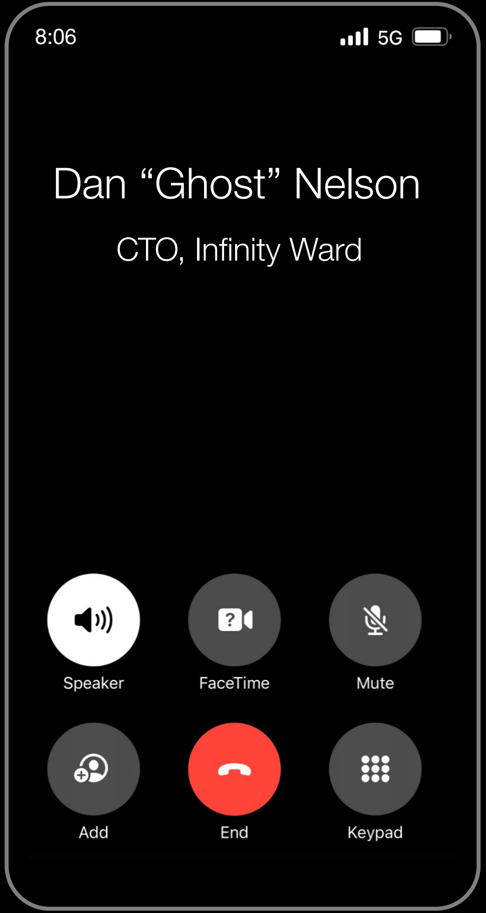
OPTIMIZING UI's CPU BOUND FRAMERATE IN CALL OF DUTY

OPERATION UI CODE

SIMON ESCHBACH | SLEDGEHAMMER GAMES

THE CALL TO ARMS

OPERATION UI CODE



HELLO?

HEY IT’S DAN. WE’VE UH.. WE’VE GOT A PROBLEM.

WHAT IS IT?

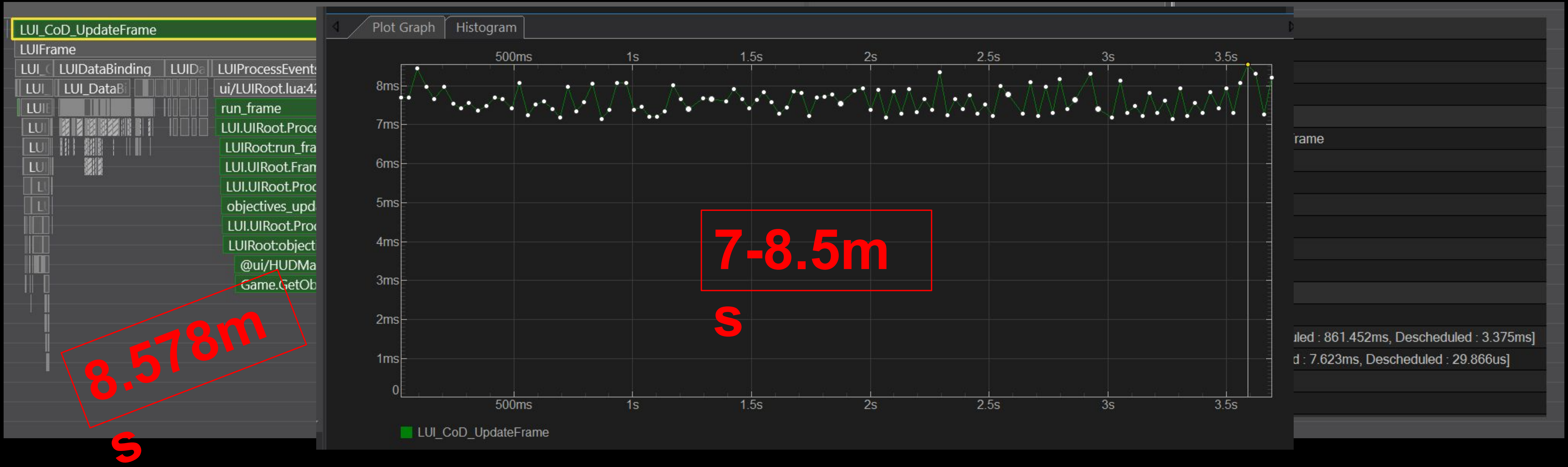
IT’S THE UI. IT’S INFILTRATED OUR BORDERS.

ALRIGHT. I CAN HELP. BUT I’M GOING TO NEED A TEAM.

ASSEMBLE IT.

PART 1: THE STATE OF AFFAIRS

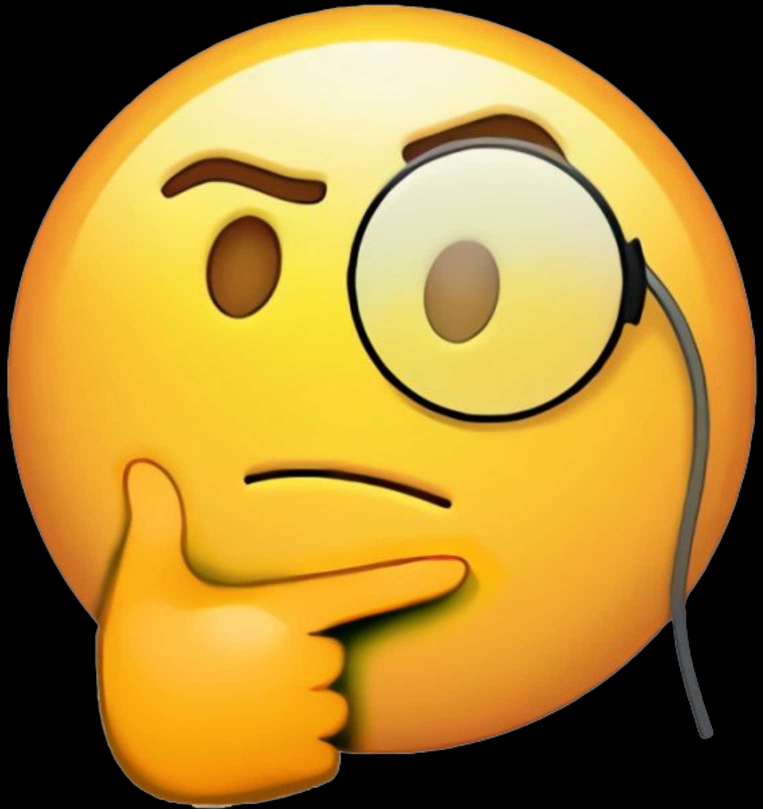
SUSTAINED HUD FRAME TIME



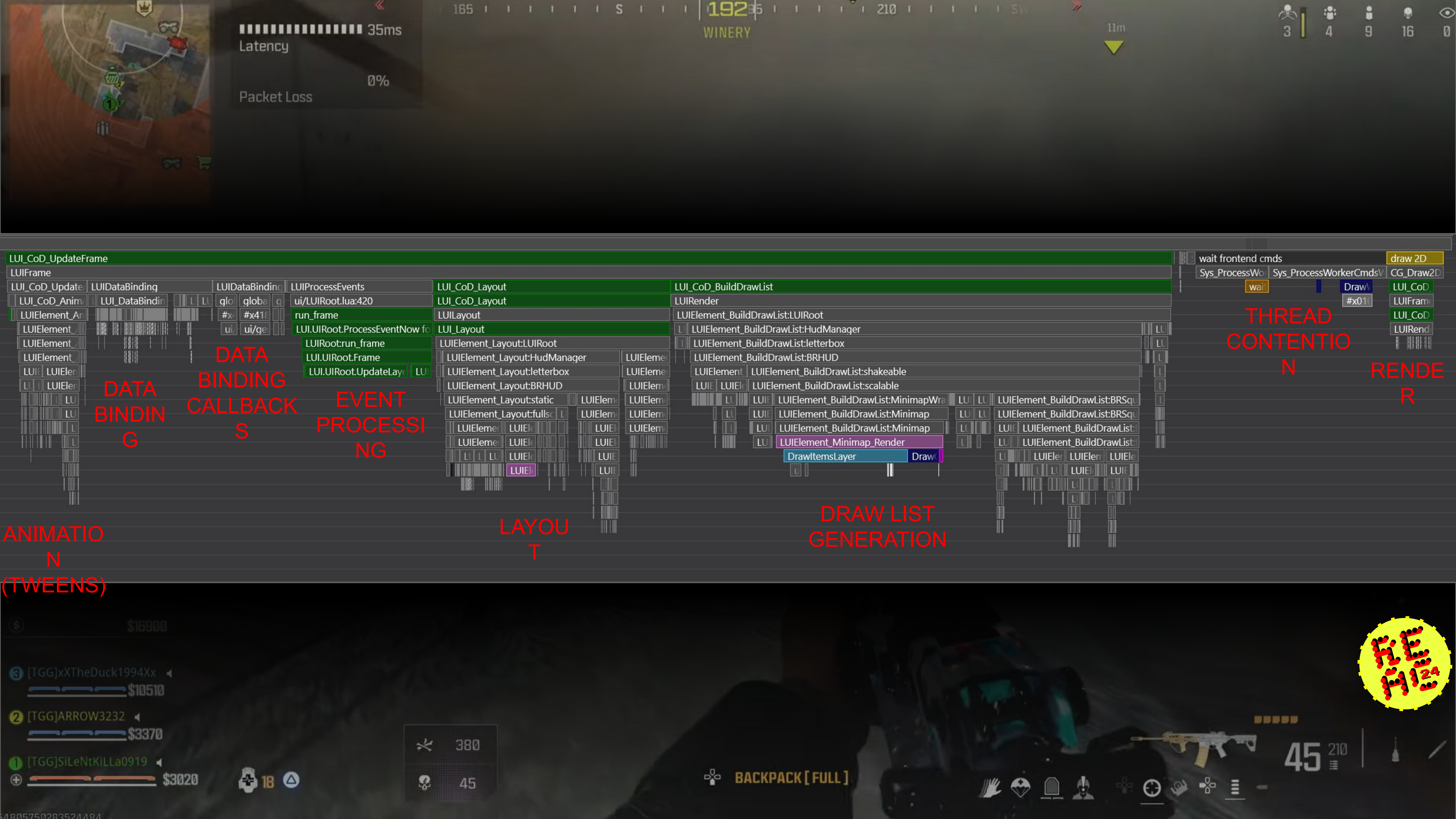
led : 861.452ms, Descheduled : 3.375ms]
d : 7.623ms, Descheduled : 29.866us]

MAIN THREAD.
GROUND WAR, LOCAL CAPTURE, 25 BOTS (PS4 BASE).

