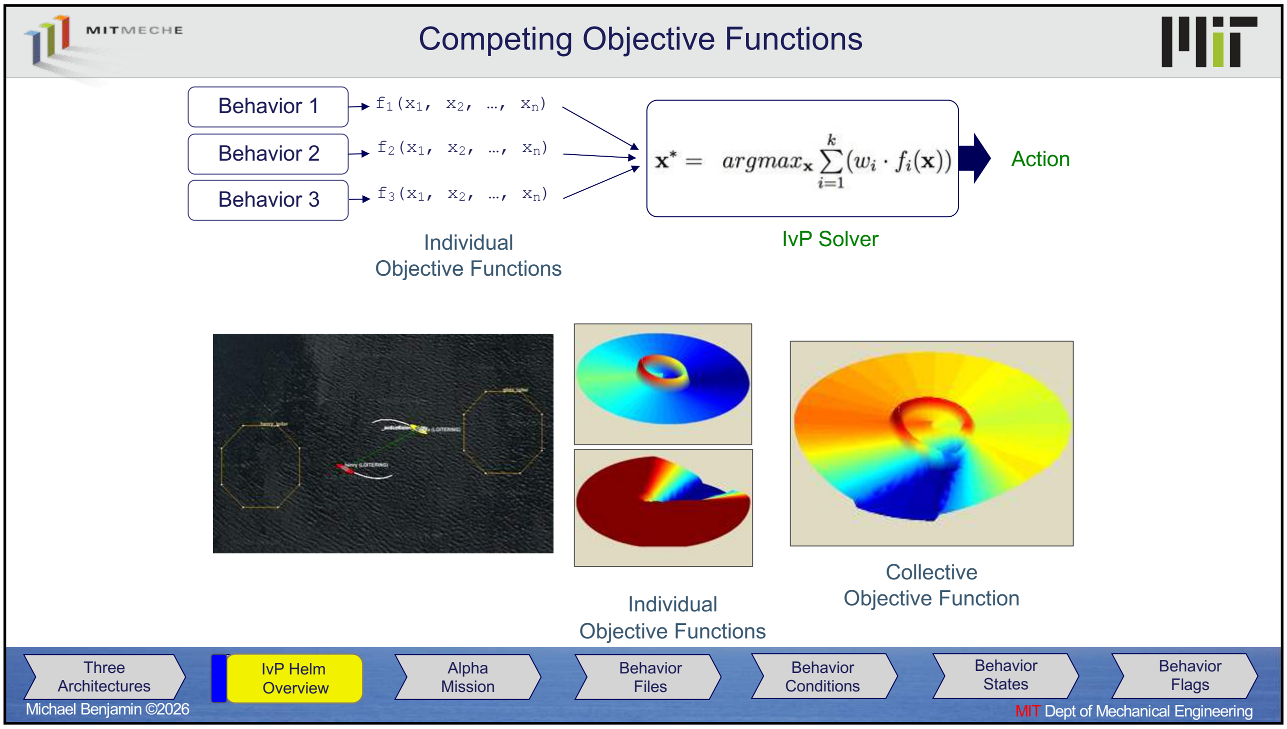

Competing Objective Functions

Behavior 1 → $f_1(x_1, x_2, \ldots, x_n)$

Behavior 2 → $f_2(x_1, x_2, \ldots, x_n)$

Behavior 3 → $f_3(x_1, x_2, \ldots, x_n)$

Individual Objective Functions

$$\mathbf{x}^* = argmax_{\mathbf{x}} \sum_{i=1}^{k}(w_i \cdot f_i(\mathbf{x}))$$

IvP Solver

Action

Individual Objective Functions

Collective Objective Function

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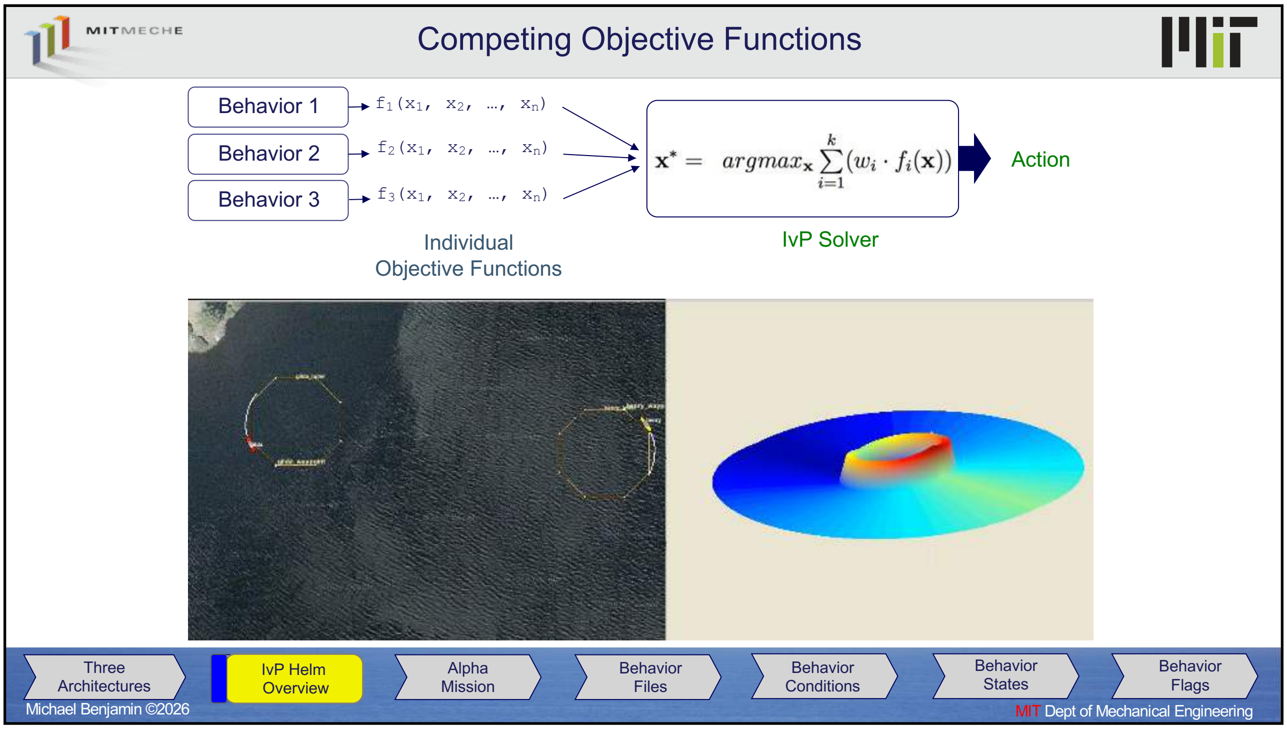

Competing Objective Functions

Behavior 1 → $f_1(x_1, x_2, \ldots, x_n)$

Behavior 2 → $f_2(x_1, x_2, \ldots, x_n)$

Behavior 3 → $f_3(x_1, x_2, \ldots, x_n)$

Individual Objective Functions

$$\mathbf{x}^* = argmax_{\mathbf{x}} \sum_{i=1}^{k}(w_i \cdot f_i(\mathbf{x}))$$

IvP Solver

Action

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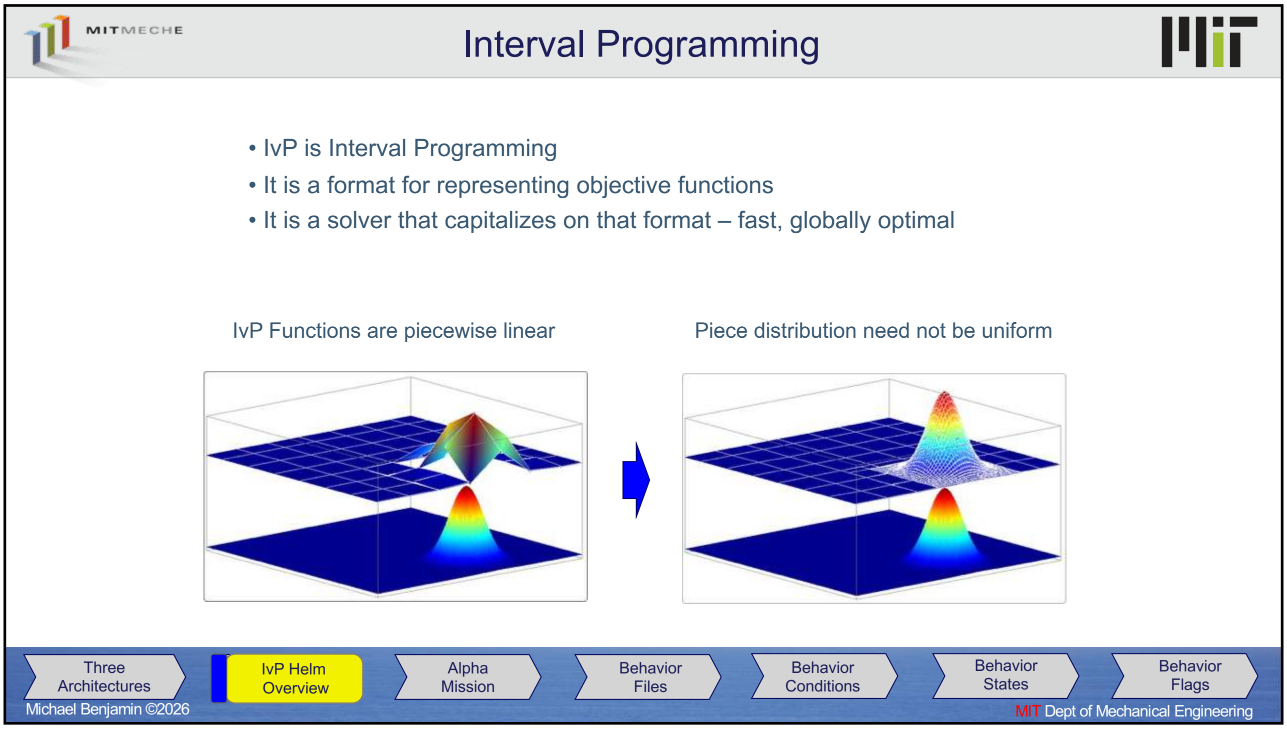

Interval Programming

- IvP is Interval Programming
- It is a format for representing objective functions
- It is a solver that capitalizes on that format – fast, globally optimal

IvP Functions are piecewise linear

Piece distribution need not be uniform

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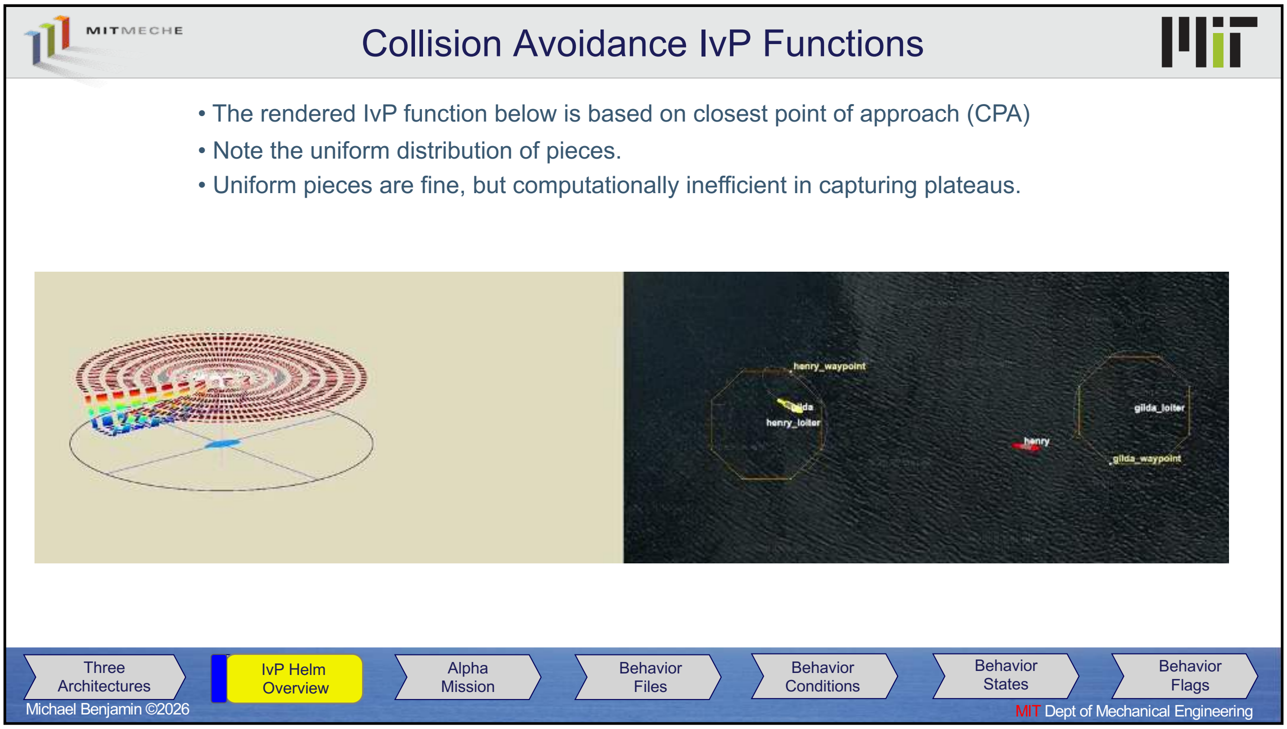

Collision Avoidance IvP Functions

- The rendered IvP function below is based on closest point of approach (CPA)
- Note the uniform distribution of pieces.
- Uniform pieces are fine, but computationally inefficient in capturing plateaus.

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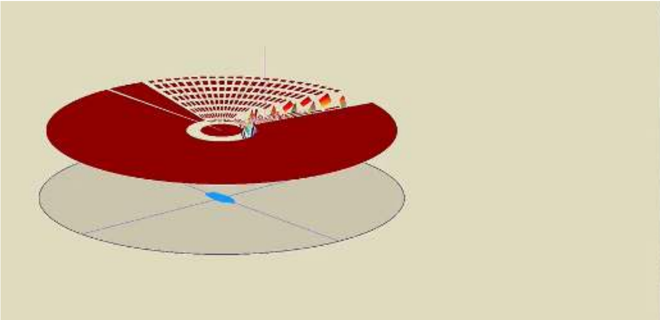
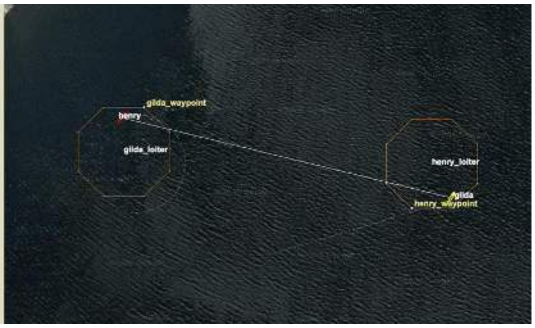
Collision Avoidance IvP Functions

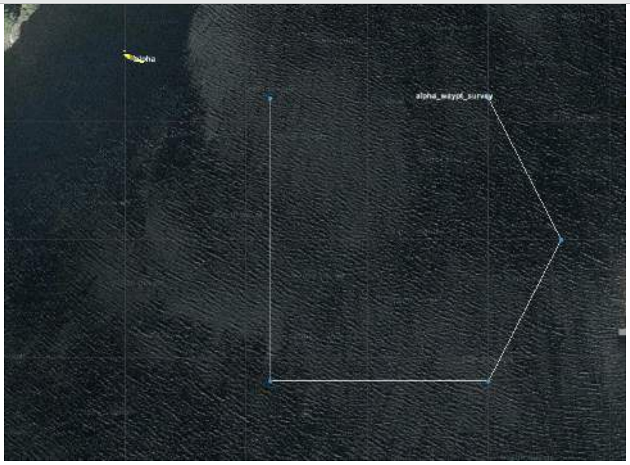
- The IvP functions need not be uniform
- The plateau regions can be identified in real time and replace many smaller pieces
- Note the large plateaus in the IvP function below.





