



Tree's Company

Systemic AI Design in **JUST CAUSE 3**

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Game Designer, Avalanche Studios

@RobotMeyer

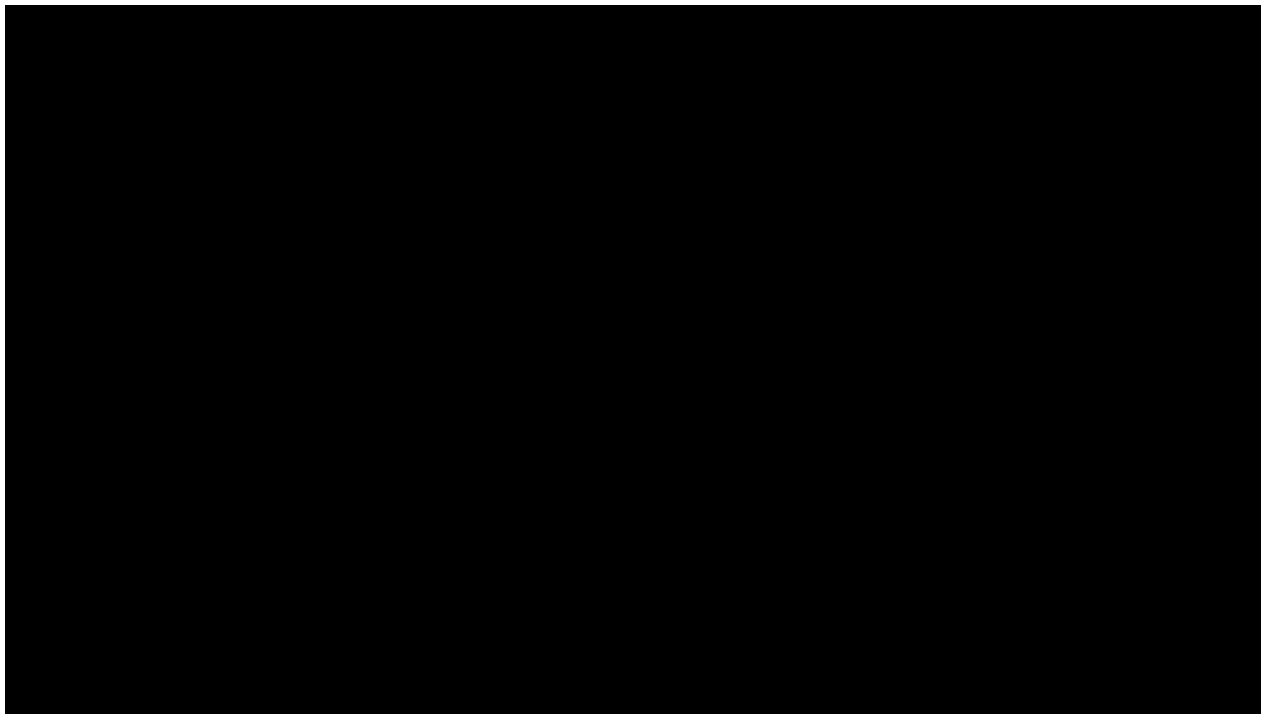


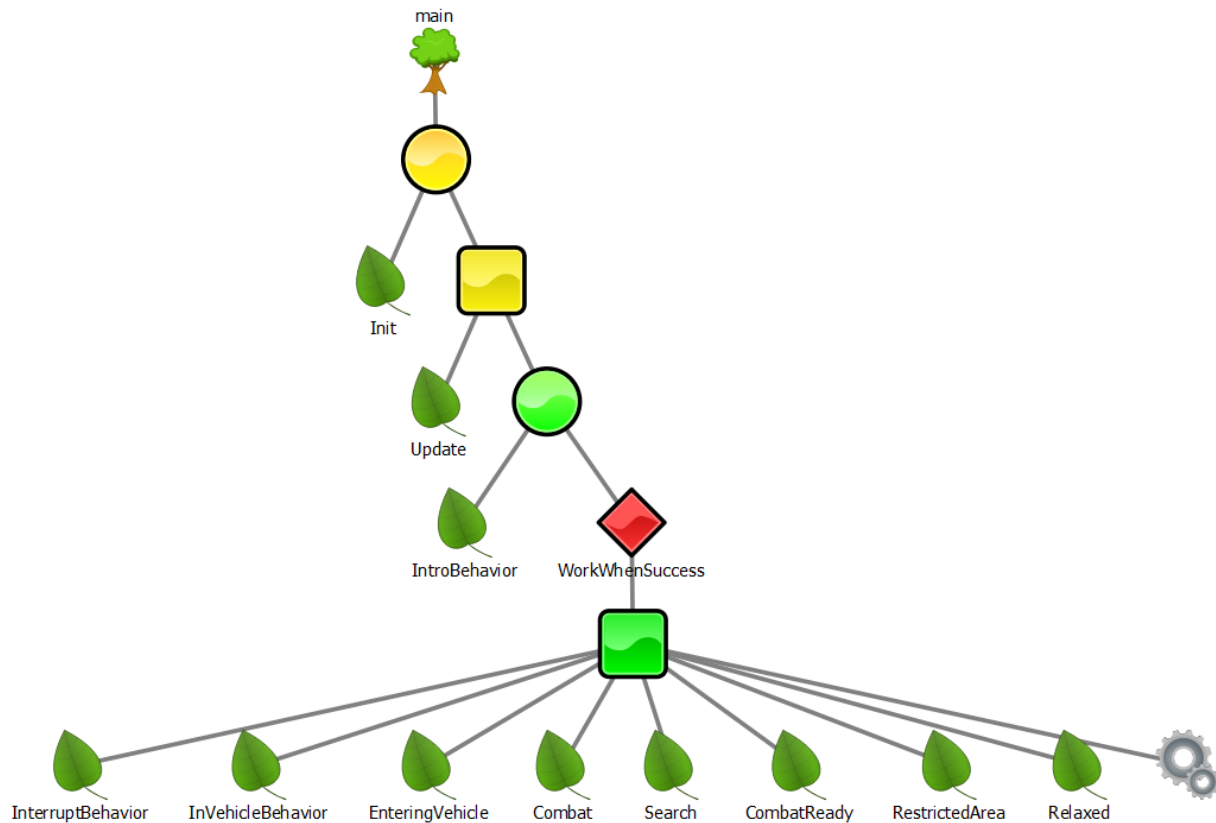
About Me

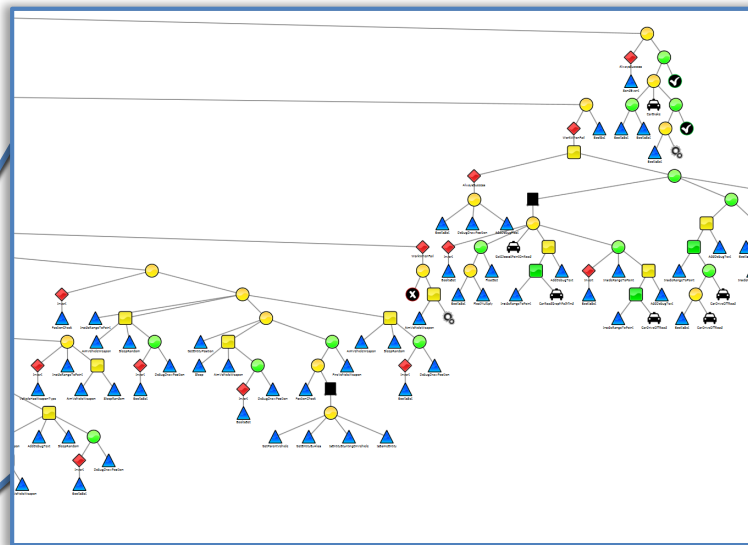
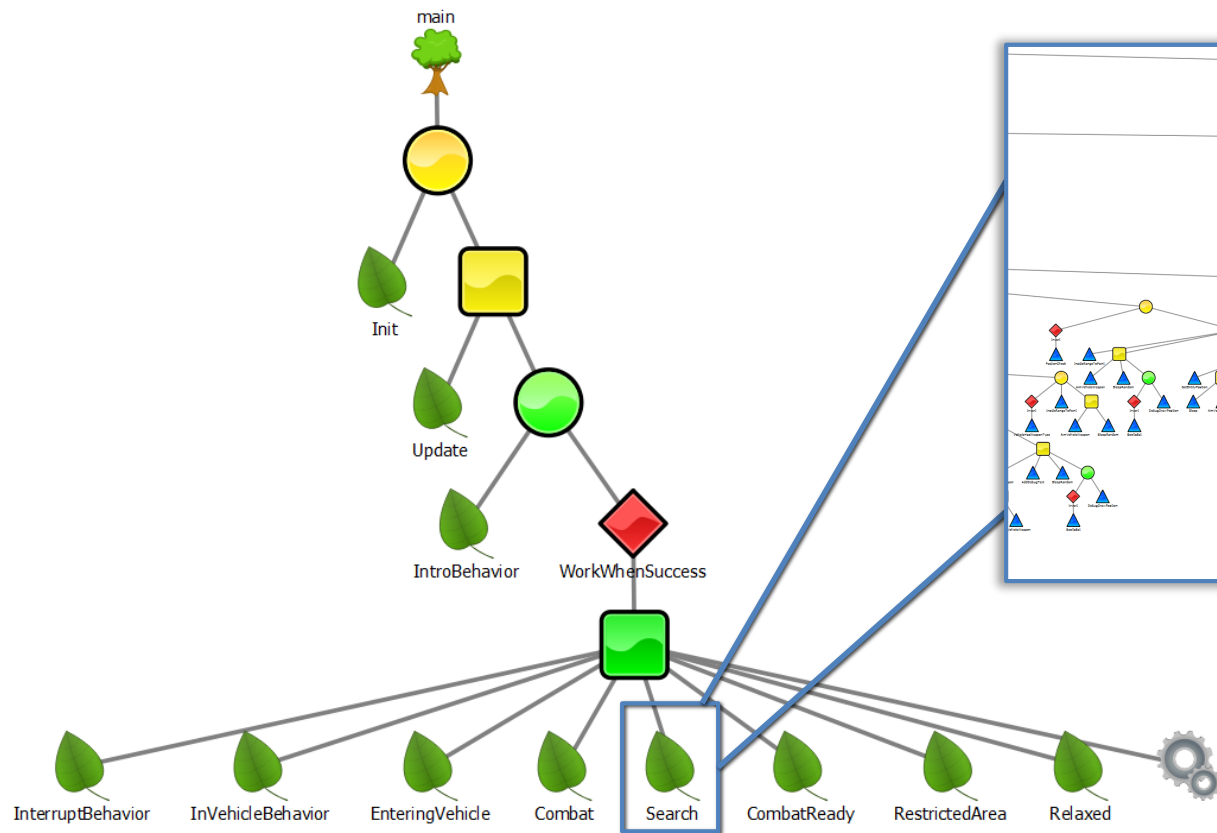




What is AI in Just Cause 3?











The Problem

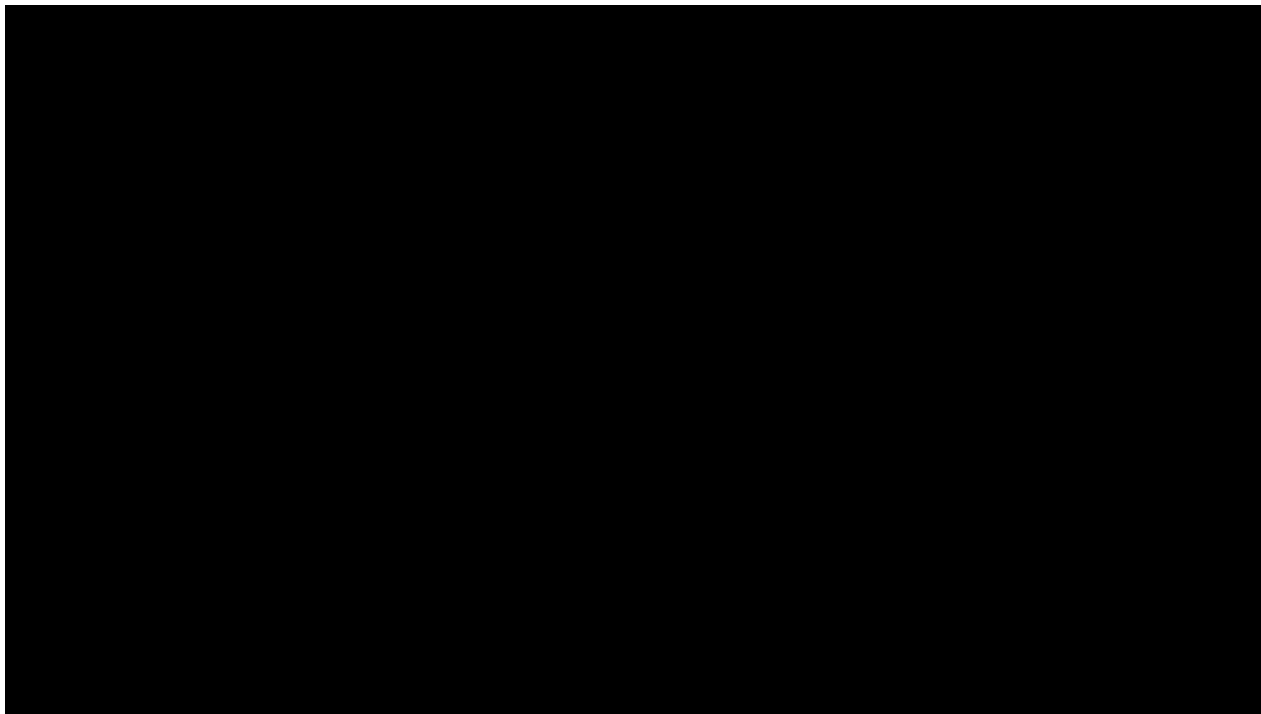
Behavior Trees and our other AI systems are:

- Bottom-up, each individual agent **makes their own decisions**.
- Originally built for **robust and emergent** systemic behaviors, **not** scripted moments.
- Trees are complex enough that **only AI Designers** can work in them directly.





But...





The Goal



&





Supporting “Content Designers...”

Create an AI technical design and interface that empowered:

- mission designers to craft **objective sequences**
- world designers to create **unique moments** in open world locations
- encounter designers to create **narrative** open-world **content**





The Division of Labor

AI Designers:

Script behavior trees

Tune utility functions

Create AI templates & packages

Technical Design side of AI

Content Designers:

Level Design of missions,
locations, encounters, etc.

Place the characters in world

Fill out exposed “arguments” on
character spawners

Call Tree Studio

File Edit Debug Compile Performer Help

localhost

rome_simple_soldier.bts*

Nodes

Filter

- Tree
- Parallel
- Fail
- CallForReinforcements
- CheckForSurvivalThreat
- CheckForThreat_Grenade
- CheckForThreat_VehicleBulletDamage
- CheckIfCarHasNoValidLivingDriver
- Combat
- CombatFireSnip
- Lookup
- Dynamic Selector
- Work
- CallForReinforcementsMoveFocus
- CheckForThreat
- CheckForThreat_InformDanger
- CheckForThreat_WeaponFire
- CheckIfFireAllowed
- CombatCheckShouldReactToExplosion
- CombatGenera
- Sequence
- Variables
- AreThereAlliesInRange
- CheckForThreat_BulletImpact
- CheckForThreat_OncomingVehicle
- CheckForVehicleCharacterActivity
- CheckShouldDisengageInVehicle
- CombatFireMachineGun
- CombatHoldCc
- Selector
- Succeed
- AuthCardrivingIfOnBrokenBridgeBehavior
- CheckForBroadcastedInformDanger
- CheckForThreat_Explosion
- CheckForThreat_OthersDamaged
- CheckFoundVehicleInsideAOOIsValid
- CheckShouldGetInVehicleToPursueTarget
- CombatFireShotgun
- CombatOperat

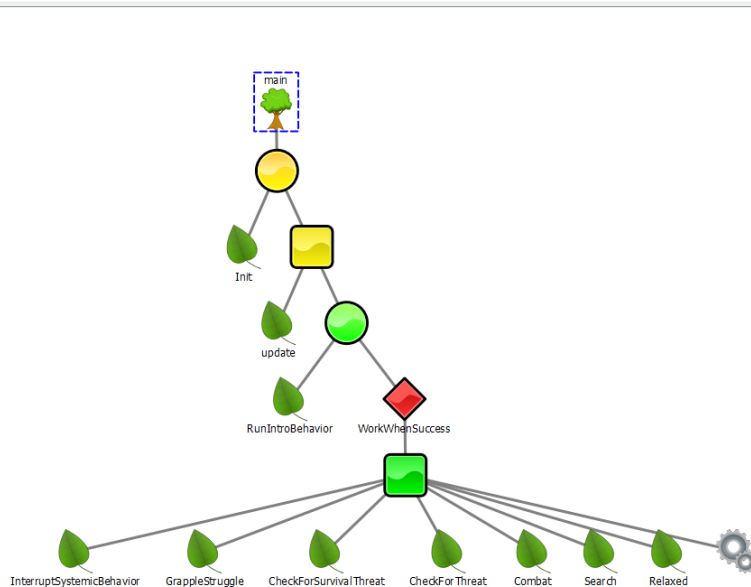
III

No documentation available.

Properties

Name main Add argument

Name	Type
AOO	entity_handle
AlwaysFinishIntroBehavior	bool
IntroBehavior	entity_handle
IdleBehavior	entity_handle
CarPassengerBehavior	entity_handle
InterruptBehavior	entity_handle
Event_RunInterruptBehavior	eventreceive
Event_ResumeSystemicBehavior	eventreceive
ExternalTarget	entity_handle
ExternalTargetAlias	alias
ExternalTargetLock	bool
ExternalTargetLockUnlockEvent	eventreceive
IsAmbientTraffic	bool
Staged_CA_Behavior	entity_handle
ExternalTargetSelectBehavior	entity_handle
MissionSpecificAltCombatPostNF	entity_handle

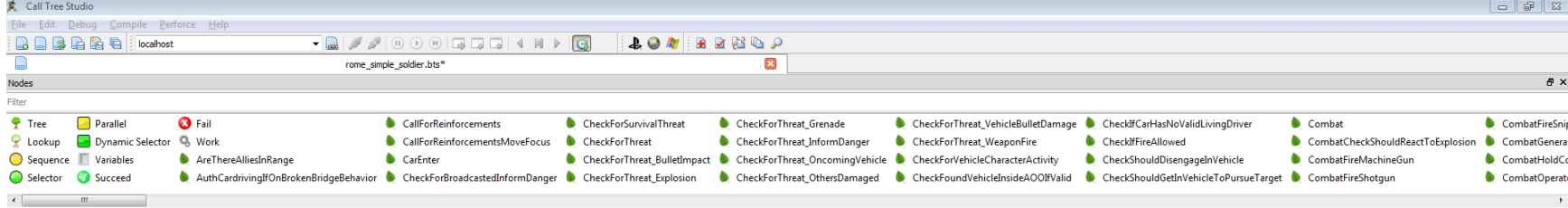


AI Designers

Global Variables

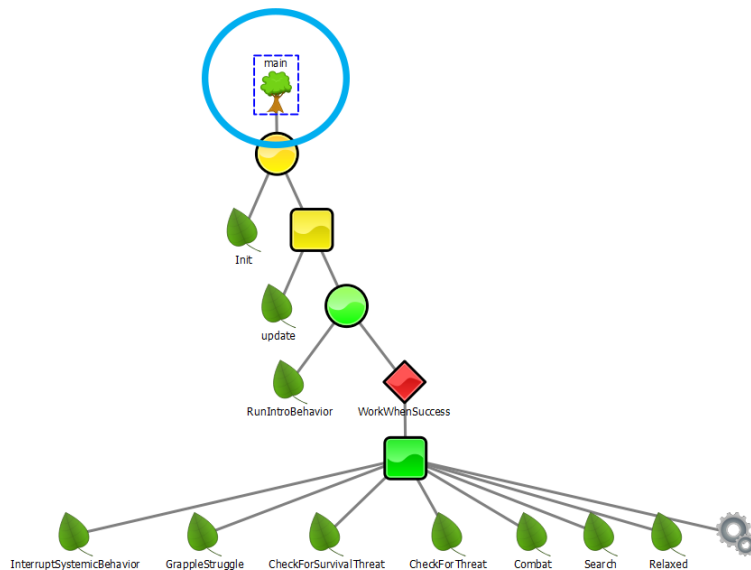
Add variable

Name	Type	Value
DistanceToTarget	float	0.0000
Executor	entity_handle	0
ExecutorPosition	vector3	<0, 0, 0>
ExecutorSpeed	float	0.0000
ExecutorVehicle	entity_handle	0
ExecutorVehicleSeat	int32	0
FireWeaponBehavior	entity_handle	0
GraphSetExternalBehavior	entity_handle	0
InternalAOO	entity_handle	0
InternalExternalTarget	entity_handle	0
IsDrivingVehicle	bool	
IsExitingVehicle	bool	
IsInIntroBehavior	bool	
IsMovingToVehicle	bool	
IsSearching	bool	
IsUsingMountedGun	bool	
IsVehicleGunner	bool	
IsVehiclePassenger	bool	
MoodRank	int32	0
Player	entity_handle	0
RebllnVehicleHasInvestigatedExplo	bool	
ResumeSystemicBehavior	bool	
RunInterruptBehavior	bool	
SeesTarget	bool	
ShouldDriveCar	bool	
ShouldInvestigate	bool	
ShouldRespondToPlayerInRestrictes	bool	
ShouldUseMountedGun	bool	
SpawnedInGroundVehicle	bool	
StartPosition	vector3	<0, 0, 0>
Target	entity_handle	0
TargetAlive	bool	
TargetFP	int32	0
TargetFPPosition	vector3	<0, 0, 0>
TargetPosition	vector3	<0, 0, 0>



No documentation available.