HOW COULD WE SPEND SO MUCH TIME

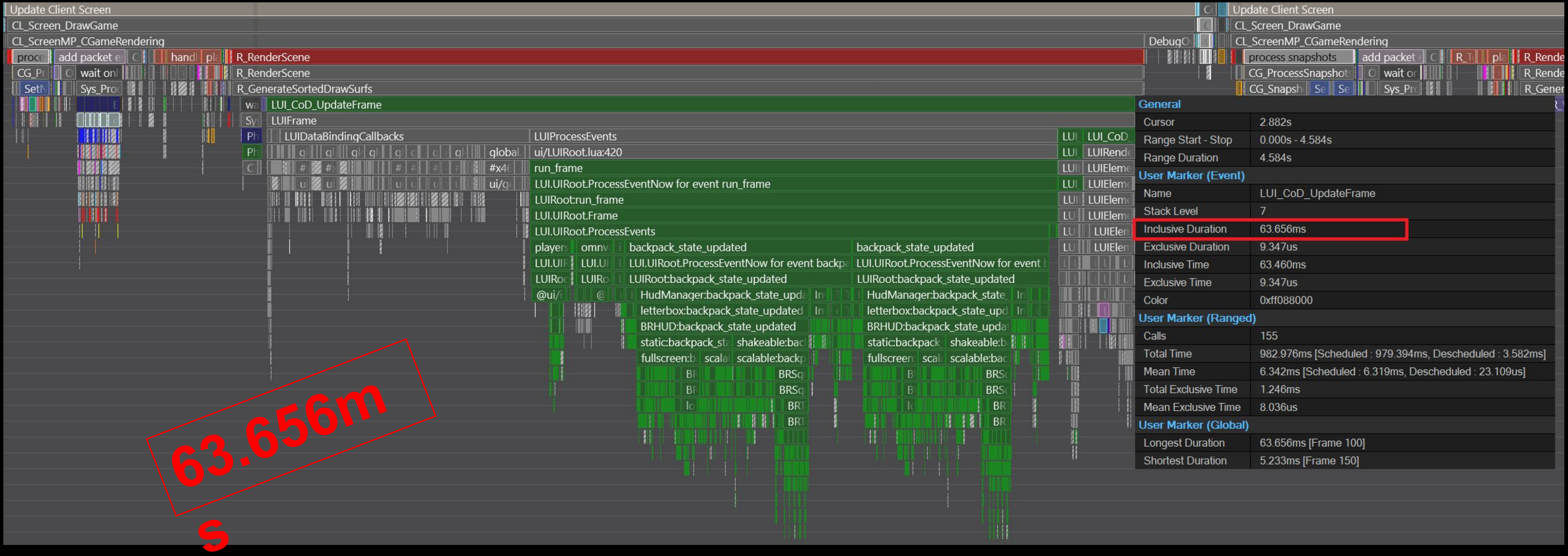


RENDERING QUADS?



LUI_CoD_UpdateFrame
LUIFrame
LUI_CoD_Update
LUIDataBinding
LUIProcessEvents
LUI_CoD_Layout
LUI_CoD_BuildDrawList
LUI_CoD_Anim
LUI_DataBindin
ui/LUIRoot.lua:420
LUIRender
run_frame
LUILayout
LUIElement_BuildDrawList:LUIRoot
LUI.UIRoot.ProcessEventNow fo
LUI_Layout
LUIElement_BuildDrawList:HudManager
LUIRoot:run_frame
LUIElement_Layout:LUIRoot
LUIElement_BuildDrawList:letterbox
LUI.UIRoot.Frame
LUIElement_Layout:HudManager
LUIElement_BuildDrawList:BRHUD
LUI.UIRoot.UpdateLay
LUIElement_Layout:letterbox
LUIElement_BuildDrawList:shakeable
LUIElement_Layout:BRHUD
LUIElement_BuildDrawList:scalable
LUIElement_Layout:static
LUIElement_BuildDrawList:MinimapWra
LUIElement_BuildDrawList:BRSqu
LUIElement_Layout:fullsc
LUIElement_BuildDrawList:Minimap
LUIElement_Minimap_Render
DrawItemsLayer
wait frontend cmds
draw 2D
Sys_ProcessWo
Sys_ProcessWorkerCmdsV
CG_Draw2D
LUI_CoD
LUIFrame
LUIRend
ANIMATION (TWEENS)
DATA BINDING
DATA BINDING CALLBACKS
EVENT PROCESSING
LAYOUT
DRAW LIST GENERATION
THREAD CONTENTION
RENDER
Latency 35ms
Packet Loss 0%
WINERY
BACKPACK [FULL]

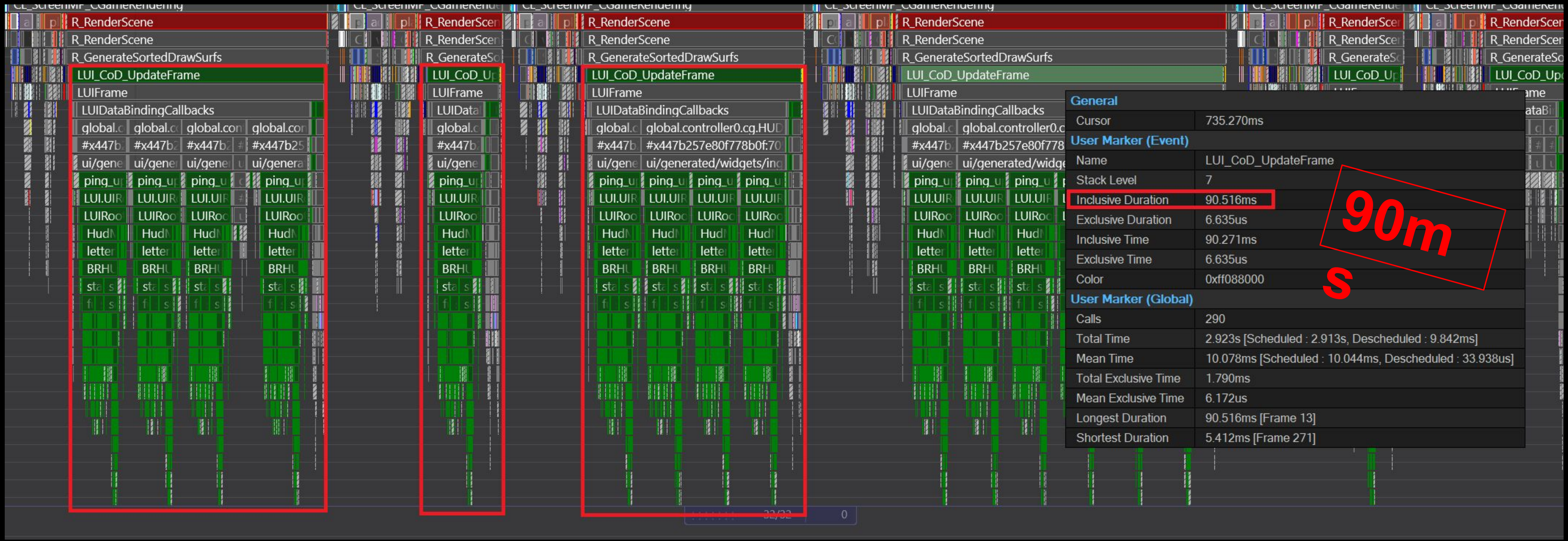
SPIKE FRAMES



General	
Cursor	2.882s
Range Start - Stop	0.000s - 4.584s
Range Duration	4.584s
User Marker (Event)	
Name	LUI_CoD_UpdateFrame
Stack Level	7
Inclusive Duration	63.656ms
Exclusive Duration	9.347us
Inclusive Time	63.460ms
Exclusive Time	9.347us
Color	0xff088000
User Marker (Ranged)	
Calls	155
Total Time	982.976ms [Scheduled : 979.394ms, Descheduled : 3.582ms]
Mean Time	6.342ms [Scheduled : 6.319ms, Descheduled : 23.109us]
Total Exclusive Time	1.246ms
Mean Exclusive Time	8.036us
User Marker (Global)	
Longest Duration	63.656ms [Frame 100]
Shortest Duration	5.233ms [Frame 150]