The Alpha Mission

The Alpha Mission



To launch yourself:

```
$ cd moos-ivp/ivp/missions/s1_alpha
$ ./launch.sh 10
```

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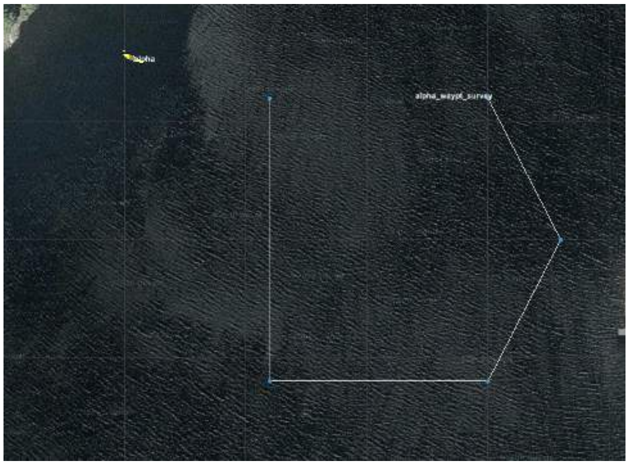
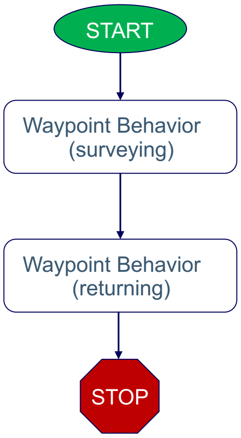
Alpha Mission Has Two Behaviors





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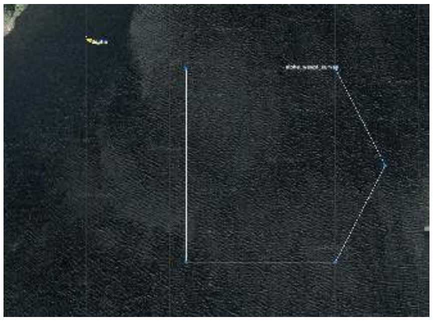
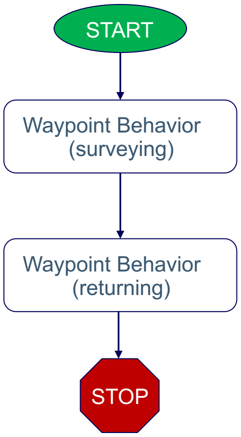
Alpha Mission Has Two Behaviors



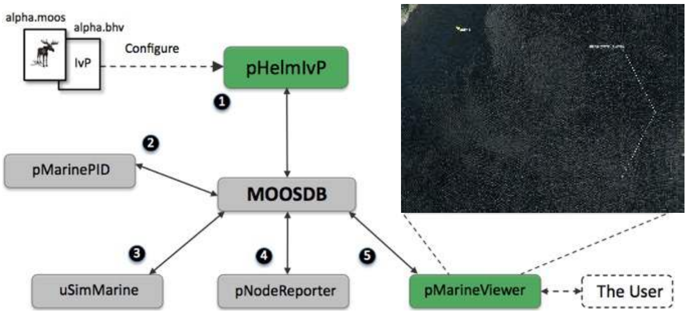


Three questions discussed next:

- How is this mission configured?
- What initiates this mission?
- How does the helm transition to return?

Configuring the Helm for a Mission

A mission is configured with two files:
`alpha.moos` – configures all MOOS apps, including general helm parameters
`alpha.bhv` – configures all Helm behaviors



To launch it yourself:

```
$ cd moos-ivp/ivp/missions/s1_alpha
$ ./launch.sh 10
```

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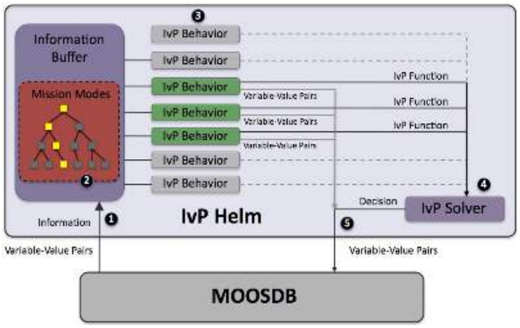
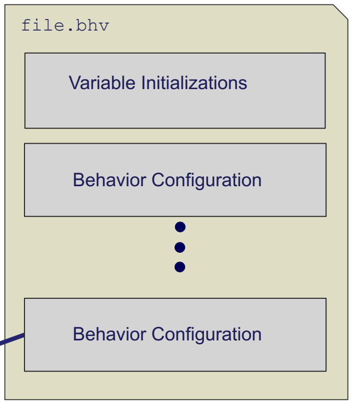
Behavior Files



```
Behavior = <behavior_name>
{
   parameter = value
   . . .
   parameter = value
}
```

Helm configuration file structure:



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Alpha Mission Behavior File

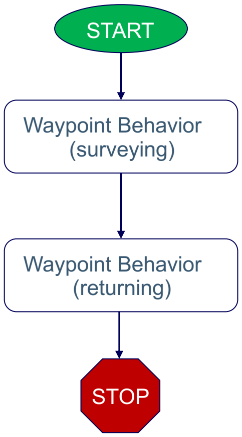
```
initialize   DEPLOY = false
initialize   RETURN = false
```

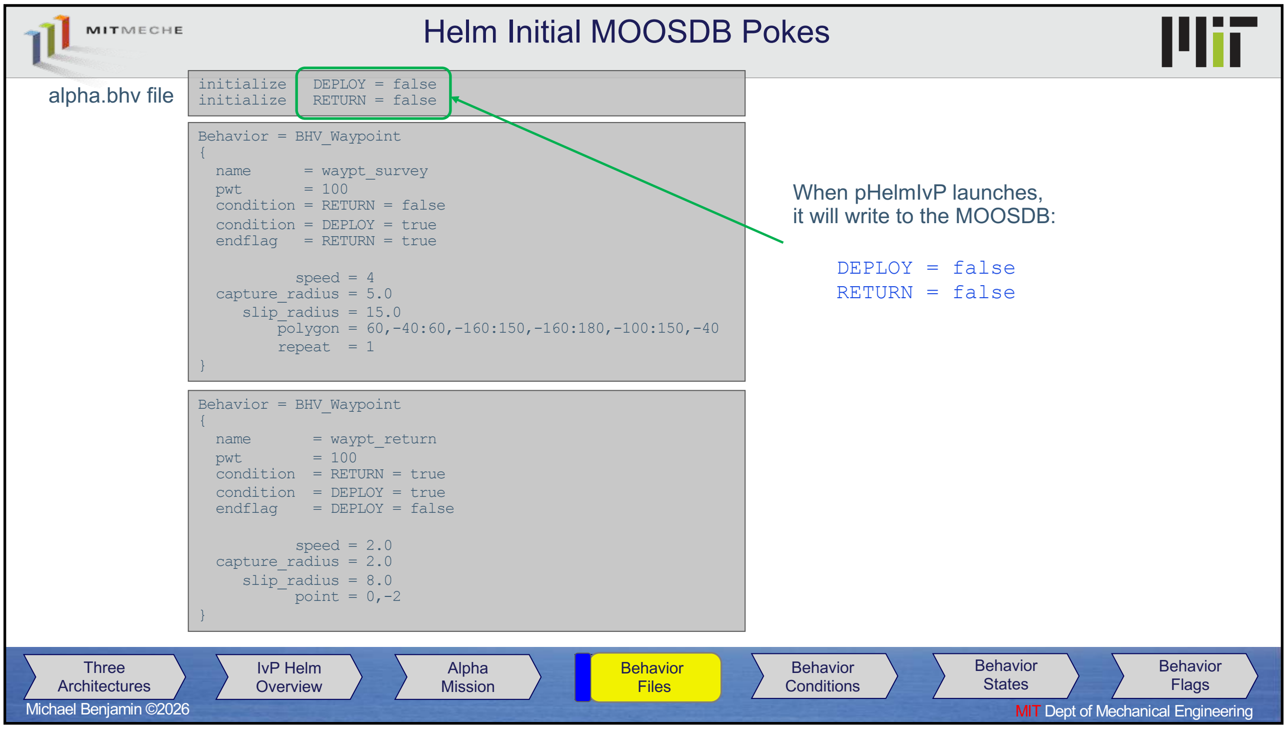
```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

```
Behavior = BHV_Waypoint
{
  name       = waypt_return
  pwt        = 100
  condition  = RETURN = true
  condition  = DEPLOY = true
  endflag    = DEPLOY = false

           speed = 2.0
  capture_radius = 2.0
     slip_radius = 8.0
          points = 0,-2
}
```





Helm Initial MOOSDB Pokes

alpha.bhv file

```
initialize  DEPLOY = false
initialize  RETURN = false
```

```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

```
Behavior = BHV_Waypoint
{
  name        = waypt_return
  pwt         = 100
  condition   = RETURN = true
  condition   = DEPLOY = true
  endflag     = DEPLOY = false

           speed = 2.0
  capture_radius = 2.0
     slip_radius = 8.0
           point = 0,-2
}
```

When pHelmIvP launches,
it will write to the MOOSDB:

```
DEPLOY = false
RETURN = false
```

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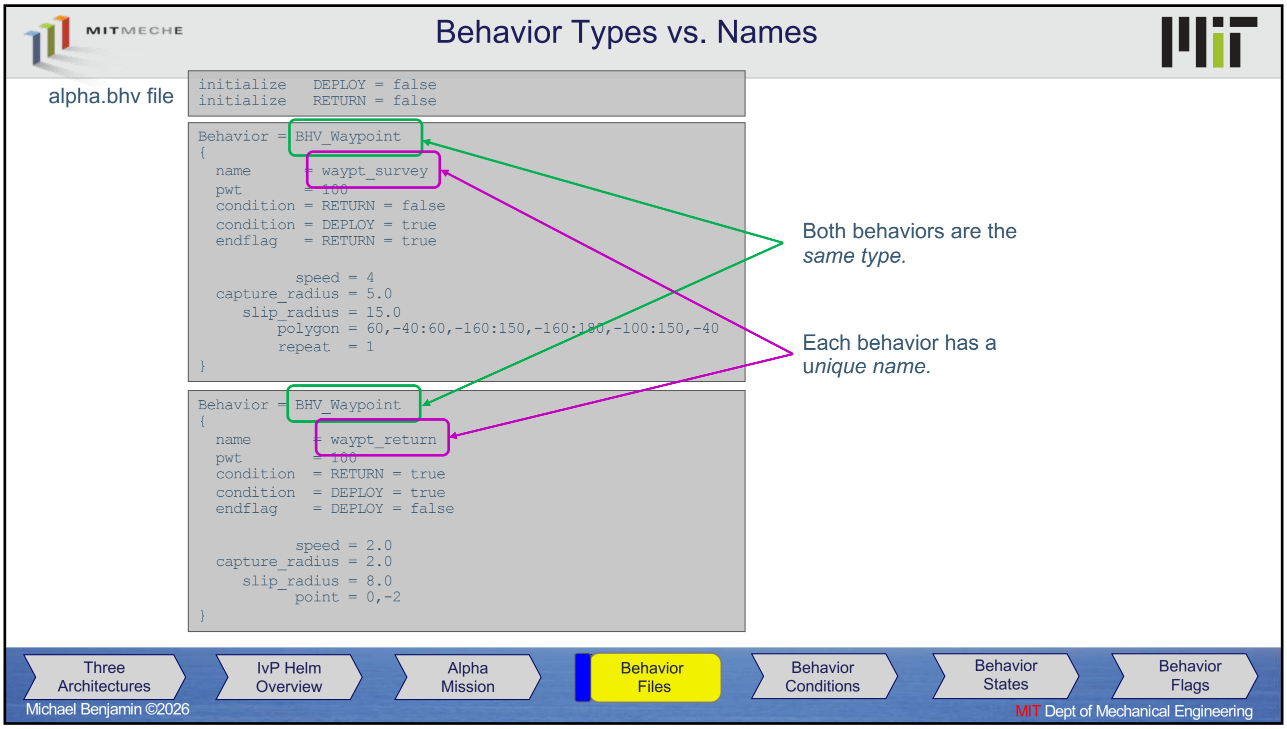

Behavior Types vs. Names

alpha.bhv file

```
initialize  DEPLOY = false
initialize  RETURN = false
```

```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

```
Behavior = BHV_Waypoint
{
  name        = waypt_return
  pwt         = 100
  condition   = RETURN = true
  condition   = DEPLOY = true
  endflag     = DEPLOY = false

           speed = 2.0
  capture_radius = 2.0
     slip_radius = 8.0
           point = 0,-2
}
```

Both behaviors are the *same type.*

Each behavior has a *unique name.*

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Waypoint Behavior Points

alpha.bhv file

