# Killzone Shadow Fall: Threading the Entity Update on PS4

**Jorrit Rouwé** Lead Game Tech, Guerrilla Games



GAME DEVELOPERS CONFERENCE EUROPE

AUGUST 11-13, 2014 · EXPD: AUGUST 11-12, 2014

# Introduction

- Killzone Shadow Fall is a First Person Shooter
- PlayStation 4 launch title
- In SP up to 60 characters @ 30 FPS
- In MP up to 24 players @ 60 FPS
- Gameplay logic has lots of
  - Branches
  - Virtual functions
  - Cache misses
- Not suitable for PS3 SPU's but PS4 has 6 x86 cores

# What do we cover?

- What is an Entity?
- What we did on PS3
- Multi threading on PS4
- Balancing Entities across frames
- Performance issues found
- Performance results achieved
- Debug tools

## What is an Entity?



# What is an Entity?

- Base class for most game objects
  - E.g. Player, Enemy, Weapon, Door
  - Not used for static world
- Has Components
  - E.g. Model, Mover, Destructibility
- Update at a fixed frequency
  - 15, 30, 60 Hz
  - Almost everything at 15 Hz
  - Player updated at higher frequency to avoid lag

#### What is a Representation?

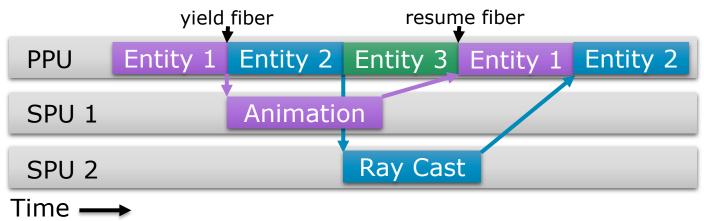
- Entities and Components have Representation
- Controls rendering, audio and VFX
- State is interpolated in frames where entity not updated
  - Cheaper to interpolate than to update
- Introduces latency
  - Always blend towards last update



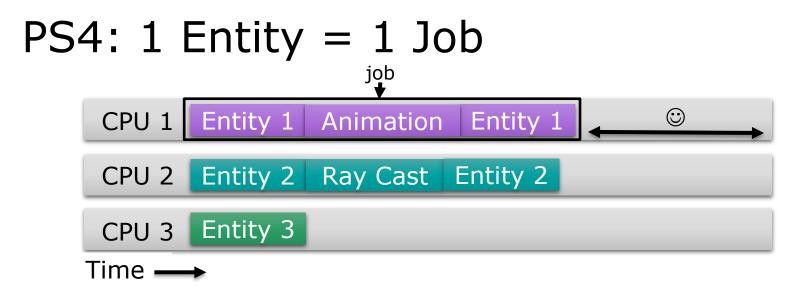
#### Multi Threading Approach



# PS3: 1 Entity = 1 Fiber



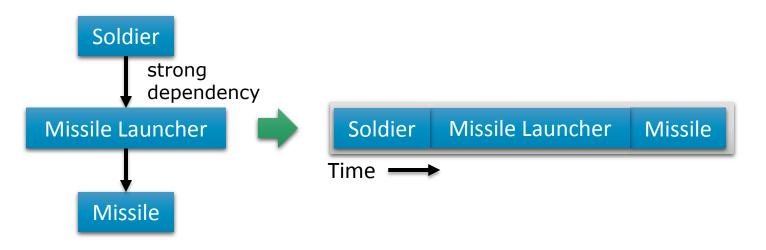
- Most time spent on PPU
- No clear concurrency model
  - Read partial updated state
  - Entities deadlock waiting for each other



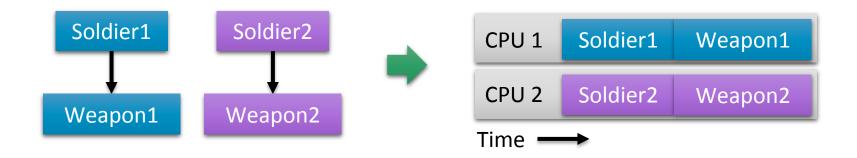
- No fibers
- Entity updates as a whole
- How to solve race conditions?

# Strong Dependencies

Make update order explicit:

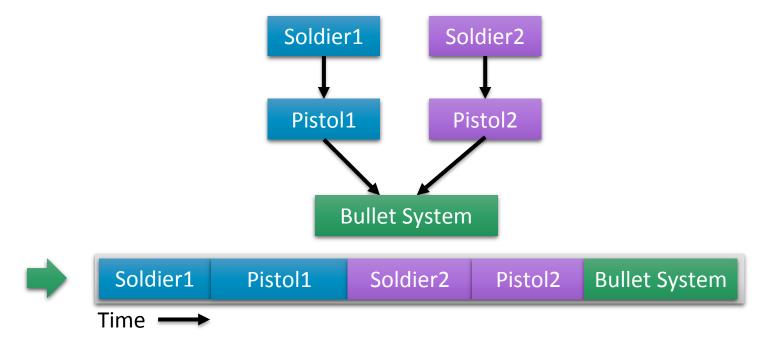


#### Non-dependent Entities can Execute Concurrently



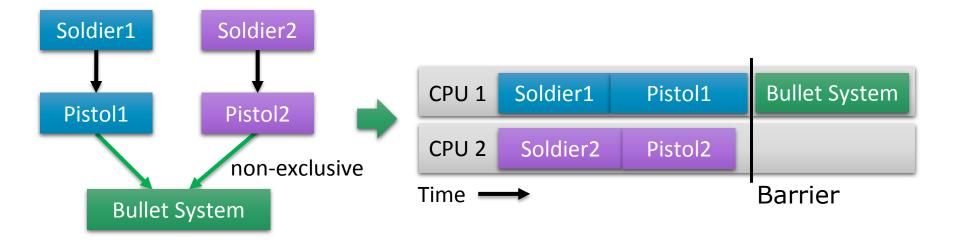
- No (indirect) dependency = no access
- Works two ways: Weapon can access Soldier too
- Create dependency has 1 frame latency
- Global systems need locks

#### What about this?



• A few entities cause huge bottleneck

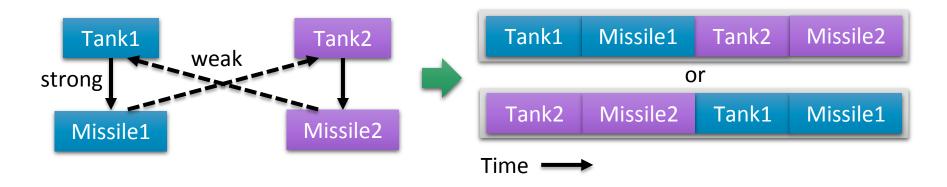
#### Non-exclusive Dependencies



Access to 'Bullet System' must be lock protected

# Weak Dependencies

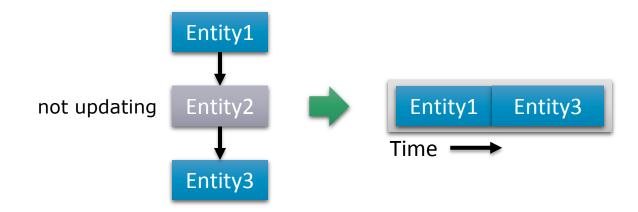
• 2 tanks fire at each other:



- Update order reversed when circular dependency occurs
- Not used very often (< 10 per frame)</li>

# Non-updating Entities

- Entity can skip updates (LOD)
- Entity can update in other frame



• Do normal scheduling!