5 FRAMES DROPPED WHEN A PARTY MEMBER DIES.

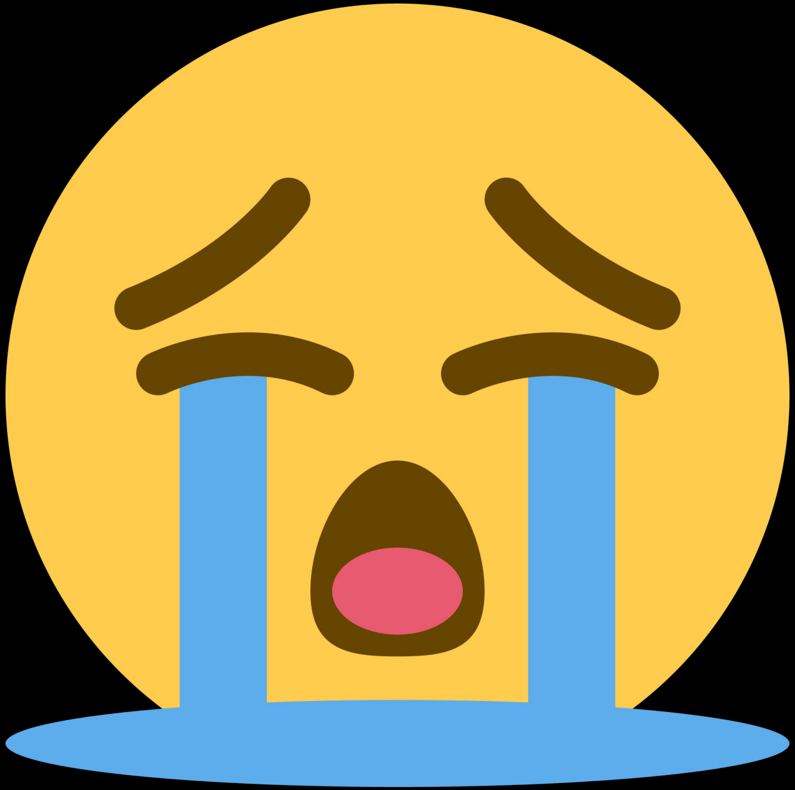
SPIKE FRAMES IN SUCCESSION



General	
Cursor	735.270ms
User Marker (Event)	
Name	LUI_CoD_UpdateFrame
Stack Level	7
Inclusive Duration	90.516ms
Exclusive Duration	6.635us
Inclusive Time	90.271ms
Exclusive Time	6.635us
Color	0xff088000
User Marker (Global)	
Calls	290
Total Time	2.923s [Scheduled : 2.913s, Descheduled : 9.842ms]
Mean Time	10.078ms [Scheduled : 10.044ms, Descheduled : 33.938us]
Total Exclusive Time	1.790ms
Mean Exclusive Time	6.172us
Longest Duration	90.516ms [Frame 13]
Shortest Duration	5.412ms [Frame 271]

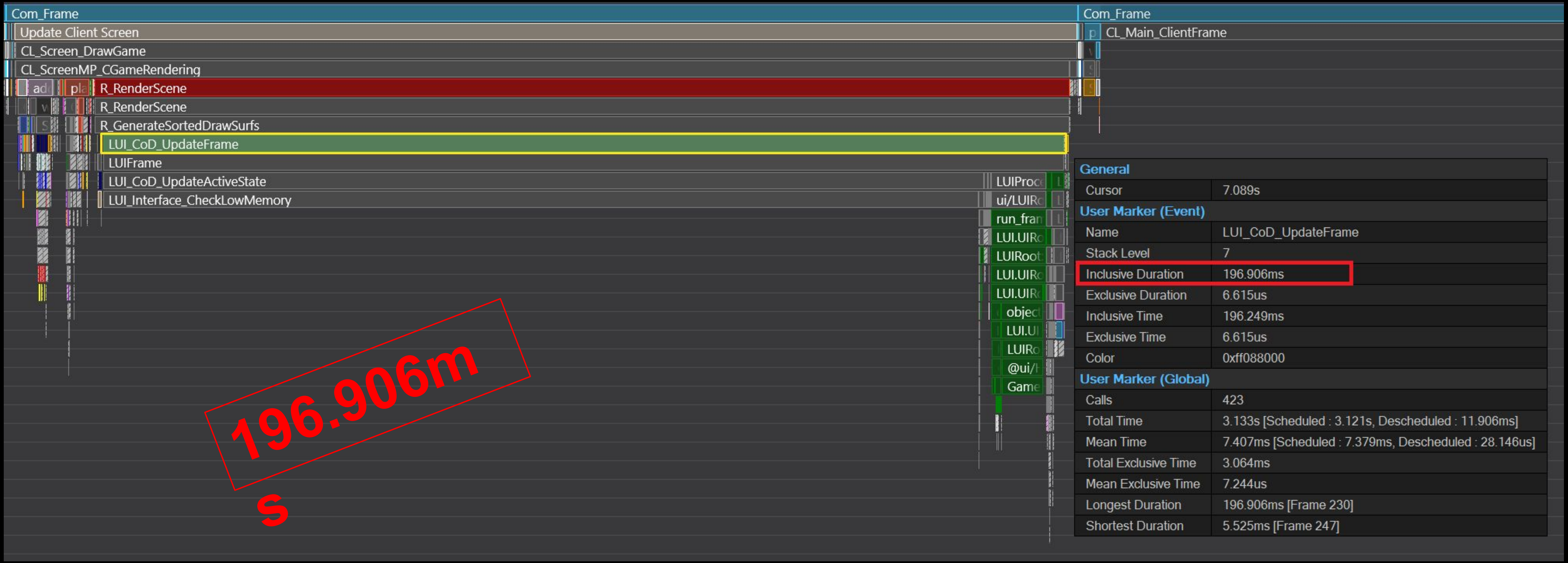
6 FRAMES DROPPED OVER MULTIPLE FRAMES IN SUCCESSION WHEN PINGING

DROPPED FRAMES



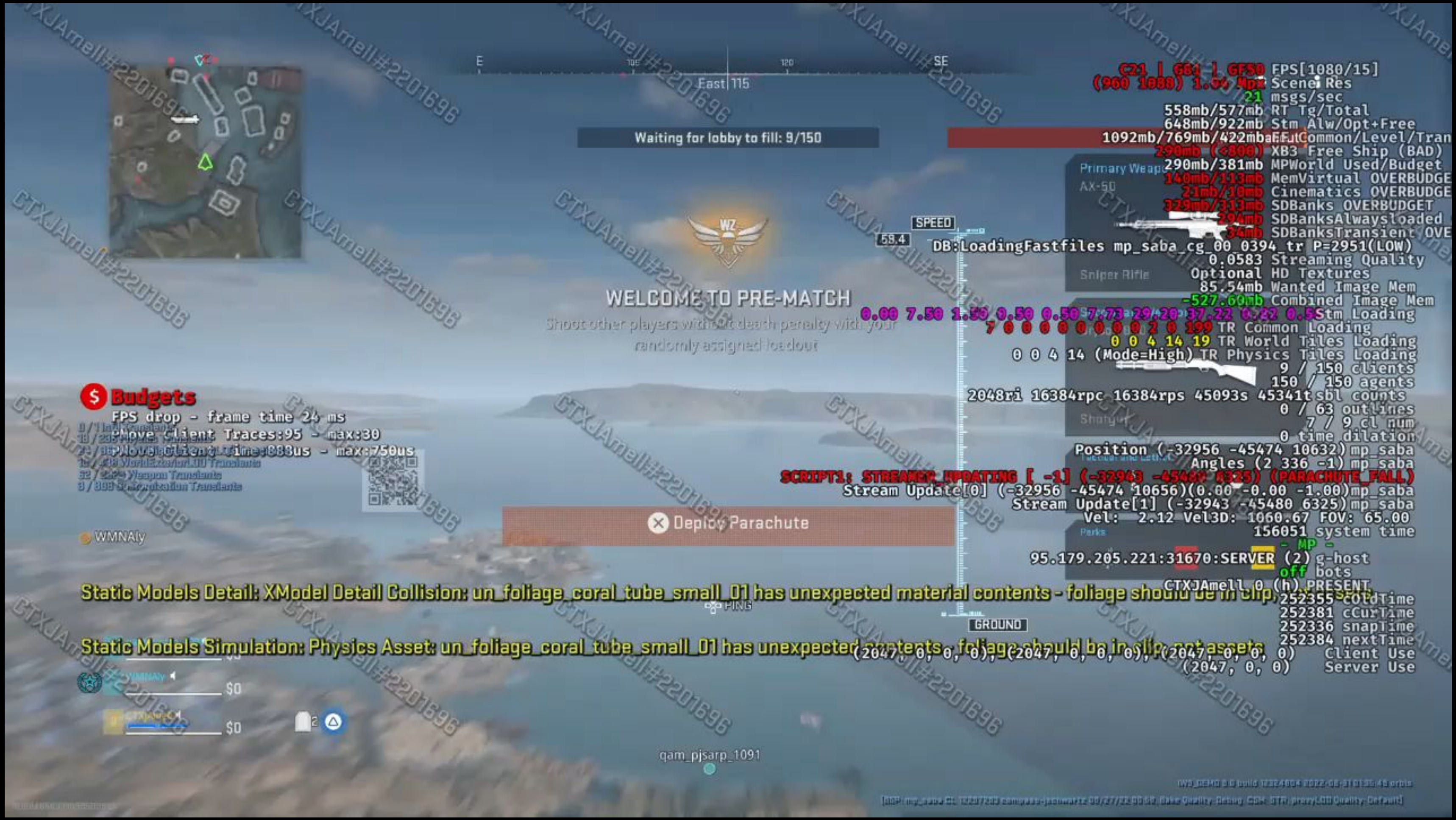
MAKE US SAD

STALL FRAMES



General	
Cursor	7.089s
User Marker (Event)	
Name	LUI_CoD_UpdateFrame
Stack Level	7
Inclusive Duration	196.906ms
Exclusive Duration	6.615us
Inclusive Time	196.249ms
Exclusive Time	6.615us
Color	0xff088000
User Marker (Global)	
Calls	423
Total Time	3.133s [Scheduled : 3.121s, Descheduled : 11.906ms]
Mean Time	7.407ms [Scheduled : 7.379ms, Descheduled : 28.146us]
Total Exclusive Time	3.064ms
Mean Exclusive Time	7.244us
Longest Duration	196.906ms [Frame 230]
Shortest Duration	5.525ms [Frame 247]