Properties		
Name	Type	Add argument
AOO	entity_handle	☐
AlwaysFinishIntroBehavior	bool	☐
IntroBehavior	entity_handle	☐
IdleBehavior	entity_handle	☐
CarPassengerBehavior	entity_handle	☐
InterruptBehavior	entity_handle	☐
Event_RunInterruptBehavior	eventreceive	☐
Event_ResumeSystemicBehavior	eventreceive	☐
ExternalTarget	entity_handle	☐
ExternalTargetAlias	alias	☐
ExternalTargetLock	bool	☐
ExternalTargetLockUnlockEvent	eventreceive	☐
IsAmbientTraffic	bool	☐
Staged_CA_Behavior	entity_handle	☐
ExternalTargetSelectBehavior	entity_handle	☐
MissionSpecificAltCombatPostNF	entity_handle	☐

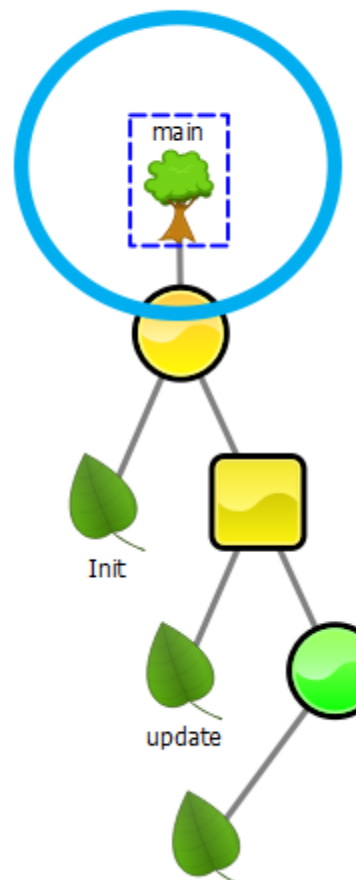


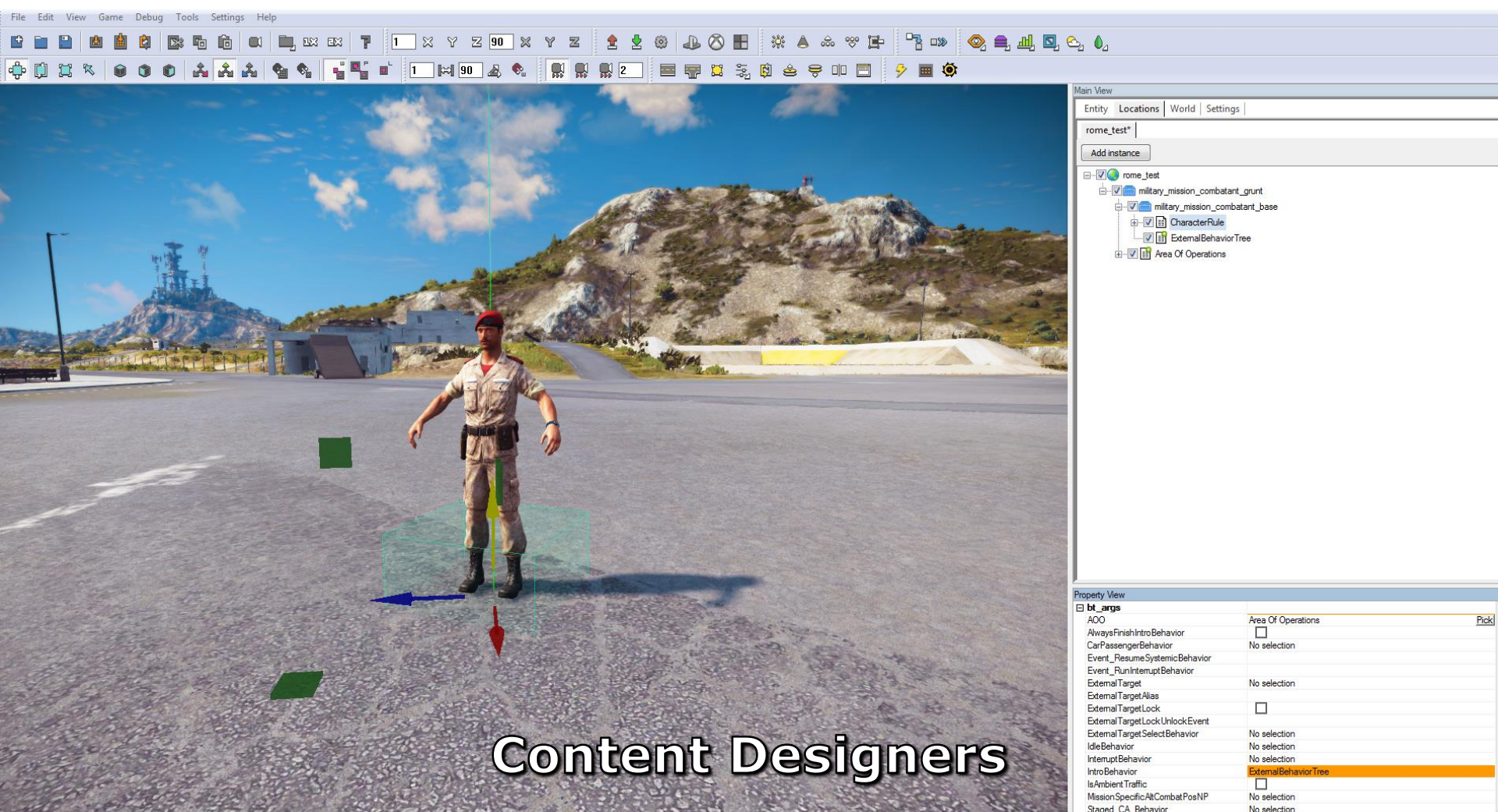
AI Designers

Global Variables			
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Executor	entity_handle	0	☐
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ExecutorVehicle	entity_handle	0	☐
ExecutorVehicleSeat	int32	0	☐
FireWeaponBehavior	entity_handle	0	☐
GraphSetExternalBehavior	entity_handle	0	☐
InternalAOO	entity_handle	0	☐
InternalExternalTarget	entity_handle	0	☐
IsDrivingVehicle	bool	☐	☐
IsExitingVehicle	bool	☐	☐
IsInIntroBehavior	bool	☐	☐
IsMovingToVehicle	bool	☐	☐
IsSearching	bool	☐	☐
IsUsingMountedGun	bool	☐	☐
IsVehicleGunner	bool	☐	☐
IsVehiclePassenger	bool	☐	☐
MoodRank	int32	0	☐
Player	entity_handle	0	☐
RebelsInVehicleHasInvestigatedExplo	bool	☐	☐
ResumeSystemicBehavior	bool	☐	☐
RunInterruptBehavior	bool	☐	☐
SeesTarget	bool	☐	☐
ShouldDriveCar	bool	☐	☐
ShouldInvestigate	bool	☐	☐
ShouldRespondToPlayerInRestrict	bool	☐	☐
ShouldUseMountedGun	bool	☐	☐
SpawnedInGroundVehicle	bool	☐	☐
StartPosition	vector3	<0, 0, 0>	☐
Target	entity_handle	0	☐
TargetAlive	bool	☐	☐
TargetFP	int32	0	☐
TargetFPPosition	vector3	<0, 0, 0>	☐
TargetPosition	vector3	<0, 0, 0>	☐

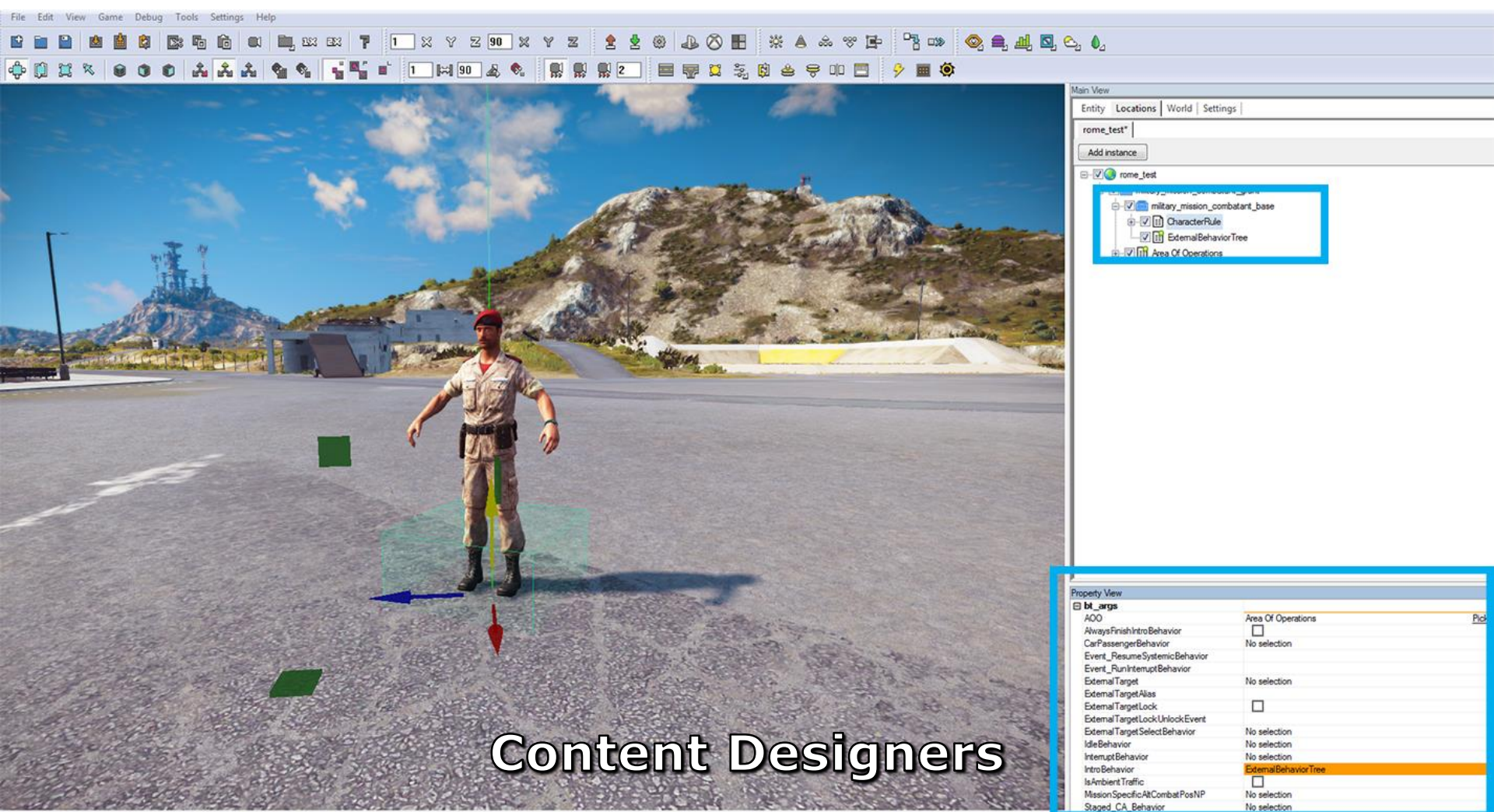
properties				
Name		Add argument		
Name	Type			
AOO	entity_handle			
AlwaysFinishIntroBehavior	bool			
IntroBehavior	entity_handle			
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ExternalTarget	entity_handle			
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IsAmbientTraffic	bool			
Staged_CA_Behavior	entity_handle			
ExternalTargetSelectBehavior	entity_handle			
MissionSpecificAltCombatPosNF	entity_handle			

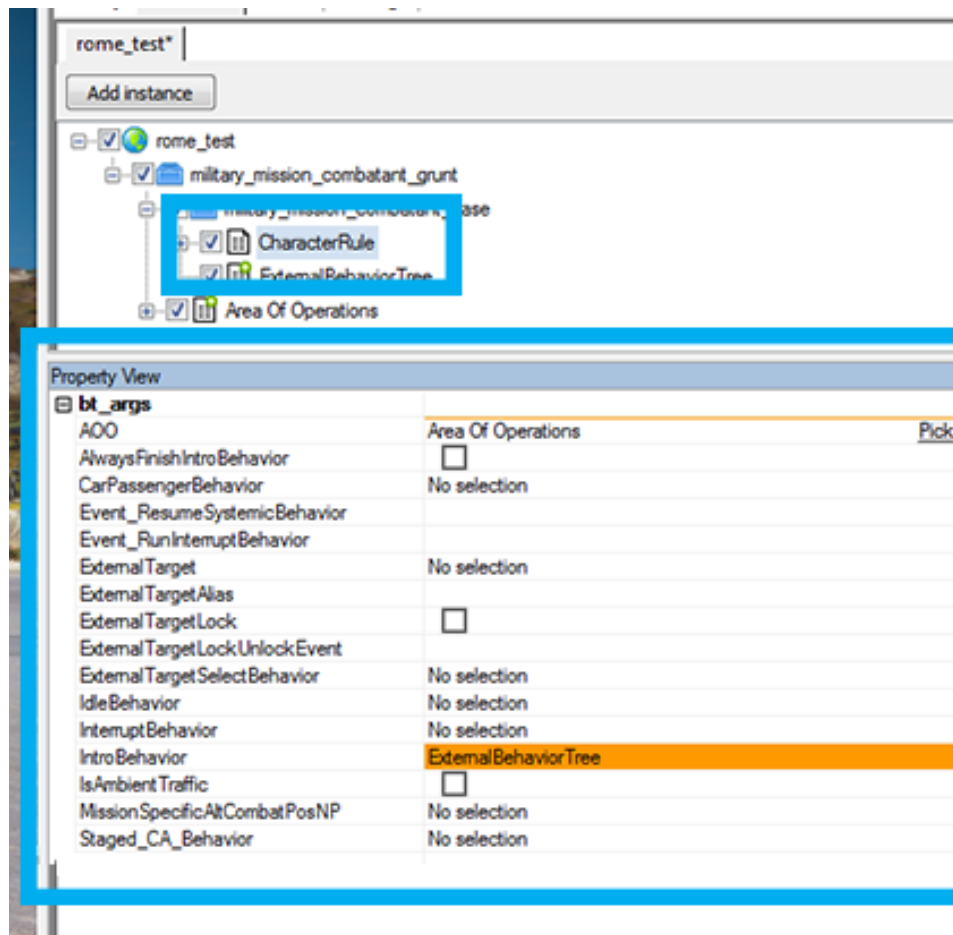
Exposed Arguments





Content Designers





Content Designer's Access to Exposed BT Args



AI

Exposes
Arguments



Access on
Spawner

Properties

Name

main

Add argument

Name	Type
AOO	entity_handle
AlwaysFinishIntroBehavior	bool
IntroBehavior	entity_handle
IdleBehavior	entity_handle
InterruptBehavior	entity_handle
Event_RunInterruptBehavior	eventreceive
PreferredTarget	entity_handle
PreferredTargetAlias	alias



Data Read
Into Tree



Fills Out
Arguments

Main View

Entity Locations World Settings

unnamed1*

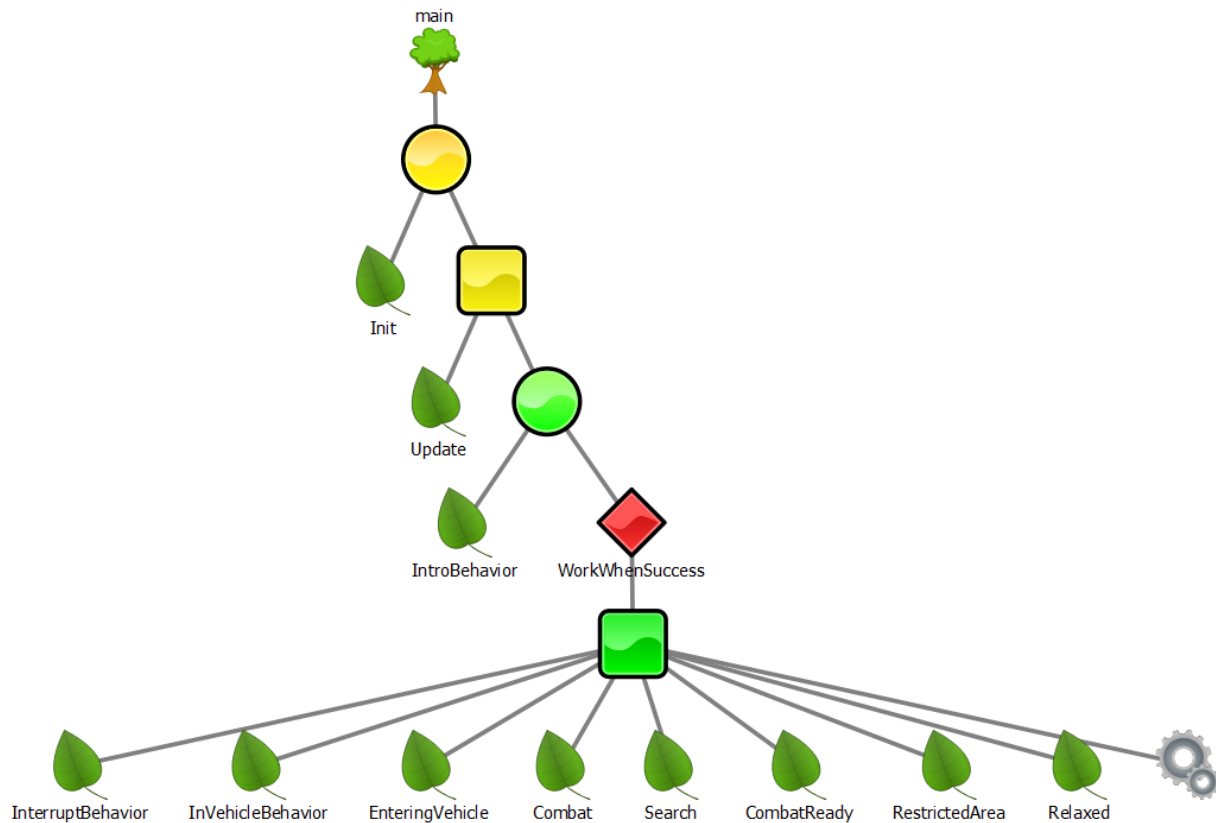
unnamed1

CharacterSpawner

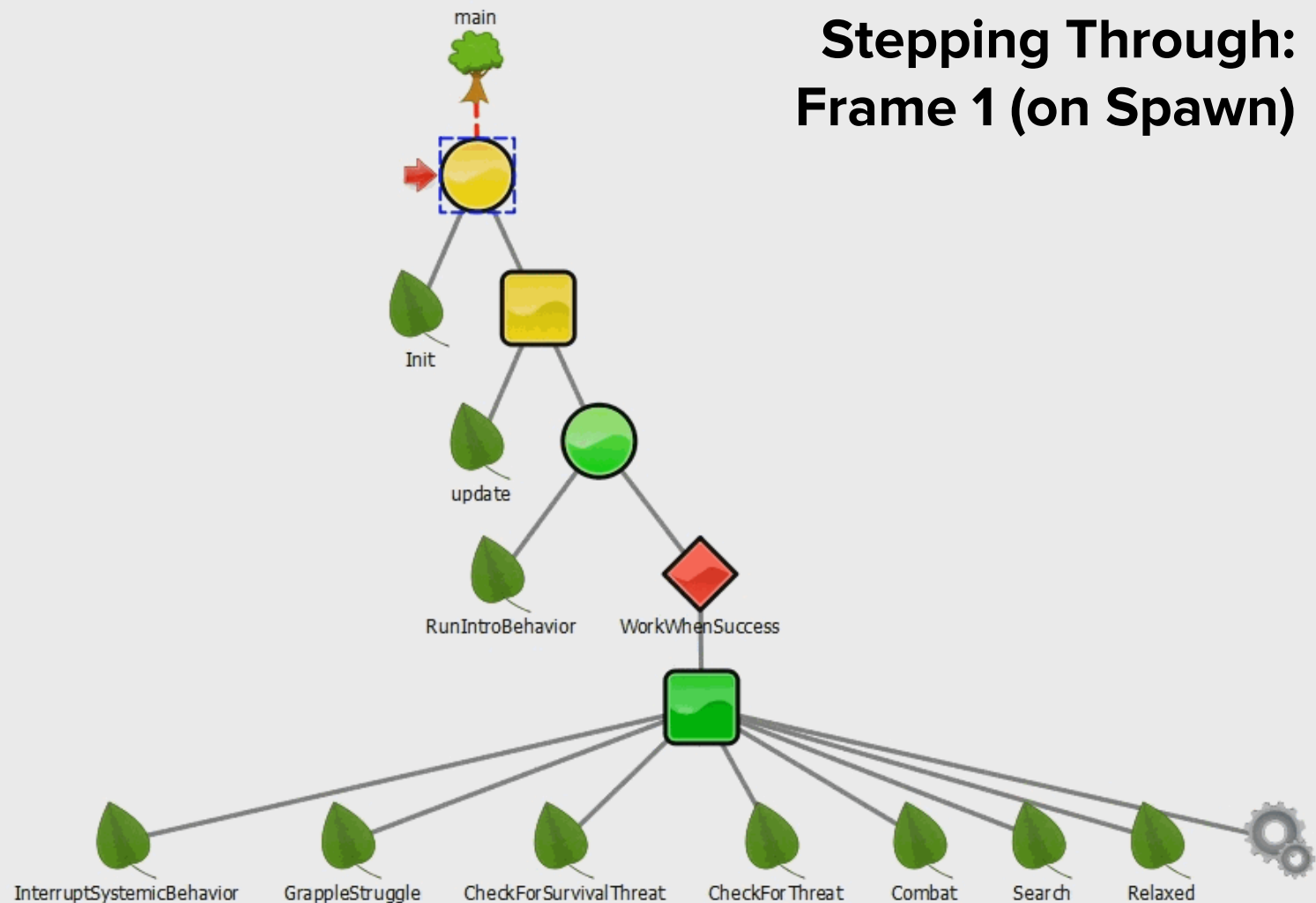
Property View

- 1 - Transform
- 2 - Activation
- 3 - Spawn Parameters
- 3 - Spawn Tags
- 4 - Character Parameters
- 5 - Character Events (RECEIVED)
- 6 - Character Events (SENT)
- 7 - Contextual Action Interactions
- bt_args
 - AOO No selection
 - AlwaysFinishIntroBehavior ☐
 - Event_RunInterruptBehavior
 - IdleBehavior No selection
 - InterruptBehavior No selection
 - IntroBehavior No selection
 - PreferredTarget No selection
 - PreferredTargetAlias
- general