## Summarizing Dependencies

	Strong Exclusive	Weak Exclusive	Strong Non-excl.	Weak Non-excl.
Symbol	$\longrightarrow$	·		
Two way access	$\checkmark$	$\checkmark$	$\checkmark$	1
Order guaranteed	$\checkmark$		$\checkmark$	
Allow concurrency	+	+	++	++
Require lock			1	$\checkmark$

# **Referencing Entities**

- Dev build: CheckedPtr<Entity>
  - Acts as normal pointer
  - Check dependency on dereference
- Retail build: Entity \*
  - No overhead!
- Doesn't catch everything
  - Can use pointers to members
  - Bugs were easy to find

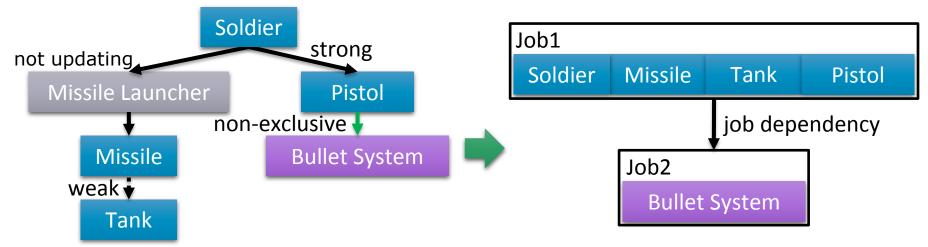
#### Working with Entities without dependency

- ThreadSafeEntityInterface
  - Mostly read only
  - Often used state (name, type, position, ...)
  - Mutex per Entity
- Send message (expensive)
  - Processed single threaded when no dependency
- Schedule single threaded callback (expensive)
  - Everything can be accessed

#### Scheduling Algorithm

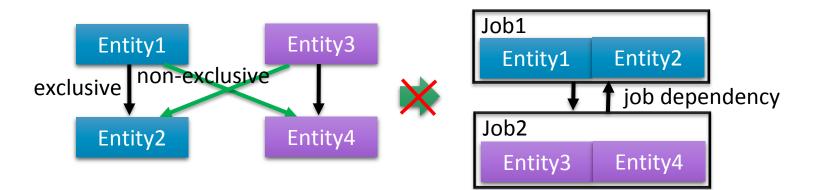


# Scheduling Algorithm

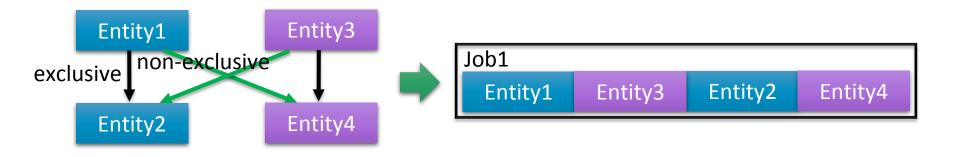


- Entities with exclusive dependencies merged to 1 job
  - Dependencies determine sorting
- Non-exclusive dependencies become job dependencies
- Expensive jobs kicked first!

# Scheduling Algorithm – Edge Case



# Scheduling Algorithm – Edge Case



- Non cyclic dependency becomes cyclic job dependency
- Job1 and Job2 need to be merged

#### **Balancing Entities Across Frames**



# Balancing Entities Across Frames

- Prevent all 15 Hz entities from updating in same frame
- Entity can move to other frame
  - Smaller delta time for 1 update
- Keep parent-child linked entities together
  - Weapon of soldier
  - Soldier on mounted gun
  - Locked close combat

#### Balancing Entities – In Action

Time in even frame (sum across cores, running average)

23.42ms

#### Balancing Entities – In Action

Time in odd frame (should be equal)

23.42ms

Balancing Entities – In Action

23.42ms 23.38ms

> Civilian @ 15Hz update even frame

GDCEUROPE.COM

GDCEUROPE.COM

#### Balancing Entities – In Action

23.42ms Civilian @ 15Hz update odd frame

GDCEUROPE.COM

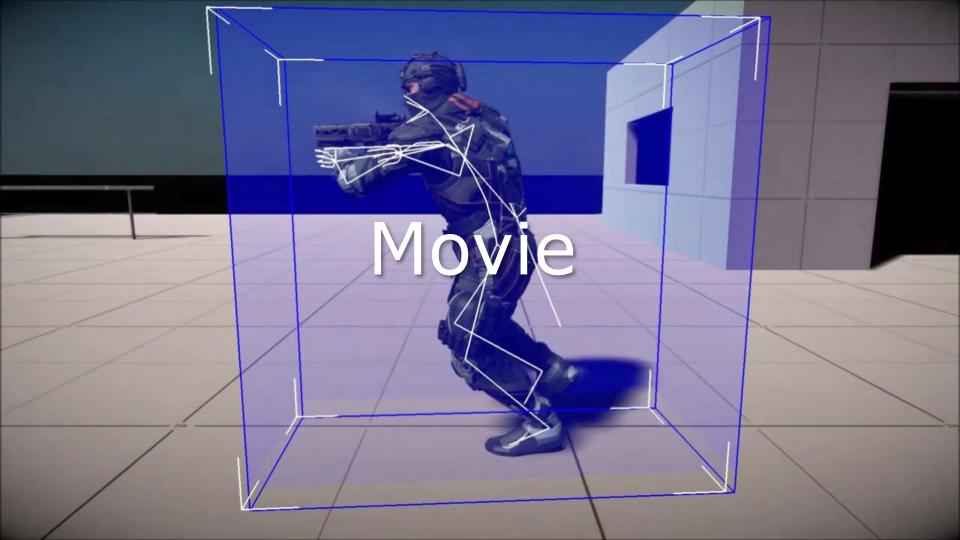
#### Balancing Entities – In Action



20.73ms

5

# Movie



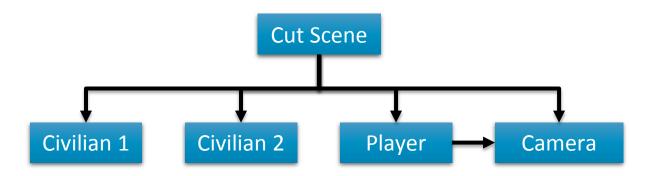
#### Performance Issues



# Performance Issues

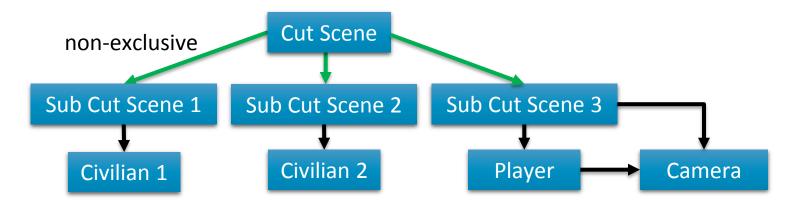
- Memory allocation mutex
  - Eliminated many dynamic allocations
  - Use stack allocator
- Locking physics world
  - R/W mutex for main simulation world
  - Second 'bullet collision' broadphase + lock
- Large groups of dependent entities
- Player update very expensive

#### Cut Scene - Problem



- Cut scene **entity** requires dependencies
- 10+ characters in cut scene creates huge job!

# Cut Scene - Solution



- Create sub cut scenes for non-interacting entities
- Master cut scene determines time and flow
- Scan 1 frame ahead in timeline to create dependency

# Using an Object

- Dependencies on useable objects not possible (too many)
- Get list of usable objects
  - Global system protected by lock
- 'Use' icon appears on screen
- Player selects
  - Create dependency
  - Start 'use' animation
- Start interaction 1 frame later (dependency valid)
- Hides 1 frame delay!

# Grenade

- Explosion damages many entities
- Creating dependencies not option (too many)
- ThreadSafeEntityInterface not an option
  - Need knowledge of parts
- Run line of sight checks inside update
- Uses scheduled callback to apply damage

#### Performance Results



# Performance Results - Synthetic

		Counts		Depen	dencies	Max	
Level	Number	Updating	Number	Strong	Strong	Entities	Speedup
	Entities	Entities	Humans	Excl	Non-Excl	in Job	
5000 Crates (20 µs each)	5019	5008	1	12	4	13	2.8X
100 Soldiers (700 µs each)	326	214	105	212	204	19	4.2X
500 Flags (160 µs each)	519	508	1	12	4	13	5.2X





5000 Crates

100 Soldiers

500 Flags

# Performance Results - Levels

		Counts		Depen	dencies	Max	
Level	Number	Updating	Number	Strong	Strong	Entities	Speedup
	Entities	Entities	Humans	Excl	Non-Excl	in Job	
The Helghast (You Owe Me)	1141	206	32	71	23	20	4.1X
The Patriot (On Vectan Soil)	435	257	44	199	107	15	4.3X
The Remains (12p Botzone)	450	128	14	97	44	18	3.7X