12 FRAMES DROPPED WHEN OBJECTIVES UPDATE IN WARZONE



```
Budgets
FPS drop - frame time 24 ms
Move Client Traces:95 - max:30
PMove Client Time:883us - max:750us
```

```
C21 | G61 | GF50 FPS[1080/15]
(960 1088) 1.04 Mpx Scene Res
21 msgs/sec
558mb/577mb RT Tg/Total
648mb/922mb Stm Alw/Opt+Free
1092mb/769mb/422mb FF Common/Level/Tran
290mb (<800) XB3 Free Ship (BAD)
290mb/381mb MPWorld Used/Budget
140mb/113mb MemVirtual OVERBUDGE
21mb/10mb Cinematics OVERBUDGE
329mb/313mb SDBanks OVERBUDGET
294mb SDBanksAlwaysloaded
34mb SDBanksTransient OVE
DB:LoadingFastfiles mp_saba_cg_00_0394_tr P=2951(LOW)
0.0583 Streaming Quality
Optional HD Textures
85.54mb Wanted Image Mem
-527.60mb Combined Image Mem
0.00 7.50 1.50 0.50 0.50 7.73 29.20 37.22 0.22 0.5 Stm Loading
7 0 0 0 0 0 0 0 0 2 0 199 TR Common Loading
0 0 4 14 19 TR World Tiles Loading
0 0 4 14 (Mode=High) TR Physics Tiles Loading
9 / 150 clients
150 / 150 agents
2048ri 16384rpc 16384rps 45093s 45341t sbl counts
0 / 63 outlines
7 / 9 cl num
0 time dilation
Position (-32956 -45474 10632) mp_saba
Angles (2 336 -1) mp_saba
SCRIPT1: STREAMER_UPDATING [ -1] (-32943 -45480 6325) (PARACHUTE_FALL)
Stream Update[0] (-32956 -45474 10656)(0.00 -0.00 -1.00)mp_saba
Stream Update[1] (-32943 -45480 6325) mp_saba
Vel: 2.12 Vel3D: 1060.67 FOV: 65.00
156051 system time
- MP -
95.179.205.221:31670:SERVER (2) g-host
off bots
CTXJAmell 0 (h) PRESENT
252355 cOldTime
252381 cCurTime
252336 snapTime
252384 nextTime
(2047, 0, 0, 0), (2047, 0, 0, 0), (2047, 0, 0, 0) Client Use
(2047, 0, 0) Server Use
```

```
Static Models Detail: XModel Detail Collision: un_foliage_coral_tube_small_01 has unexpected material contents - foliage should be in clip,
Static Models Simulation: Physics Asset: un_foliage_coral_tube_small_01 has unexpected contents - foliage should be in clip, not assets
```

HARD STALLS

DANGEROUS FOR TELEVISIONS

PART 2: THE

CPU PERFORMANCE DEFINITIONS

SUSTAINED FRAMES:	< 10ms
SPIKE FRAMES:	10-100ms
STALL FRAMES:	> 100ms

OPTIMIZING IN A PINCH

BETTER SUITED TO SUSTAINED FRAMES (<10ms)

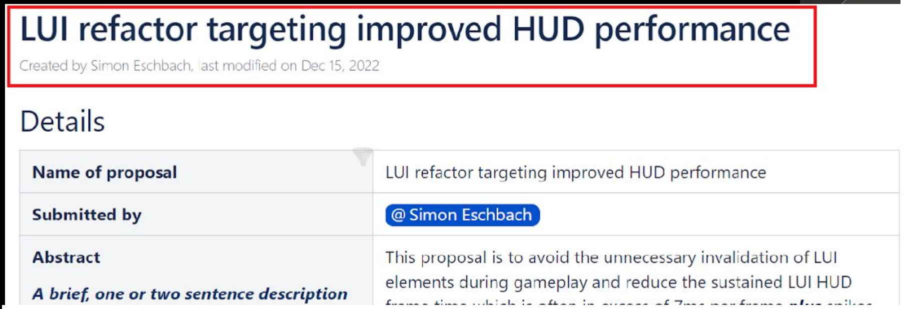
- UI SYSTEM ANALYSIS
  - ELEMENT INVALIDATION
  - QUAD CACHING
  - ELEMENT TRAVERSAL
- HOT CODE PATH OPTIMIZATION
- GARBAGE COLLECTION TUNING
- LAZY INITIALIZATION
- STAGGERED PROCESSING

BETTER SUITED TO SPIKES AND STALLS (>10ms)

- ALGORITHMIC COMPLEXITY REDUCTION
- DATA CACHING (MEMORY TRADEOFF)
- DIRECT EVENT DISPATCHING
- FONT CACHE PRIMING
- HAND OPTIMIZATION

UI SYSTEM ANALYSIS

lui/LUI_CustomElement_AARMinimap.cpp#13
lui/LUI_CustomElement_Anchored.cpp#22
lui/LUI_CustomElement_Blood.cpp#5
lui/LUI_CustomElement_Blur.cpp#4

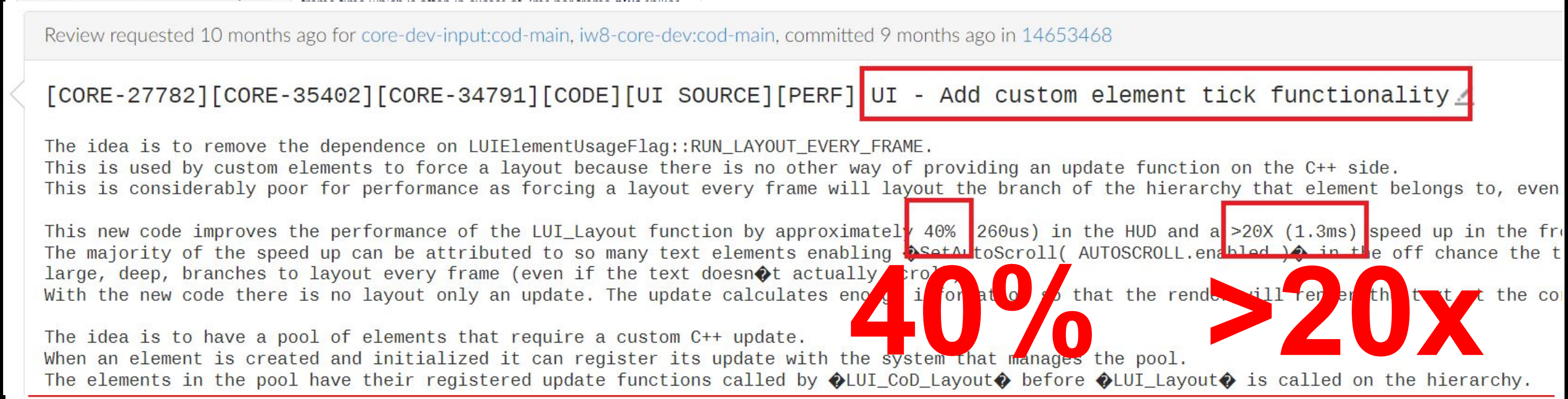


LUI refactor targeting improved HUD performance

Created by Simon Eschbach, last modified on Dec 15, 2022

Details

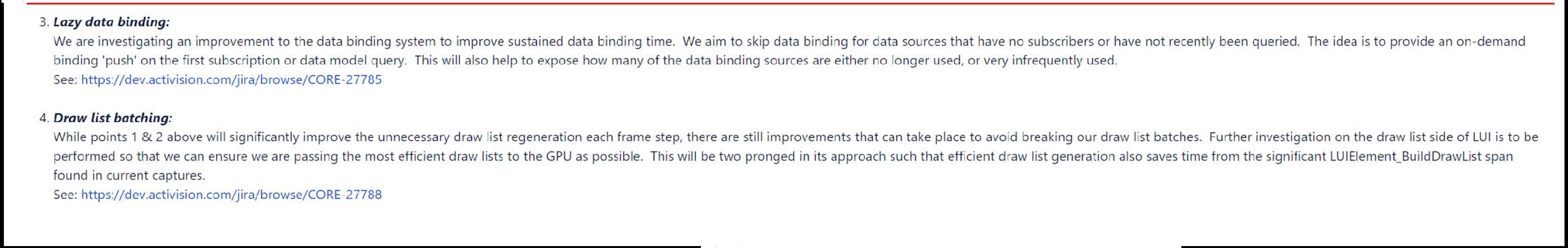
Name of proposal	LUI refactor targeting improved HUD performance
Submitted by	@ Simon Eschbach
Abstract ***A brief, one or two sentence description***	This proposal is to avoid the unnecessary invalidation of LUI elements during gameplay and reduce the sustained LUI HUD



Review requested 10 months ago for core-dev-input:cod-main, iw8-core-dev:cod-main, committed 9 months ago in 14653468