```
initialize   DEPLOY = false
initialize   RETURN = false
```

```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
          repeat  = 1
}
```

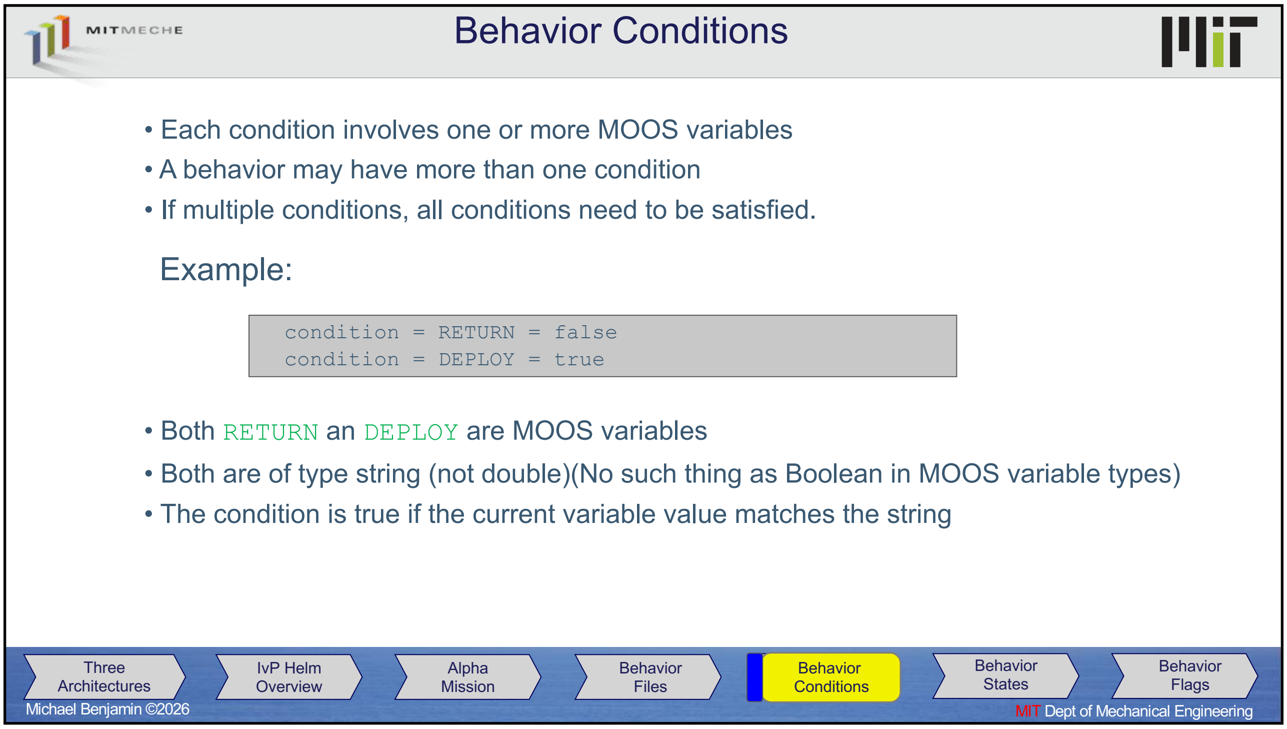
```
Behavior = BHV_Waypoint
{
  name        = waypt_return
  pwt         = 100
  condition   = RETURN = true
  condition   = DEPLOY = true
  endflag     = DEPLOY = false

           speed = 2.0
  capture_radius = 2.0
     slip_radius = 8.0
           point = 0,-2
}
```

The waypoint behavior accepts either:

- *a polygon*
- *a single point*

Behavior Conditions



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Behavior Conditions

- Each condition involves one or more MOOS variables
- A behavior may have more than one condition
- If multiple conditions, all conditions need to be satisfied.

Example:

```
condition = RETURN = false
condition = DEPLOY = true
```

- Both `RETURN` an `DEPLOY` are MOOS variables
- Both are of type string (not double)(No such thing as Boolean in MOOS variable types)
- The condition is true if the current variable value matches the string

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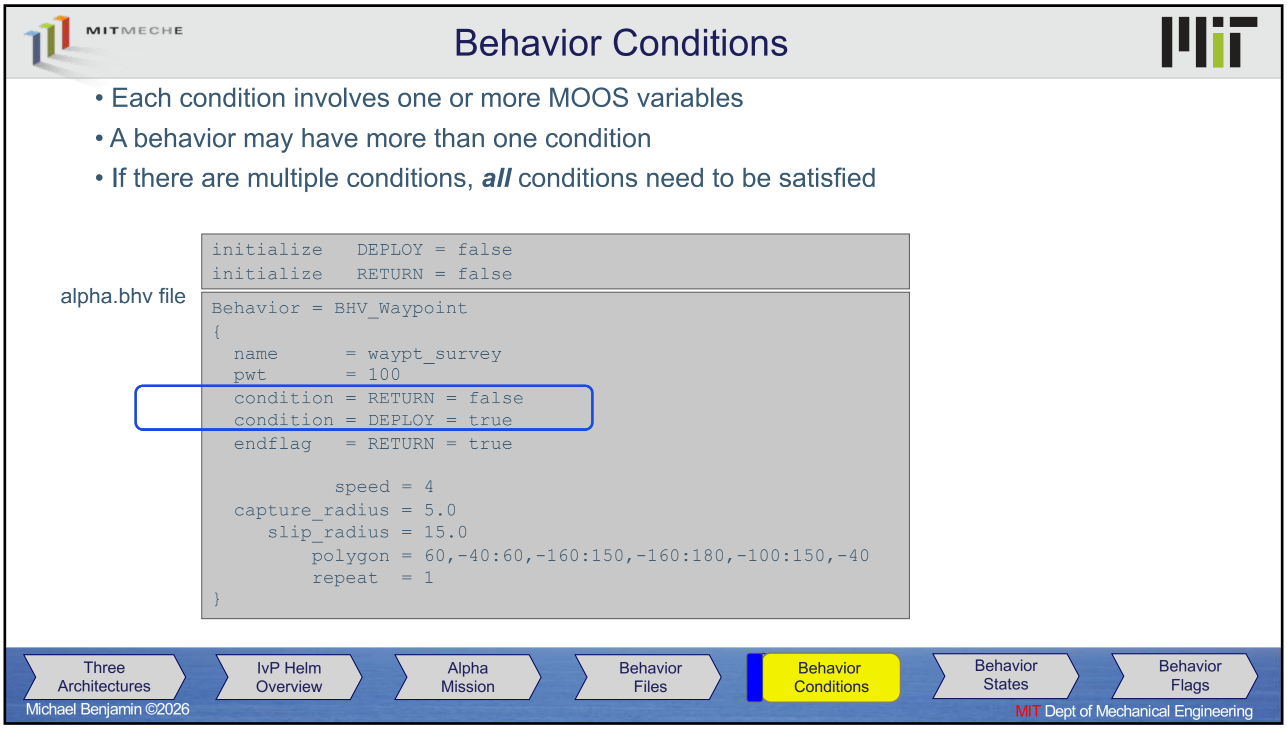

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Behavior Conditions

- Each condition involves one or more MOOS variables
- A behavior may have more than one condition
- If there are multiple conditions, ***all*** conditions need to be satisfied

alpha.bhv file

```
initialize   DEPLOY = false
initialize   RETURN = false
```

```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

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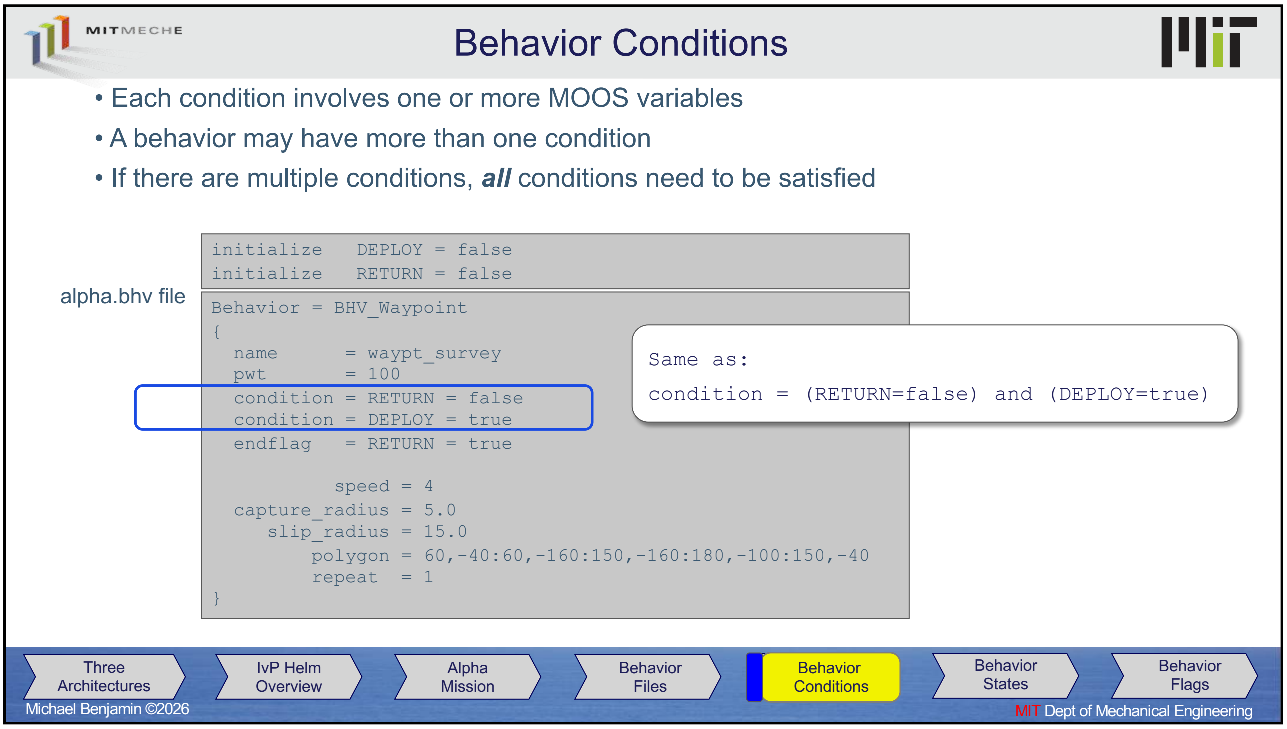

Behavior Conditions

- Each condition involves one or more MOOS variables
- A behavior may have more than one condition
- If there are multiple conditions, ***all*** conditions need to be satisfied

alpha.bhv file

```
initialize   DEPLOY = false
initialize   RETURN = false
```

```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

```
Same as:
condition = (RETURN=false) and (DEPLOY=true)
```

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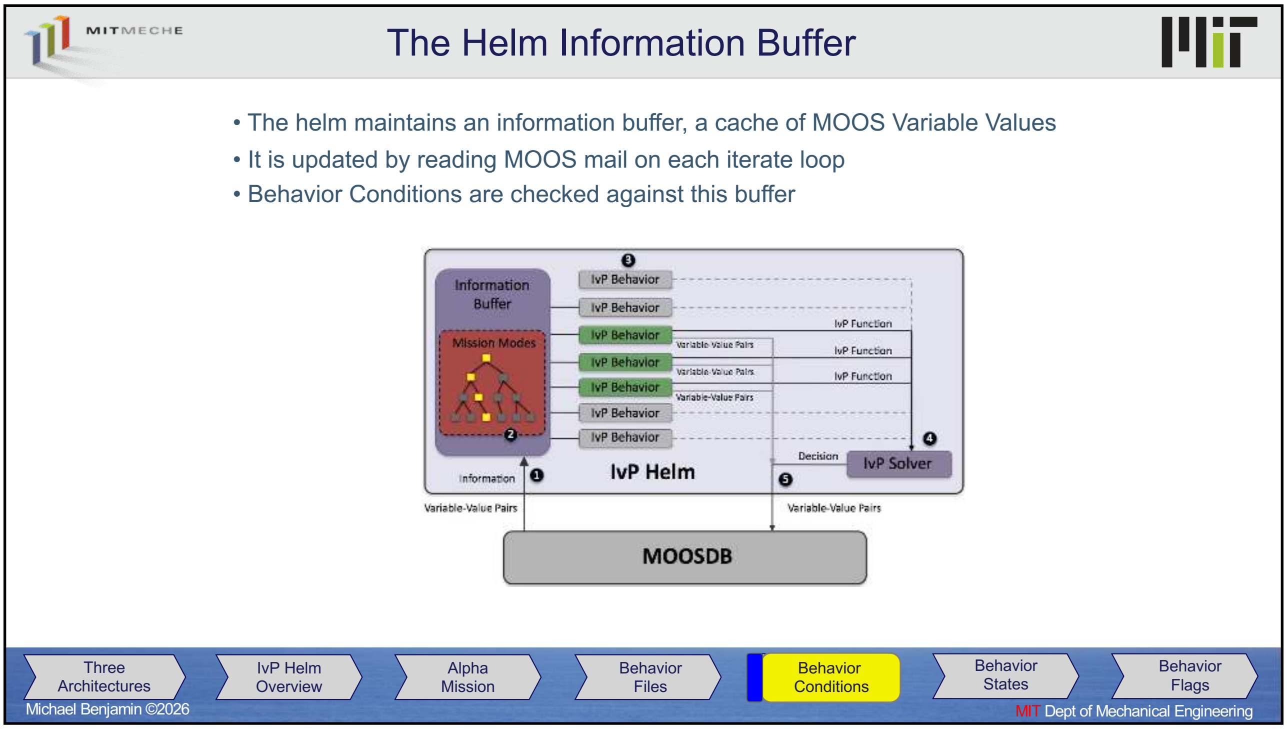

The Helm Information Buffer

- The helm maintains an information buffer, a cache of MOOS Variable Values
- It is updated by reading MOOS mail on each iterate loop
- Behavior Conditions are checked against this buffer

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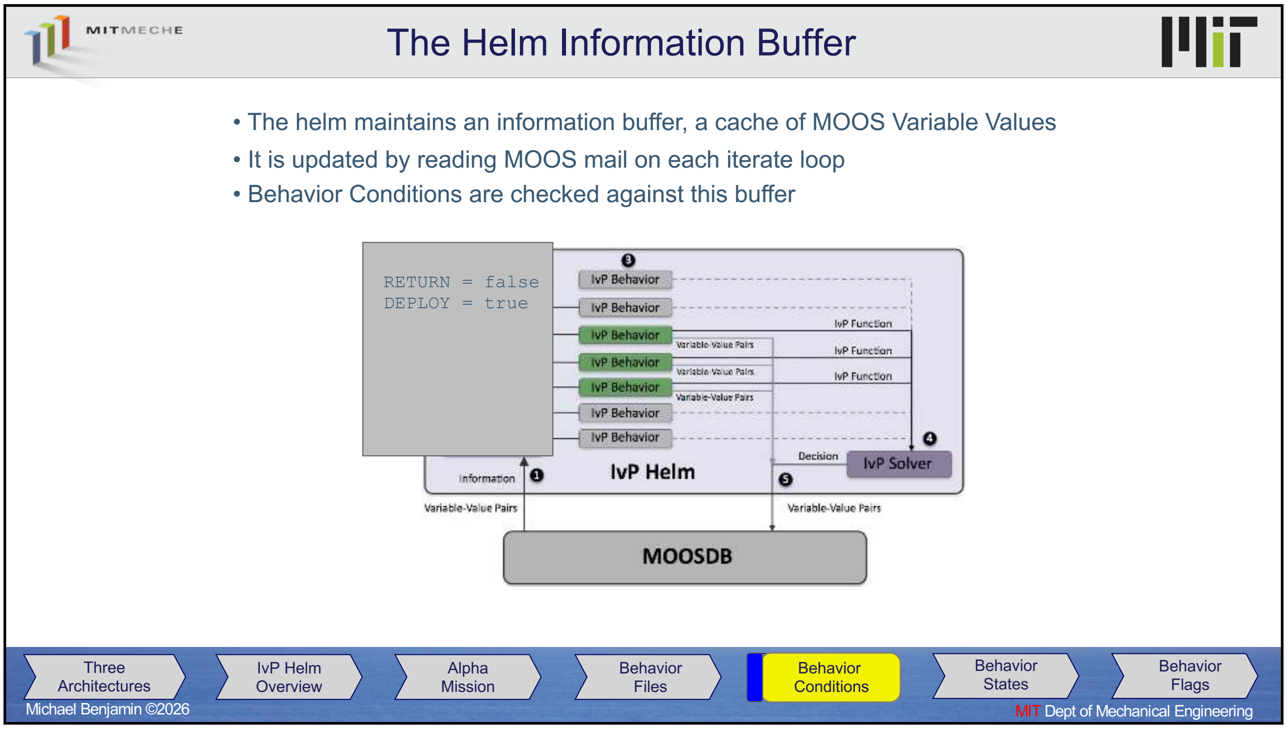
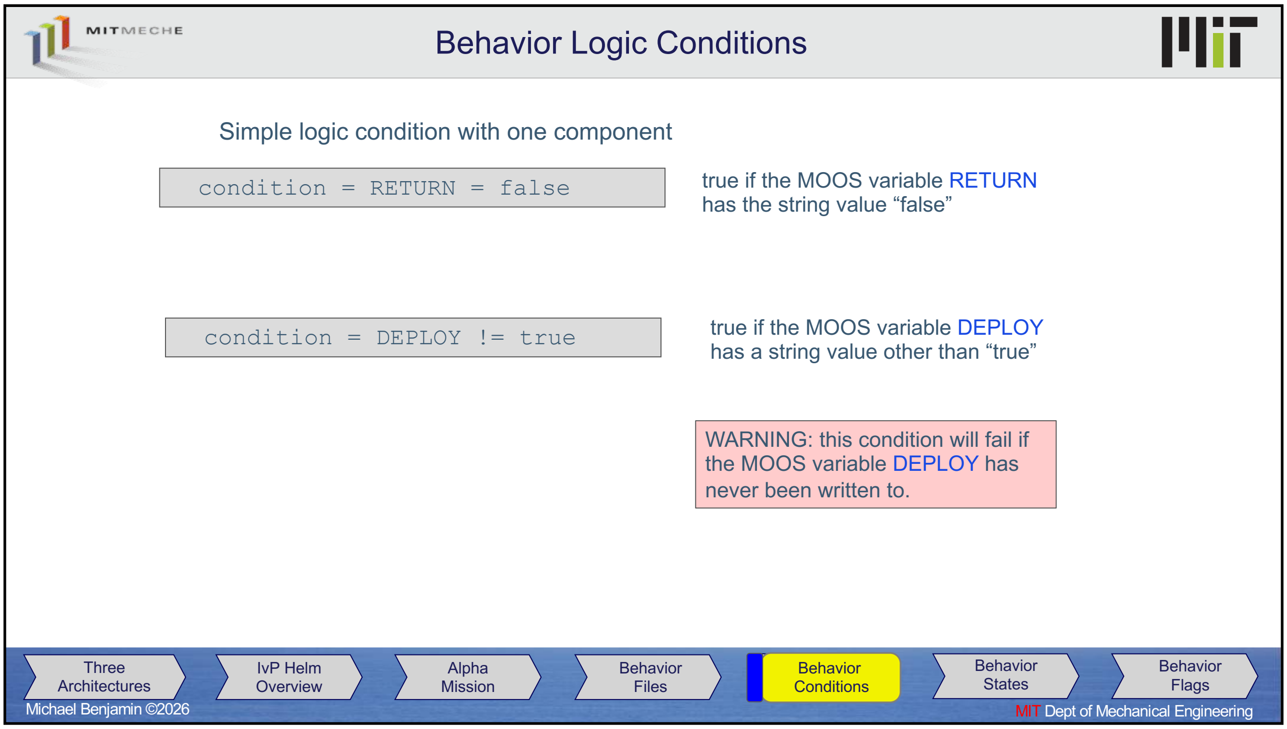


The Helm Information Buffer

- The helm maintains an information buffer, a cache of MOOS Variable Values
- It is updated by reading MOOS mail on each iterate loop
- Behavior Conditions are checked against this buffer

53



Behavior Logic Conditions

Simple logic condition with one component