The Helghast

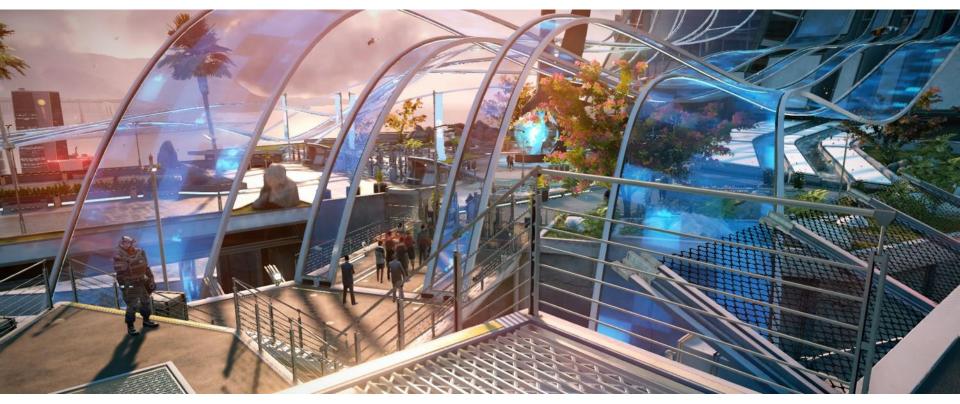
The Patriot

The Remains

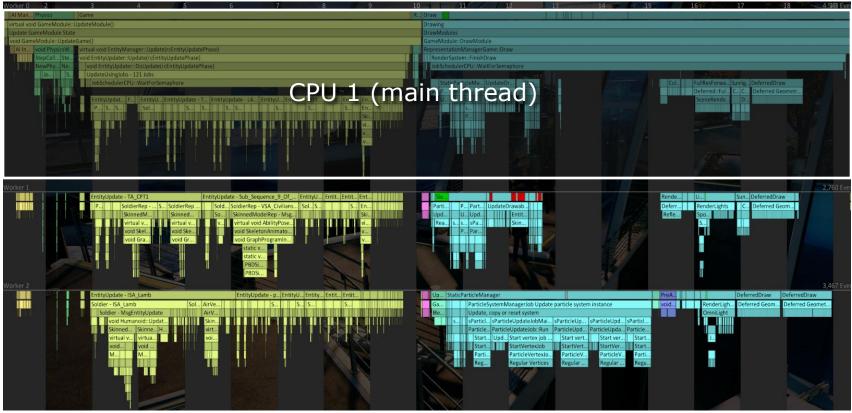
GAME DEVELOPERS CONFERENCE<sup>™</sup> EUROPE 2014 AUGUST 11−13, 2014

GDCEUROPE.COM

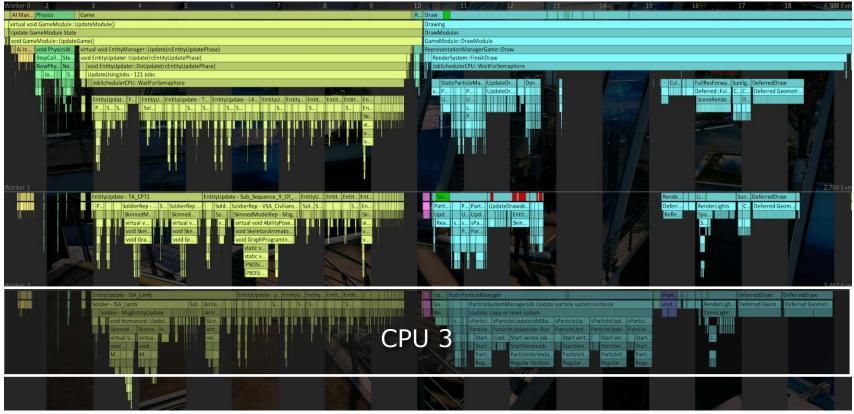
#### Game Frame - The Patriot

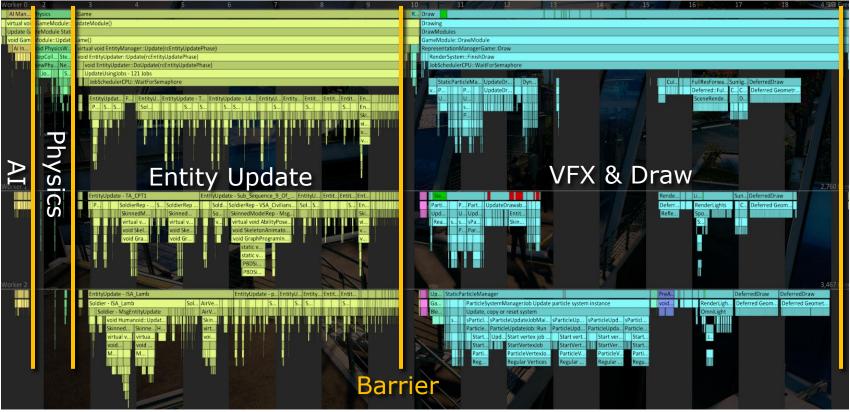


	10 11 12 13 14 15 15 16 17 17 18 18 4 988 Eve
	R. Draw
virtual void GameModule:/UpdateModule()	Drawing Caraving
Update GameModule State	DrawModules
void GameModule::UpdateGame()	GameModule::DrawModule
A In., Void PhysicsW., Vittual void EntityManage::Update(rcEntityUpdatePhase)	RepresentationManagerGame:Draw
StepColl Ste	RenderSystem::FinishDraw JobSchedulerCPU::WaitForSemaphore
NewPhy         Ne         void EntityUpdater::DoUpdate(rcEntityUpdatePhase)           Jo         Js         UpdateUsingJobs - 121 Jobs	DuschedulerCPU, watchisemaphore
Jobs JobSchedulerCPU://WaitForSemaphore	StaticParticleMa UpdateDr Dyn Cul. FullResForwa Sunig DeferredDraw
Prosteriourie of their ordering hole of the second s	V. P. UpdateDr. UpdateDr. C. Deferred Geometr.
EntityUpdat F EntityU EntityU EntityUpdate - T EntityUpdate - L4 EntityU Entity Entit Entit Entit Entit Entit	U U SceneRende D
P., S., S., S., S., S., S., S., S., S., S	
Worker 1	2,760 Ever
EntityUpdate - TA_CPT1 EntityUpdate - Sub_Sequence 9_0f EntityU Entit Ent [Int]	Sie. Sun. DeferredDraw
P., SoldierRep S., SoldierRep Sold. SoldierRep - VSA_Civilians Sol. S., S., En.,	Parti P., Part UpdateDrawab Deferred Geom
SkinnedM Skinned So SkinnedModelRep - Msg Ski	Partu Partu Partu Opareorava Partu
winted v Virtual v V Virtual void AbilityPose Vi	Real S.
void Skel void Skel void Skel void SkeletonAnimato	
void Gra void Gra void Gra void Gra void GraphProgramin	
static v.	
static v	
PBDSI	
	3,467 Eve
Worker 2	
EntityUpdate - ISA_Lamb EntityUpdate - pEntityUEntityEntitEntit	Up StaticParticleManager PreA. DeferredDraw DeferredDraw
Soldier - ISA_Lamb Sol AirVe S S S S Soldier - MsgEntityUpdate AirV	Ga ParticleSystemManagerJob Update particle system instance void RenderLigh Deferred Geom Deferred Geomet Be Update, copy or reset system OmniLight
void Humanoid::Updat	sParticleUpdateJobMain. sParticleUpdateJobMain. sParticleUpd sParticleUpd SParticleUpdateJobMain SParticleUpdateJobSun ParticleUpdateJobParticleUpdateJobParticleUpdateJobParticleUpdateJobParticleUpdateJobParticleUpdateJob
Skinned SkinneH virtu voi	starture Uda, Start vertex job Start vert
void	Start Start Startvert.kib Startvert Startvert Startvert
	Partin. ParticleVertexIo ParticleV Par
Time — → · · · · · · · · · · · · · · · · · ·	
	me
	ms —





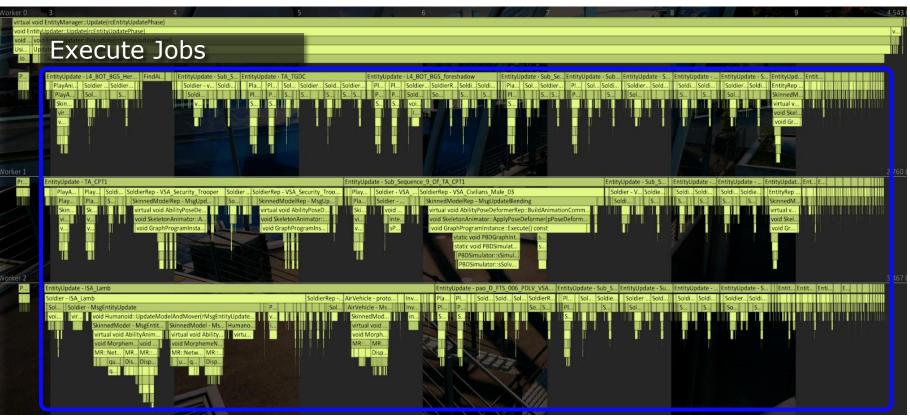




Variable Contraction	Inter Weak Dependency Cycles	
P	thryUpdate - 14 BOT BGS_Her FindA PlayAni Soldier Sold PlayAni Sold Soldier Sold Soldier Sold Soldier Sold S	
Worker 1	2760 1947. Play Soldi Soldier.Rep - VSA_Security_Trooper Play Play Soldier.ep - VSA_Security_Trooper Play Soldier.ep - VSA_Security_Trooper Play Soldier.ep - VSA_Security_Trooper Play Soldier.ep - VSA_Security_Trooper SkinnedModelRep - MsgUpdate - IntityUpdate - Sub_Security_Troo SkinnedModelRep - MsgUpd SkinnedModelRep - MsgUp	7.1
Port	intryUpdate - ISA_Lamb       EntityUpdate - Subs       EntityUpdate -	