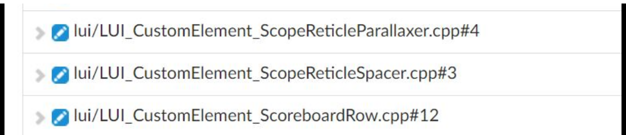
```
[CORE-27782][CORE-35402][CORE-34791][CODE][UI SOURCE][PERF] UI - Add custom element tick functionality

The idea is to remove the dependence on LUIElementUsageFlag::RUN_LAYOUT_EVERY_FRAME.
This is used by custom elements to force a layout because there is no other way of providing an update function on the C++ side.
This is considerably poor for performance as forcing a layout every frame will layout the branch of the hierarchy that element belongs to, even

This new code improves the performance of the LUI_Layout function by approximately 40% (260us) in the HUD and a >20X (1.3ms) speed up in the fr
The majority of the speed up can be attributed to so many text elements enabling �SetAutoScroll( AUTOSCROLL.enabled )� in the off chance the t
large, deep, branches to layout every frame (even if the text doesn�t actually scroll
With the new code there is no layout only an update. The update calculates enough information so that the renderer will render the text at the co

The idea is to have a pool of elements that require a custom C++ update.
When an element is created and initialized it can register its update with the system that manages the pool.
The elements in the pool have their registered update functions called by �LUI_CoD_Layout� before �LUI_Layout� is called on the hierarchy.
```

40% >20x



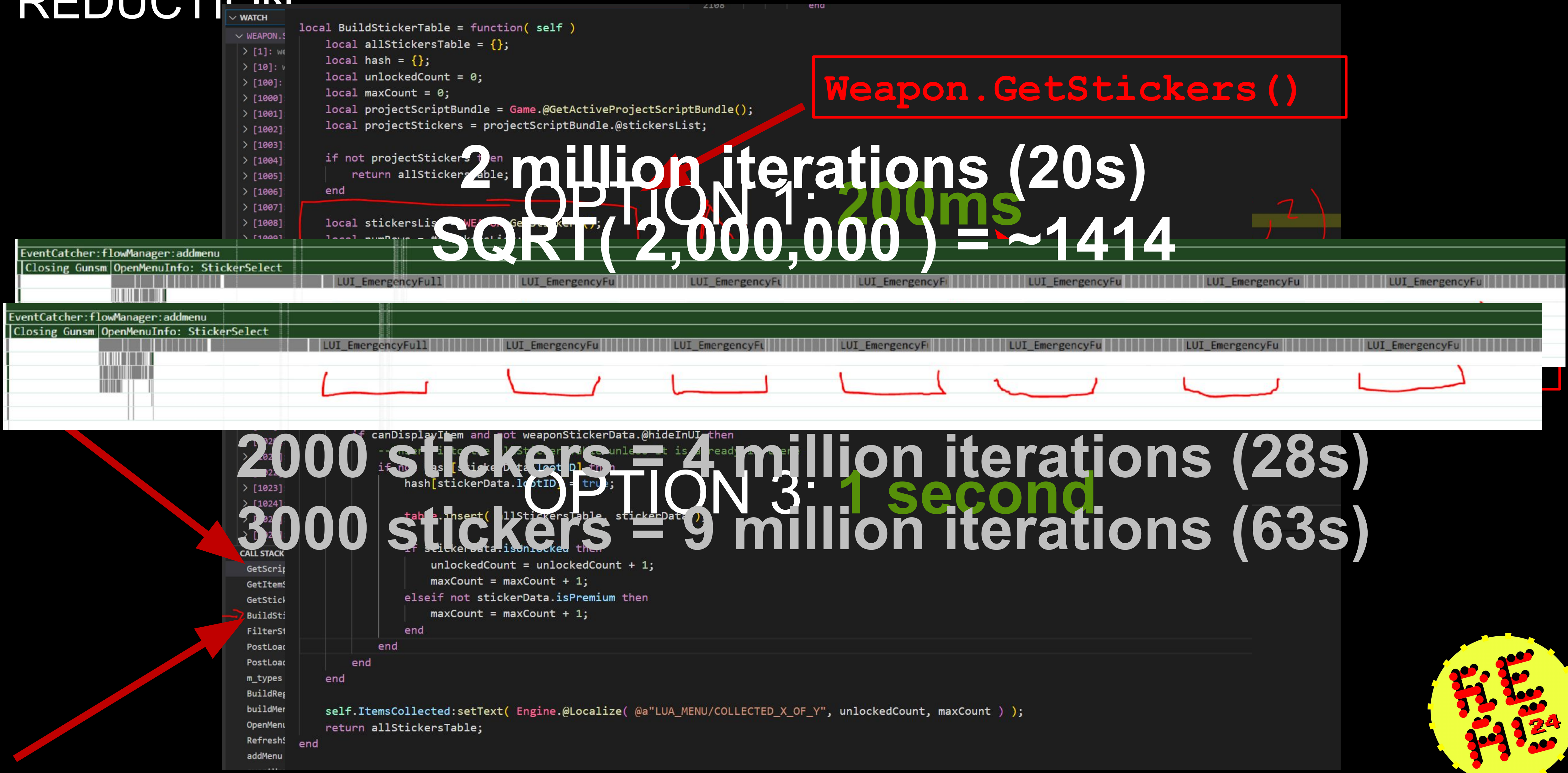
3. ***Lazy data binding:***
We are investigating an improvement to the data binding system to improve sustained data binding time. We aim to skip data binding for data sources that have no subscribers or have not recently been queried. The idea is to provide an on-demand binding 'push' on the first subscription or data model query. This will also help to expose how many of the data binding sources are either no longer used, or very infrequently used.
See: https://dev.activision.com/jira/browse/CORE-27785

4. ***Draw list batching:***
While points 1 & 2 above will significantly improve the unnecessary draw list regeneration each frame step, there are still improvements that can take place to avoid breaking our draw list batches. Further investigation on the draw list side of LUI is to be performed so that we can ensure we are passing the most efficient draw lists to the GPU as possible. This will be two pronged in its approach such that efficient draw list generation also saves time from the significant LUIElement_BuildDrawList span found in current captures.
See: https://dev.activision.com/jira/browse/CORE-27788



lui/LUI_CustomElement_ScopeReticleParallaxer.cpp#4
lui/LUI_CustomElement_ScopeReticleSpacer.cpp#3
lui/LUI_CustomElement_ScoreboardRow.cpp#12

ALGORITHM COMPLEXITY REDUCTION



```
local BuildStickerTable = function( self )
    local allStickersTable = {};
    local hash = {};
    local unlockedCount = 0;
    local maxCount = 0;
    local projectScriptBundle = Game.@GetActiveProjectScriptBundle();
    local projectStickers = projectScriptBundle.@stickersList;

    if not projectStickers then
        return allStickersTable;
    end

    local stickersLis
    local numRows =
...
            if canDisplayItem and not weaponStickerData.@hideInUI then
                -- 
                if not hash[stickerData.lootID] then
                    hash[stickerData.lootID] = true;

                    table.insert( allStickersTable, stickerData )

                    if stickerData.isUnlocked then
                        unlockedCount = unlockedCount + 1;
                        maxCount = maxCount + 1;
                    elseif not stickerData.isPremium then
                        maxCount = maxCount + 1;
                    end
                end
            end
        end
    end

    self.ItemsCollected:setText( Engine.@Localize( @a"LUA_MENU/COLLECTED_X_OF_Y", unlockedCount, maxCount ) );
    return allStickersTable;
end
```

Weapon.GetStickers()

2 million iterations (20s)

OPTION 1: 200ms

SQRT(2,000,000) = ~1414

2000 stickers = 4 million iterations (28s)

OPTION 3: 1 second

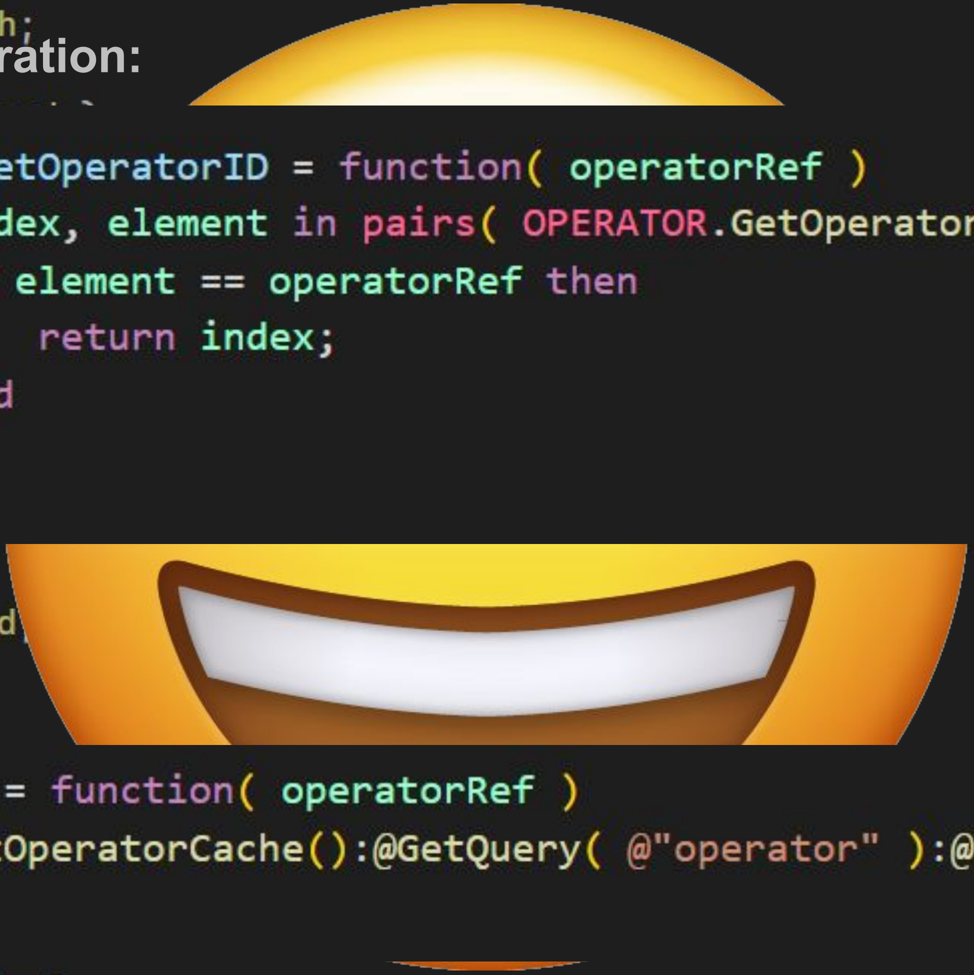
3000 stickers = 9 million iterations (63s)