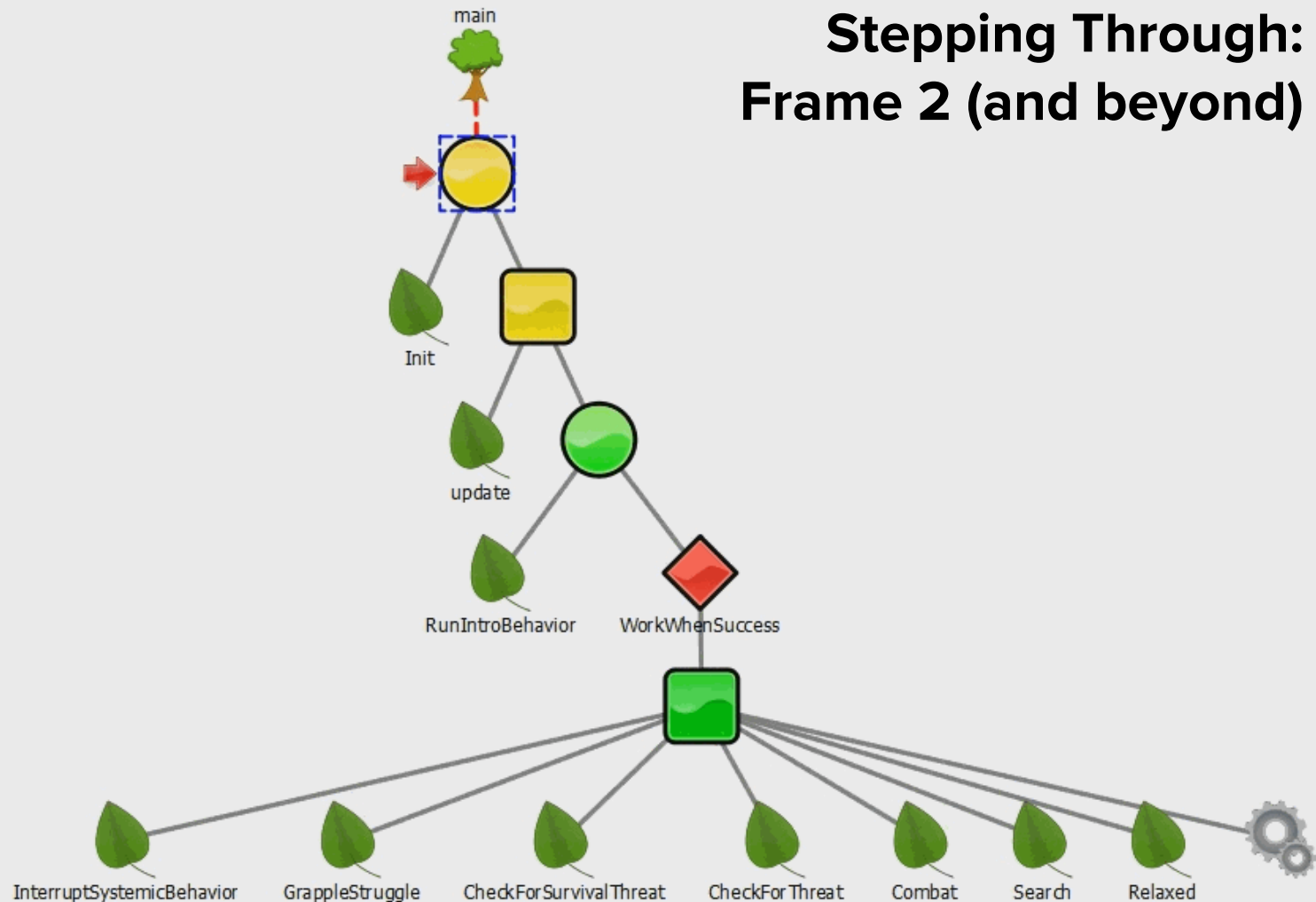
Content



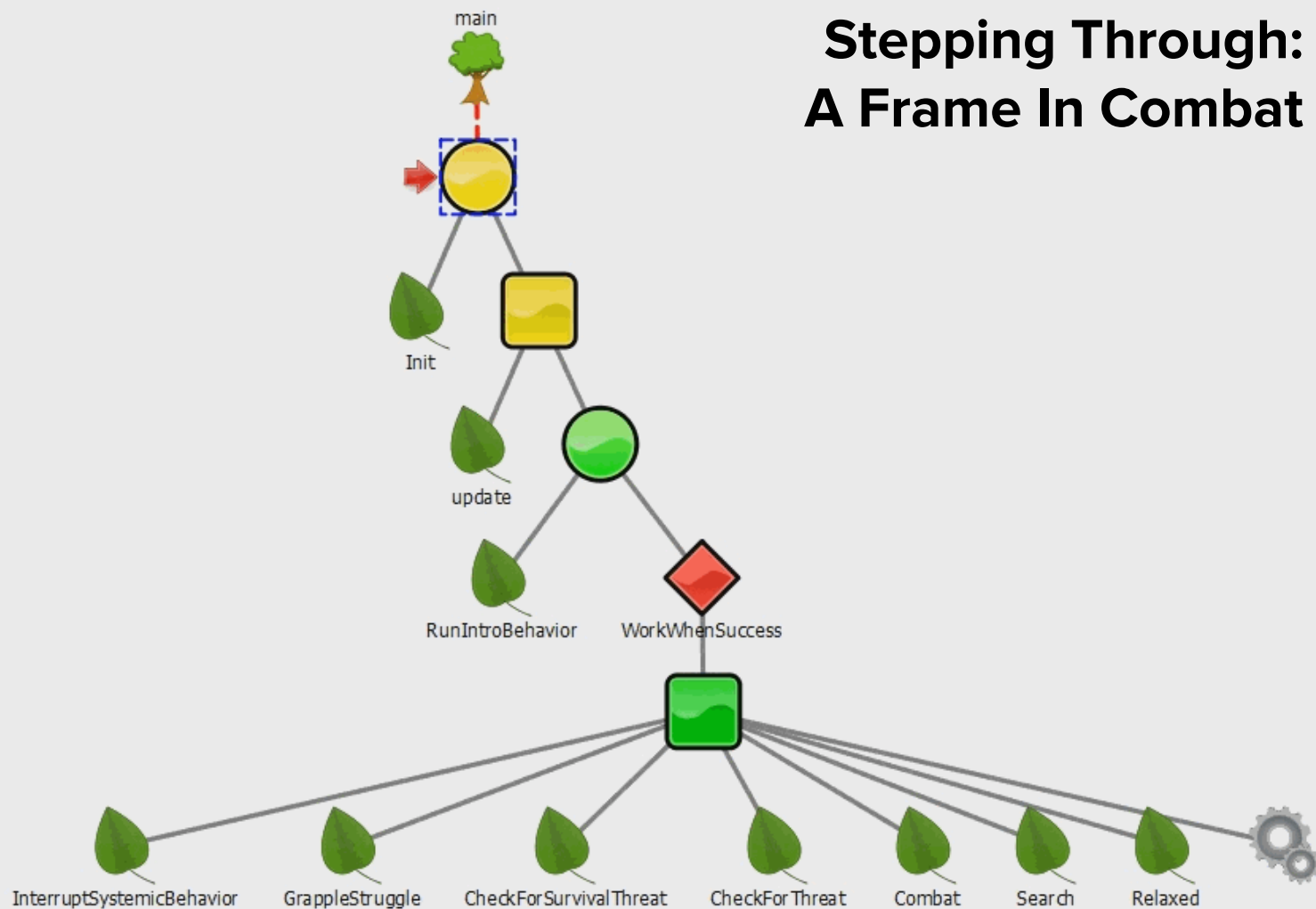
Stepping Through: Frame 1 (on Spawn)



Stepping Through: Frame 2 (and beyond)

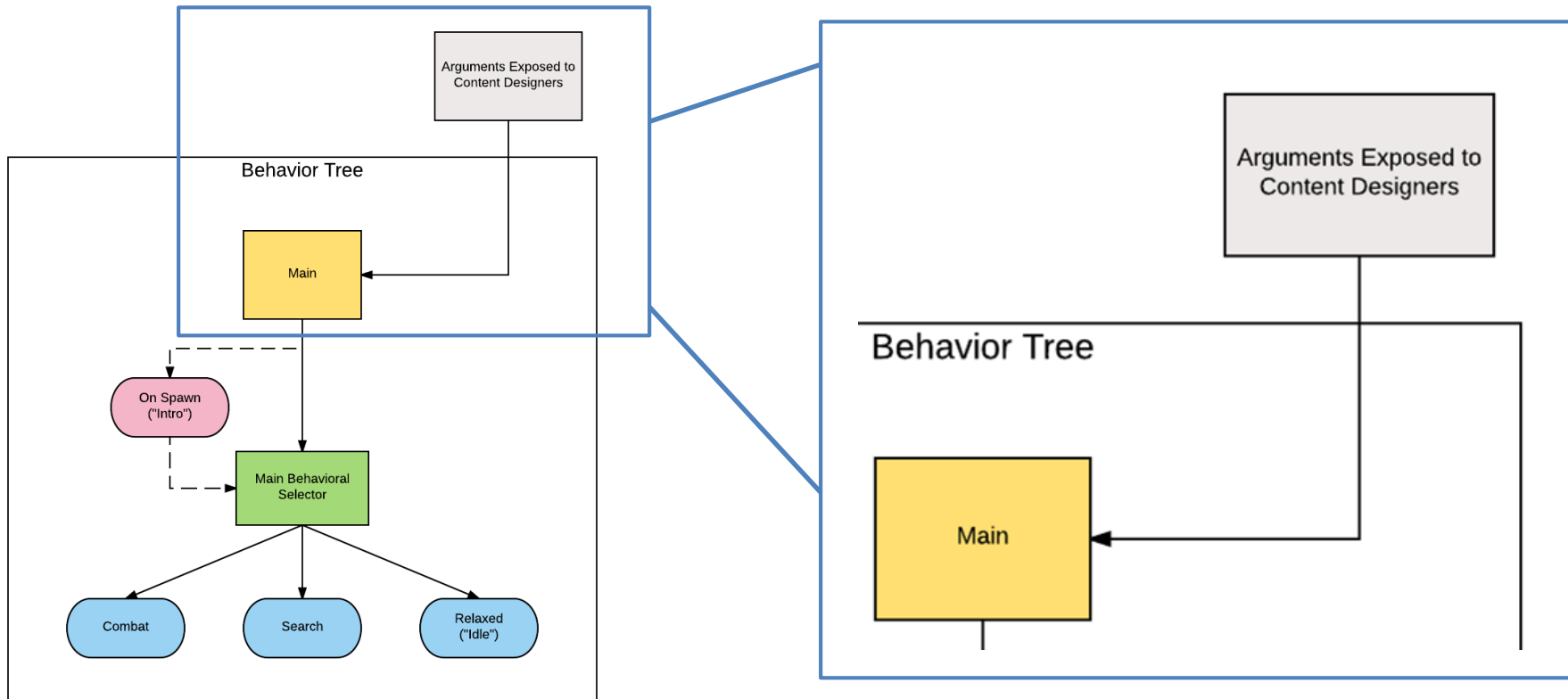


Stepping Through: A Frame In Combat





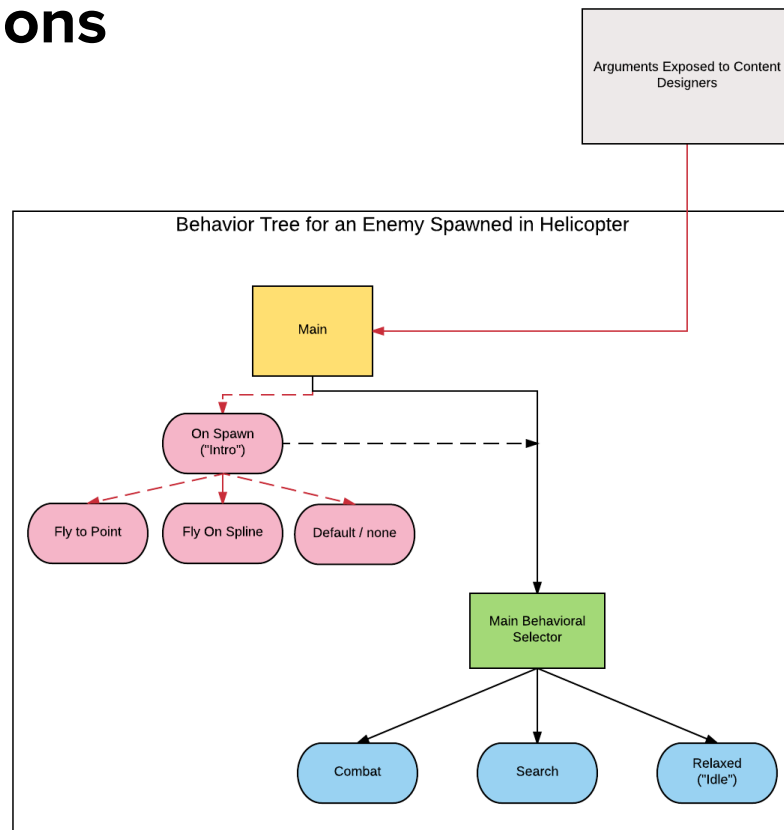
How can this enable content designers to create their custom content?





First Step: Built-In On-Spawn Options

- Intro Point (go here on spawn)
- Intro Spline (move along this path on spawn)



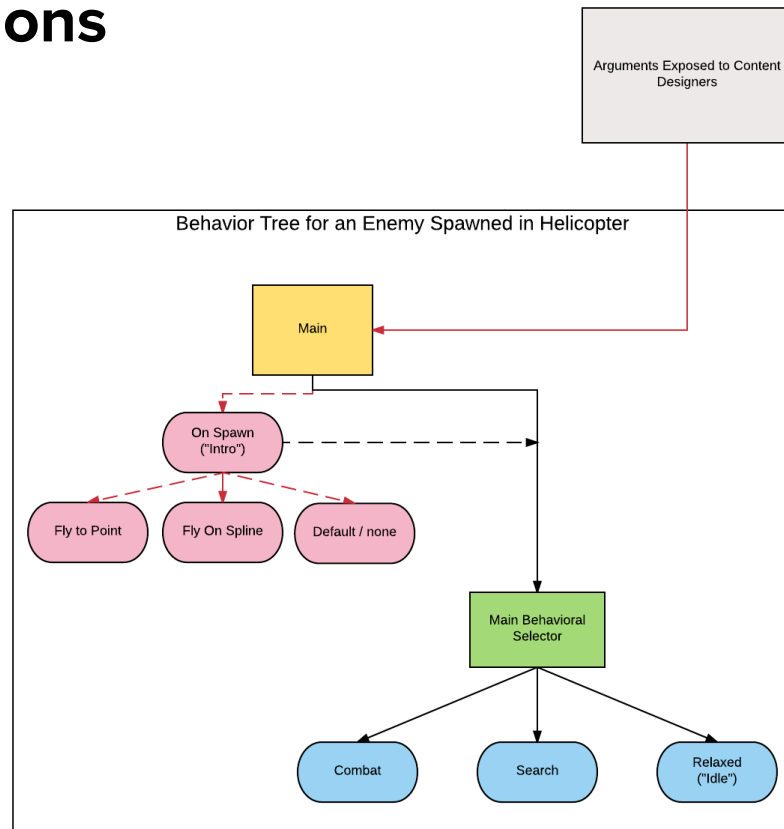


First Step: Built-In On-Spawn Options

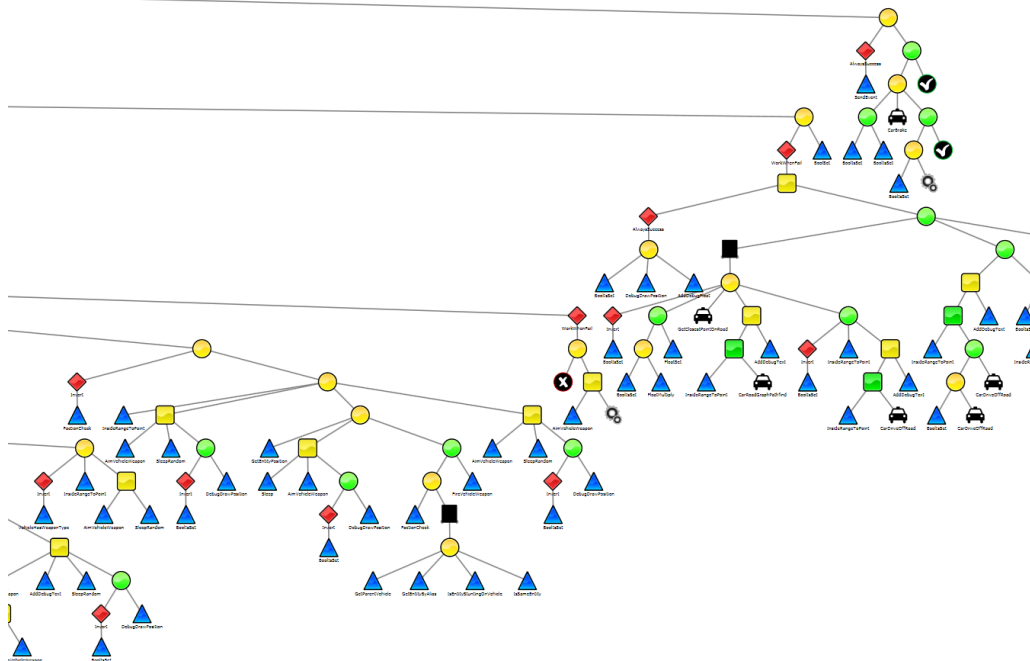
- Intro Point (go here on spawn)
- Intro Spline (move along this path on spawn)

But these only beget more args:

- Helicopter land at the point or hover?
- Speed options?
- Stop at the point or move through it?



It doesn't scale.