Wor	ker C virtu void - ht	PreparentyJobs void entityUpdater::boUpdate(rctnttyUpdatePhase)
	Usi Jo	UpdateUsingJobs - 121 Jobs
	P	EntityUpdate - L4_BOT_BGS_Hen. FindA & EntityUpdate - Sub_S EntityUpdate - TA_TGDC EntityUpdate - L4_BOT_BGS_foreshadow EntityUpdate - Sub_Se EntityUpdate - Sub_S
		PlayA Sol S Sol S Sol S S
		Skin S., S., S., S., S., S., S., S., S.,
Wor	er 1 Pr.	EntityUpdate - TA_CPT1         EntityUpdate - Sub_Sequence 9_Of_TA_CPT1         EntityUpdate
/		PlayA., Play., Soldi.,
		Plav. Plav. SkinnedModelRep - MsgUpd So SkinnedModelRep - MsgUpd So SkinnedModelRep - MsgUpdateBlending Soldi S S S S S SkinnedModelRep - MsgUpdateBlending Soldi
		vi void SkeletonAnimator::A void SkeletonAnimator::A void SkeletonAnimator::A void SkeletonAnimator::A void SkeletonAnimator::A
		v void GraphProgramInsta void GraphProgramInsta void GraphProgramInstance:Execute() const void GraphProgr
		static void PBD/Graphint s static void PBD/Graphint s
		I I I I I I I I I I I I I I I I I I I
Wor	er 2	3,467 ( EntityUpdate - ISA_Lamb EntityUpdate - Sub_S
		Cincroppage so Unit Sold and S
		Sol Solder - MsgEntityUpdate P Sol Solder - MsgEntityUpdate Sol Sol Solder - MsgEntityUpdate
		vol vir vold Humanoid::UpdateModelAndMover(rMsgEntityUpdate v in SkinnedMod in S S S SkinnedModel - MsgEntit SkinnedModel - Ms Humano i Humano i virtual vold
		virtual void AbilityAnim
		void Morphem void Void MorphemeN Write MR: MR: MR: MR: Disp Disp Disp
5.6		

Worker 0 virtua vo void Ent void v Usi Jo.	3 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	8	9 4,543 V
P		Sol Soldi Soldier Sold	ntityUpdate EntityUpdate - S EntityUpdate Soldi Soldier Soldi EntityRep S Sol Sol SkinnedM viritual v void Skel void Gr
Worker 1	EntityUpdate - TA_CPT1 EntityUpdate - Sub_Sequence_9_Of_TA_CPT1 Play Soldier.soldierRep - VSA_Security_Trooper Soldier SoldierRep - VSA_Security_Troo Play Soldier - VSA SoldierRep - VSA_Civilians_Male_03 SkinnedModelRep - MsgUpdateBending Virtual void AbilityPoseDe Virtual void GraphProgramInstance:Execute() const Static void GraphProgramInstance PBDSimulator::sSmul PBDSimulator::sSvv PBDSimulator::sSv		2,760 # ntityUpdate EntityUpdate EntityUpdate EntityUpdate EntityUpdate EntityUpdate EntityRep Soldi Soldi Soldi Soldie EntityRep S S S S Sinned M virtual v void Skel void Skel 3,467 #
	EntityUpdate - ISA_Lamb EntityUpdate - JSA_Lamb Soldier - ISA_Lamb Sol	-	IntityUpdate EntityUpdate - S Entit Entit Entit Entit Entit Sold Sold Sold Solder Sold S S S So S



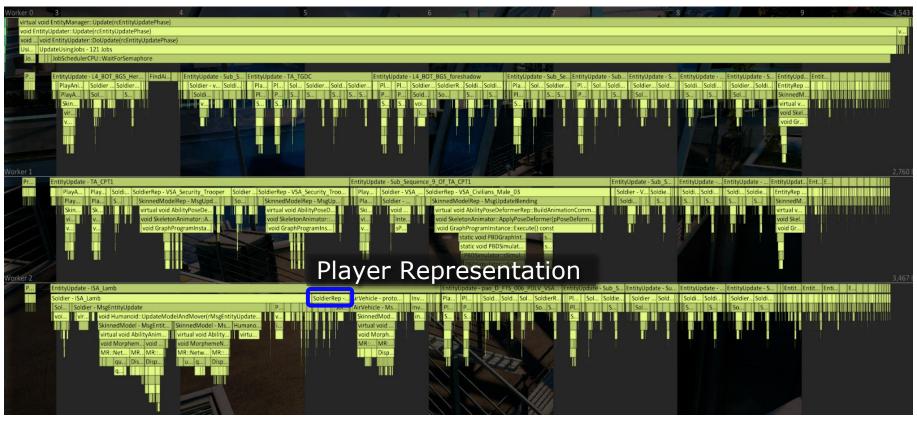
Worker 0 3 4 5 6 1 7	Single Inreaded Callbacks
viciual void EntityManager::Update(rcEntityUpdatePhase)	
void EntityUpdater::Update(rcEntityUpdatePhase)	v
void/void EntityUpdater::DoUpdate(rcEntityUpdatePhase)	
Usi UpdateUsingJobs - 121 Jobs	
Jo    JobSchedulerCPU::WaitForSemaphore	
PEntityUpdate - L4 BOT BGS Her   FindA   EntityUpdate - Sub S EntityUpdate - TA TGDC EntityUpdate - L4 BOT BGS foreshadow   EntityUpdate - Sub Sec.	EntityUpdate - Sub EntityUpdate - S EntityUpdate EntityUpdate - S EntityUpdate - Sub
Proc. Entryplane - Solder - Solder - Market - Chryppane - Sub-Solder - Nach - Plan, Plan, Sold. Solder - Sol	. Pl., Sol., Soldia, Soldier., Soldi, Soldia, Soldia, Soldia, Soldia, Entryopaters, Entryopaters, Entryopaters,
PlayAu, Solu, S., S., Seldu, PlayAu, Solu, S., Seldu, Seldu, S., S	P., S., Sol., S., S., Sol., SkinedM.,
Skin	n i an
	void Skel
	void Gr
Worker 1	2,760
Pr EntityUpdate -TA_CPT1 EntityUpdate -Sub-Sequence 9_0f_TA_CPT1	EntityUpdate - Sub_S   EntityUpdate EntityUpdate EntityUpdat Ent E
PlayA         Play         Soldier.Rep - VSA_Security_Trooper         Soldier.Rep - VSA_Security_Troo         Play         Soldier - VSA	Soldier - V         Soldi         Soldi         Soldi         EntityRep           Soldi         S         S         S         SkinnedM         Soldi
Play Pla S SkinnedModelRep - MsgUpd So SkinnedModelRep - MsgUp Pla Soldier SkinnedModelRep - MsgUpdateBlending Skin Sk Violation Virtual void AbilityPoseDe Violation Virtual void AbilityPoseD Ski Violation Virtual void AbilityPoseDeformerRep:BuildAnimati	
v v void SkeletonAnimator:.A void SkeletonAnimator: vv vv vv void SkeletonAnimator:: vv vv void SkeletonAnimator:: vv vv void SkeletonAnimator:: vv	
v v void GraphProgramInsta void GraphProgramInsta v sP void GraphProgramInstance::Execute() const	void Gr
static void PBDGraphint	
static void PBDSimulat S	
static void PBDSimulat S PBDSimulator::sSimul PBDSimulator::sSimul PBDSimulator::sSimul	
PBDSimulator::solv	
Worker 2	3,467
P EntityUpdate - ISA_Lamb EntityUpdate - ISA_Lamb	intityUpdate - Sub_S EntityUpdate - Su EntityUpdate EntityUpdate - S Entit Entit Entit Entit
	Pl., Sol., Soldie., Soldier., Sold., Soldi., Soldi., Soldi., Soldier., Soldi.,
Sol Soldier - MsgEntityUpdate P Sol AirVehicle - Ms Inv Pl P So So S	Plan S., Solar S., S., Solar S.,
voi vir void Humanoid::UpdateModelAndMover(rMsgEntityUpdate v SkinnedMod in S S S S S S	
virtual void Ability-and void Ability-an	
void Morphem void void MorphemeN	
MR::Net., MR., MR:., MR.:, MR::, MR:	