```
condition = RETURN = false
```

true if the MOOS variable RETURN has the string value “false”

```
condition = DEPLOY != true
```

true if the MOOS variable DEPLOY has a string value other than “true”

WARNING: this condition will fail if the MOOS variable DEPLOY has never been written to.

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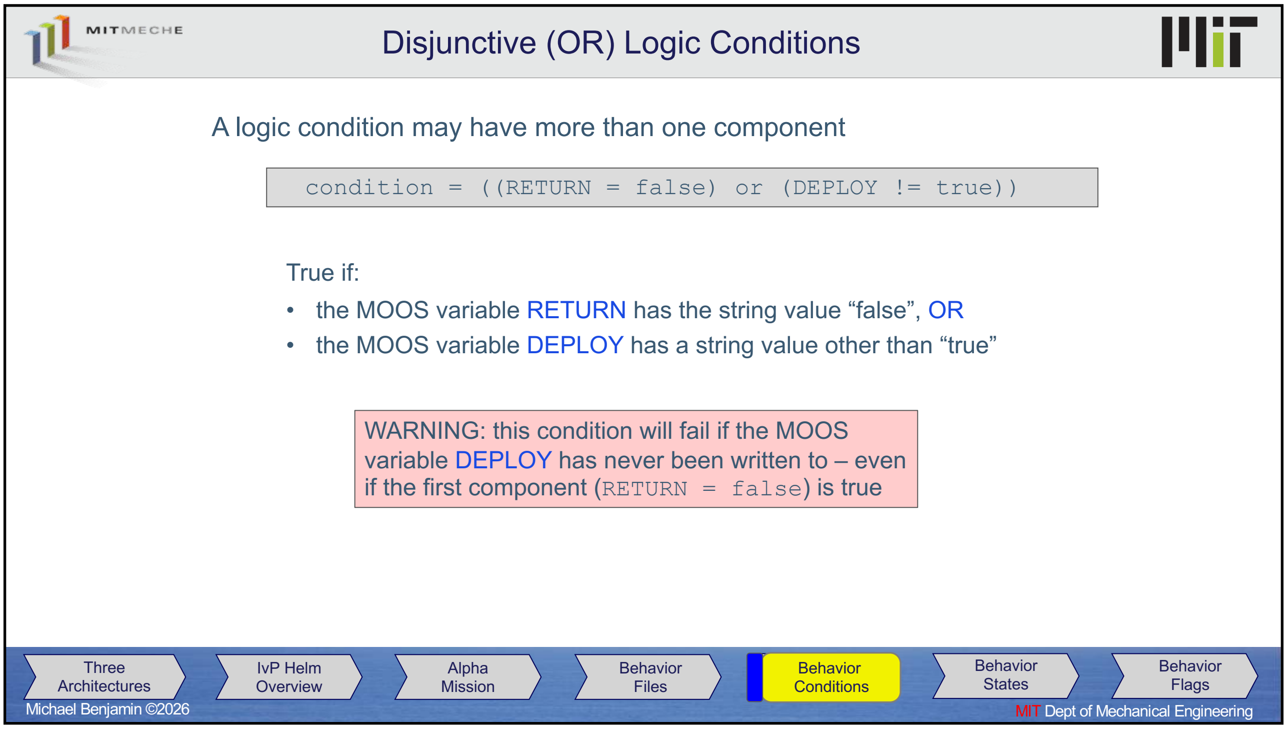

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Disjunctive (OR) Logic Conditions

A logic condition may have more than one component

```
condition = ((RETURN = false) or (DEPLOY != true))
```

True if:

- the MOOS variable RETURN has the string value “false”, OR
- the MOOS variable DEPLOY has a string value other than “true”

WARNING: this condition will fail if the MOOS variable DEPLOY has never been written to – even if the first component (`RETURN = false`) is true

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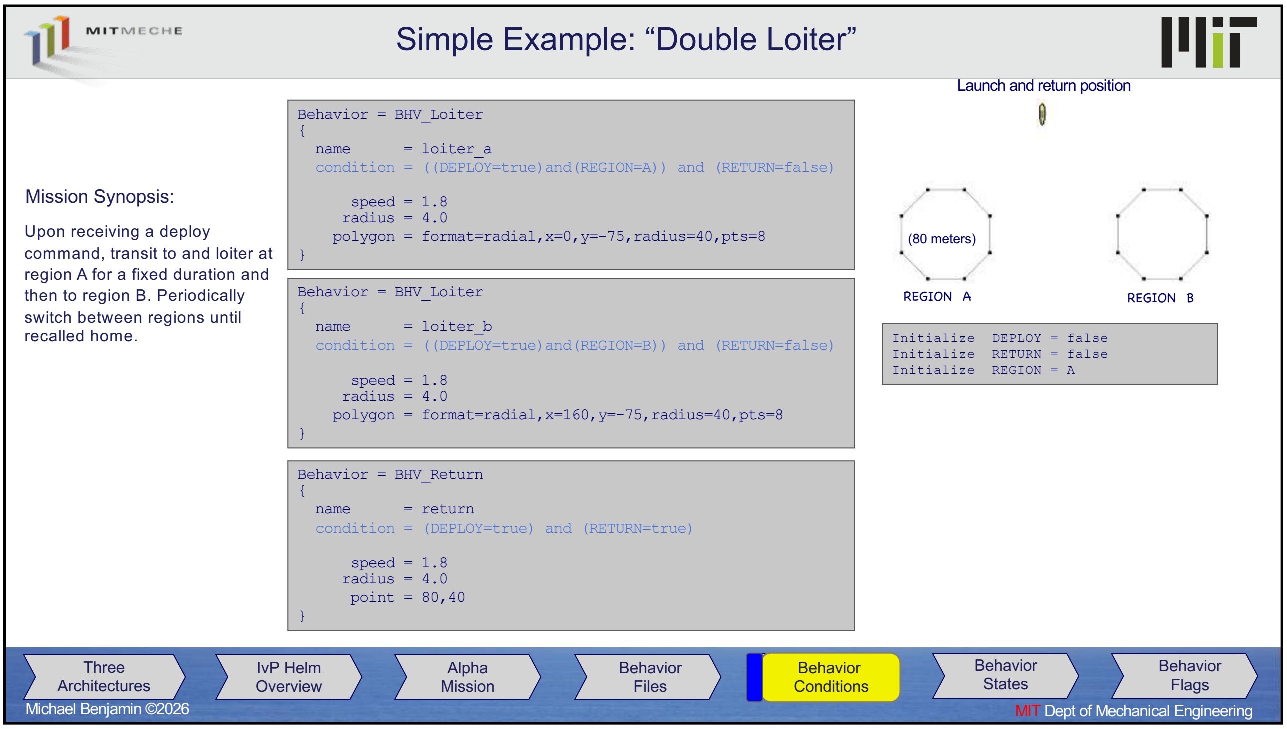

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Simple Example: “Double Loiter”

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

```
Behavior = BHV_Loiter
{
  name      = loiter_a
  condition = ((DEPLOY=true)and(REGION=A)) and (RETURN=false)

      speed = 1.8
     radius = 4.0
    polygon = format=radial,x=0,y=-75,radius=40,pts=8
}
```

```
Behavior = BHV_Loiter
{
  name      = loiter_b
  condition = ((DEPLOY=true)and(REGION=B)) and (RETURN=false)

      speed = 1.8
     radius = 4.0
    polygon = format=radial,x=160,y=-75,radius=40,pts=8
}
```

```
Behavior = BHV_Return
{
  name      = return
  condition = (DEPLOY=true) and (RETURN=true)

      speed = 1.8
     radius = 4.0
      point = 80,40
}
```

```
Initialize  DEPLOY = false
Initialize  RETURN = false
Initialize  REGION = A
```

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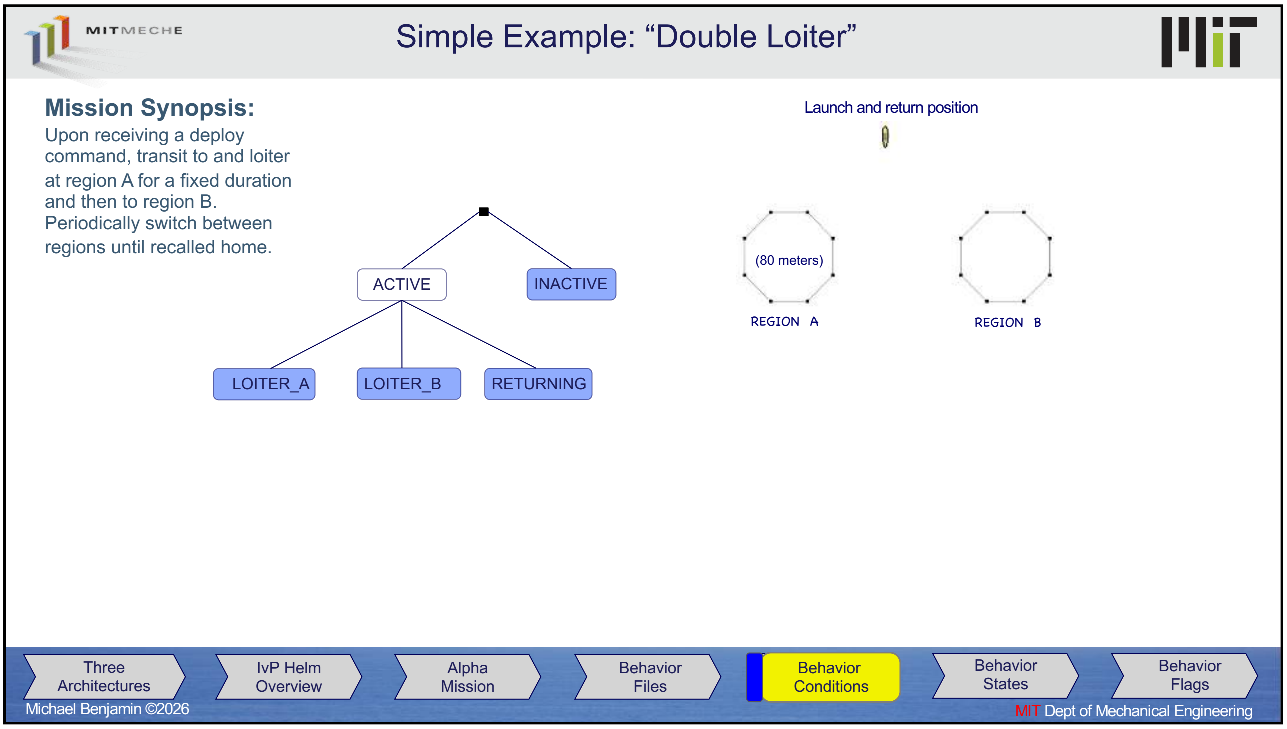

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Simple Example: "Double Loiter"

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

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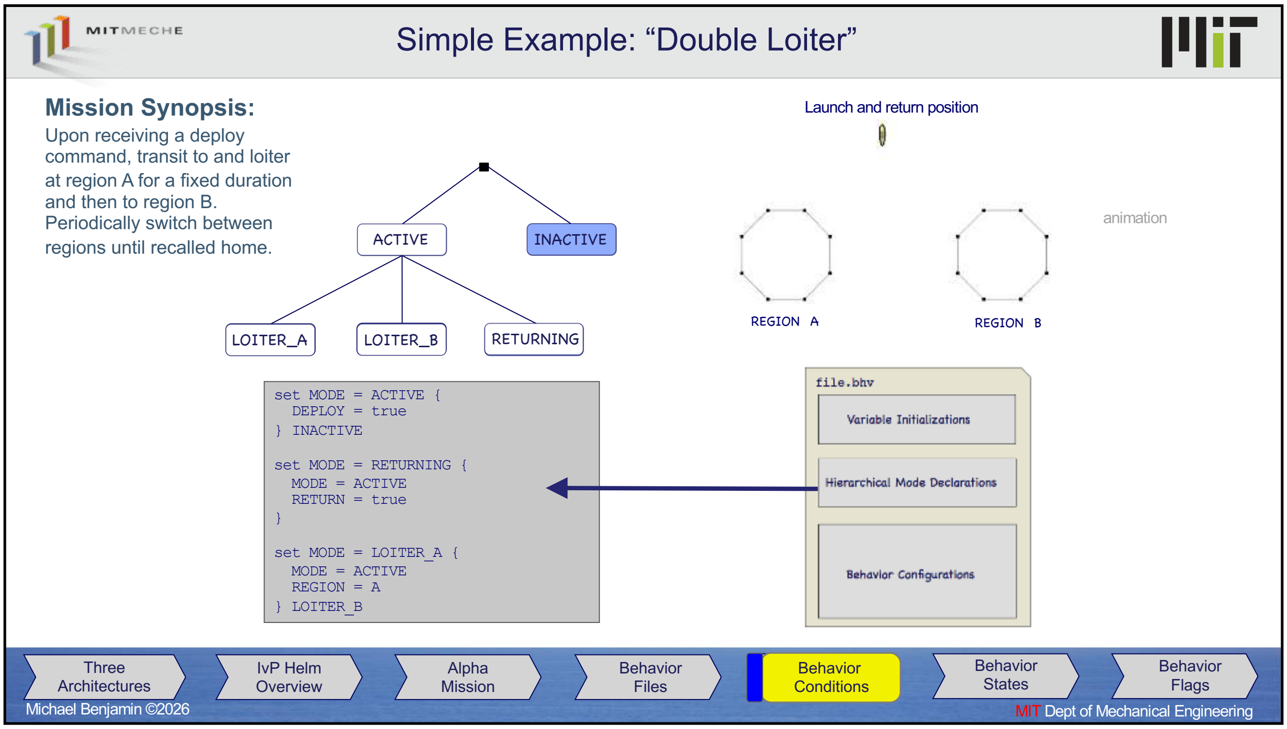

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Simple Example: "Double Loiter"

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