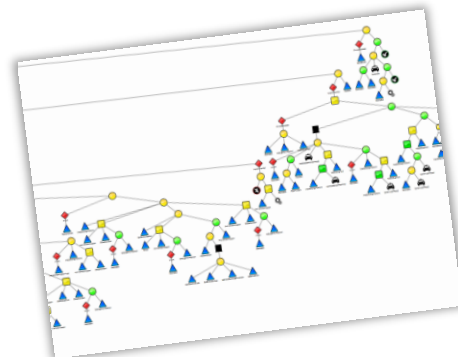
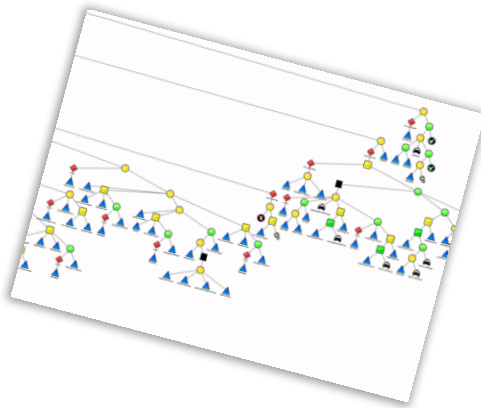
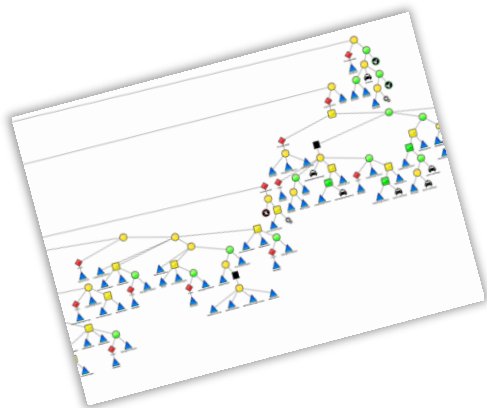


Property View

☒ bt_args	
ActivateAfterTime	0.000000
ActivateAutomatically	☐
ActivationEvent	
AliasOfEntityToDriveTo	
AutoComplete_Event	
AvoidAuthorityRoads	☐
DriveAroundTraffic	☐
DriveOffroadToActualPointAtEnd	☐
EVENT_arived_at_point	
EventSend_GoingFloorSpeed	
EventSend_IsSuperStuck	
EventSend_IsUnSuperStuck	
EventSend_StoppingForWaitForEntity	
IdleAtPoint	☐
IfPathfindFailsBlindlyDriveToPoint	☐
IgnoreJunctionBehavior	☐
IgnoreRoadsDriveDirectToPoint	☐
IntroPoint	No selection
IsTankShouldFireWhileDriving	☐
MaxSpeed	0.000000
ObeySpeedLimit	☐
ReverseToPoint	☐
ScaleSpeedRelativeToPlayer	☐
ScaleSpeedRelativeToPlayerFloorSpeed	0.000000
ShowDebugInfo	☐
StopAtAutoComplete	☐
StopAtPoint	☐
StopDistance	0.000000
WaitForEntityAlias	
zEventRec_SetMaxSpeed_2	
zEventRec_SetMaxSpeed_3	
zEventRec_SetMaxSpeed_Default	
zMaxSpeed_2	0.000000
zMaxSpeed_3	0.000000
...	

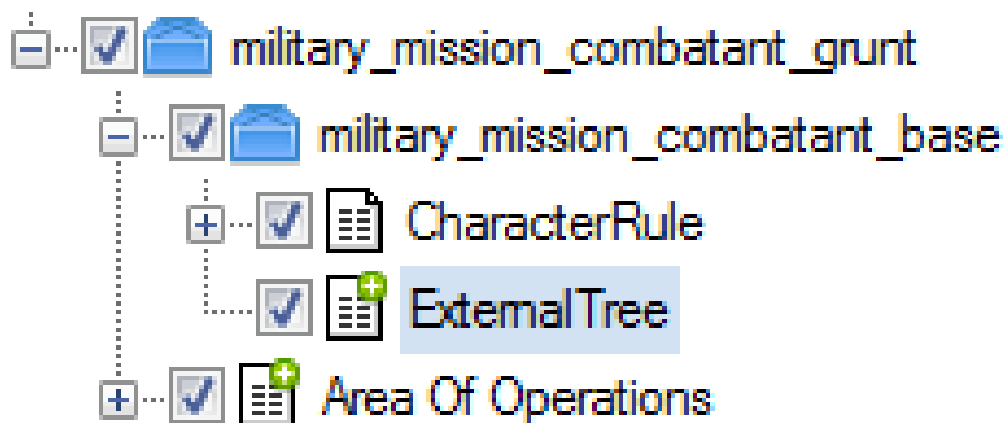


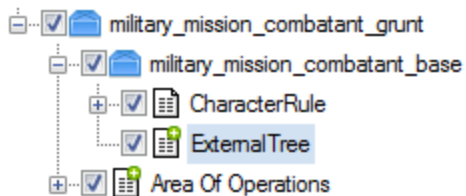
Make it Modular





External Behavior Trees





Content Designer- Selected External Tree

**Take Cover
In Area**



Character's Exposed BT Arguments

Arguments Exposed to
Content Designers

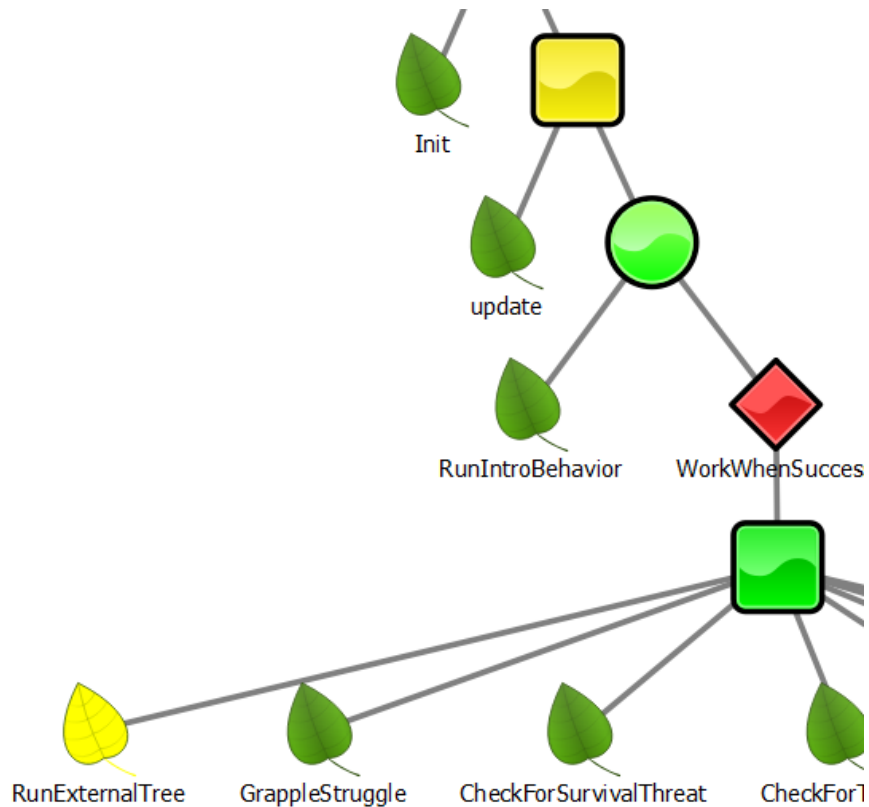
Behavior Tree

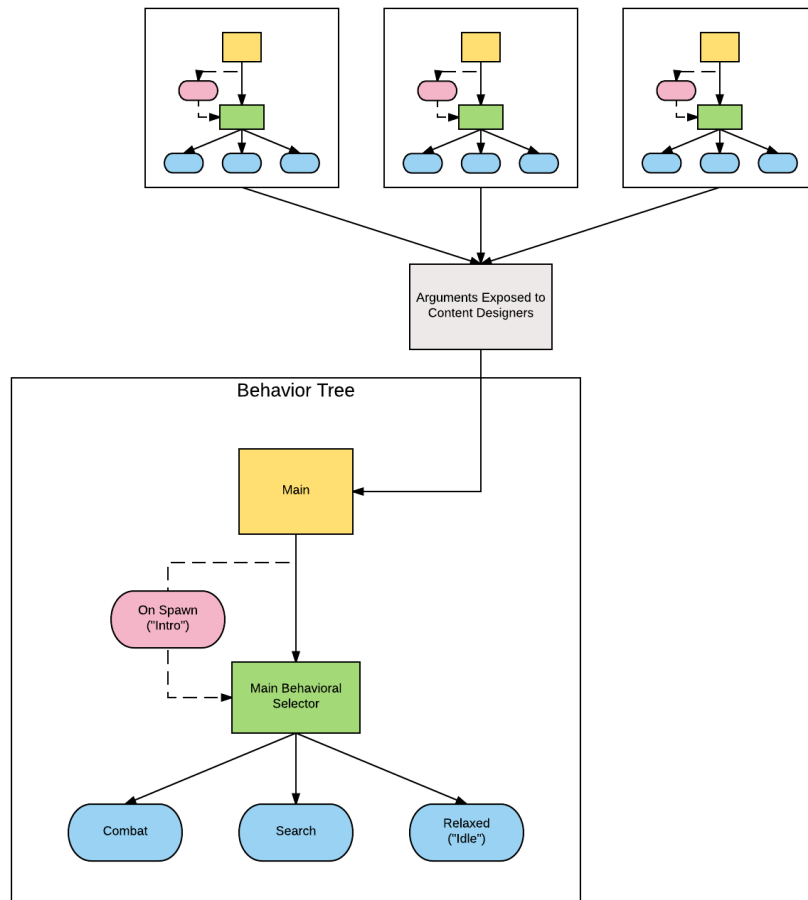
Main



Content Designer- Selected External Tree

Take Cover
In Area







Main View

Entity | Locations | World | Settings

unnamed1*

Add instance

unnamed1

- ExternalBehaviorTree
- HelicopterSpawner
 - PilotSpawnSeat
 - PointToFlyTo

Property View

bt_args

ActivateAutomatically	☒
ActivationEvent	
AutoComplete_Event	
CompleteWhenWithinDistanceToPoint	0.000000
DesiredAltitudeOverrideValue	0.000000
IdleAtPoint	☐
IntroPoint	PointToFlyTo
LandAtPoint	☒
ReachedPoint_Event	
Speed	30.000000
TrackPlayerPositionDuringFlight	☐
WaitAtPointForTime	☐
WaitAtPointForTimeDuration	0.000000

files

behaviour_tree	ai/bts/D1_micro_behaviors/vehicle/heli_fly_to_point.bts
----------------	---

general

_class	CExternalBehaviorTree
alias	





Main View

Entity | Locations | World | Settings

unnamed1*

Add instance

unnamed1

- ExternalBehaviorTree
- HelicopterSpawner
- PilotSpawnSeat
- PointToFlyTo

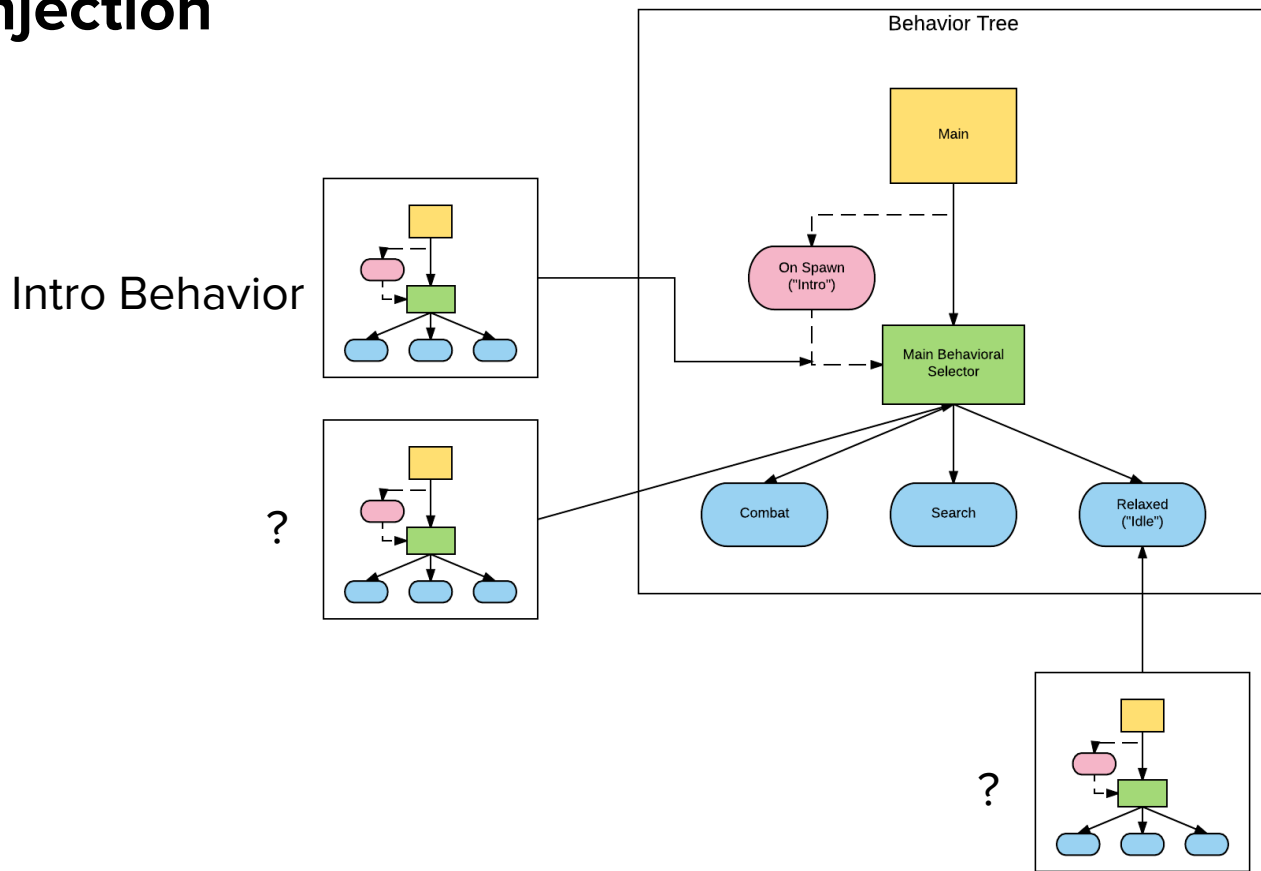
Property View

- 1 - Spawn Parameters
- 2 - Character Parameters
- 3 - AI Events (RECEIVED)
- 4 - AI Events (SENT)
- bt_args
 - AOO No selection
 - AlwaysFinishIntroBehavior ☐
 - CarPassengerBehavior No selection
 - Event_ResumeSystemicBehavior
 - Event_RunInterruptBehavior
 - ExternalTarget No selection
 - ExternalTargetAlias
 - ExternalTargetLock ☐
 - ExternalTargetLockUnlockEvent
 - ExternalTargetSelectBehavior No selection
 - IdleBehavior No selection
 - InterruptBehavior No selection
 - IntroBehavior
 - IsAmbientTraffic ☐
 - ExternalBehaviorTree



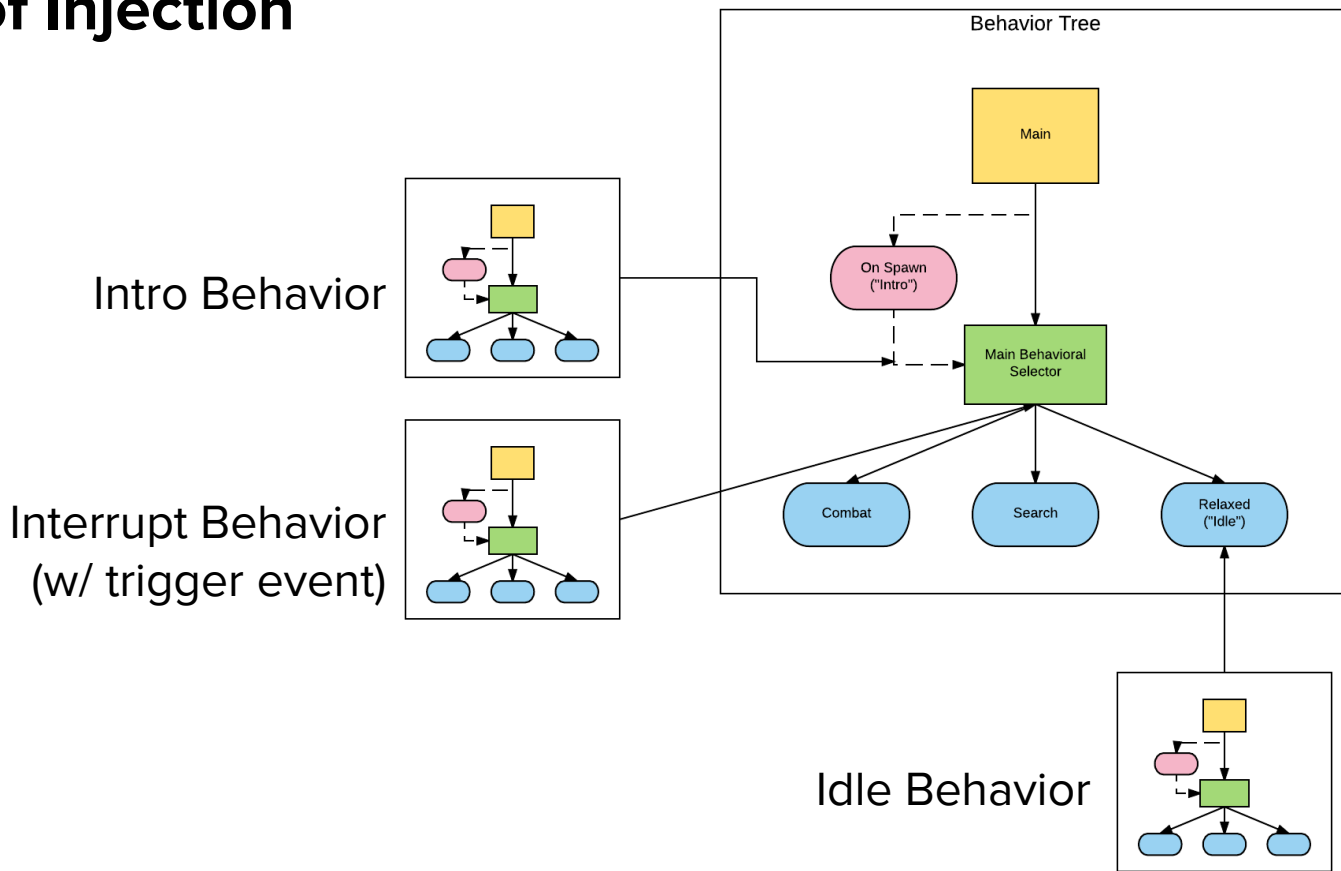


Points of Injection



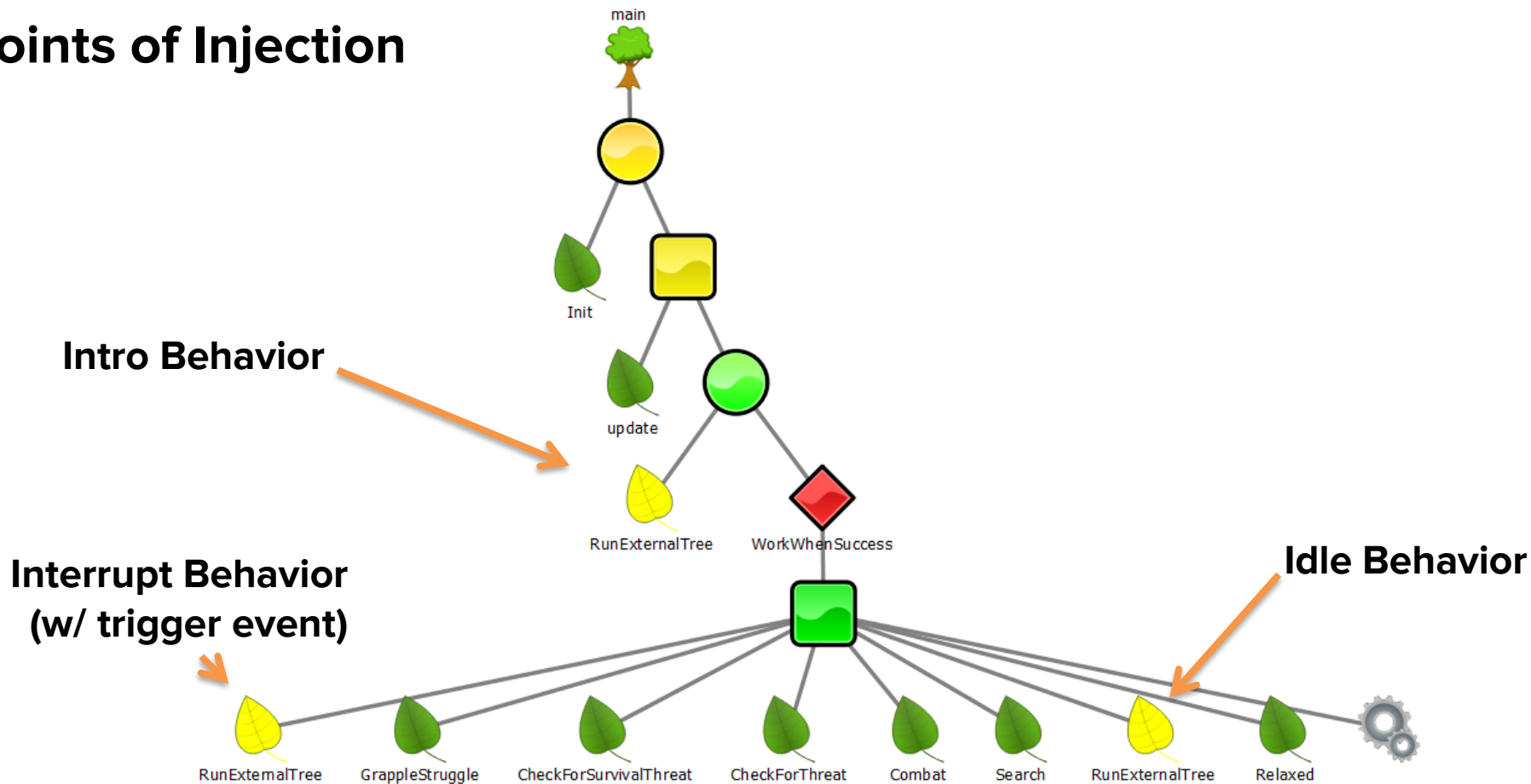


Points of Injection





Points of Injection

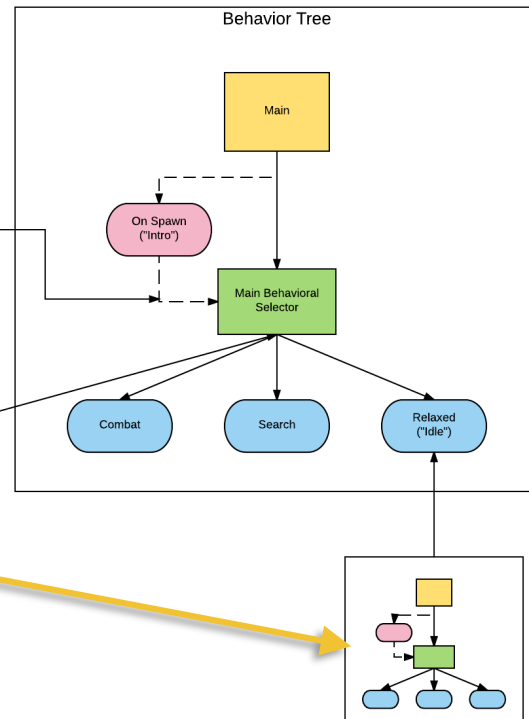
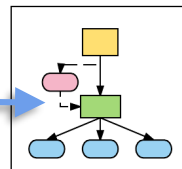
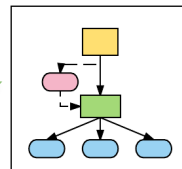