EFFICIENT RUNTIME DATA QUERYING

```
uint begin = 0;
uint end = length;

whi
{
    {
        end = mid
    }
    else

    return std::nullopt;
```

Lua O(n) iteration:

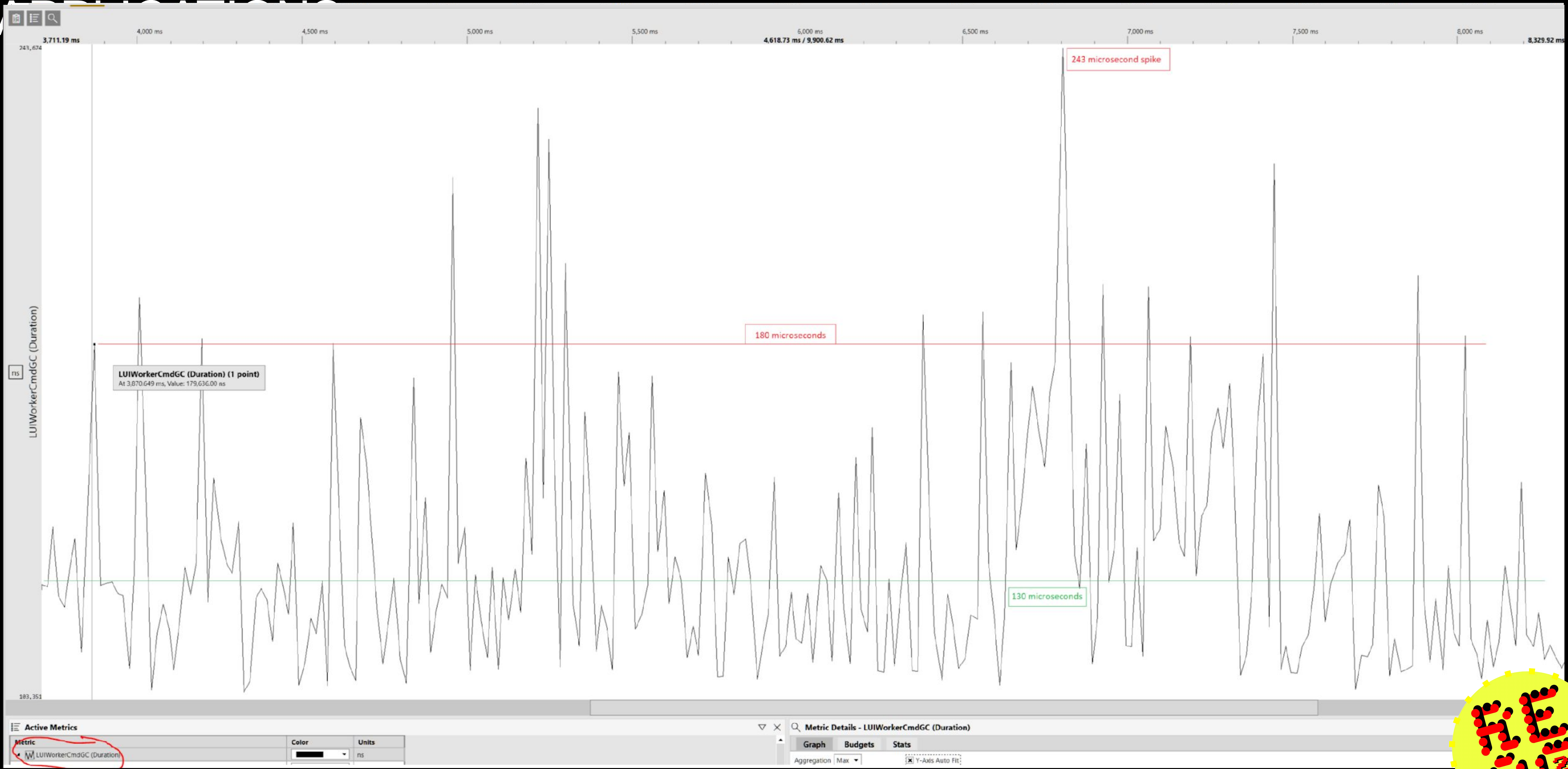
```
OPERATOR.GetOperatorID = function( operatorRef )
    for index, element in pairs( OPERATOR.GetOperatorCache() ) do
        if element == operatorRef then
            return index;
        end
    end
end
```



C++ O(log n) query:

```
OPERATOR.GetOperatorID = function( operatorRef )
    return OPERATOR.GetOperatorCache():@GetQuery( @"operator" ):@FindIndex( operatorRef );
end
```

GARBAGE COLLECTION IN REAL TIME APPLICATIONS

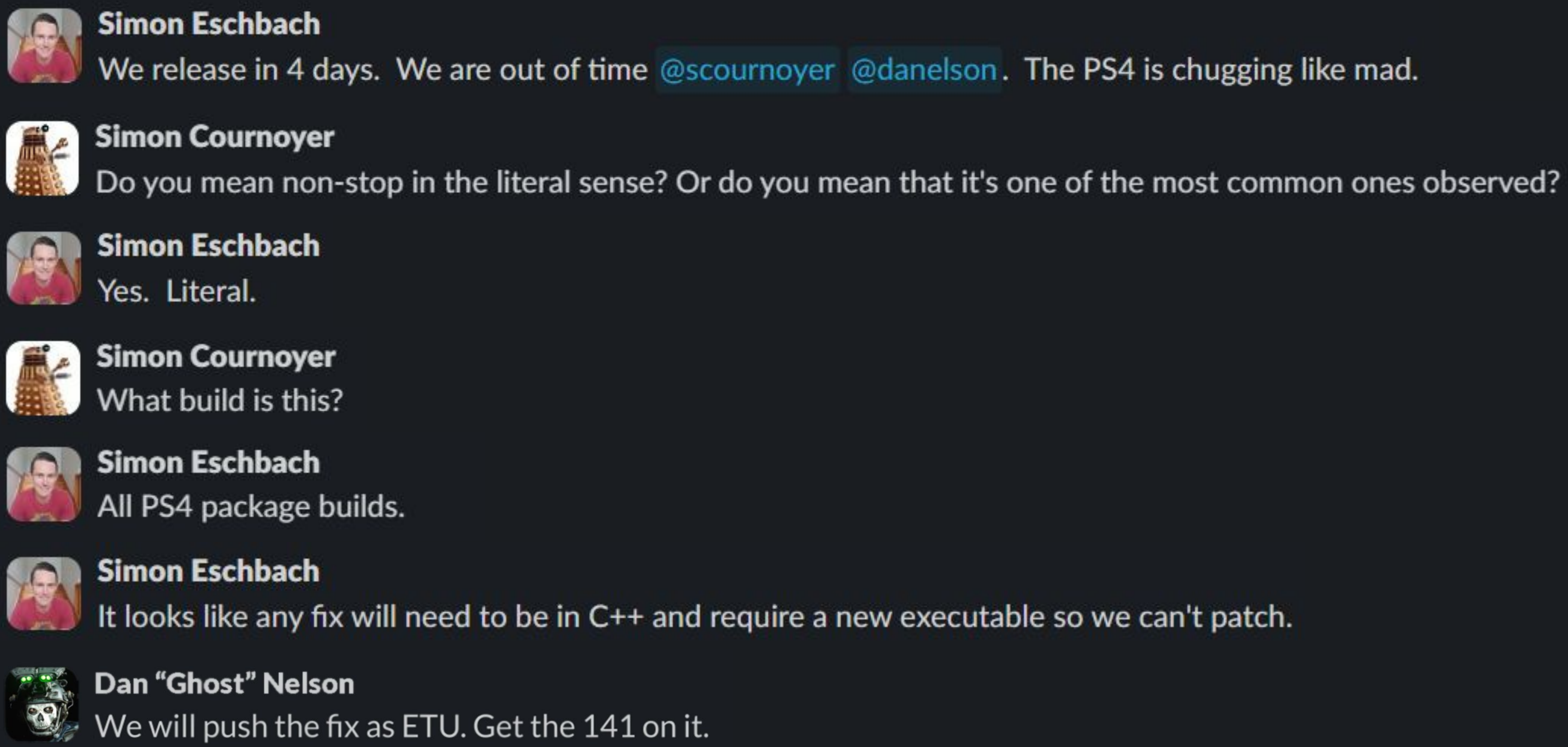


LUIWorkerCmdGC (Duration) (1 point)
At 3,870.649 ms, Value: 179,636.00 ns

Metric	Color	Units
LUIWorkerCmdGC (Duration)	■	ns

PART 3: THE

4 DAYS TO LAUNCH



Simon Eschbach
We release in 4 days. We are out of time @scournoyer @danelson. The PS4 is chugging like mad.

Simon Cournoyer
Do you mean non-stop in the literal sense? Or do you mean that it's one of the most common ones observed?

Simon Eschbach
Yes. Literal.