```
set MODE = ACTIVE {
  DEPLOY = true
} INACTIVE

set MODE = RETURNING {
  MODE = ACTIVE
  RETURN = true
}

set MODE = LOITER_A {
  MODE = ACTIVE
  REGION = A
} LOITER_B
```

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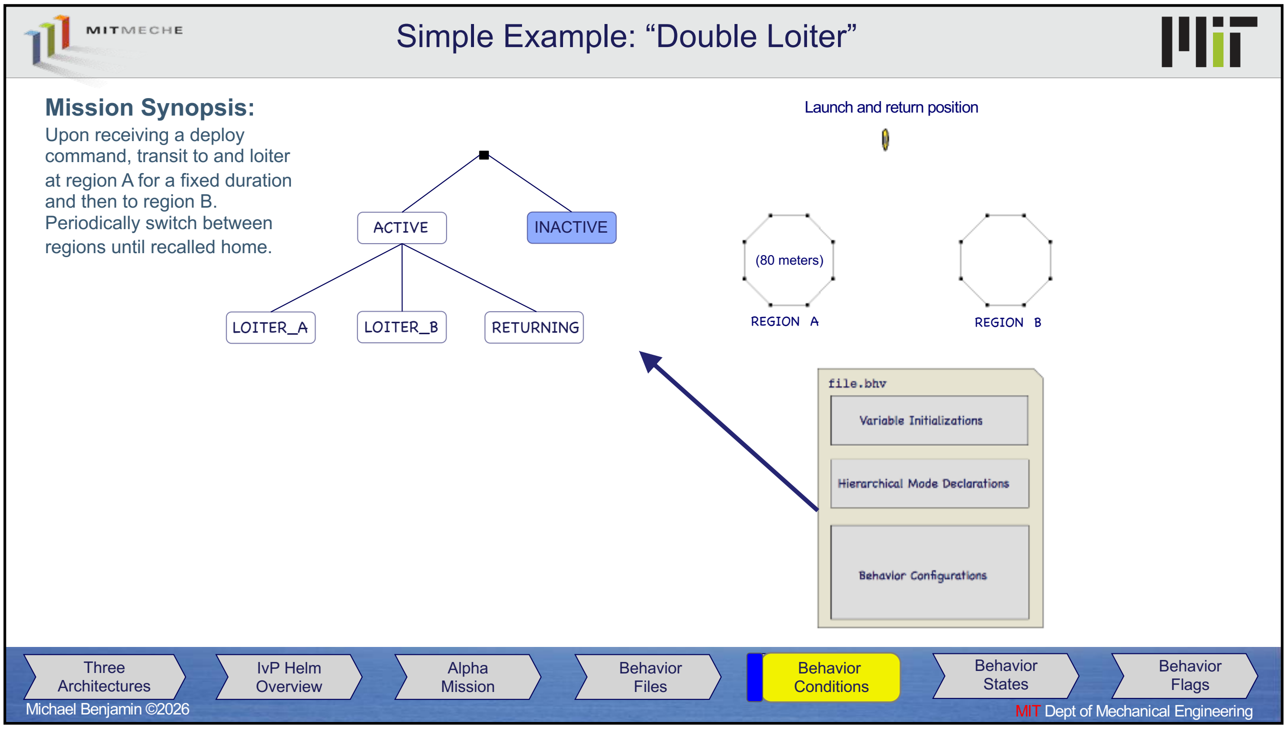

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Simple Example: “Double Loiter”

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

Launch and return position

ACTIVE

INACTIVE

LOITER_A

LOITER_B

RETURNING

(80 meters)

REGION A

REGION B

file.bhv

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Behavior Configurations

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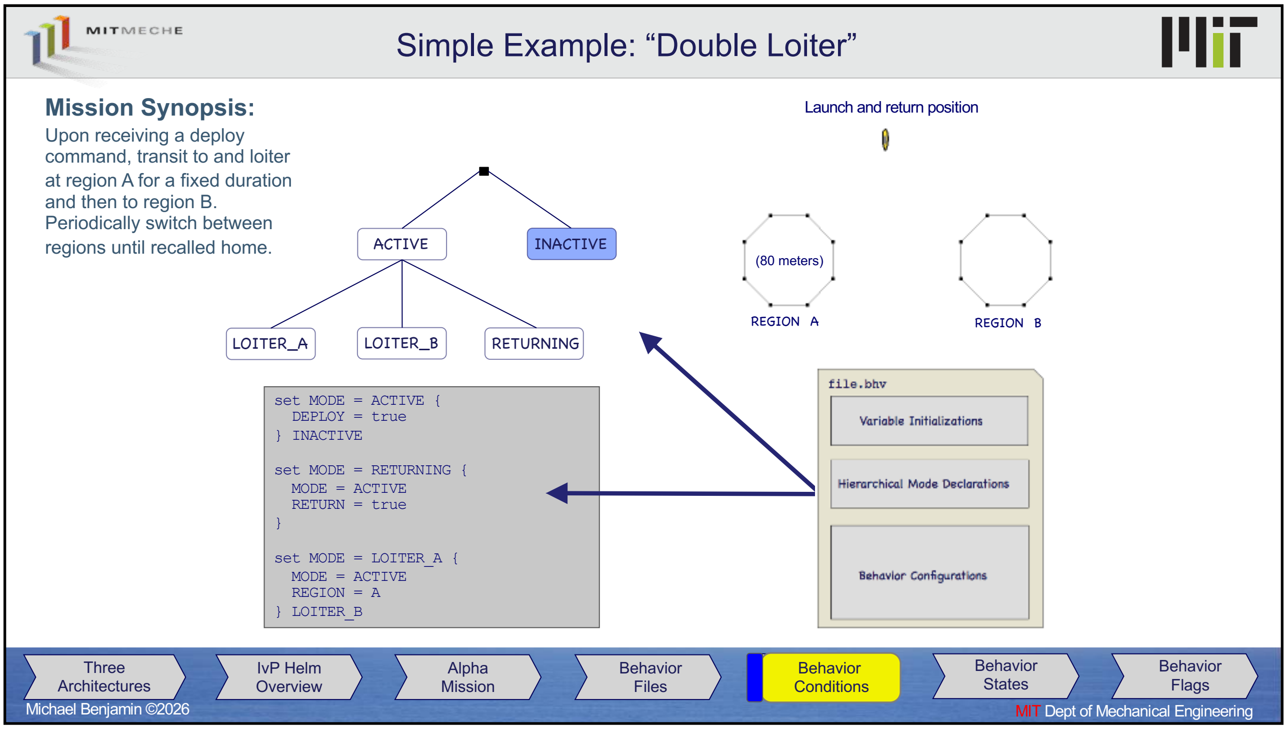

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Simple Example: “Double Loiter”

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

Launch and return position

ACTIVE

INACTIVE

LOITER_A

LOITER_B

RETURNING

(80 meters)

REGION A

REGION B

```
set MODE = ACTIVE {
  DEPLOY = true
} INACTIVE

set MODE = RETURNING {
  MODE = ACTIVE
  RETURN = true
}

set MODE = LOITER_A {
  MODE = ACTIVE
  REGION = A
} LOITER_B
```

file.bhv

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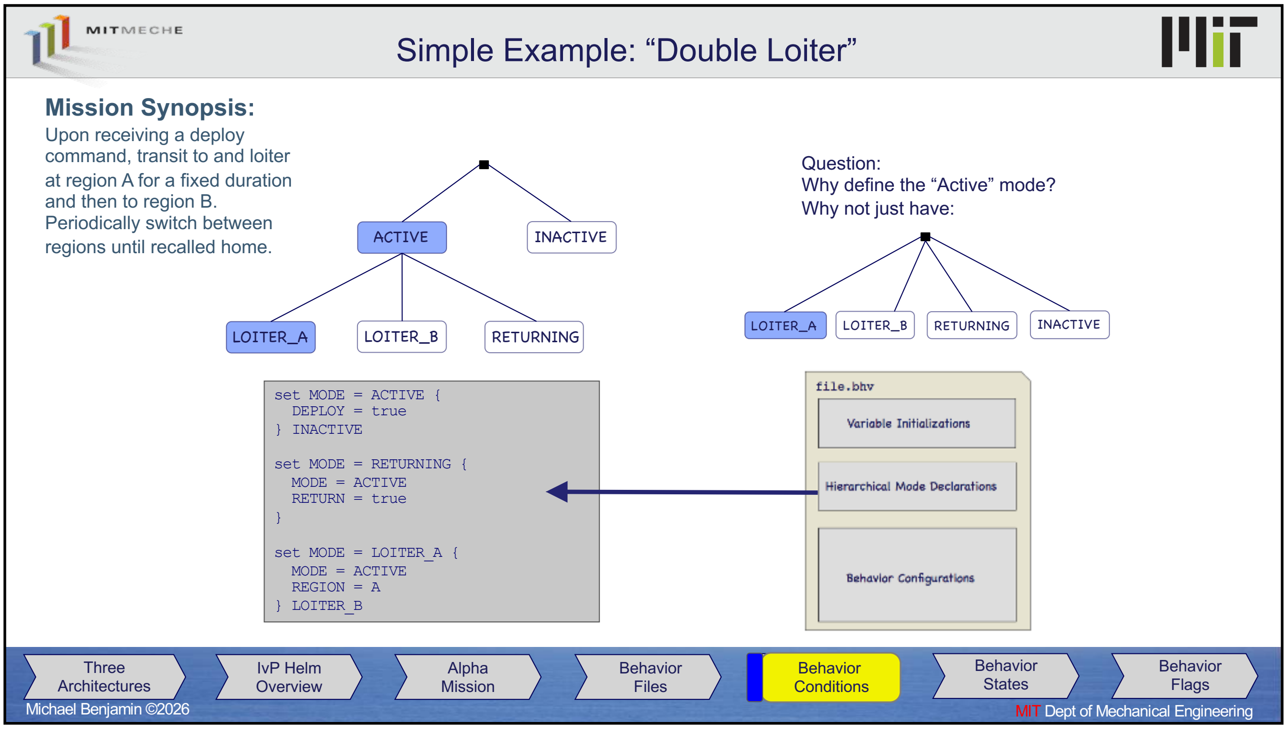

Simple Example: “Double Loiter”

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

Question:
Why define the “Active” mode?
Why not just have:

```
set MODE = ACTIVE {
  DEPLOY = true
} INACTIVE

set MODE = RETURNING {
  MODE = ACTIVE
  RETURN = true
}

set MODE = LOITER_A {
  MODE = ACTIVE
  REGION = A
} LOITER_B
```

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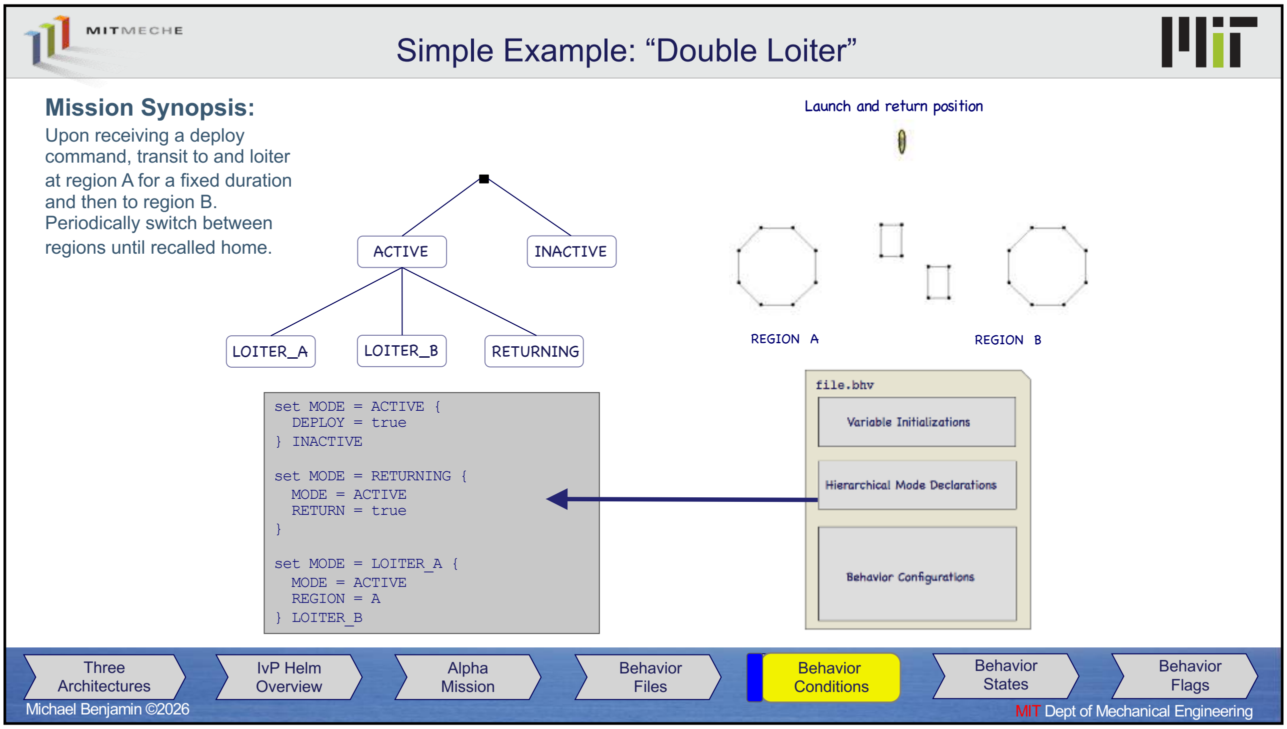

Simple Example: “Double Loiter”

Mission Synopsis:

Upon receiving a deploy command, transit to and loiter at region A for a fixed duration and then to region B. Periodically switch between regions until recalled home.