Points of Injection

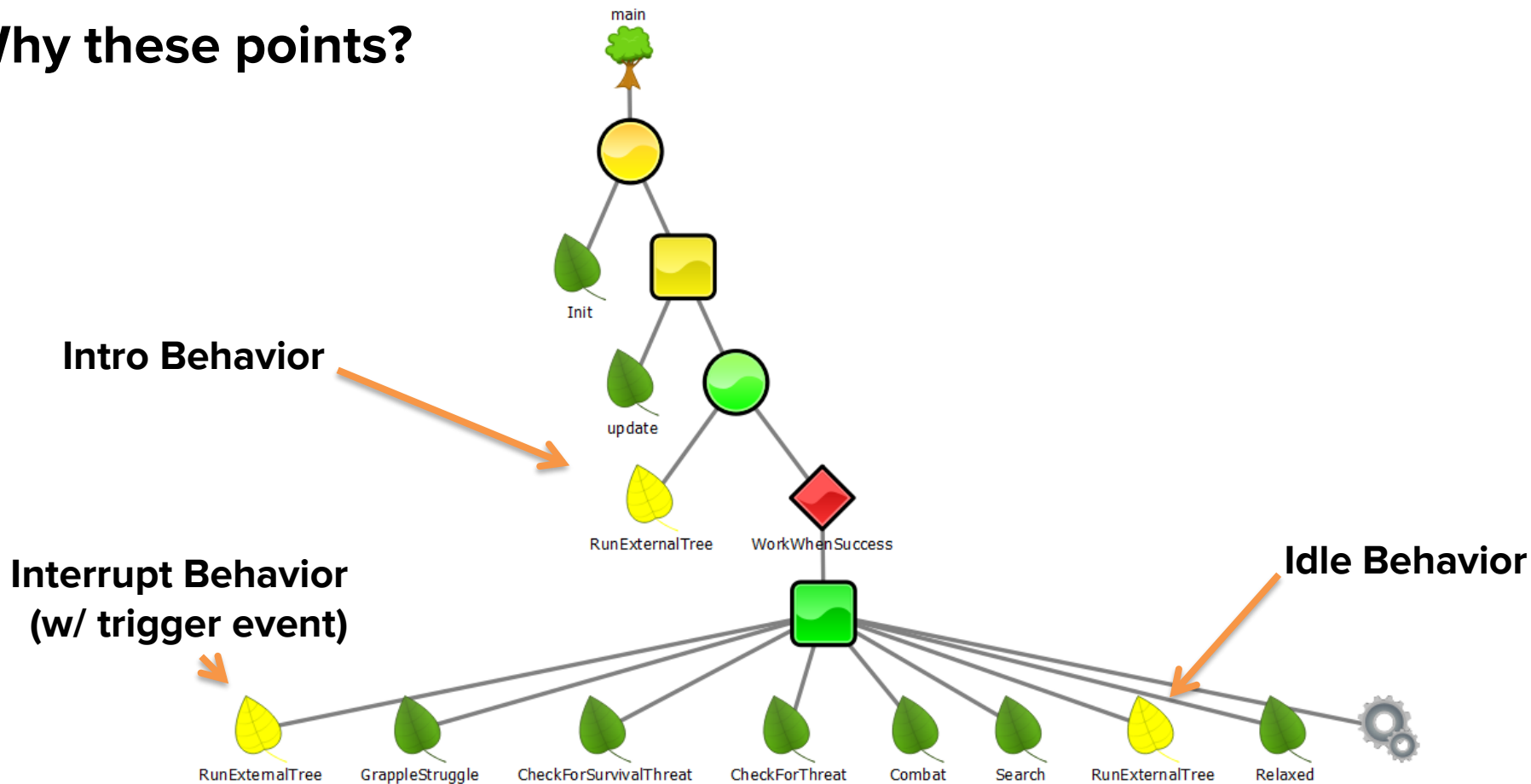
bt_args

AOO	No selection
AlwaysFinishIntroBehavior	☐
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	No selection
IntroBehavior	No selection
PreferredTarget	No selection
PreferredTargetAlias	





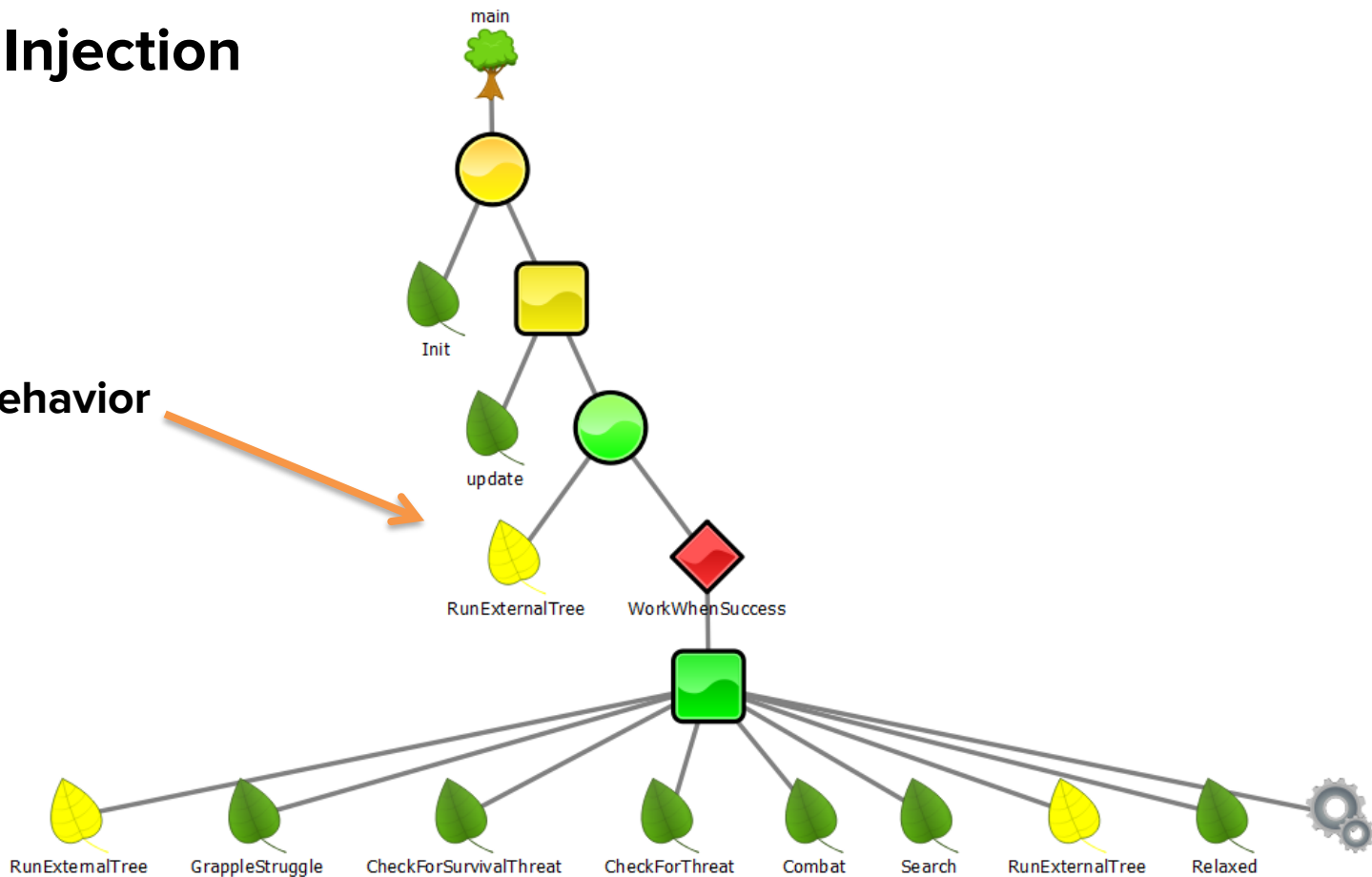
Why these points?





Points of Injection

Intro Behavior





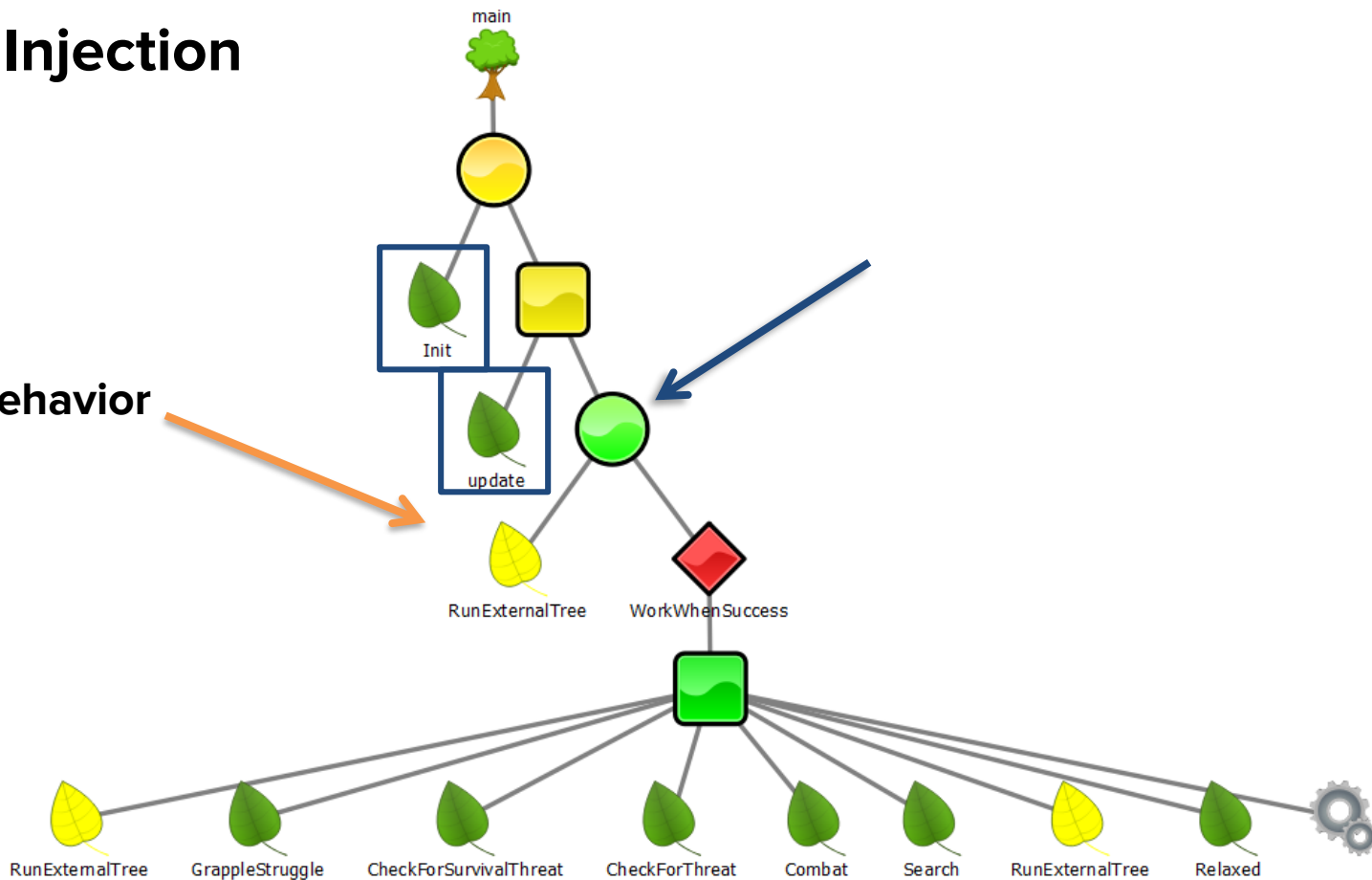
Intro Behavior





Points of Injection

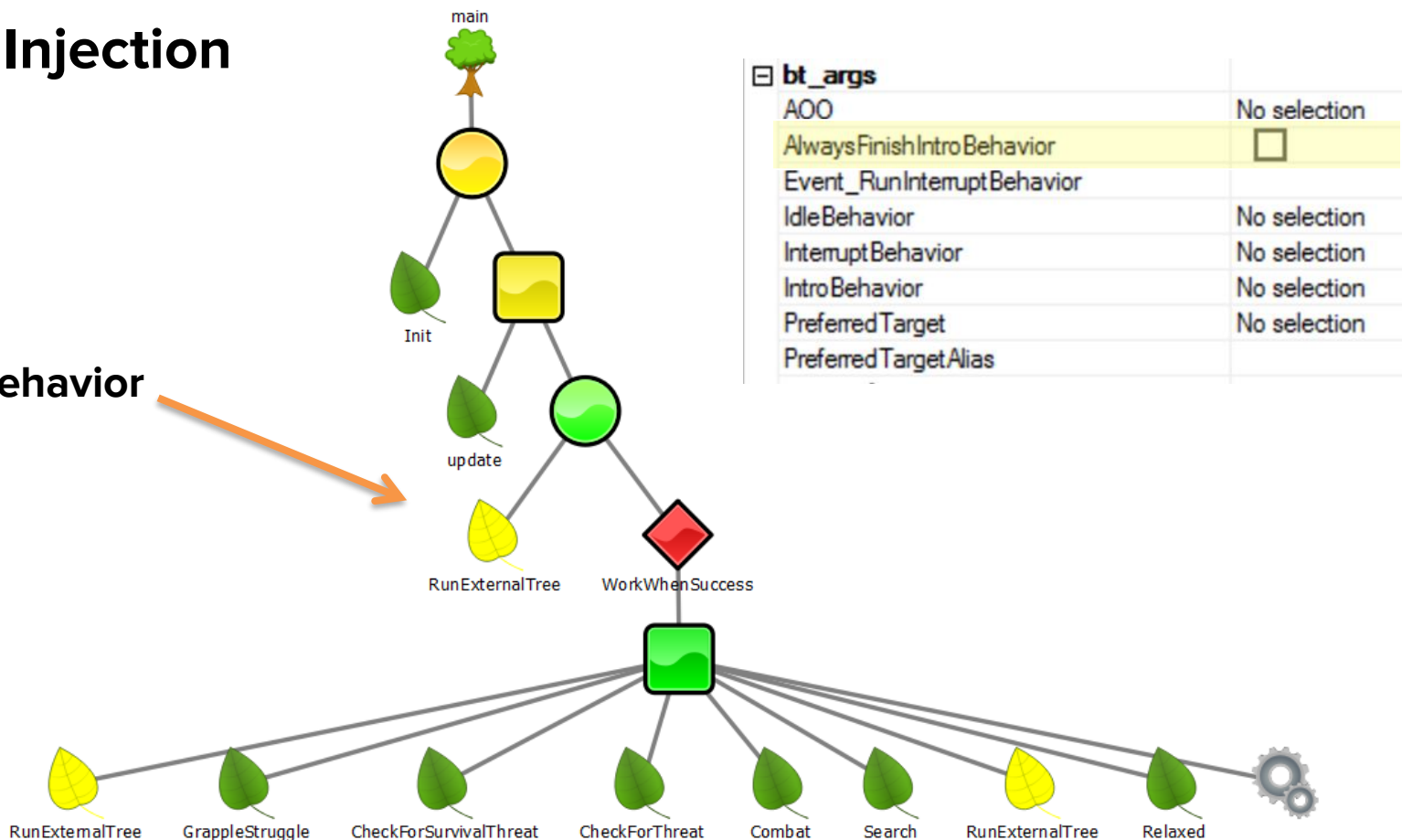
Intro Behavior

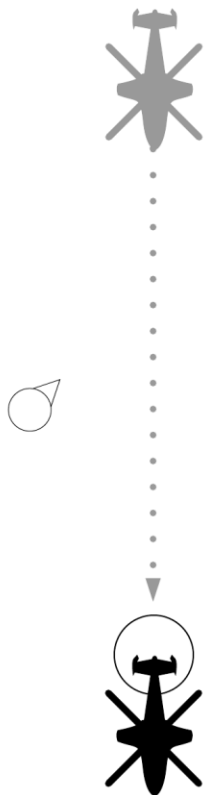




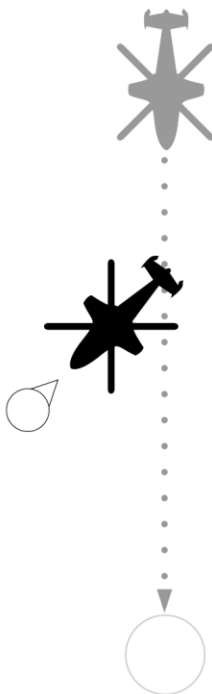
Points of Injection

Intro Behavior





Always Finish



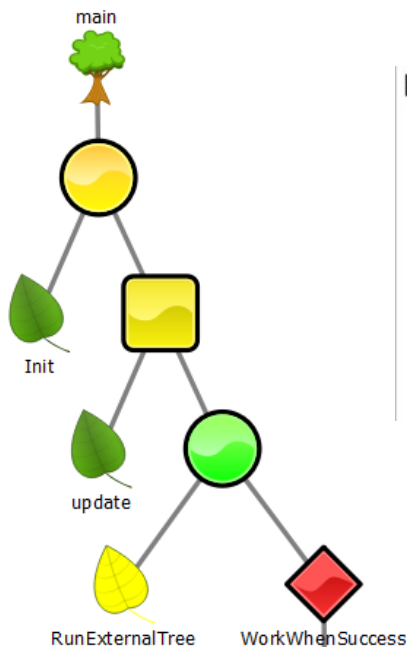
Allowed To Exit

bt_args

AOO	No selection
AlwaysFinishIntroBehavior	☒
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	No selection
IntroBehavior	No selection
PreferredTarget	No selection
PreferredTargetAlias	



Points of Injection



bt_args	
AOO	No selection
AlwaysFinishIntroBehavior	☐
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	No selection
IntroBehavior	No selection
PreferredTarget	No selection
PreferredTargetAlias	

Interrupt Behavior (w/ trigger event)