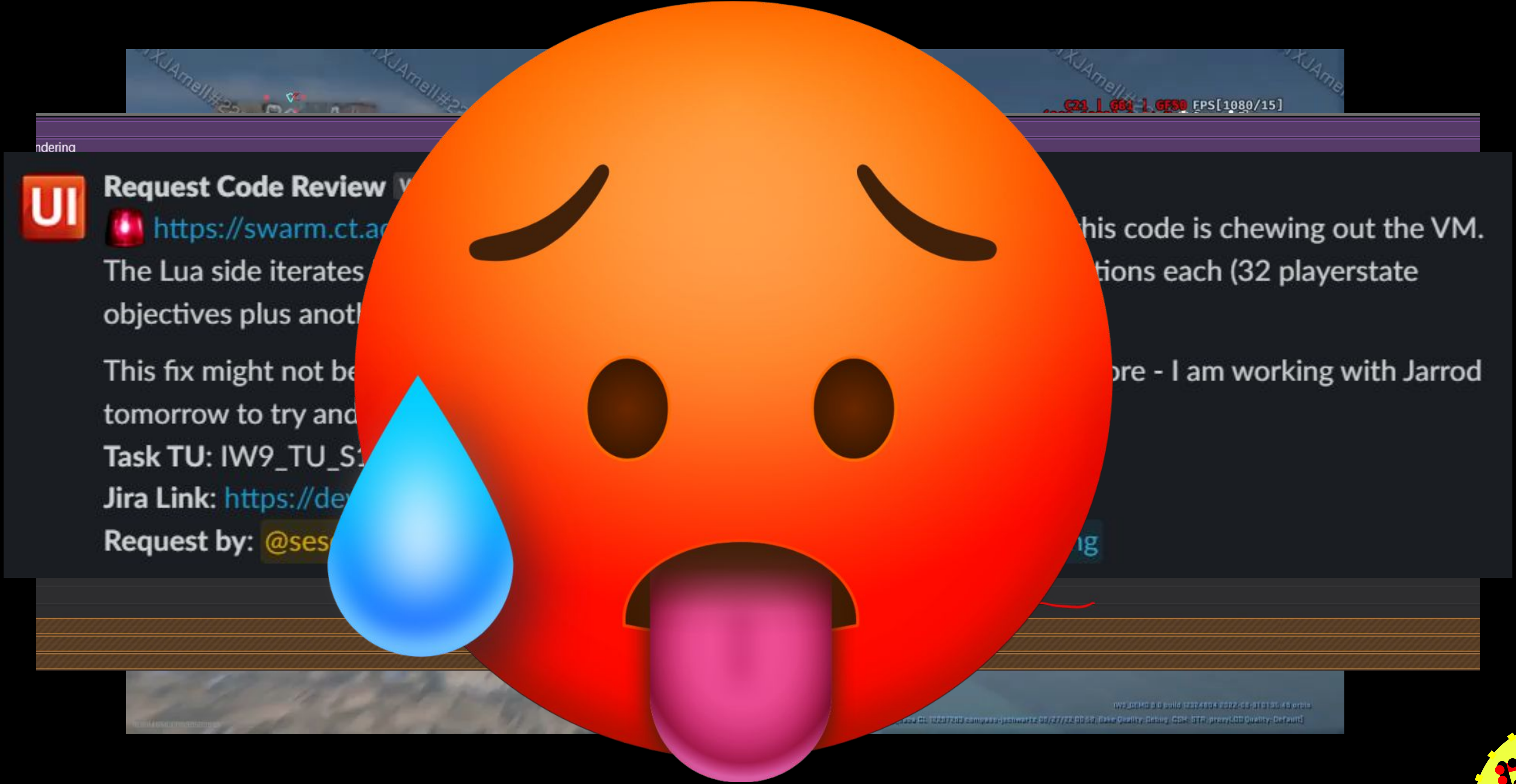
Simon Cournoyer
What build is this?

Simon Eschbach
All PS4 package builds.

Simon Eschbach
It looks like any fix will need to be in C++ and require a new executable so we can't patch.

Dan "Ghost" Nelson
We will push the fix as ETU. Get the 141 on it.

IN THE NICK OF TIME



Request Code Review V

https://swarm.ct.ac

his code is chewing out the VM.

The Lua side iterates

tions each (32 playerstate

objectives plus anot

This fix might not be

ore - I am working with Jarrod

tomorrow to try and

Task TU: IW9_TU_S1

Jira Link: https://de

Request by: @ses

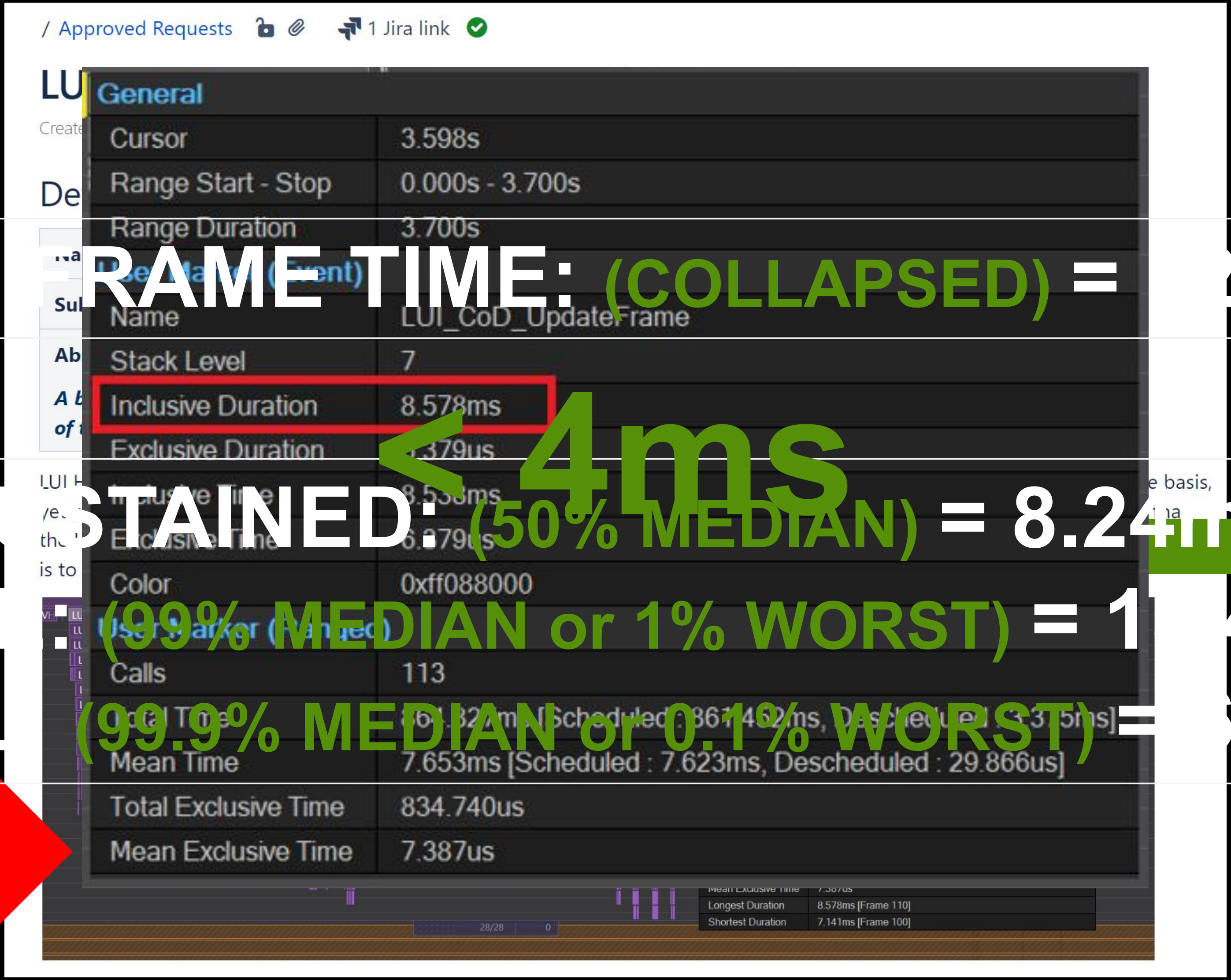
ng

MISSION ACCOMPLISHED

OR WAS IT?