void Entity	PlayA Sol S Skin Vr V EntityUpdate - TA_CPT1	S       S	Soldier., Soldier., Soldi, Soldi, Soldier., Soldier., Soldi, EntityRep., Soldier., Soldier.
Worker 2	PlayA     Play     Soldier     Soldier	MsgUp         Pla         Soldier         SkinnedModelRep - MsgUpdateBlending           PoseD         Ski         void         virtual void AbilityPoseDeformerRep::BuildAnimationComm           ator::         vi         Inte         void SkeletonAnimator::ApplyPoseDeformer(pPoseDeform	Soldier - V, Soldie       Soldi
	EntityUpdate - ISA_Lamb politier - ISA_Lamb politier - ISA_Lamb politier - ISA_Lamb politier - MsgEntitiVUpdate voi vir void Humanoid::UpdateModelAndMover(rMsgEntityUpdate v SkinnedModel - Msg. Humano i virtual void AbilityAnim void Morphemvoid MR::Net MRMR: q.u Qis Disp q		Sub_S         EntityUpdate - Su         EntityUpdate - Su<

Worker 0 3	A E	6 55 10 1	0
virtual void EntityManager::Update(rcEntityUpdatePhase			2,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4
void EntityUpdater::Update(rcEntityUpdatePhase)			yI
void void EntityUpdater::DoUpdate(rcEntityUpdatePha	ase)		
Usi UpdateUsingJobs - 121 Jobs			
Jo JobSchedulerCPU::WaitForSemaphore			
P EntityUpdate - L4_BOT_BGS_Her FindAi		EntityUpdate - L4_BOT_BGS_foreshadow EntityUpdate - Sub_Se EntityUpdate	
PlayAni Soldier Soldier	Soldier - v Soldi Pl Pl Sol Soldier Sold		Soldi Soldier Sold Soldi Soldi Soldier Soldi EntityRep
PlayA Sol S	Soldino Pluo Pin Sun Sun Sun	S S P P Sold So S S Pl S S P	S Sol Sol S Sol SkinnedM
Skin	S S	S., S., VOI., I S.,	virtual v
vir			void Skel
			void Gr
Pr EntityUpdate - TA_CPT1		Extended to Concern 1 of 14 CB11	2.760 : EntityUpdate - Sub S EntityUpdate EntityUpdate EntityUpdatEntE
	FA Converte Transmer Coldina ColdinaDon MEA Converte Trans	EntityUpdate - Sub_Sequence_9_Of_TA_CPT1	
	/SA_Security_Trooper Soldier SoldierRep - VSA_Security_Troo delRep - MsgUpd So SkinnedModelRep - MsgUp	Play Soldier - VSA SoldierRep - VSA_Civilians_Male_03 Pla Soldier SkinnedModelRep - MsgUpdateBlending	Soldier - V., Soldie., Soldi., Soldi., Soldi., Soldie., EntityRep Soldi., S., S., S., S., S., S., SkinnedM.,
	d AbilityPoseDe	Ski void Skintedviddenep * Wisgopdatebending Ski void void	Store San
	tonAnimator::A	vi Inte void SkeletonAnimator::ApplyPoseDeformer(pPoseDeform	void Skel
The second	hProgramInsta	v sP void GraphProgramInstance::Execute() const	Void Gr
		static void PBDGraphInts.s	
		static void PBDSimulat s	
		PBDSimulator::sSimul	
Dlavor En		PBDSimulator::sSolv	
Worker 2 Player En			3,4671
Par Estimitada 151 hauk		EntityUpdate - pao_D_FTS_006_PDLV_VSA EntityUpdate - S	iub_S EntityUpdate - Su EntityUpdate EntityUpdate - S Entit Entit Enti E
Soldier - ISA_Lamb	oldierRep		Soldie Soldier Sold Soldi Soldi Soldier Soldi
John Johner - Wisgentityopuate	Sol	AirVehicle - Ms Inv Pl P So S Pl	S Sol Sol S S So S
	odelAndMover(rMsgEntityUpdate v	SkinnedMod in S S S	
SkinnedModel - MsgEntit	SkinnedModel - Ms Humano	virtual void	
virtual void AbilityAnim	virtual void Ability virtu	void Morph	
void Morphem void MR::Net MR MR::	Write Morphemen Market Ma	MR:: Disp	
gu., Dis., Disp.,	U. O. Disp.		
gui dan bibri			

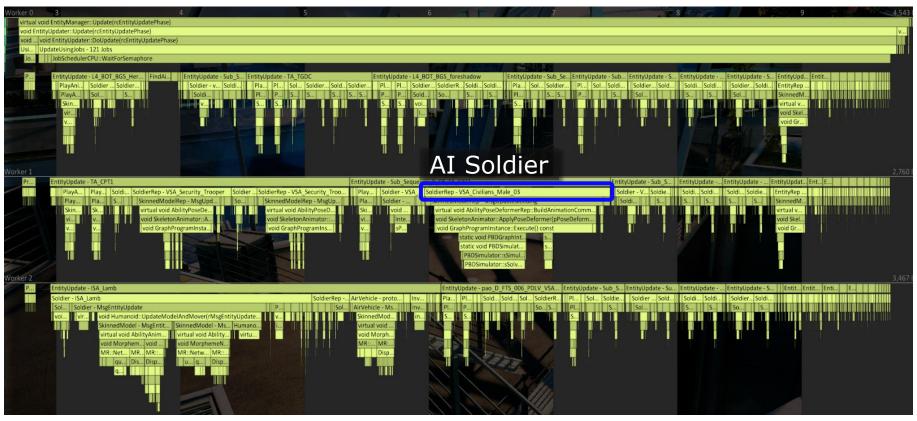
Worker 0 3 4 5 6 1 7 8 8 9	4 5431
vicital void EntityManager::Update/rcEntityUpdatePhase)	
void EntityUpdate::uDpdate(rcEntityUpdatePhase)	V.
void void futityUpdater::DoUpdate(rcEntityUpdatePhase)	
Usi   UpdateUsingJobs - 121 Jobs	im i
Jo   JobSchedulerCPU::WaitForSemaphore	
P., EntityUpdate - L4_BOT_BGS_Her., Find4., EntityUpdate - Sub_S., EntityUpdate - Sub_S., EntityUpdate - Sub_Se., EntityUpdate	
PlayAni., Soldier, Soldier, Soldier, Soldier, Soldier, Soldier, Soldier, Soldi, Pla., Pl., Soldier, Soldi, Pla., Soldier,	
PlayA Sol S Sol S Sol S S	
Sin S. S. S. Vo. I S. S. Vo. I S. Vo. I S. S. Vo. I S.	(1111)
v	
Worker 1	2,760 8
Pr EntityUpdate - Sub_Sequence_9_0f_TA_CPT1 EntityUpdate Enti	
PlayA., Play., Soldier. Rep. vSA. Security_Trooper Soldier., SoldierRep. vSA. Security_Troo., Play., Soldier. v. Soldier. v. Soldier. v. Soldier. V. Soldi., Soldi., Soldi., Soldi., Soldi., Soldi., Soldi., Soldi., EntityRep.	
Pla., Pla., S., SkinnedModelRep - MsgUpd So., SkinnedModelRep - MsgUpd So., SkinnedModelRep - MsgUpd Solidier SkinnedModelRep SkinnedModelRep SkinnedModelRep SkinnedModelRep SkinnedModelRep Skint	
Skin. Skin	limi –
vi v void Skeleton Animator:: A void Skeleton Animator:: vi Inte void Skeleton Animator:: ApplyPoseDeformer(pPose	
v v void GraphProgramInsta v sP void GraphProgramInstance::Execute() const	
static void PBDGraphint s	
static void PBDSimulat	
Image: Static void PBDSimulator::Simul	
PBDSimulator::Solv	
Worker 2	3,4671
P., C EntityUpdate - ISA, Land EntityUpdate - Su., EntityUpdate -	
Soldier-ISA_Lamb Animation SoldierRep Arvehicle-proto Inv Pla Pl Sold Sold Soldier Sold Soldier	
Sol Sodier-Manual IIIIIICUUII P Sol Aivehicie-Ms Inv P Sol P Sol	
vol., Ivir., P	(mini
SkinnedModel - MsgEntitu. SkinnedModel - Ms., Jumano., Ju	Converting of the second secon
void Morpheme. void void MorphemeN void void MorphemeN	
MR::Net. MR:: MR::. MR::	