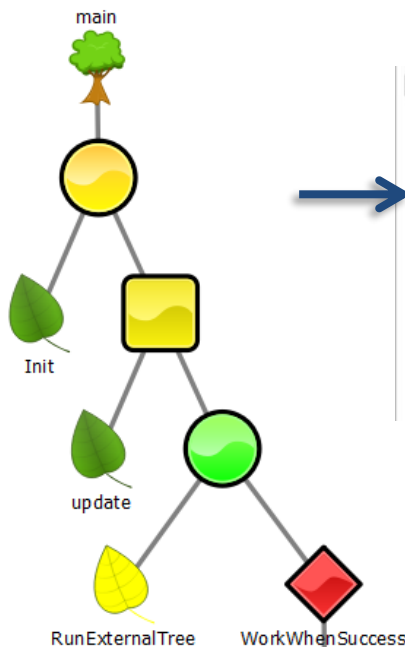


Interrupt Behavior



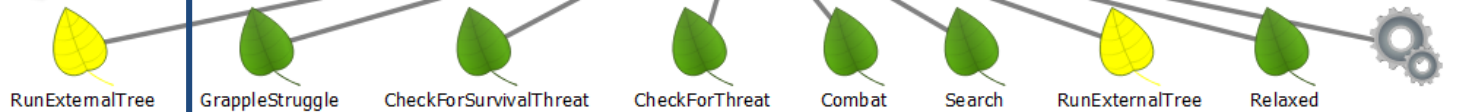


Points of Injection



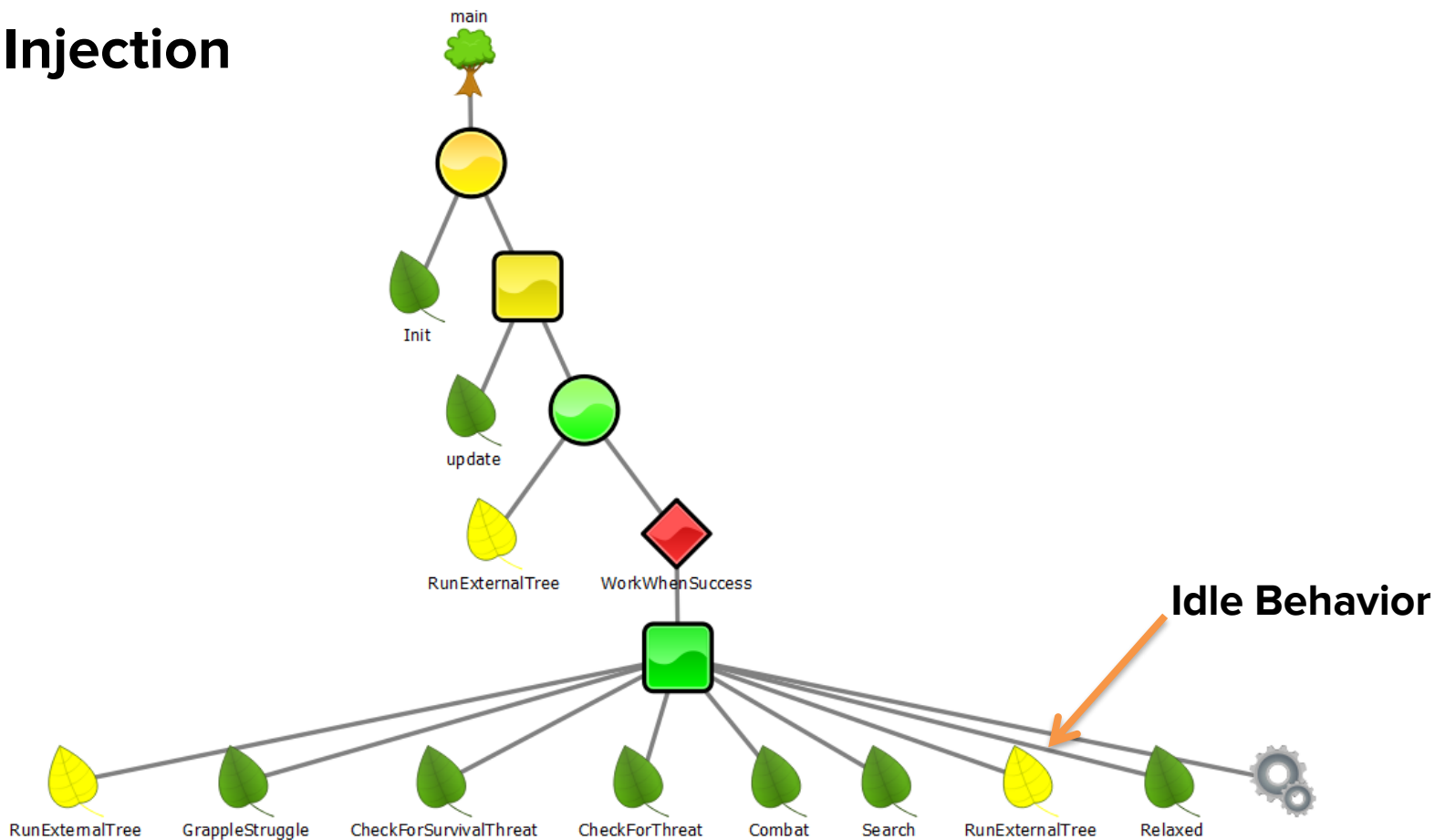
bt_args	
AOO	No selection
AlwaysFinishIntroBehavior	☐
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	No selection
IntroBehavior	No selection
PreferredTarget	No selection
PreferredTargetAlias	

Interrupt Behavior (w/ trigger event)





Points of Injection



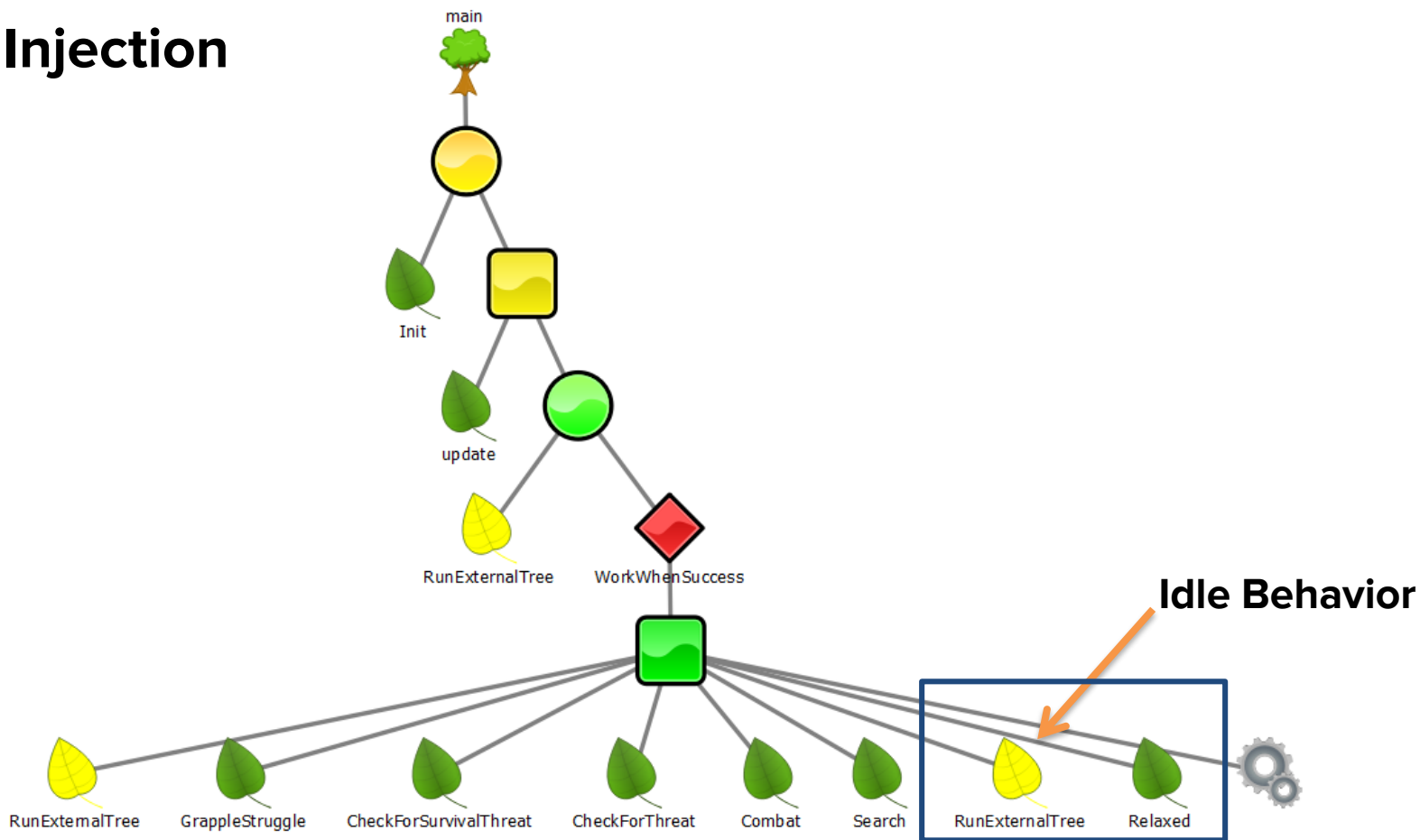


Idle Behavior



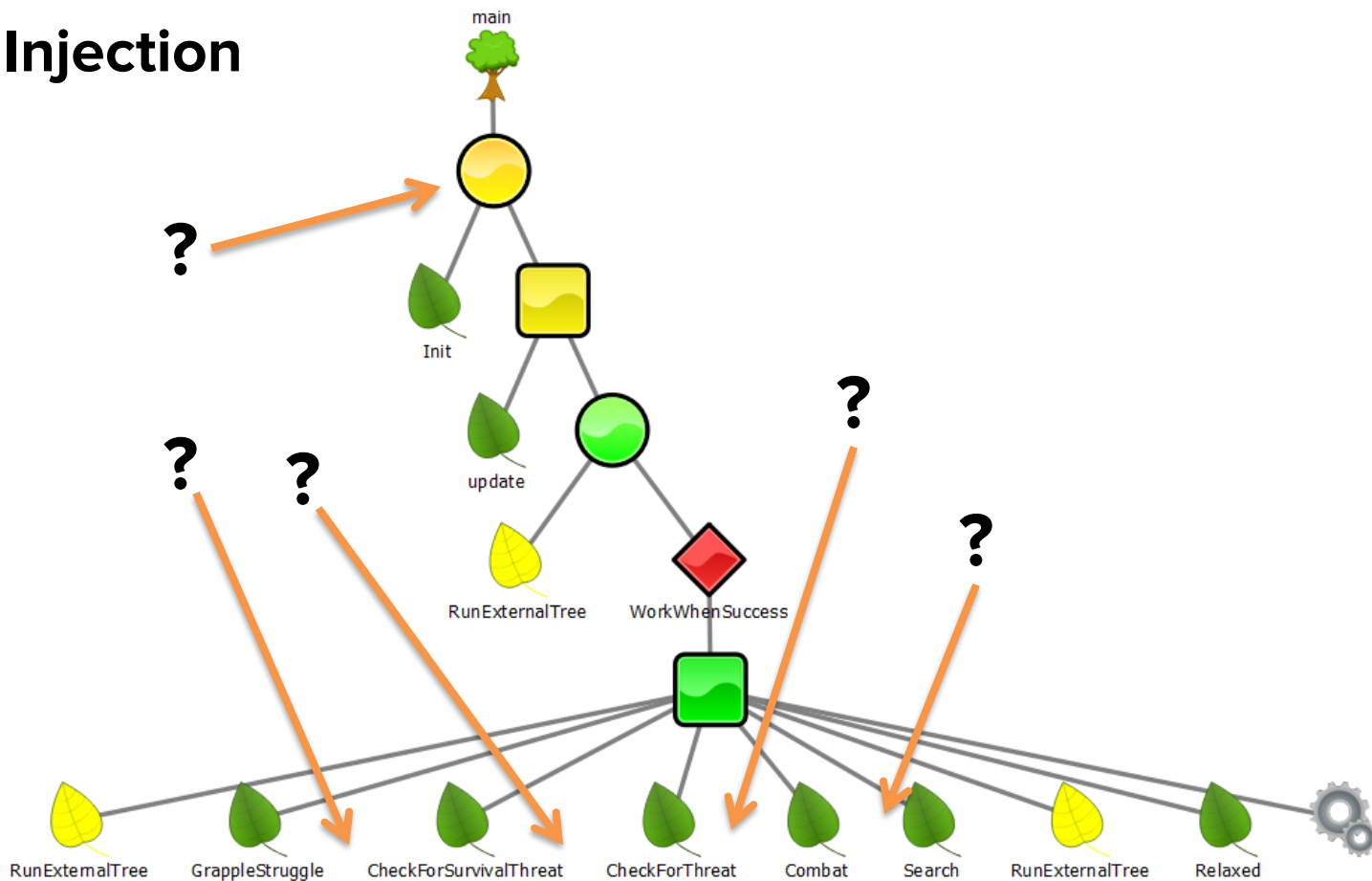


Points of Injection



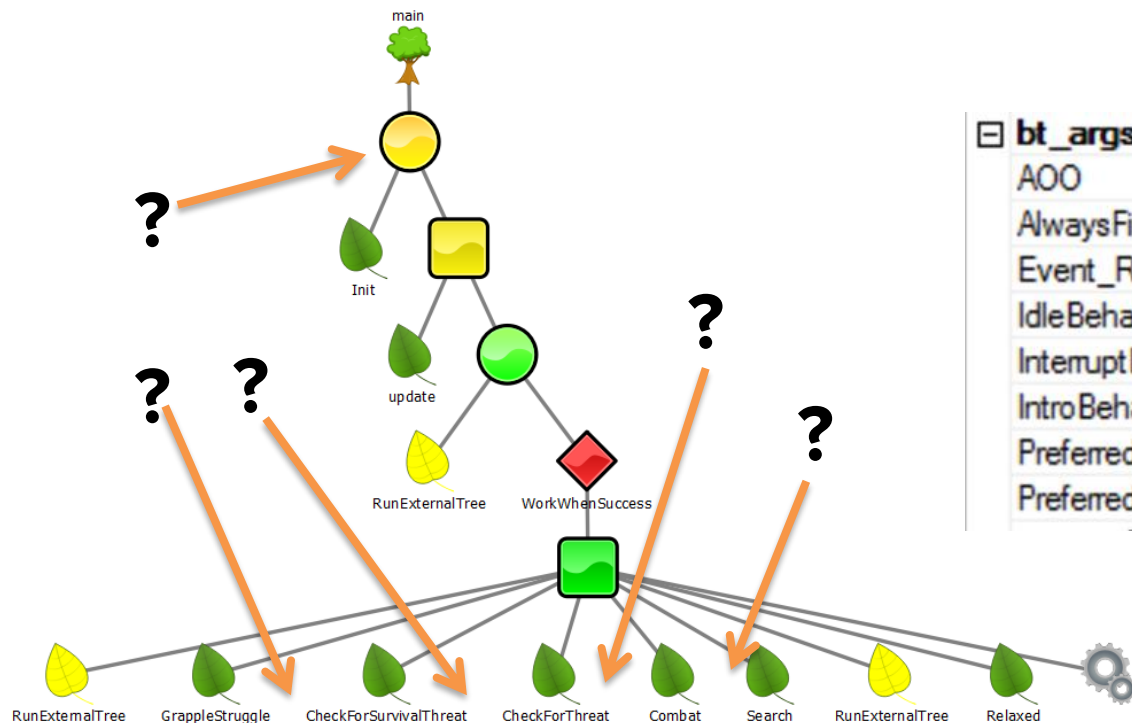


Points of Injection





Points of Injection



bt_args

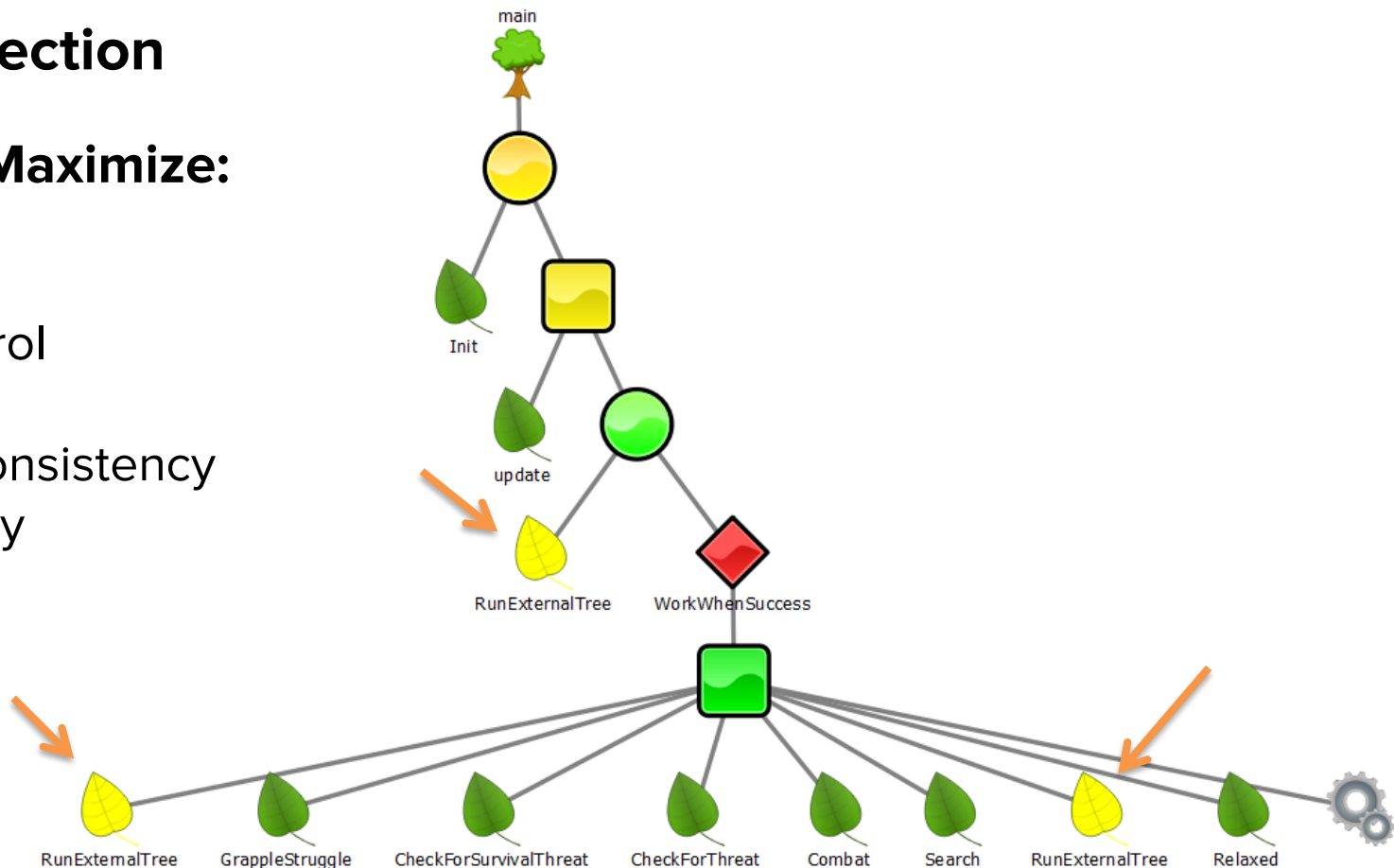
AOO	No selection
AlwaysFinishIntroBehavior	☐
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	No selection
IntroBehavior	No selection
PreferredTarget	No selection
PreferredTargetAlias	



Points of Injection

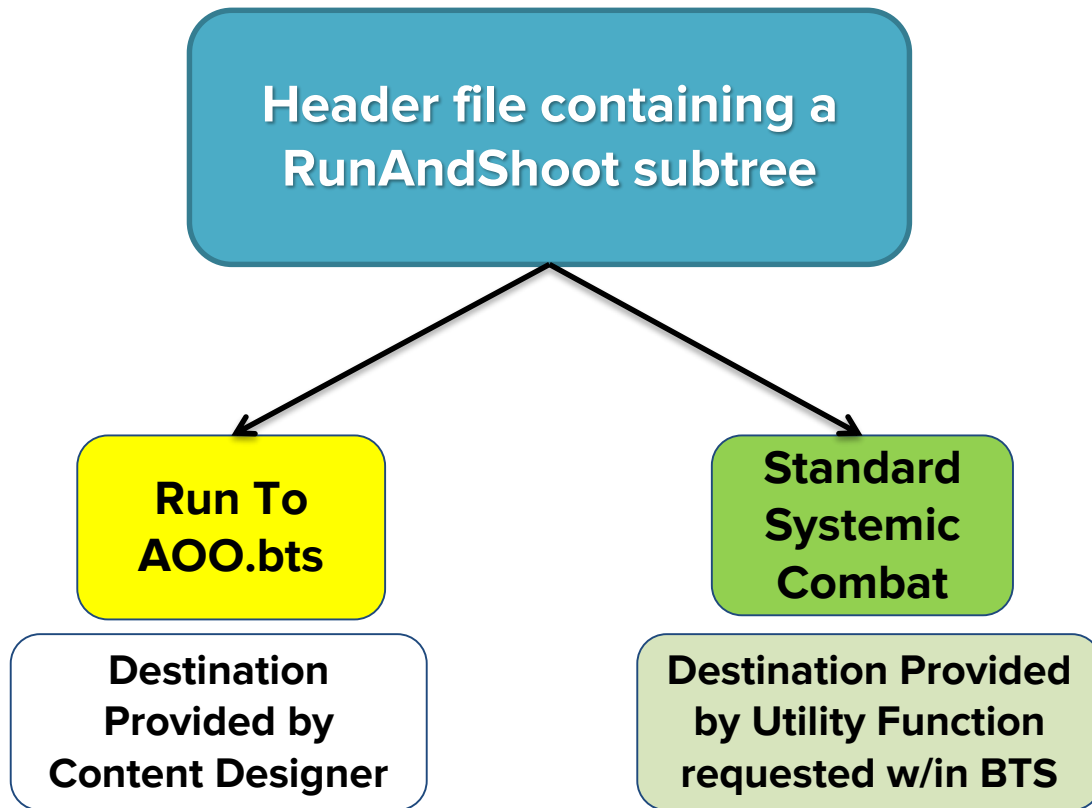
Selected To Maximize:

- Simplicity
- Flexible Control
- Robustness
- Behavioral Consistency
- Visual Integrity