```
set MODE = ACTIVE {
  DEPLOY = true
} INACTIVE

set MODE = RETURNING {
  MODE = ACTIVE
  RETURN = true
}

set MODE = LOITER_A {
  MODE = ACTIVE
  REGION = A
} LOITER_B
```

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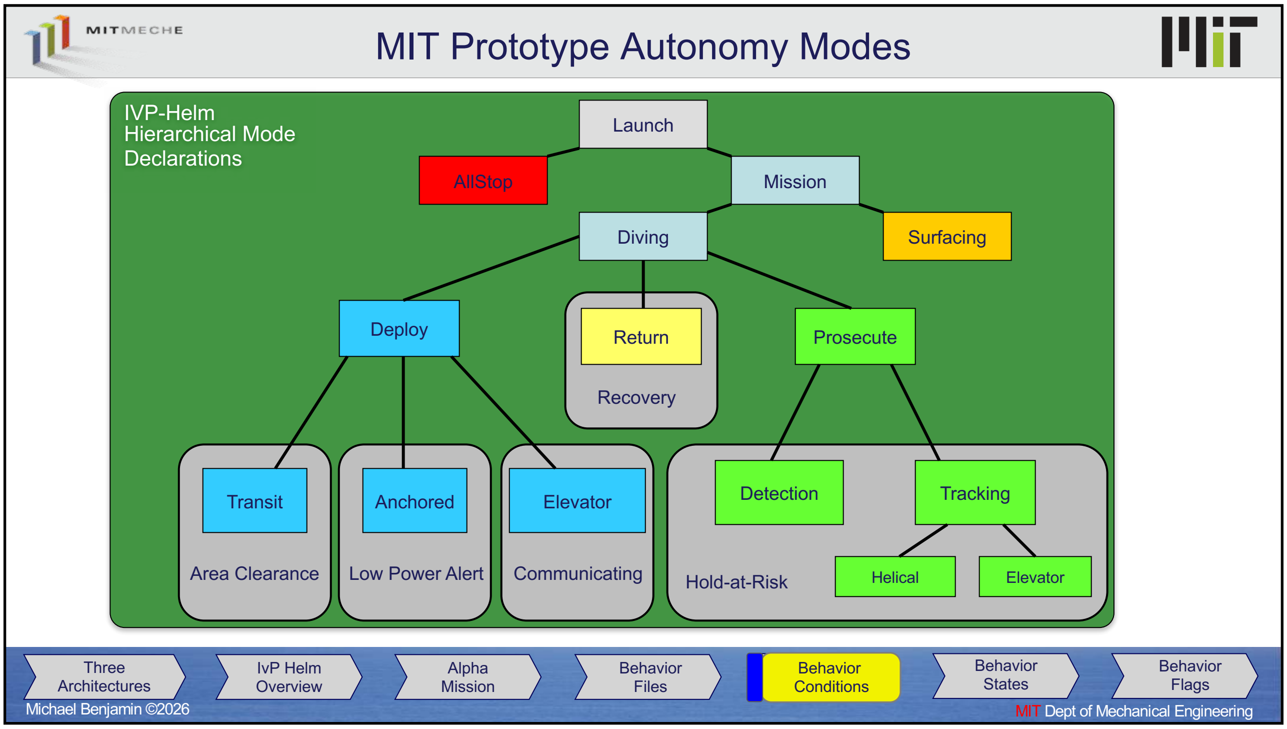

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MIT Prototype Autonomy Modes

IVP-Helm
Hierarchical Mode
Declarations

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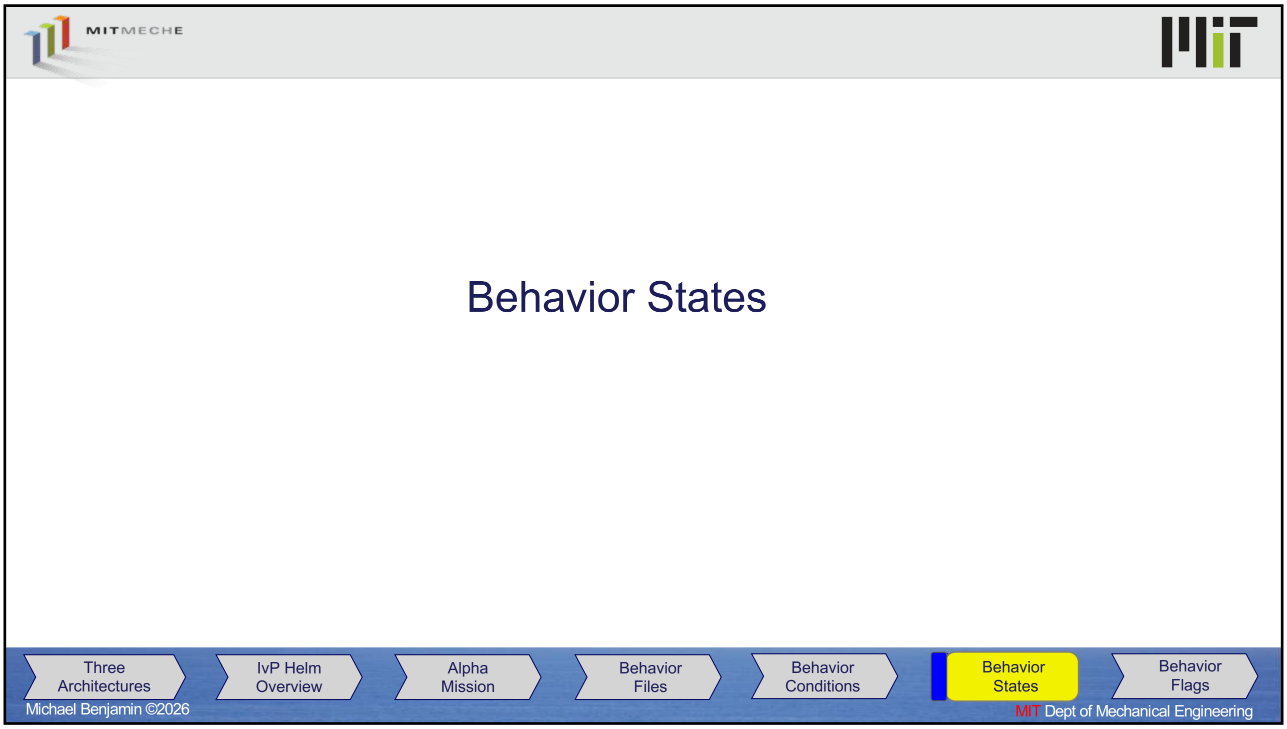

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Behavior States

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Behavior States

Behaviors may be in one of four states:

Idle | Running Active | Completed

The idle state: a behavior has not met its run condition, as defined by the condition parameter.

The running state: a behavior has met its run conditions

The active state: a behavior is running state and is producing an objective function

The completed state: Completion is specific to a behavior, or may be due to a duration timeout defined generally for all behaviors.

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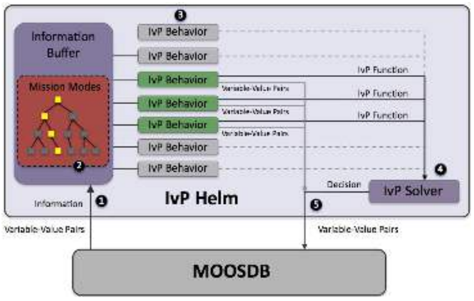
Active vs. Running States

Idle | Running Active | Completed



The running state: behavior has met its run conditions.
The active state: behavior is running and producing an objective function.

The helm's primary job is to produce a helm decision. A behavior is participating in that decision only if it is producing an objective function.

A behavior may participate in the helm decision based on:

(1) The run conditions (mostly dependent on an external decision process)

(2) The behavior's own logic (a local decision based on a more nuanced understanding of the situation).

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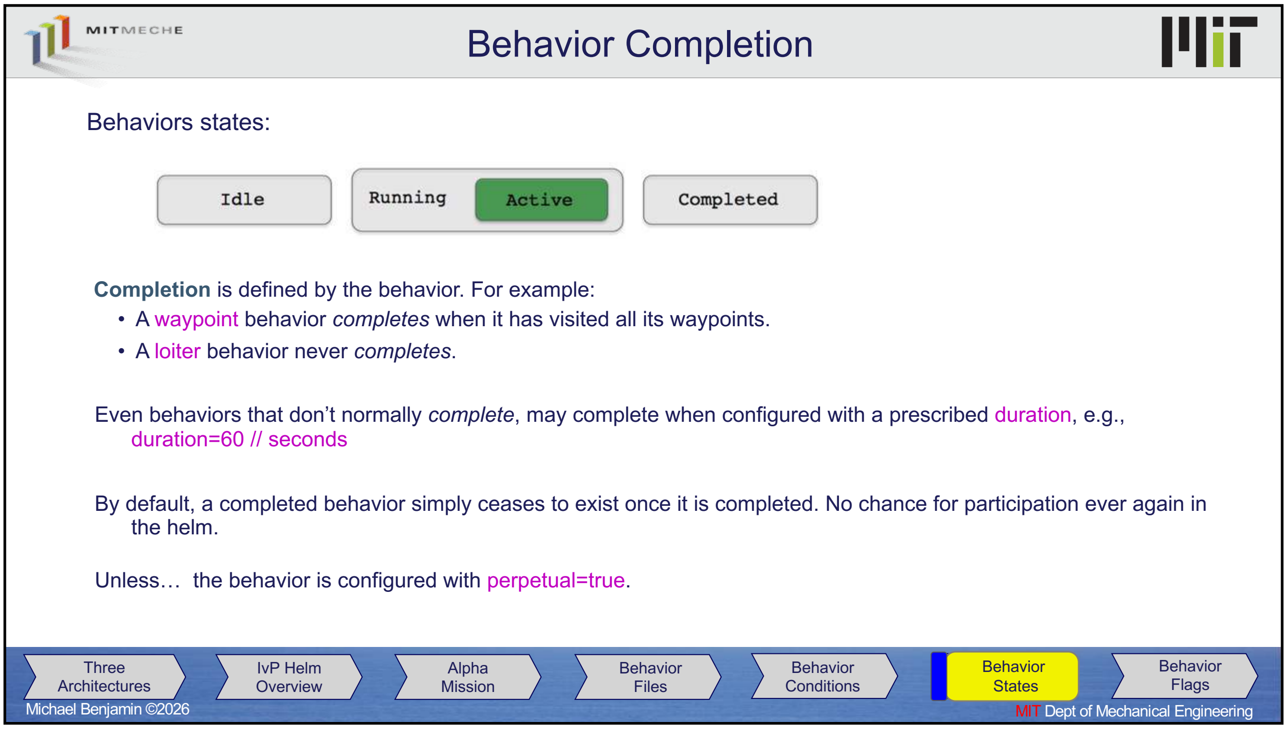

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Behavior Completion

Behaviors states:

Idle | Running Active | Completed

Completion is defined by the behavior. For example:

- A waypoint behavior *completes* when it has visited all its waypoints.
- A loiter behavior never *completes*.

Even behaviors that don't normally *complete*, may complete when configured with a prescribed duration, e.g., duration=60 // seconds

By default, a completed behavior simply ceases to exist once it is completed. No chance for participation ever again in the helm.

Unless… the behavior is configured with perpetual=true.

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Behavior Flags

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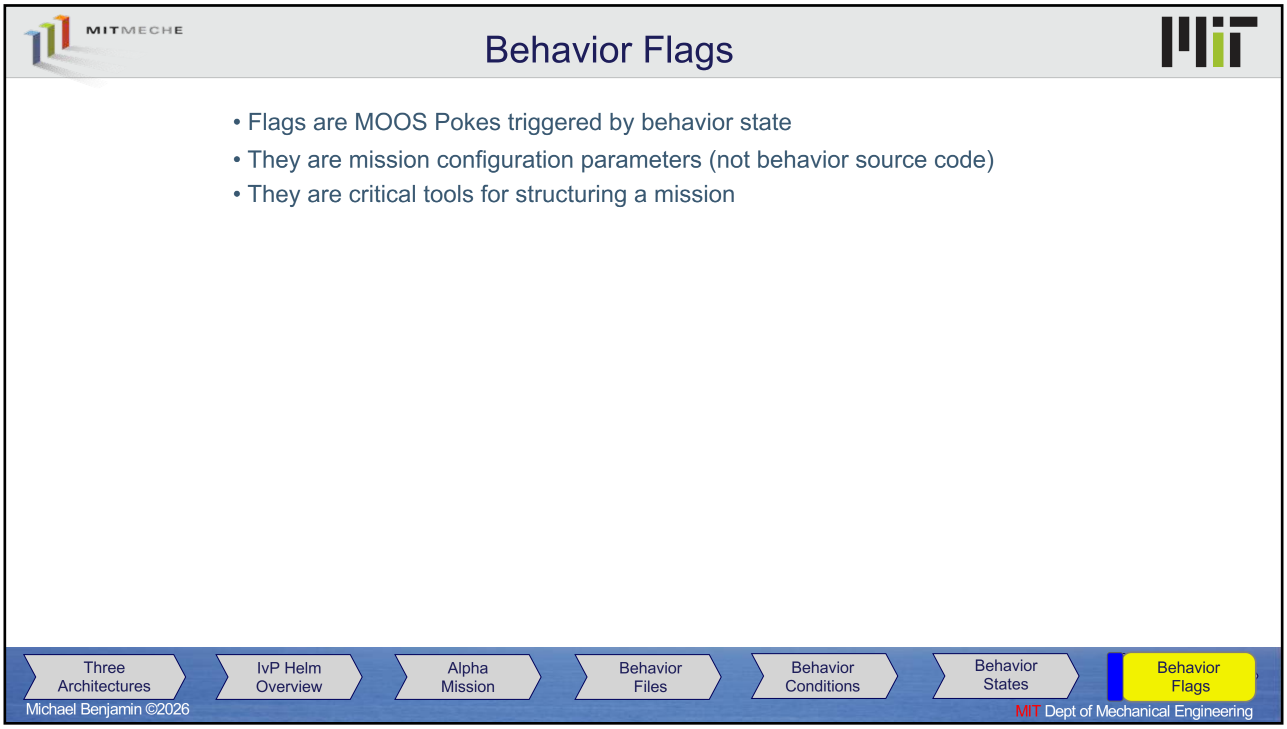

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Behavior Flags

- Flags are MOOS Pokes triggered by behavior state
- They are mission configuration parameters (not behavior source code)
- They are critical tools for structuring a mission

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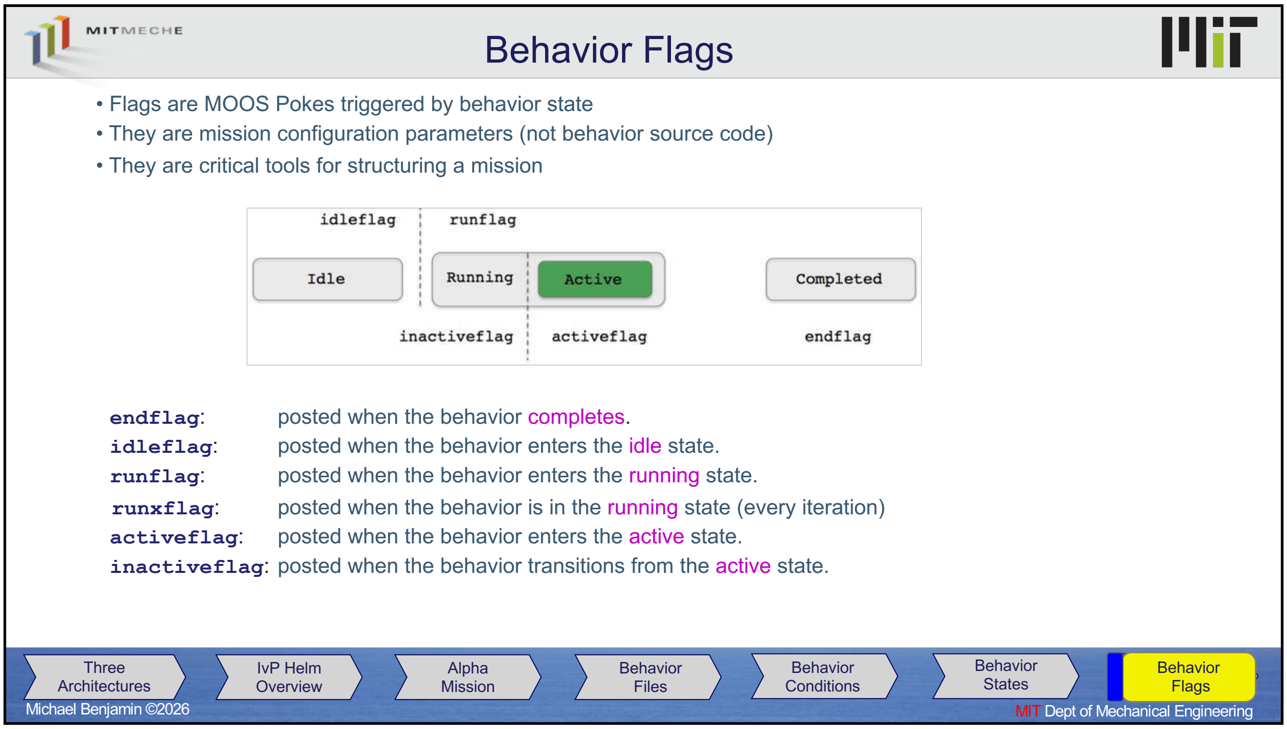

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Behavior Flags

- Flags are MOOS Pokes triggered by behavior state
- They are mission configuration parameters (not behavior source code)
- They are critical tools for structuring a mission

idleflag runflag

Idle | Running | Active | Completed

inactiveflag activeflag endflag

`endflag`: posted when the behavior completes.

`idleflag`: posted when the behavior enters the idle state.

`runflag`: posted when the behavior enters the running state.

`runxflag`: posted when the behavior is in the running state (every iteration)

`activeflag`: posted when the behavior enters the active state.

`inactiveflag`: posted when the behavior transitions from the active state.

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End Flags

- End Flags are posted when a behavior completes
- An endflag may trigger the condition of another behavior
- Alpha mission as an example. The end of the survey behavior triggers the start of the return behavior.