Worker 0 3 4	5 6 -1 -	7 8 4 543
virtual void EntityManager::Update(rcEntityUpdatePhase)		
void EntityUpdater::Update(rcEntityUpdatePhase)		v
void void EntityUpdater::DoUpdate(rcEntityUpdatePhase)		
Usi UpdateUsingJobs - 121 Jobs		
Jo JobSchedulerCPU::WaitForSemaphore		
	tityUpdate - TA_TGDC EntityUpdate - L4_BOT_BGS_foreshadow EntityUpdate	
		Soldier Pl., Sol., Soldi Soldier Sold Soldi Soldi Soldi Soldier Soldier Soldier Soldier Soldier
PlayA Sol S Soldi	PL., P., S., S., S., S., P., P., Sold., So., S., S., Pl.,	S., S., P., Strand S., Sol., Sol., Strand S., Sol., Sol., SkinnedM.,
Skin	S., S., Voi., J. S., S., Voi., J. C. S., S., Voi., J. C. S., S., M. S., S., S., S., S., S., S., S., S., S.	
vir.		void Skel
		void Gr
Worker 1		2,760
Pr EntityUpdate - TA_CPT1	EntityUpdate - Sub_Sequence_9_Of_TA_CPT1	EntityUpdate - Sub_S EntityUpdate EntityUpdate EntityUpdate EntityUpdate
PlayA Play Soldi SoldierRep - VSA Security Trooper Soldier	SoldierRep - VSA Security Troo Play Soldier - VSA SoldierRep - VSA Civilians Male 03	Soldier - V., Soldie, Soldi, Soldi, Soldi, Soldi, EntityRep
Play Pla S SkinnedModelRep - MsgUpd So	SkinnedModelRep - MsgUp Pla Soldier SkinnedModelRep - MsgUpdateBlending	Soldi S S S S SkinnedM
Skin Sk virtual void AbilityPoseDe	virtual void AbilityPoseD Ski void virtual void AbilityPoseDeformerRep::Buil	IdAnimationComm
Skin Sk virtual void AbilityPoseDe vi v void SkeletonAnimator::A	virtual void AbilityPoseD Vi Void Void Void AbilityPoseDeformerKep::Buil void SkeletonAnimator:: Vi Inte void SkeletonAnimator::ApplyPoseDeform	
		mer(pPoseDeform
vi v void SkeletonAnimator::A	void SkeletonAnimator:: vi vi Inte Void SkeletonAnimator::ApplyPoseDeform	mer(pPoseDeform
vi v void Skeleton Animator:: A	void SkeletonAnimator:: vi Inte void SkeletonAnimator::ApplyPoseDeform void GraphProgramIns v sP void GraphProgramInstance:Execute() cd	mer(pPoseDeform
vi v void Skeleton Animator:: A	void Skeleton Animator:: v v void Skeleton Animator::ApplyPoseDeform void GraphProgramIns v sP void GraphProgramInstance::Execute() c static void PBDGraphInt.	mer(pPoseDeform
vi v void Skeleton Animator:: A	void SkeletonAnimator:: v Inte void SkeletonAnimator::ApplyPoseDeform void GraphProgramIns v sP void GraphProgramInstance::Execute[] of static void PBDSimulat static void PBDSimulat	mer(pPoseDeform
vi v void Skeleton Animator:: A	void SkeletonAnimator::vi intevoid SkeletonAnimator::ApplyPoseDeform void GraphProgramInsvsp sp static void PBDGraphint pBDSimulator::sSimul	mer(pPoseDeform onst s s s s s s
Vi V V V Worker 2	void SkeletonAnimator:: void GraphProgramIns v SP void GraphProgramInstance::fxecute[] of static void PBOGraphInt Static void PBOSimulator::SSimula PBDSimulator::SSiv	mer(pPoseDeform onst S S 3,467
Vi V V V Worker 2	void SkeletonAnimator:: void GraphProgramIns v SP void GraphProgramInstance::fxecute[] of static void PBOGraphInt Static void PBOSimulator::SSimula PBDSimulator::SSiv	mer(pPoseDeform S
Vi V V V Worker 2	void SkeletonAnimator:: void GraphProgramIns v SP void GraphProgramInstance::fxecute[] of static void PBOGraphInt Static void PBOSimulator::SSimula PBDSimulator::SSiv	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2       P       EntityUpdate - ISA_Lamb       Soldier - ISA_Lamb       Soldier - MsgEntityUpdate	void SkeletonAnimator::void GraphProgramIns	mer(pPoseDeform S S Void Gr S Void Gr S S Void Gr Solde:::: Sold:::: Sold::: S
Worker 2       P       EntityUpdate - ISA_Lamb       Solier - ISA_Lamb       Solier - ISA_Lamb       Sol       Sol       Sol       Sol       Sol       Sol       Void Humanoid::UpdateModelAndMover(rMsgEr	void SkeletonAnimator:::       v         void GraphProgramins       v         so       so         so       so         so       so         pBDSimulator:::Smul       pBDSimulator::Smul         pBDSimulator::Solo       static void PBDSimulator::Solo         pBDSimulator::Solo       static void PBDSimulator::Solo         static void PBDSimulator::Solo       pBDSimulator::Solo         static void PBDSimulator::Solo       static void PBDSimulator::Solo         static void PBDSimulator::Solo       pBDSimulator::Solo         static void PBDSimulator::Solo       pBDSimulator::Solo         static void PBDSimulator::Solo       static void PBDSimulator::Solo <td< td=""><td>mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier</td></td<>	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2       P     EntityUpdate - ISA_Lamb       Soldier - ISA_Lamb       Soldier - ISA_Lamb       Soldier - MsgEntityUpdate       Vol       Vol       Vol       Soldier - MsgEntityUpdate       Soldier - MsgEntityUpdate       Soldier - MsgEntityUpdate       Soldier - MsgEntityUpdate       Vol       Vol       Vol       Soldier - MsgEntityUpdate       Soldier - MsgEntityUpdate       Vol       Vol       Vol       Vol       Vol       Soldier - MsgEntityUpdate	void SkeletonAnimator:: void GraphProgramins v se v v se v v v v se void GraphPrograminstance: Executed for static void PBOSimulator::sSimul PBDSimulator::sSimul P	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2         P       EntityUpdate - ISA_Lamb         Soldier - ISA_Lamb         Soldier - MsgEntityUpdate         void JkateModel - MsgEntityUpdate         void Vir         Vvir         Vir         Vir         Vir         Vir         Vir         Vir         Vir         Vir         Void Humanoid::UpdateModelAndMover(rMsgEr         SkinedModel - MsgEntit,         SkinedModel - MsgInttityUpdate         Virtual void AbilityAnim         Virtual void AbilityAnim	void SkeletonAnimator:::       vi       inte         void GraphProgramins       vi       sp	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Vi     v     void Skeleton Animator::A       V     v     void GraphProgramInsta       Notker 2     P     EntityUpdate - ISA_Lamb       Solicer - ISA_Lamb     Solicer - MsgEntityUpdate       Void Humanoid::UpdateModelAndMover(rMsgEr     SkinnedModel - MsgEntityUpdate       Void     Vir     Void Humanoid::UpdateModelAndMover(rMsgEr       Void Humanoid::UpdateModelAndMover(rMsgEr     SkinnedModel - MsgEntityUpdate       Void Humanoid::UpdateModelAndMover(rMsgEr     Void Humanoid::UpdateModelAndMover(rMsgEr       Virtual void AbilityAnim     Virtual void AbilityAnim       Void Morphemvoid     void Morphemet	void SkeletonAnimator:::       v       inte:         void GraphProgramins       v       ise         void GraphProgramins       v       istaic void PBDSimulator::sSmul         PBDSimulator::sSimul       PBDSimulator::sSolv       istaic void PBDSimulator::sSolv         Sold       Sold       Sold       Sold         Virtual void       imat:       Sold       Sold         void Morph       MR:       MR:       MR:	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2       Norker 2       Soldier - ISA_Lamb       Soldier - ISA_Lamb </td <td>void SkeletonAnimator:::       vi       inte         void GraphProgramins       vi       sp</td> <td>mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier</td>	void SkeletonAnimator:::       vi       inte         void GraphProgramins       vi       sp	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Vi     v     void Skeleton Animator::A       V     v     void GraphProgramInsta       Notker 2     P     EntityUpdate - ISA_Lamb       Solicer - ISA_Lamb     Solicer - MsgEntityUpdate       Void Humanoid::UpdateModelAndMover(rMsgEr     SkinnedModel - MsgEntityUpdate       Void     Vir     Void Humanoid::UpdateModelAndMover(rMsgEr       Void Humanoid::UpdateModelAndMover(rMsgEr     SkinnedModel - MsgEntityUpdate       Void Humanoid::UpdateModelAndMover(rMsgEr     Void Humanoid::UpdateModelAndMover(rMsgEr       Virtual void AbilityAnim     Virtual void AbilityAnim       Void Morphemvoid     void Morphemet	void Skeleton Animator::: void GraphProgramIns v v v v v se v v v se v v se v se v v se v v se v v se v se v v v se v	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2       Norker 2       Soldier - ISA_Lamb       Soldier - ISA_Lamb </td <td>void SkeletonAnimator:::       v       inte:         void GraphProgramins       v       ise         void GraphProgramins       v       istaic void PBDSimulator::sSmul         PBDSimulator::sSimul       PBDSimulator::sSolv       istaic void PBDSimulator::sSolv         Sold       Sold       Sold       Sold         Virtual void       imat:       Sold       Sold         void Morph       MR:       MR:       MR:</td> <td>mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier</td>	void SkeletonAnimator:::       v       inte:         void GraphProgramins       v       ise         void GraphProgramins       v       istaic void PBDSimulator::sSmul         PBDSimulator::sSimul       PBDSimulator::sSolv       istaic void PBDSimulator::sSolv         Sold       Sold       Sold       Sold         Virtual void       imat:       Sold       Sold         void Morph       MR:       MR:       MR:	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2         P       EntityUpdate - ISA_Lamb         Soldier - ISA_Lamb         Soldier - ISA_Lamb         Soldier - ISA_Lamb         Soldier - WagEntityUpdate         Voil.       Voil GraphProgramInstall         Voil.       Soldier - WagEntityUpdate         Soldier - WagEntityUpdate       SkinnedModel - MsgEntit         Voil.       Void Morphem	void Skeleton Animator::::::::::::::::::::::::::::::::::::	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Worker 2         P       EntityUpdate - ISA_Lamb         Soldier - ISA_Lamb         Soldier - ISA_Lamb         Soldier - ISA_Lamb         Soldier - WagEntityUpdate         Voil.       Voil GraphProgramInstall         Voil.       Soldier - WagEntityUpdate         Soldier - WagEntityUpdate       SkinnedModel - MsgEntit         Voil.       Void Morphem	void Skeleton Animator::::::::::::::::::::::::::::::::::::	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier
Vii     V     void Skeleton Animator::A       V     V     void GraphProgramInsta       Worker 2.     P     EntityUpdate - ISA_Lamb       Soldier - ISA_Lamb     Soldier - MsgEntityUpdate       Voi     Soldier - MsgEntityUpdate       Voi     Void GraphProgramInsta       Void     Soldier - MsgEntityUpdate       Voi     Void GraphProgramInsta       Void     SkinnedModel - MsgEntit       Void Morphem     Void AbilityAnim       Void Morphem     Void Morphem       Void Morphem     MR::Netw	void Skeleton Animator::::::::::::::::::::::::::::::::::::	mer(pPoseDeform s S Void Gr S Void Gr Soldier Soldier