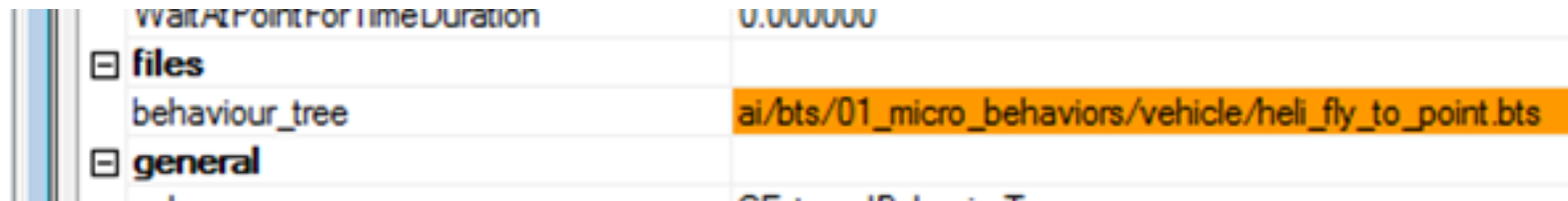


Behavior Tree “Headers”





Building A Library of Micro-Behaviors



Heli Fly To
Point

Run To
AOO

Patrol
Spline

Enter
Target
Vehicle

Exit Vehicle

Take Cover
In Area

Plane
Takeoff

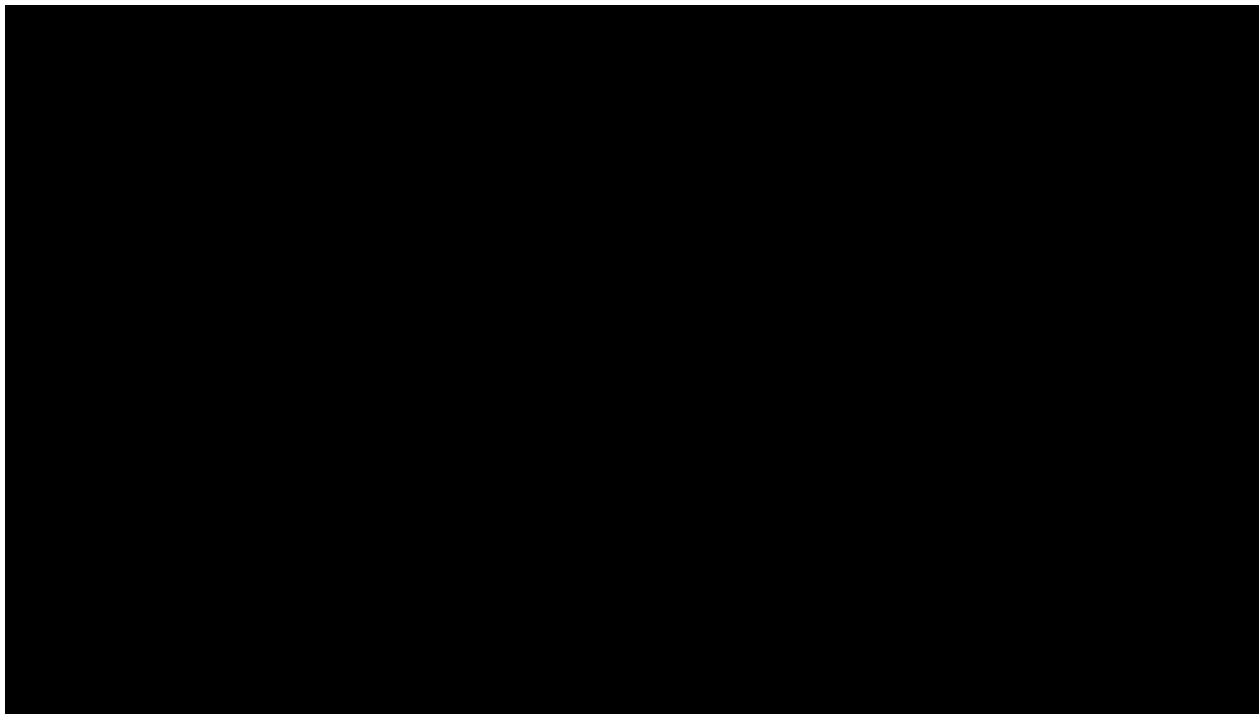
Loop Anim
At Point

Idle Until
Event

Car Follow



What now? Giant Mission-Specific Micro-Behaviors?





Breaking Mario's Behavior Down Into A Sequence

**Take Cover in
Police Station**

**Fight With
Rico Inside
Station**

**Wait For Gate
position and
loop**

**Enter the
Rebel Car**

**Fight From
Passenger
Seat**





Breaking Mario's Behavior Down Into A Sequence

Take Cover in
Police Station

Fight With
Rico Inside
Station

Wait For Gate
position and
loop

Enter the
Rebel Car

Fight From
Passenger
Seat

Take Cover
In Area

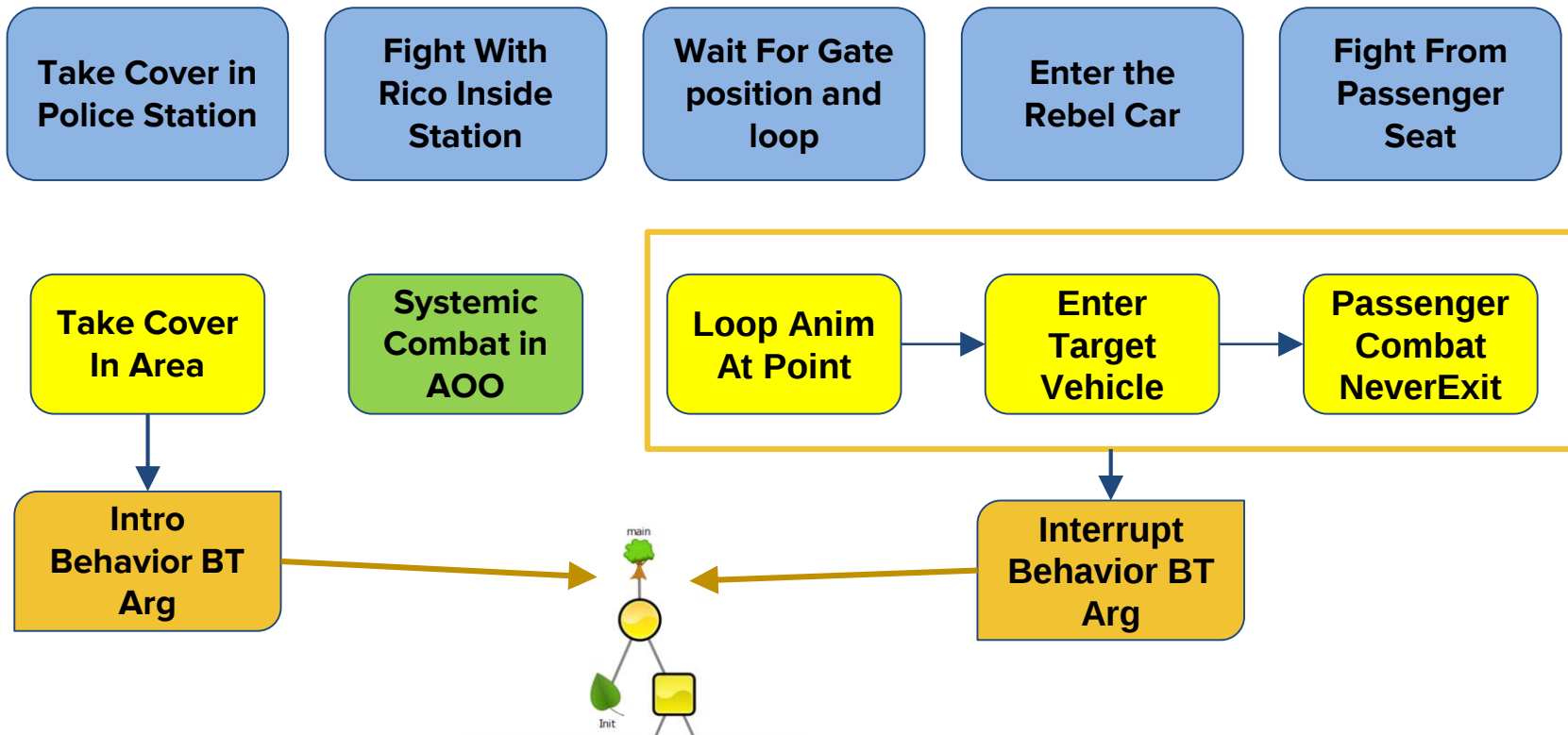
Systemic
Combat in
AOO

Loop Anim
At Point

Enter
Target
Vehicle

Passenger
Combat
NeverExit

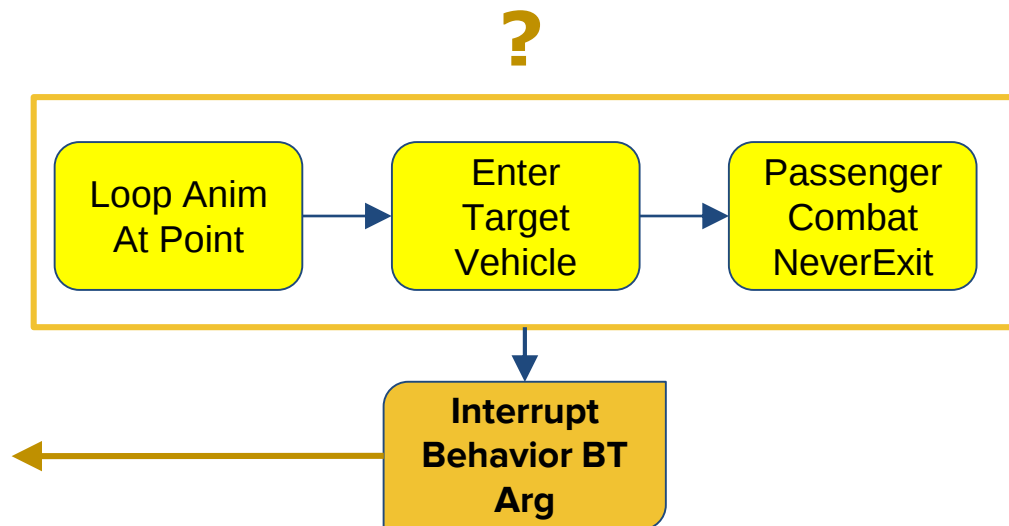






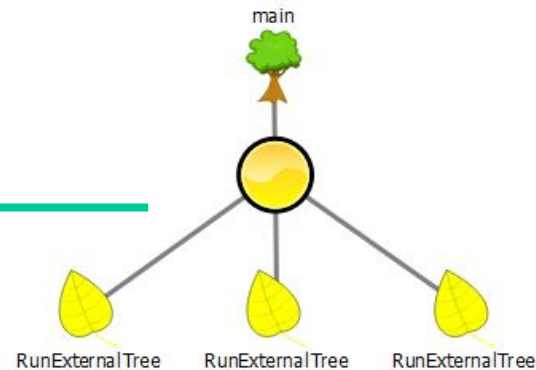
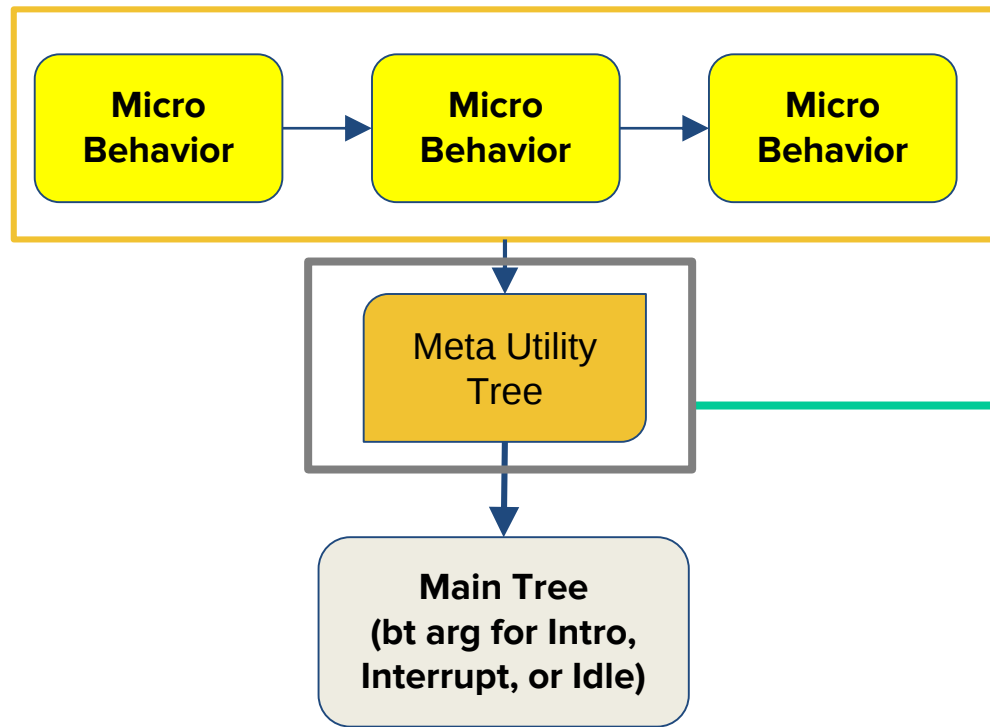
bt_args

AOO	No selection
AlwaysFinishIntroBehavior	☐
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	No selection
IntroBehavior	No selection
PreferredTarget	No selection
PreferredTargetAlias	





Meta Utility Trees





Meta Utility Trees

The screenshot shows a utility tree with the following structure:

- CharacterRule_Mario
 - EBT_Mario_Interrupt_Sequence
 - 1.LoopAnimAtPoint
 - 2.EnterTargetvehicle
 - 3.PassengerCombatNeverExit
 - EBT_Mario_Intro_TakeCoverInArea

Property View

bt_args	
AOO	No selection
AlwaysFinishIntroBehavior	☐
Event_RunInterruptBehavior	
IdleBehavior	No selection
InterruptBehavior	EBT_Mario_Interrupt_Sequence
IntroBehavior	EBT_Mario_Intro_TakeCoverInArea
PreferredTarget	No selection
PreferredTargetAlias	
general	

The screenshot shows a utility tree with the following structure:

- CharacterRule_Mario
 - EBT_Mario_Interrupt_Sequence
 - 1.LoopAnimAtPoint
 - 2.EnterTargetvehicle
 - 3.PassengerCombatNeverExit
 - EBT_Mario_Intro_TakeCoverInArea

Property View

bt_args	
ExternalBehavior1	1.LoopAnimAtPoint
ExternalBehavior2	2.EnterTargetvehicle
ExternalBehavior3	3.PassengerCombatNeverExit
file	





Meta Utility Trees

**Sequence of
External
Behaviors**

Sequence of External Behaviors

- (tree 1)
- (tree 2), etc...

**Selector of
External
Behaviors**

Selector of External Behaviors

- (tree a)
- (tree b - only executed if a fails)

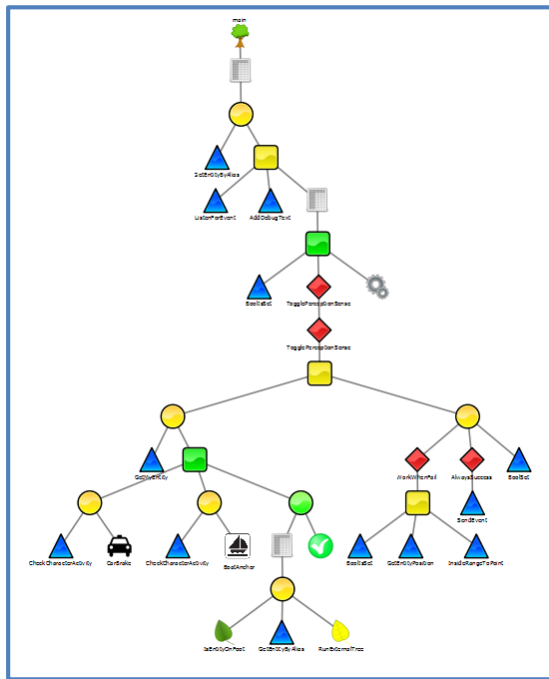
**External
Behavior with
AutoComplete**

External Behavior with autocomplete

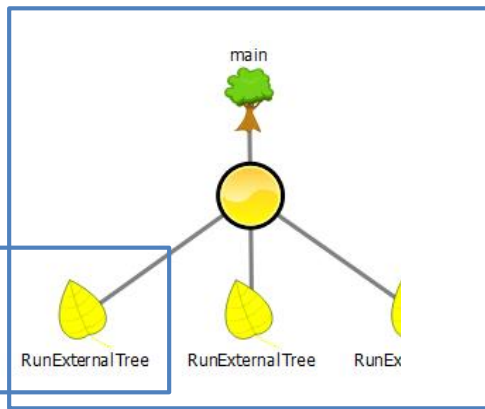
- (tree)
- Event_receive - autocomplete above tree



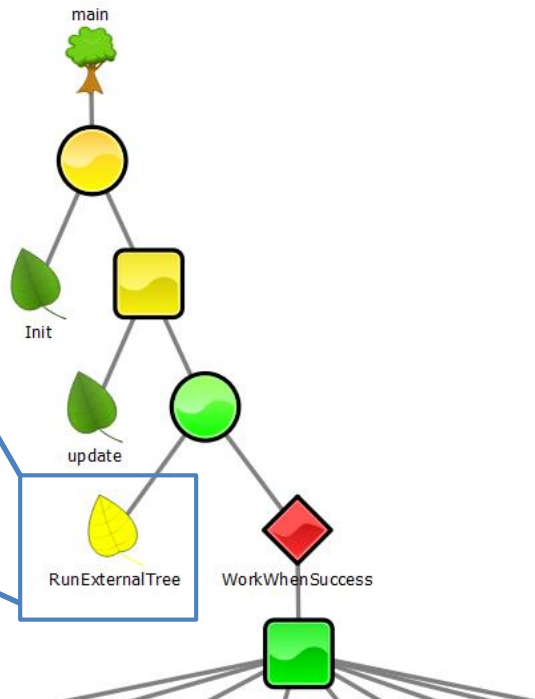
Trees All The Way Down. Why?



Micro-Behavior



Meta Utility Tree



Main Tree



Trees All The Way Down. Why?

“Only by placing the stimulus behavior into the tree itself can we be assured that all the higher-level and higher-priority behaviors have had their say before the stimulus behavior can consider taking action.”

– Damian Isla, GDC 2005

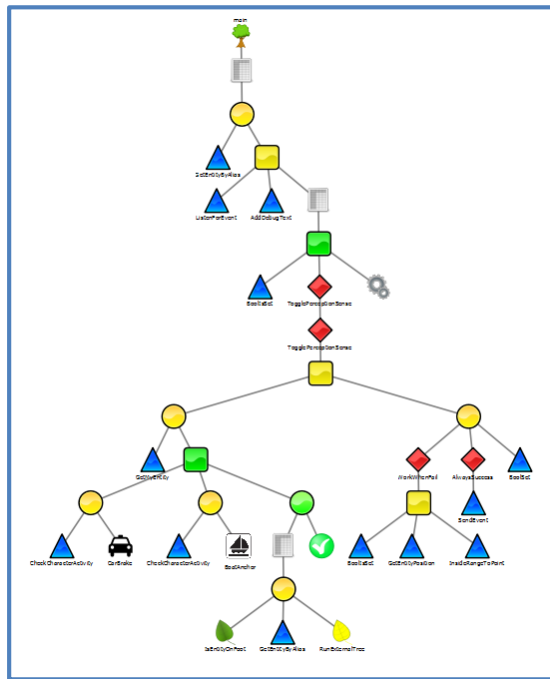
Micro-Behavior

Meta-Utility Tree

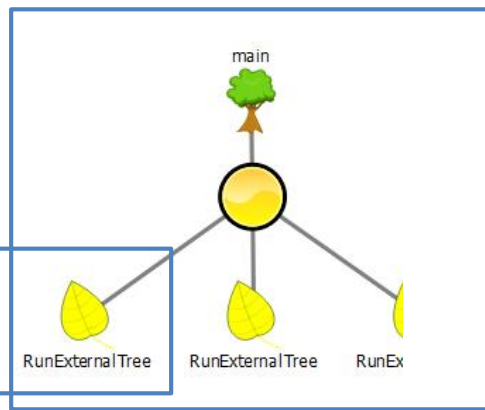
Main Tree



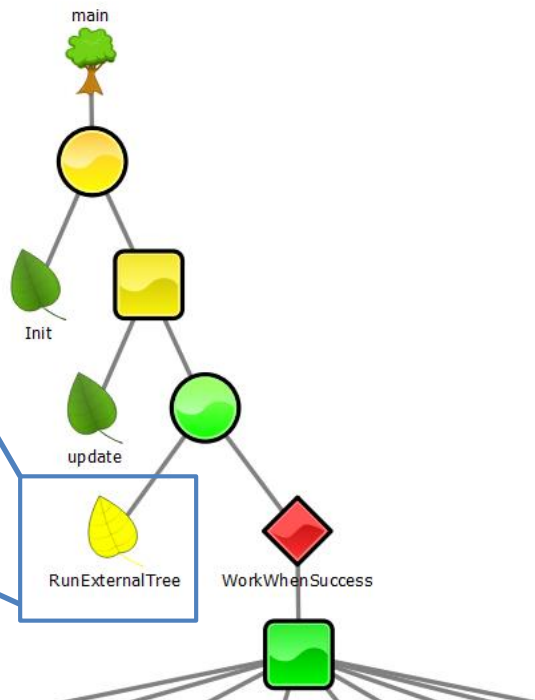
This Three Tree Type Interface...