```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
  condition = DEPLOY = true
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

```
Behavior = BHV_Waypoint
{
  name        = waypt_return
  pwt         = 100
  condition   = RETURN = true
  condition   = DEPLOY = true
  endflag     = DEPLOY = false

           speed = 2.0
  capture_radius = 2.0
     slip_radius = 8.0
           point = 0,-2
}
```

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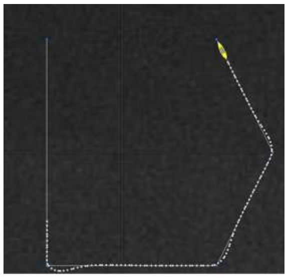
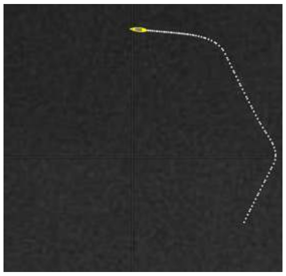
Alpha Mission End Flag Example



1 survey waypoints completes

2 endflags posted
RETURN=true

3 return waypoint behavior begins



```
Behavior = BHV_Waypoint
{
  name      = waypt_survey
  pwt       = 100
  condition = RETURN = false
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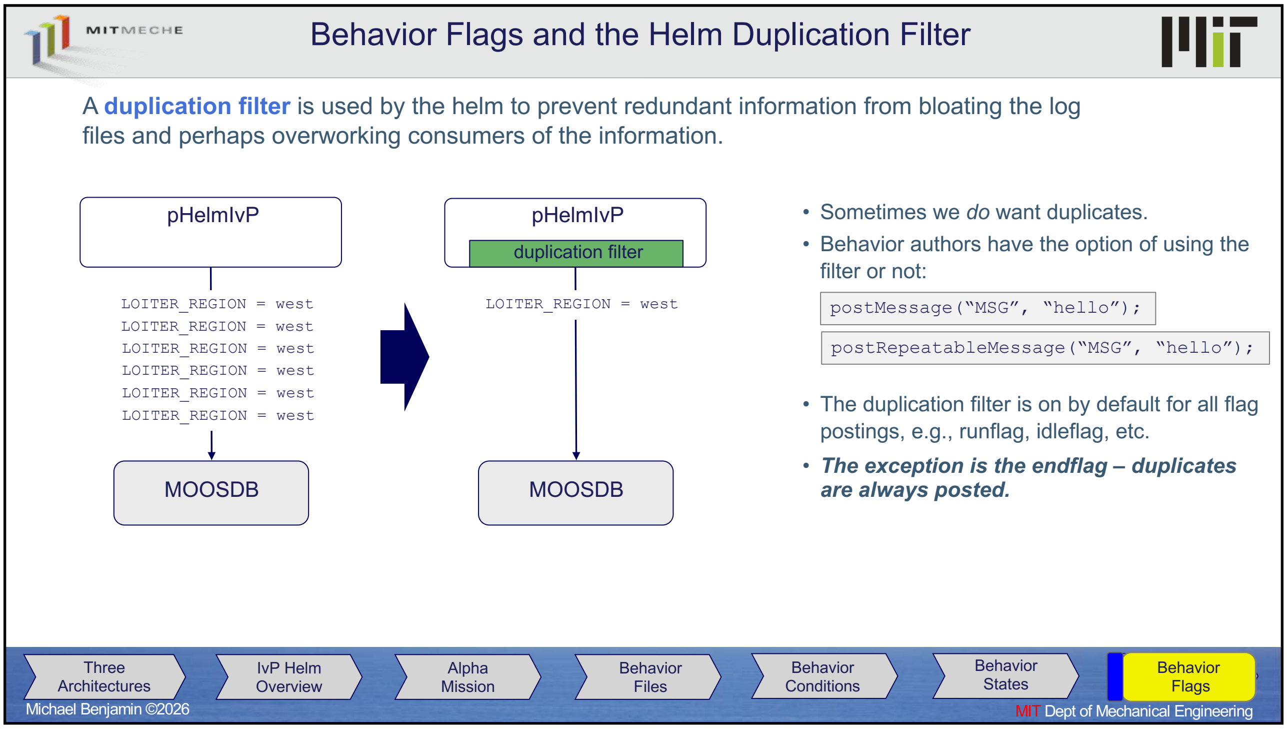
  endflag   = RETURN = true

           speed = 4
  capture_radius = 5.0
     slip_radius = 15.0
         polygon = 60,-40:60,-160:150,-160:180,-100:150,-40
         repeat  = 1
}
```

```
Behavior = BHV_Waypoint
{
  name        = waypt_return
  pwt         = 100
  condition   = RETURN = true
  condition   = DEPLOY = true
  endflag     = DEPLOY = false

           speed = 2.0
  capture_radius = 2.0
     slip_radius = 8.0
           point = 0,-2
}
```



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Behavior Flags and the Helm Duplication Filter

A **duplication filter** is used by the helm to prevent redundant information from bloating the log files and perhaps overworking consumers of the information.

pHelmIvP

```
LOITER_REGION = west
LOITER_REGION = west
LOITER_REGION = west
LOITER_REGION = west
LOITER_REGION = west
LOITER_REGION = west
```

MOOSDB

pHelmIvP

duplication filter

```
LOITER_REGION = west
```

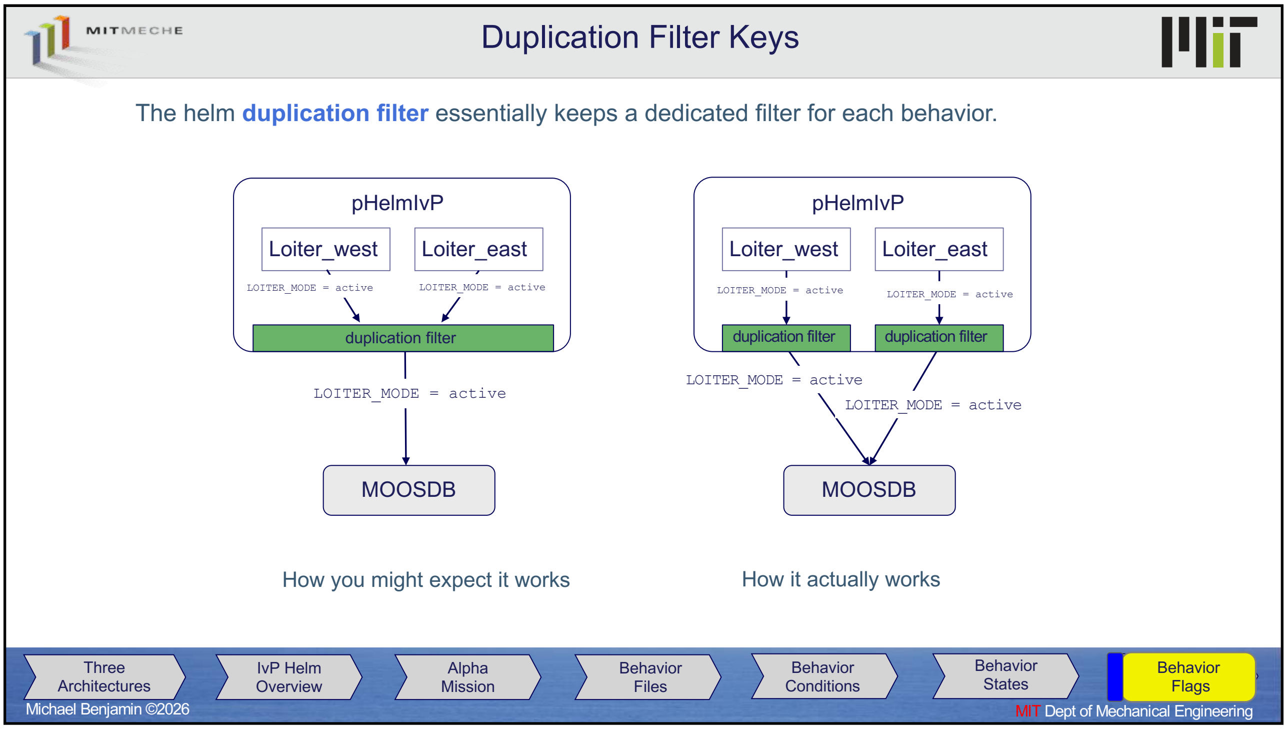
MOOSDB

- Sometimes we *do* want duplicates.
- Behavior authors have the option of using the filter or not:

```
postMessage("MSG", "hello");
```

```
postRepeatableMessage("MSG", "hello");
```

- The duplication filter is on by default for all flag postings, e.g., runflag, idleflag, etc.
- ***The exception is the endflag – duplicates are always posted.***



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Duplication Filter Keys

The helm **duplication filter** essentially keeps a dedicated filter for each behavior.