Worker 0	3 4	5	5 - F 7	8 8 7 1	9 4 543
	vid EntityManager::Update(rcEntityUpdatePhase)				
void Entit	tyUpdater::Update(rcEntityUpdatePhase)				V
	pid EntityUpdater::DoUpdate(rcEntityUpdatePhase)				
	pdateUsingJobs - 121 Jobs				
Jo	JobSchedulerCPU::WaitForSemaphore				
	Entrated and a part part time of the second second			Charles and the Charles and the	
Pin			bdate - L4_BOT_BGS_foreshadow EntityUpdate - Sub_Se EntityUpdate Pl Soldier Soldier Soldi Soldi Pla Sol Soldier Pl Sol		tyUpdate - S EntityUpd Entit Idier Soldi EntityRep
	PlayAni Soldier Soldier Soldier - v So PlayA Sol S Soldi	Plan Plan Son Son Son Son Son Plan Plan Plan	P Soldier Soldier Soldi Soldi Soldi Soldier Pl Sol Soldier Pl Sol	Sul Solar Solar Sul	
	Skin		S vn		and wirtual v
	Virz.				void Skel
-	v				void Gr
Worker 1					2,7601
Pr	EntityUpdate - TA_CPT1	EntityUpdate - Su	ub_Sequence_9_Of_TA_CPT1	EntityUpdate - Sub_S EntityUpdate Entit	Update EntityUpdat Ent E
	PlayA Play Soldi SoldierRep - VSA_Security_Trooper	Soldier SoldierRep - VSA_Security_Troo Play Soldie	er - VSA SoldierRep - VSA_Civilians_Male_03	Soldier - V., Soldie., Soldi., Soldi., Soldi., Sold	i Soldie EntityRep
	Play Pla S SkinnedModelRep - MsgUpd	So SkinnedModelRep - MsgUp Pla Soldie	er SkinnedModelRep - MsgUpdateBlending	Soldi S S S S	S SkinnedM
	Skin Sk virtual void AbilityPoseDe		pid virtual void AbilityPoseDeformerRep::BuildAnimationComm		virtual v
	vi v void SkeletonAnimator:: A	void Skeleton Animator:	Inte Void SkeletonAnimator::ApplyPoseDeformer(pPoseDeform		void Skel
				이 이 이 아이는 것 같아요. 이 아이 아	
	v v void GraphProgramInsta	void GraphProgramIns	sP void GraphProgramInstance::Execute() const	T'' I (T'I T	void Gr
			sP void GraphProgramInstance::Execute() const static void PBDGraphInt	п' і П' і п	
		Void GraphProgramIns v g	sP void GraphProgramInstance::Execute() const		
		Void GraphProgramIns v g	sP void GraphProgramInstance::Execute[] const static void PBOGraphInt S static void PBOGraphInt S PBDSimulator::sSimul	п і п і п	
			sP void GraphProgramInstance::Execute[] const static void PBOGraphInt S static void PBOGraphInt S PBDSimulator::sSimul		void Gr
Worker 2	v v void GraphProgramInsta	Void GraphProgramIns v g	sp void GraphProgramInstance::Execute() const static void PBOGraphInt 5 static void PBDSimulat 5 PBDSimulator::stamulator: Inventory		void Gr
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb	void GraphProgramIns	sp void GraphProgramInstance::Execute() const static void PBOGraphInt		void Gr 
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb	Void GraphProgramIns	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si SoldSoldSoldSolderR Pla Pla		void Gr
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldler - ISA_Lamb Soldler - ISA_Lamb	SoldierRep AirVehicle - proto	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si SoldSoldSoldSolderR Pla Pla		void Gr 
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb ISol   Soldier - MsgEntityUpdate Voi vir void Humanoid::UpdateModelAndMover(rMsgEnt	SoldierRep AirVehicle - proto P	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si SoldSoldSoldSolderR Pla Pla		void Gr 
Worker 2 P	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb (Sol) [Soldier - MsgEntityUpdate voi vir] void Humanoid::UpdateModelAndMover(rMsgEnti	SoldierRep AirVehicle - proto P	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si SoldSoldSoldSolderR Pla Pla		void Gr 
Worker 2 P	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb Soldier - ISA_Lamb Soldier - MsgEntityUpdate voi vir void Humanoid::UpdateModelAndMover(rMsgEnt SkinnedModel - MsgEntit skinnedModel - MsgEntityUpdate virtual void AbilityAnim virtual void Ability virtual void AbilityAnim void MorphemeN	SoldierRep AirVehicle - proto SoldierRep AirVehicle - proto P ityUpdate wmano virtual void virtual void virtual woid writh MR: MR: MR: MR:	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si SoldSoldSoldSolderR Pla Pla		void Gr 
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier -	Void GraphProgramIns V SoldierRep AirVehicle - proto SoldierRep AirVehicle - Ms SityUpdate V Humano I Virtual void Virtual void Void Morph	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si SoldSoldSoldSolderR Pla Pla		void Gr 
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb Sol Soldier - MsgEntityUpdate Voi Virt Void Humanoid::UpdateModelAndMover(rMsgEnt SkinnedModel - MsgEntt SkinnedModel - Mss virtual void AbilityAnim void MorphermVoid MR::Net MR::Net MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR:	Void GraphProgramIns V V V V V V V	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si Soid		void Gr 
Worker 2	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier -	SoldierRep AirVehicle - proto SoldierRep AirVehicle - proto P ityUpdate wmano virtual void virtual void virtual woid writa MR: MR: MR:	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si Soid		void Gr 
Worker 2 P	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb Sol Soldier - MsgEntityUpdate Voi Virt Void Humanoid::UpdateModelAndMover(rMsgEnt SkinnedModel - MsgEntt SkinnedModel - Mss virtual void AbilityAnim void MorphermVoid MR::Net MR::Net MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR:	Void GraphProgramIns V V V V V V V	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si Soid		void Gr 
Worker 2 P	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb Sol Soldier - MsgEntityUpdate Voi Virt Void Humanoid::UpdateModelAndMover(rMsgEnt SkinnedModel - MsgEntt SkinnedModel - Mss virtual void AbilityAnim void MorphermVoid MR::Net MR::Net MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR:	Void GraphProgramIns V V V V V V V	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si Soid		void Gr 
Worker 2 P	v v void GraphProgramInsta EntityUpdate - ISA_Lamb Soldier - ISA_Lamb Sol Soldier - MsgEntityUpdate Voi Virt Void Humanoid::UpdateModelAndMover(rMsgEnt SkinnedModel - MsgEntt SkinnedModel - Mss virtual void AbilityAnim void MorphermVoid MR::Net MR::Net MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR: MR: MR: MR:: MR::Net MR MR:	Void GraphProgramIns V V V V V V V	SP void GraphProgramInstance::Execute() const Static void PBOSmulat S Inventod PBOSimulat PBDSimulator::SSimula EntityUpdate=pao.D_FTS_000_PDLV_VSA EntityUpdate=Si Soid		void Gr 