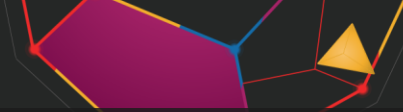
Micro-Behavior



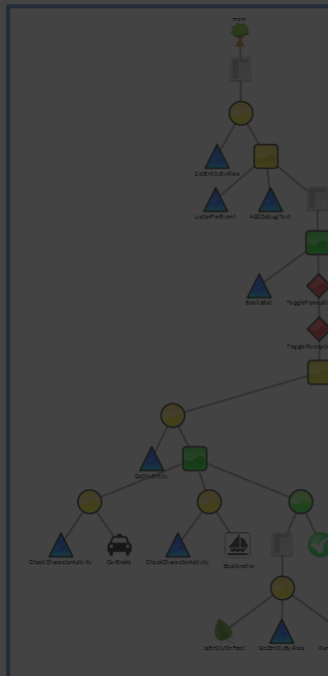
Meta Utility Tree



Main Tree



Trees All Th





How This Synced With the Mission System

Player's Mission Objectives

Reach Mario

Defeat
Enemies

Open The
Gate

Escort To
Trigger

Mario's AI Behaviors

Take Cover in
Police Station

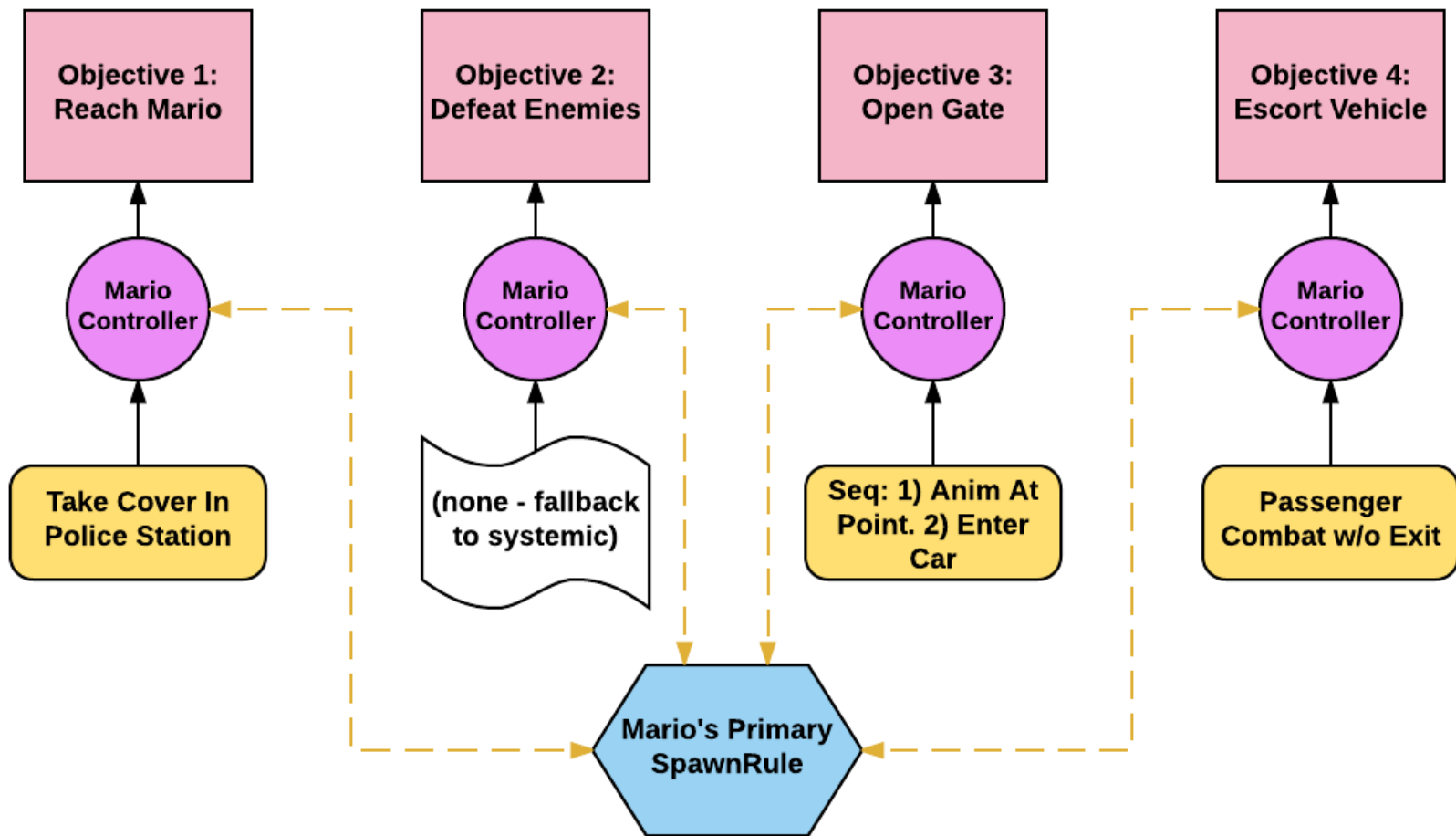
Fight With
Rico Inside
Station

Wait For Gate
position and
loop

Enter the
Rebel Car

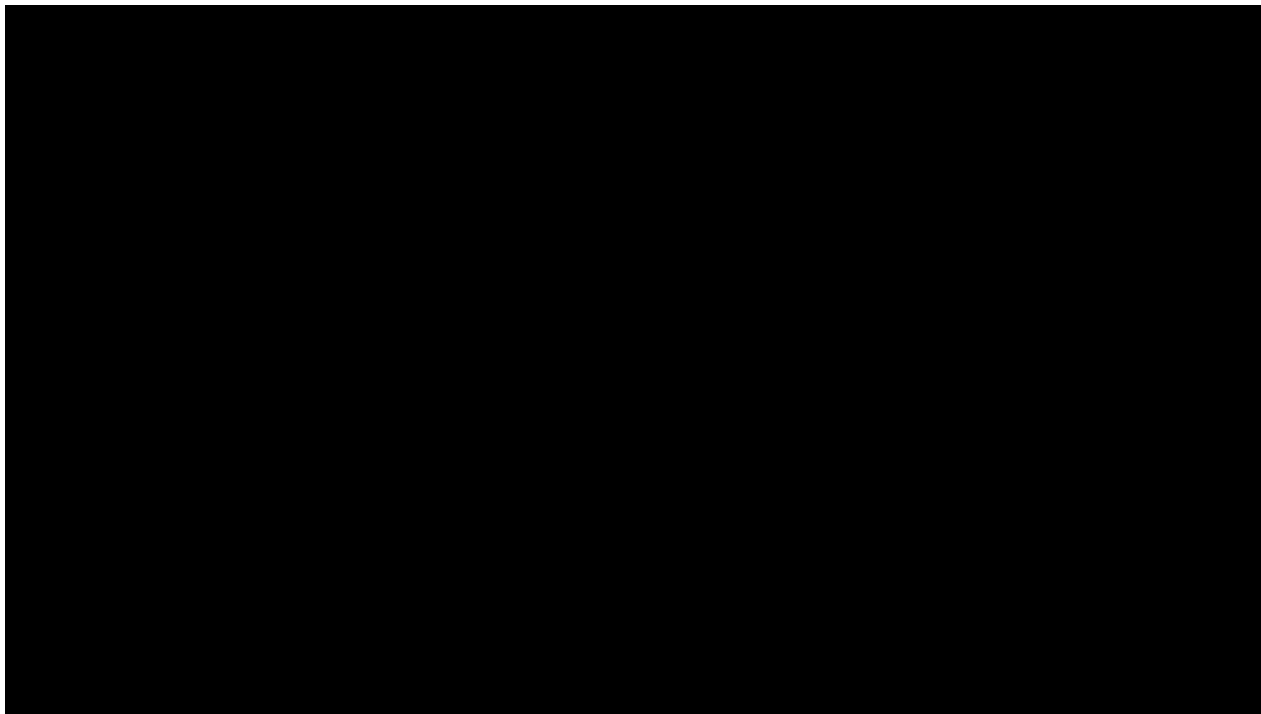
Fight From the
Passenger Seat

Solution: Assigning Trees to each Objective's CharController



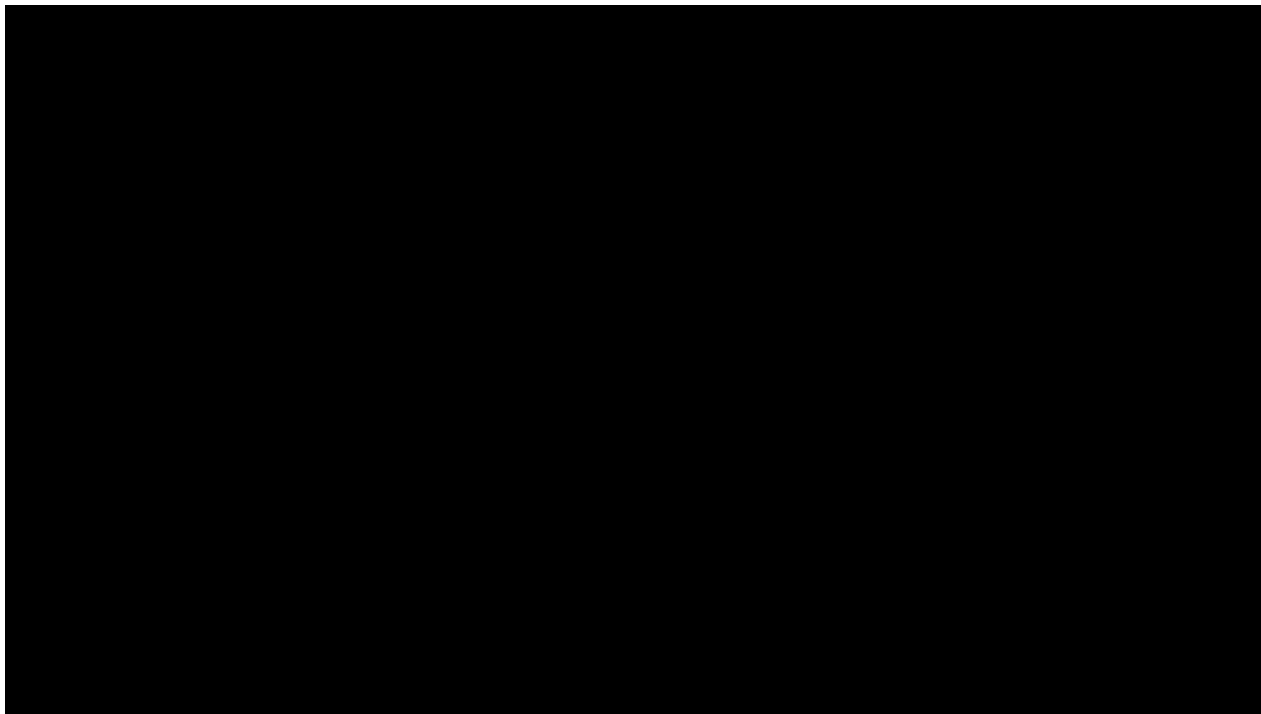


Beyond Missions...





Beyond Missions...





Solving the “Systemic Yet Authorable Problem”... Beyond External Trees...



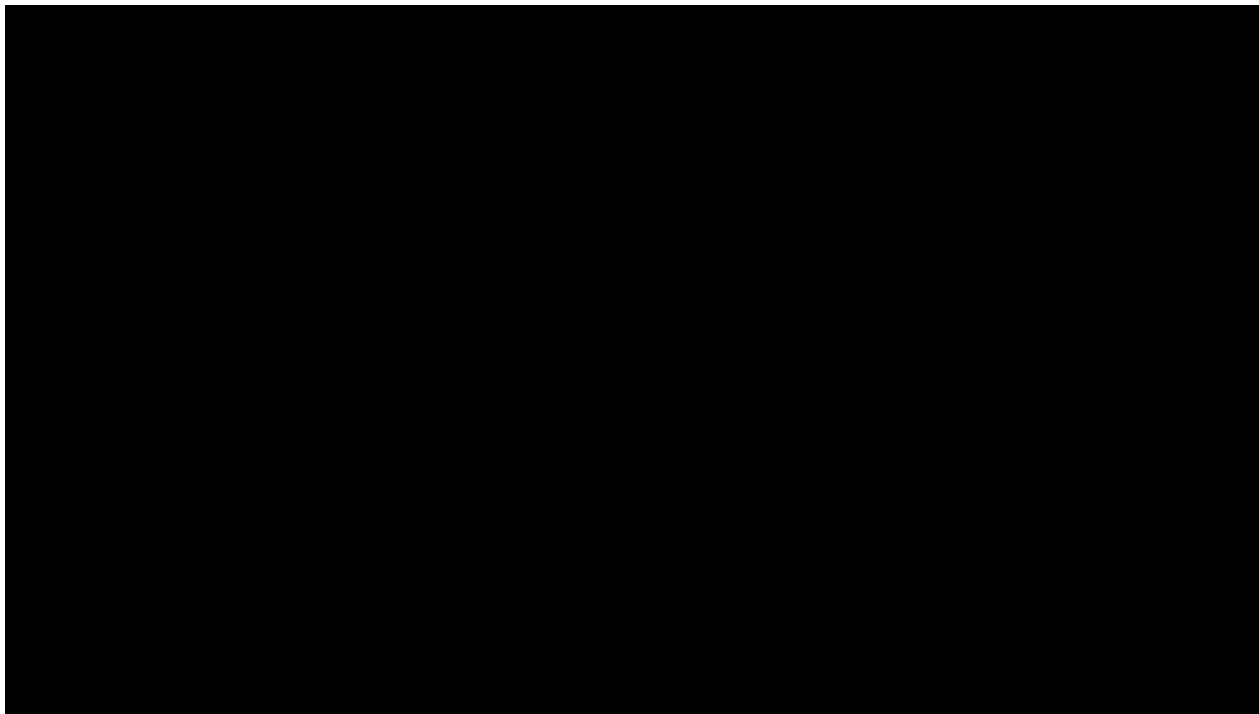


AOOs & Systemic Positioning > Points or Splines





AOOs & Systemic Positioning > Points or Splines





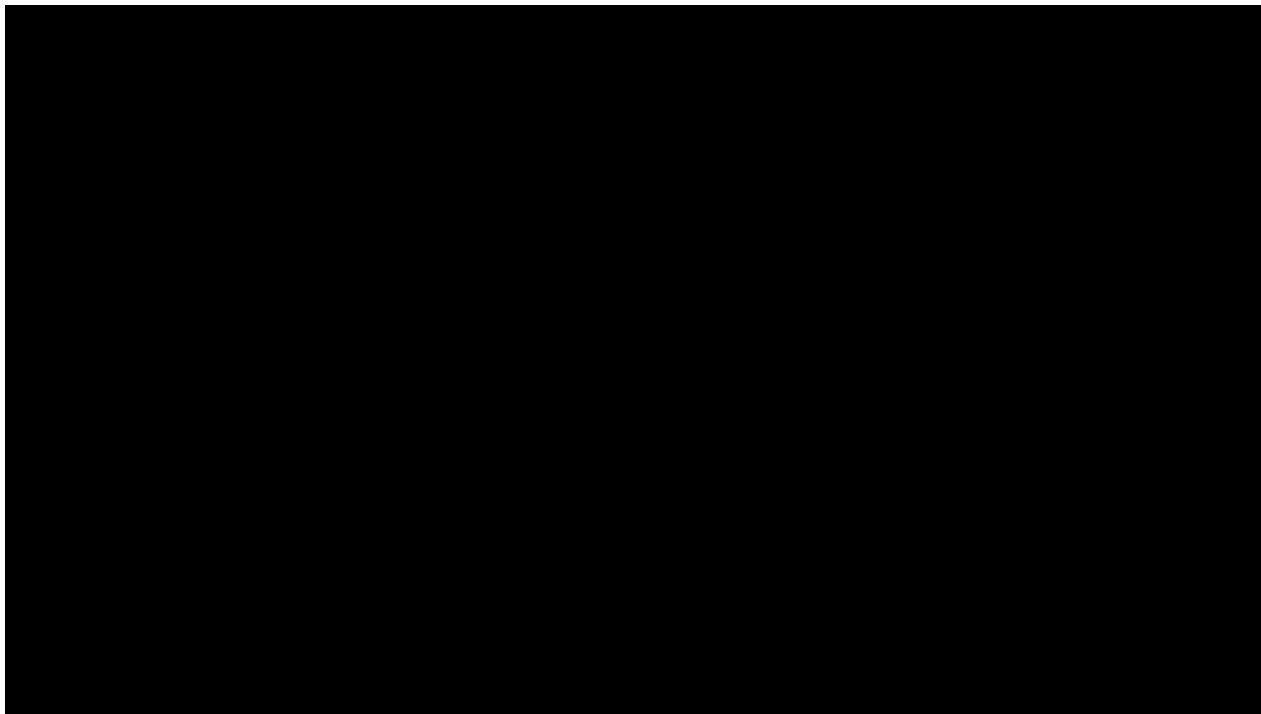








Restricted Areas > Assigned Guard AI





Starting to sense a theme?



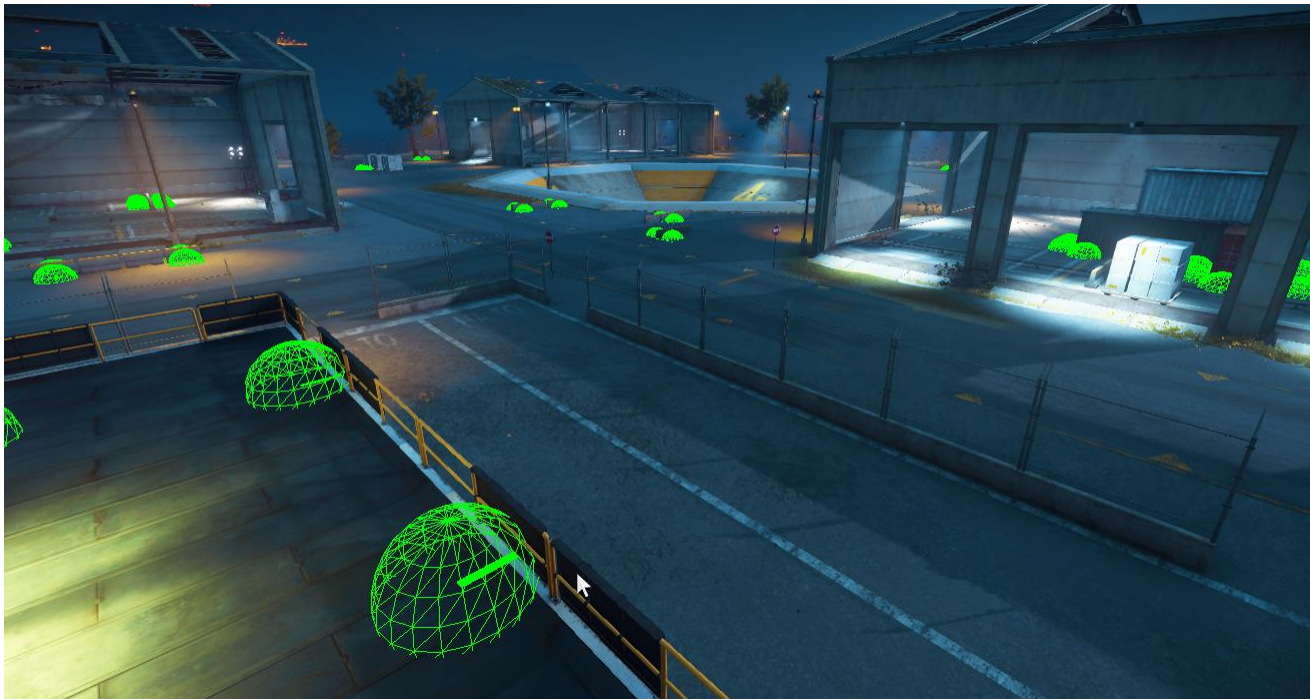


“The more chaotic and unpredictable your game, the more of an intelligence edge the runtime AI will have over the designers.”

– Robert Meyer, GDC 2017



Annotation is Your Friend





Annotation is Your Friend





Built Into Entities/Prefabs? Or Hand-Placed?





Summary

- We created an interface to empower content creators to **safely, yet powerfully “script” their own AI without ever having to open an AI Behavior Tree**, while making sure the core of the systemic brain was preserved.
- We did this using **modular Micro Behaviors on External Trees** that could be packaged with **Meta-Utility Trees** and inserted in **Intro, Interrupt, or Idle** points.
- We successfully synced this with the **Mission System**’s checkpointing by having **Mission Objectives provide the behaviors** to be run during them.
- We **influenced** AI using more **bottom-up, systemic, and annotation-based tools** that could guide the AI, but still let them decide things on their own terms. This is more accommodating to a Just Cause level of unpredictability.





Tree's Company

Systemic AI Design in **JUST CAUSE 3**

@RobotMeyer 

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Special Thanks: Steve Woodzell, Than Bryan, Mark Cerny, and my co-workers at Avalanche.