pHelmIvP

Loiter_west

Loiter_east

```
LOITER_MODE = active
LOITER_MODE = active
```

duplication filter

```
LOITER_MODE = active
```

MOOSDB

How you might expect it works

pHelmIvP

Loiter_west

Loiter_east

```
LOITER_MODE = active
LOITER_MODE = active
```

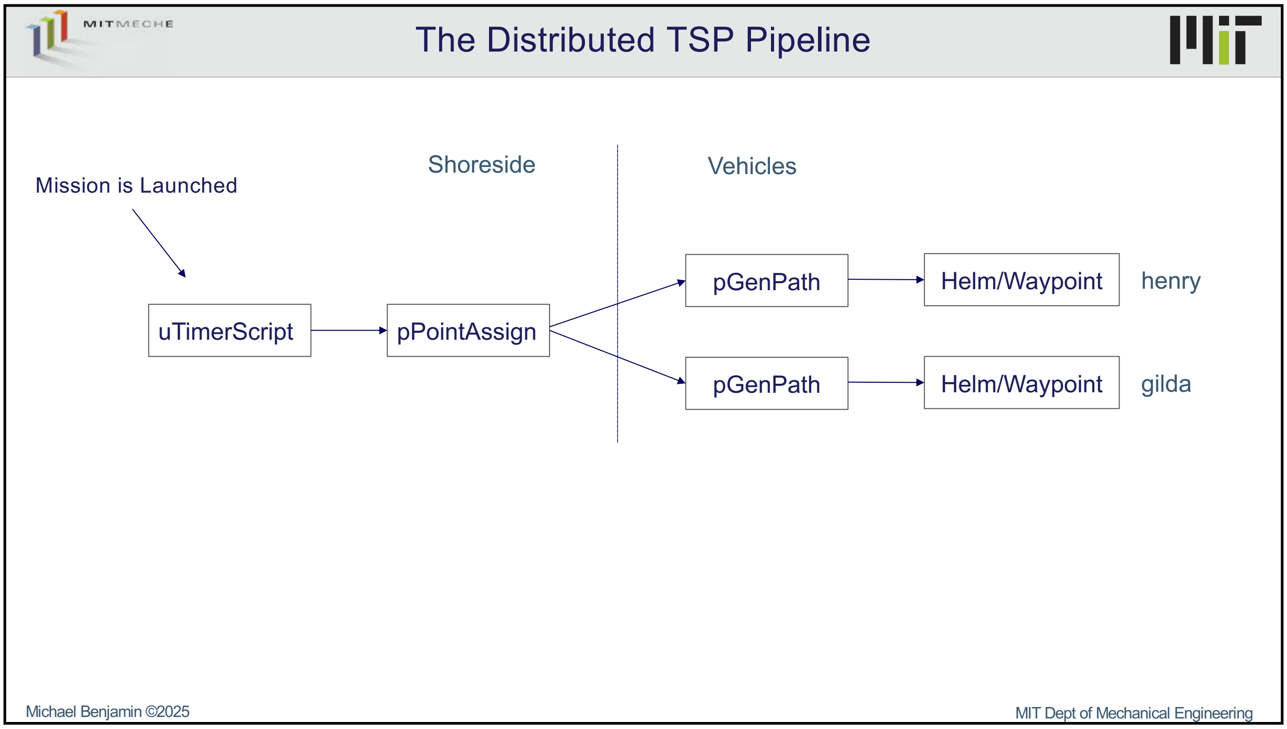
duplication filter

duplication filter

```
LOITER_MODE = active
LOITER_MODE = active
```

MOOSDB

How it actually works



The Distributed TSP Pipeline

Shoreside

Vehicles

Mission is Launched

uTimerScript

pPointAssign

pGenPath

Helm/Waypoint

henry

pGenPath

Helm/Waypoint

gilda

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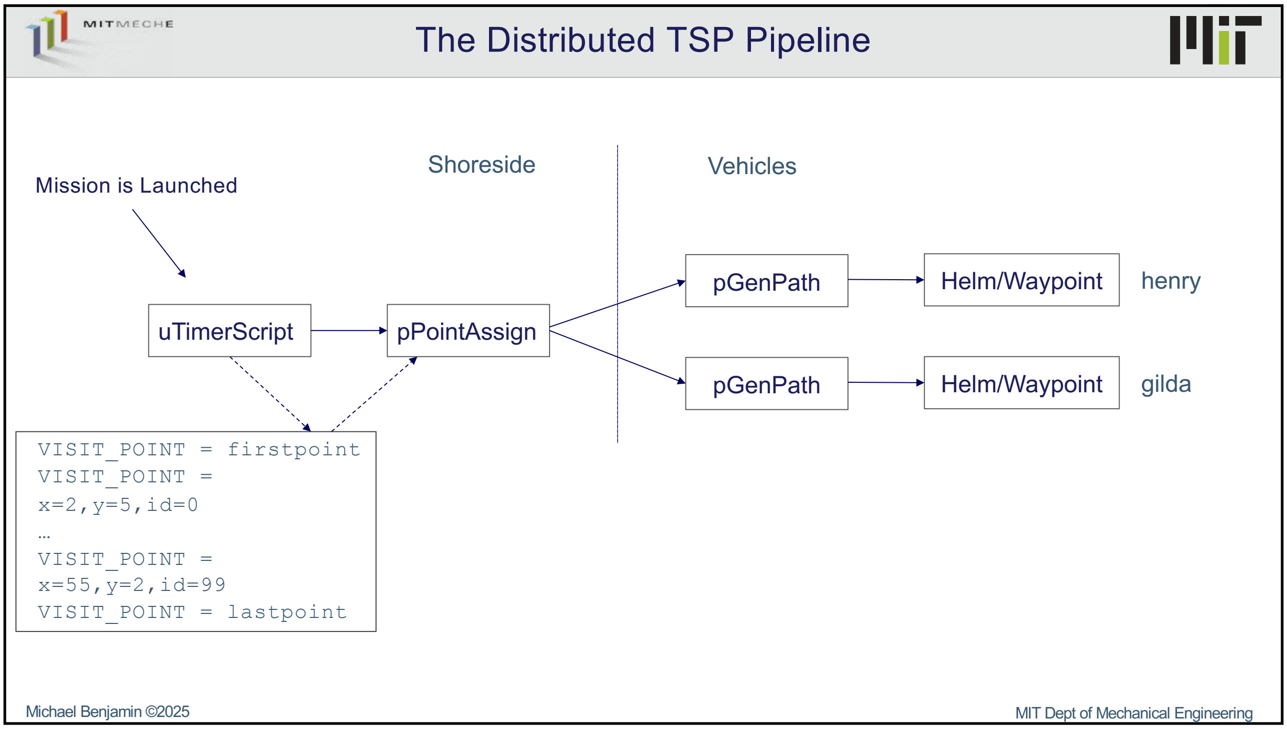

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Helm/Waypoint

gilda

```
VISIT_POINT = firstpoint
VISIT_POINT =
x=2,y=5,id=0
…
VISIT_POINT =
x=55,y=2,id=99
VISIT_POINT = lastpoint
```

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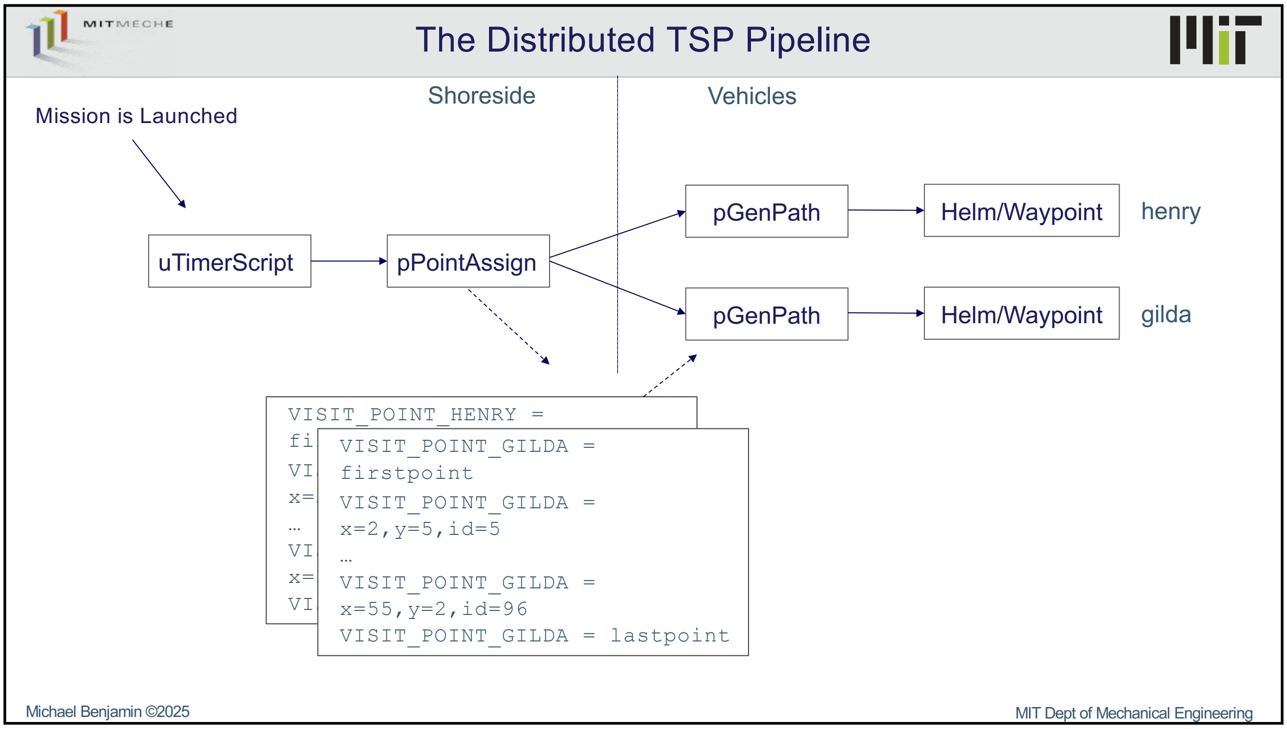

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gilda

```
VISIT_POINT_HENRY =
fi
VI
x=
…
VI
x=
VI
```

```
VISIT_POINT_GILDA =
firstpoint
VISIT_POINT_GILDA =
x=2,y=5,id=5
…
VISIT_POINT_GILDA =
x=55,y=2,id=96
VISIT_POINT_GILDA = lastpoint
```

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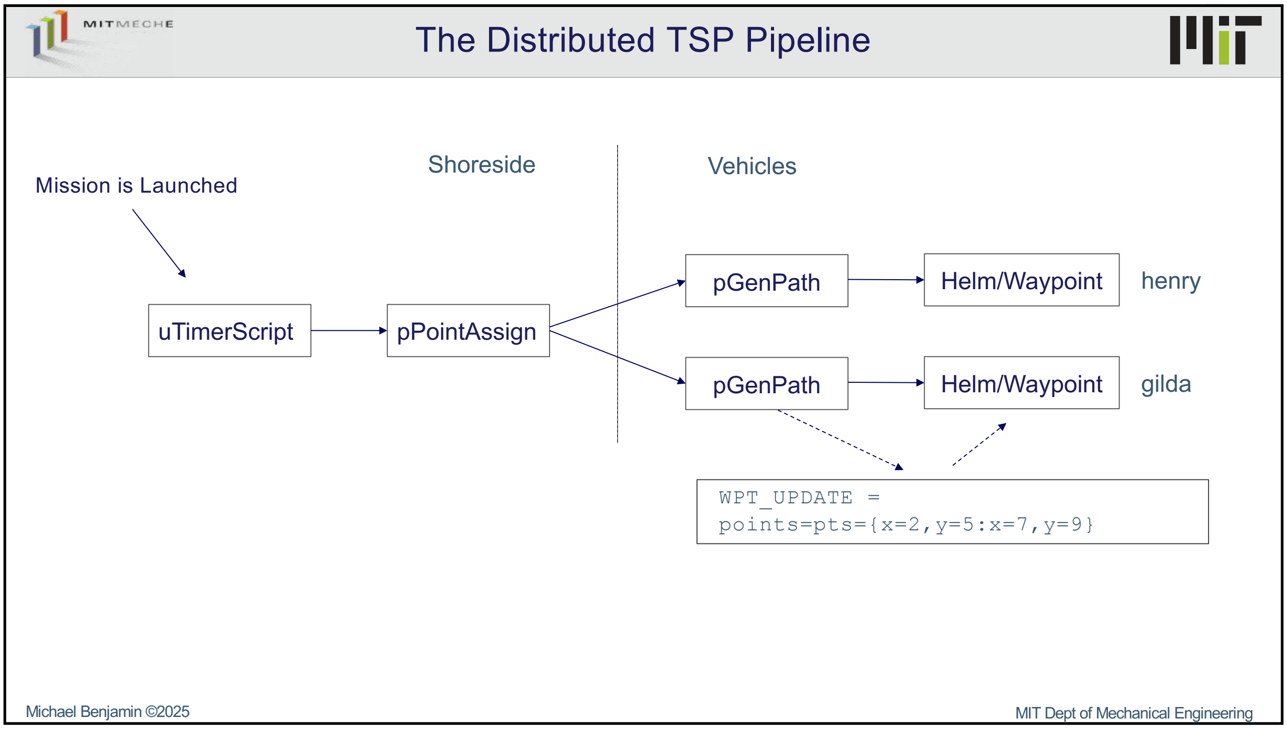

The Distributed TSP Pipeline

Mission is Launched

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Vehicles

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pPointAssign

pGenPath

Helm/Waypoint

henry

pGenPath

Helm/Waypoint

gilda

```
WPT_UPDATE =
points=pts={x=2,y=5:x=7,y=9}
```

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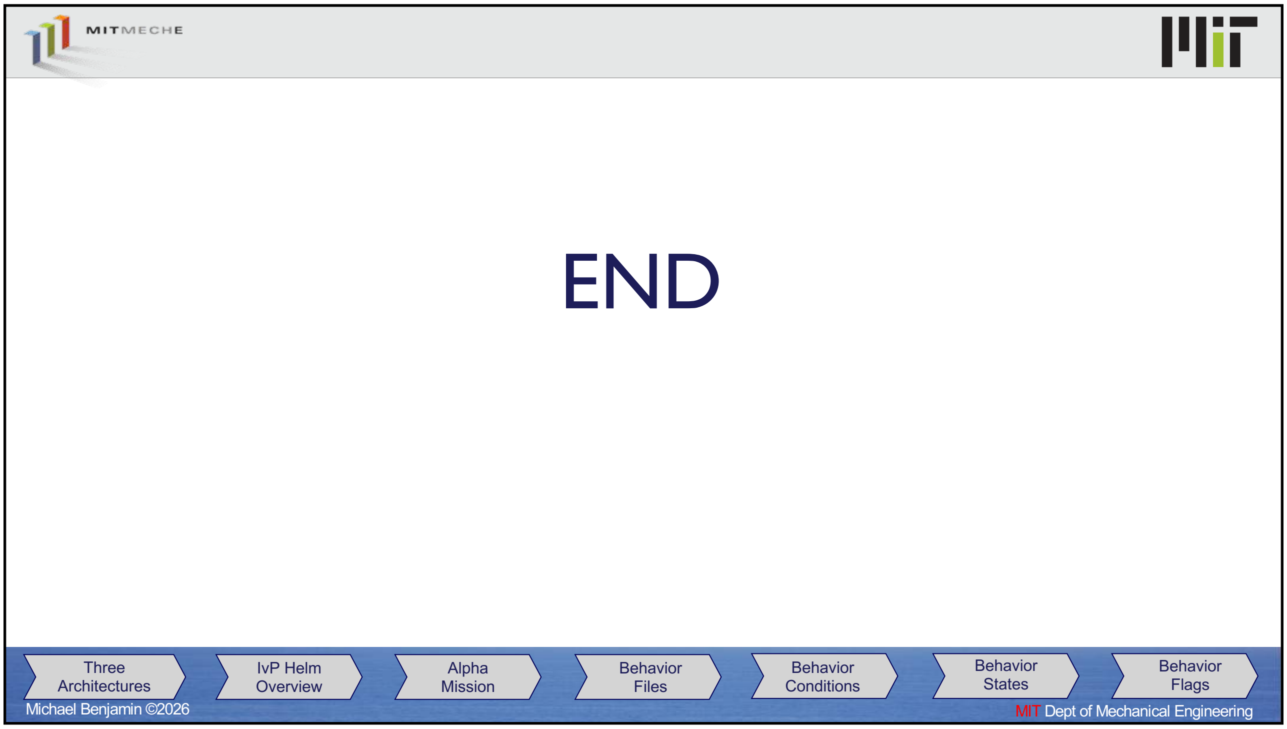

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END

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