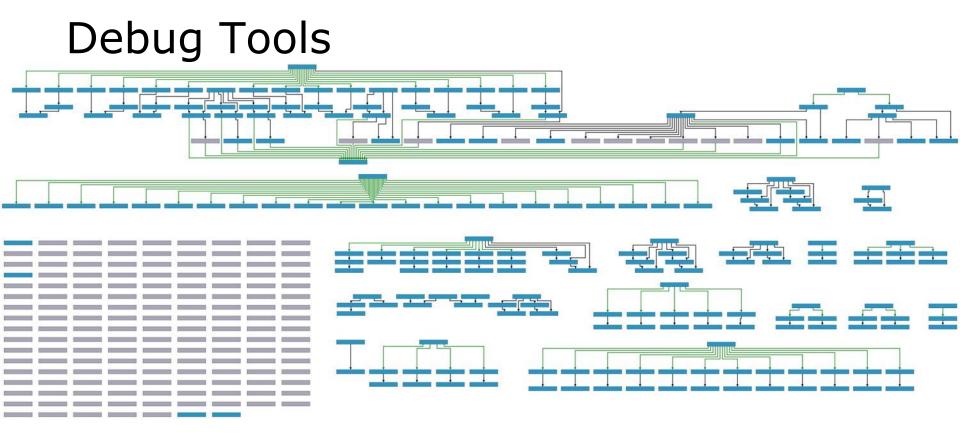




void Enti	3 6 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	Cheap Entities (Destructibles)
P	PlayAni Soldier	trtyUpdate - Sub_Se EntityUpdate - Sub EntityUpdate - S E
Worker 1		760 I
Pr	EntityUpdate - TA_CPT1       EntityUpdate - Sub_Sequence 9_Of_TA_CPT1         PlayA       PlayA       Soldier-Rep - VSA_Security_Trooper       Soldier-Rep - VSA_Security_Troo         PlayA       Pla       S.       SxinnedModelRep - MsgUpd       So.         Skin       Sk       Virtual void AbilityPoseDe       Virtual void AbilityPoseDe       Virtual void AbilityPoseDe       Virtual void AbilityPoseDe         V       V       void GraphProgramInsta       void GraphProgramInstance:       void GraphProgramInstance:       void GraphProgramInstance:       void GraphProgramInstance:         PBDSimulator::Sin       PBDSimulator::Sin       PBDSimulator::Sin       PBDSimulator::Sin       PBDSimulator::Sin	Biending         Sold         S
	EntityUpdate - ISA_Lamb Soldier - ISA_Lamb S	

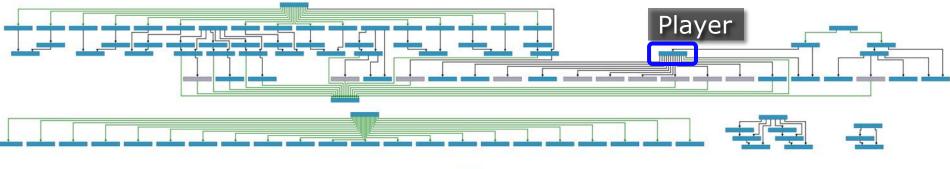
# Debug Tools

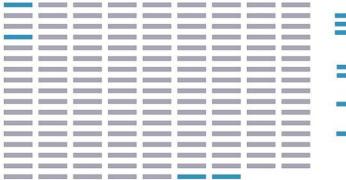


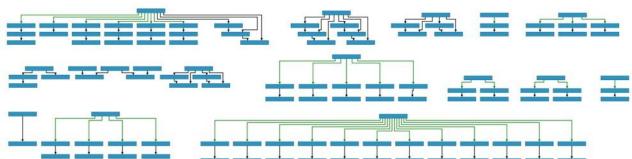


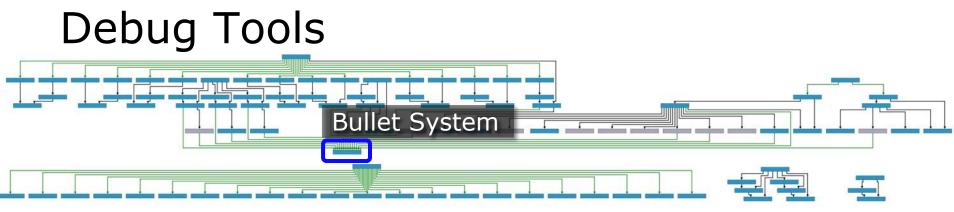
• Dependencies get complex, we use yEd to visualize!

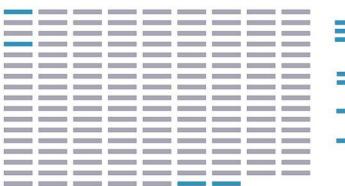


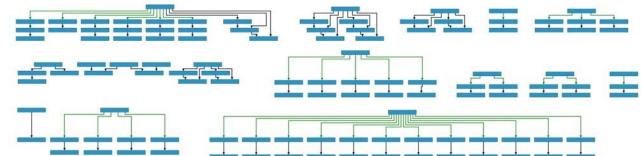




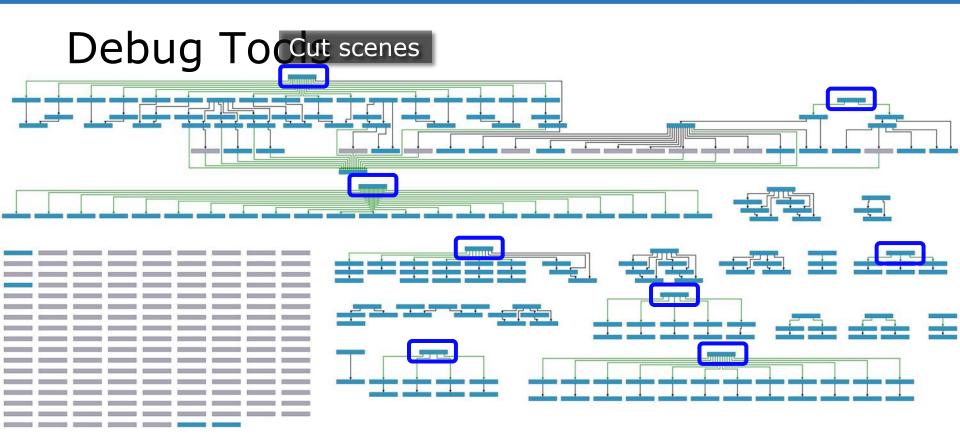








GAME DEVELOPERS CONFERENCE<sup>™</sup> EUROPE 2014 AUGUST 11–13, 2014



GDCEUROPE.COM

# Conclusions

- Easy to implement in existing engine
- Game programmers can program as if single threaded
- Very few multithreading issues

GAME DEVELOPERS CONFERENCE<sup>™</sup> EUROPE 2014 AUGUST 11−13, 2014



#### jorrit@guerrilla-games.com