PART 4: BATTLE

MEASUREMENT



/ Approved Requests 1 Jira link

General	
Cursor	3.598s
Range Start - Stop	0.000s - 3.700s
Range Duration	3.700s
Name	LUI_CoD_UpdateFrame
Stack Level	7
Inclusive Duration	8.578ms
Exclusive Duration	[illegible]379us
Inclusive Time	8.538ms
Exclusive Time	6.[illegible]79us
Color	0xff088000
Calls	113
Total Time	[illegible]
Mean Time	7.653ms [Scheduled : 7.623ms, Descheduled : 29.866us]
Total Exclusive Time	834.740us
Mean Exclusive Time	7.387us

Longest Duration	8.578ms [Frame 110]
Shortest Duration	7.141ms [Frame 100]

MEAN FRAME TIME: (COLLAPSED) = [illegible].26ms

< 4ms

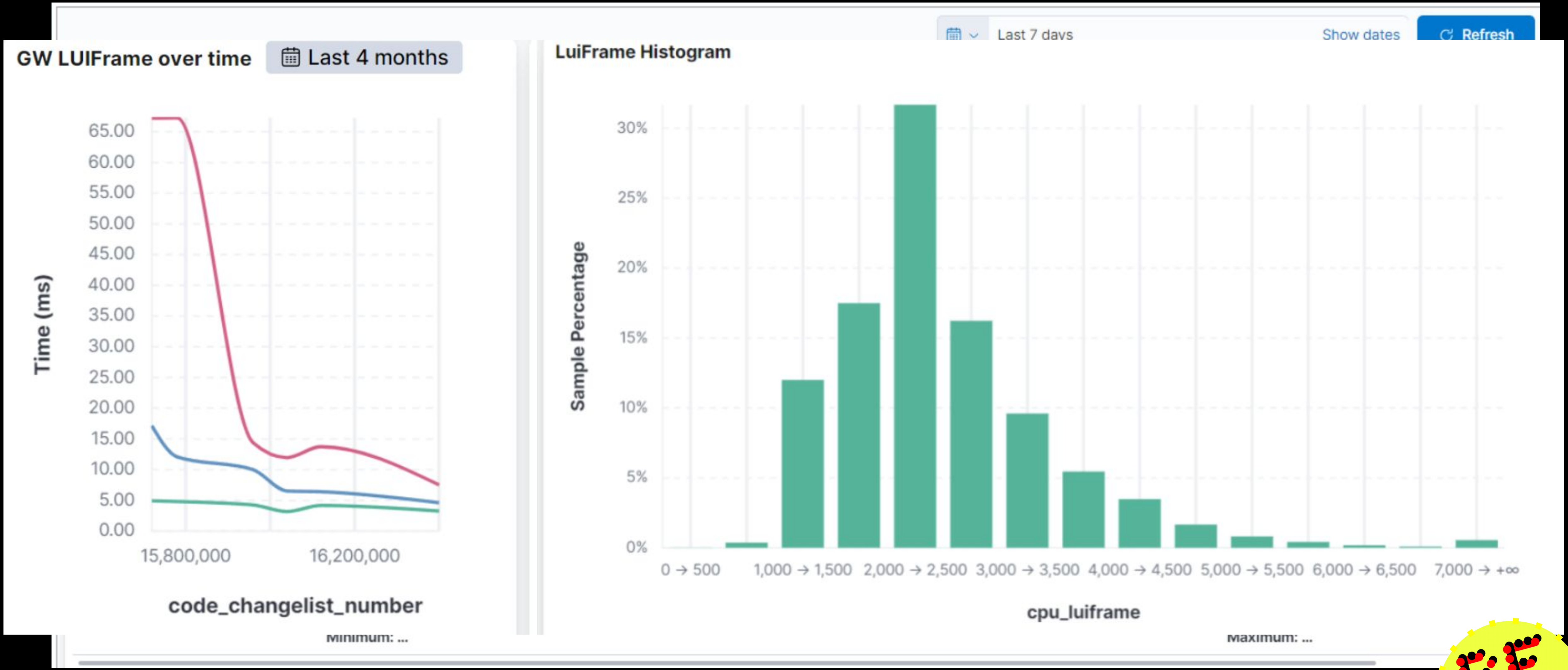
SUSTAINED: (50% MEDIAN) = 8.24ms

SPIKE: (99% MEDIAN or 1% WORST) = 1[illegible].42ms

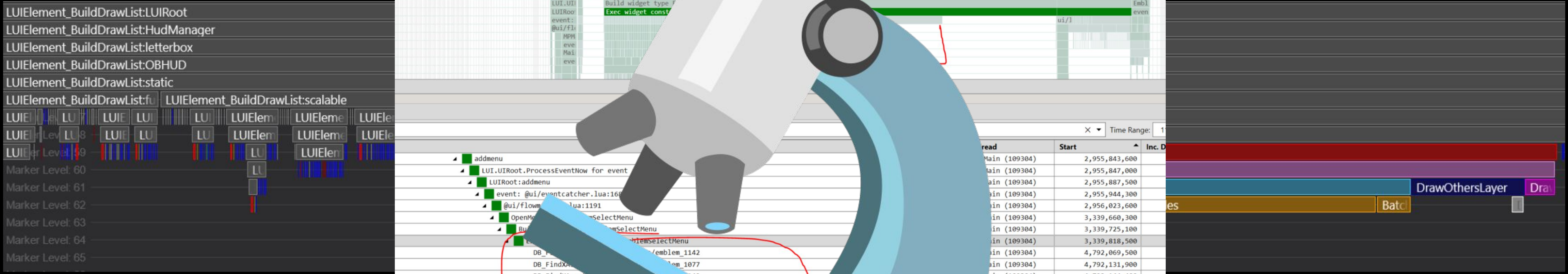
STALL: (99.9% MEDIAN or 0.1% WORST) = [illegible]5.7ms

4ms

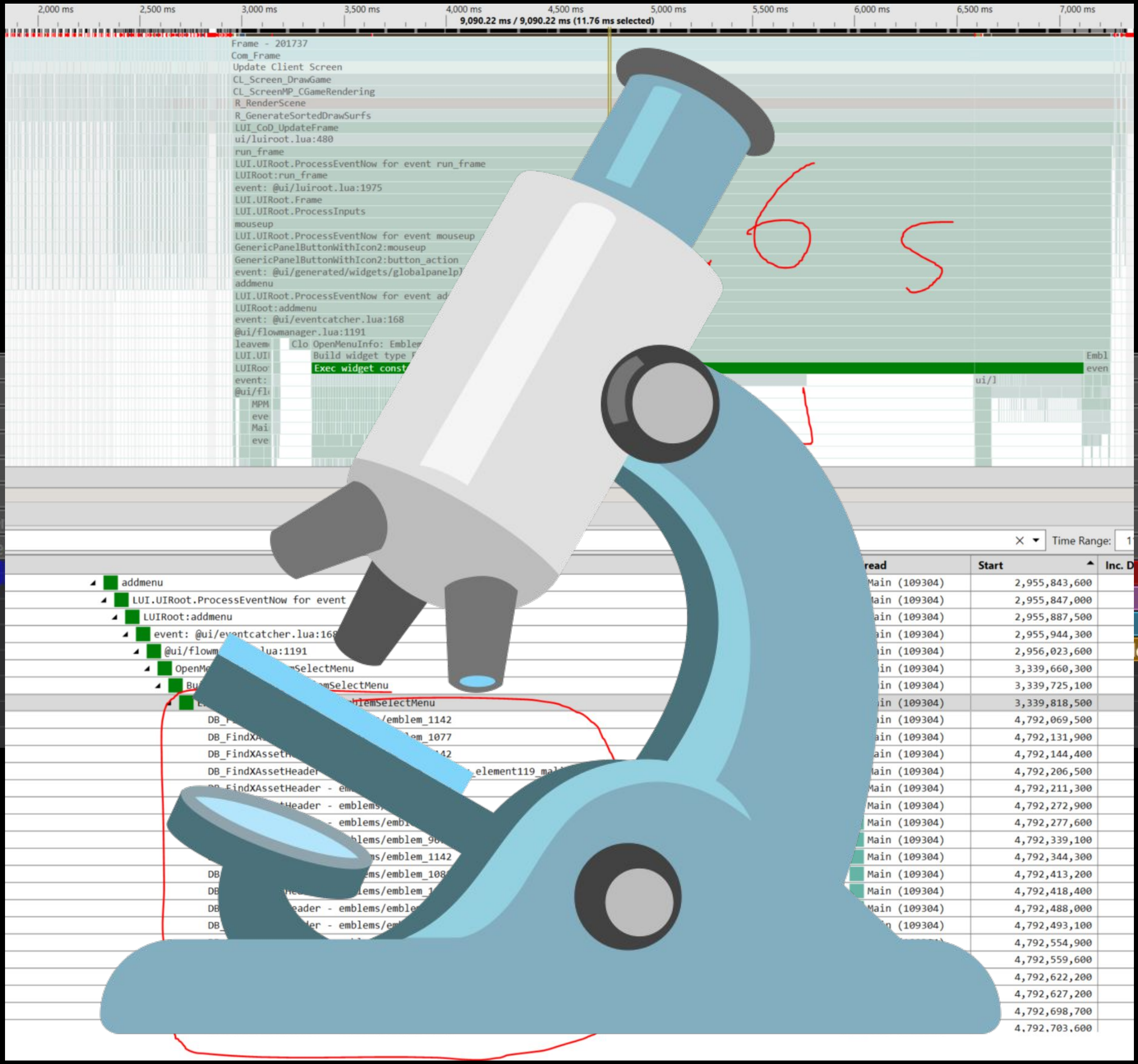
DASHBOARDS


Last 7 days
Show dates
Refresh
GW LUIFrame over time
Last 4 months
Time (ms)
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
15,800,000
16,200,000
code_changelist_number
LuiFrame Histogram
Sample Percentage
30%
25%
20%
15%
10%
5%
0%
0 → 500
1,000 → 1,500
2,000 → 2,500
3,000 → 3,500
4,000 → 4,500
5,000 → 5,500
6,000 → 6,500
7,000 → +∞
cpu_luiframe
Minimum: ...
Maximum: ...

PROCESSESES AND DIAGNOSTICS



```
LUIElement_BuildDrawList:LUIRoot
LUIElement_BuildDrawList:HudManager
LUIElement_BuildDrawList:letterbox
LUIElement_BuildDrawList:OBHUD
LUIElement_BuildDrawList:static
LUIElement_BuildDrawList:fu  LUIElement_BuildDrawList:scalable
LUIE LU LUIE LUI LUI LUIElem LUIEleme LUIEle
LUIE Lev LU 8 LUIE LU LU LUIElem LUIEleme LUIEle
LUIE er Level 59 LU LUIElen
Marker Level: 60
Marker Level: 61
Marker Level: 62
Marker Level: 63
Marker Level: 64
Marker Level: 65
```

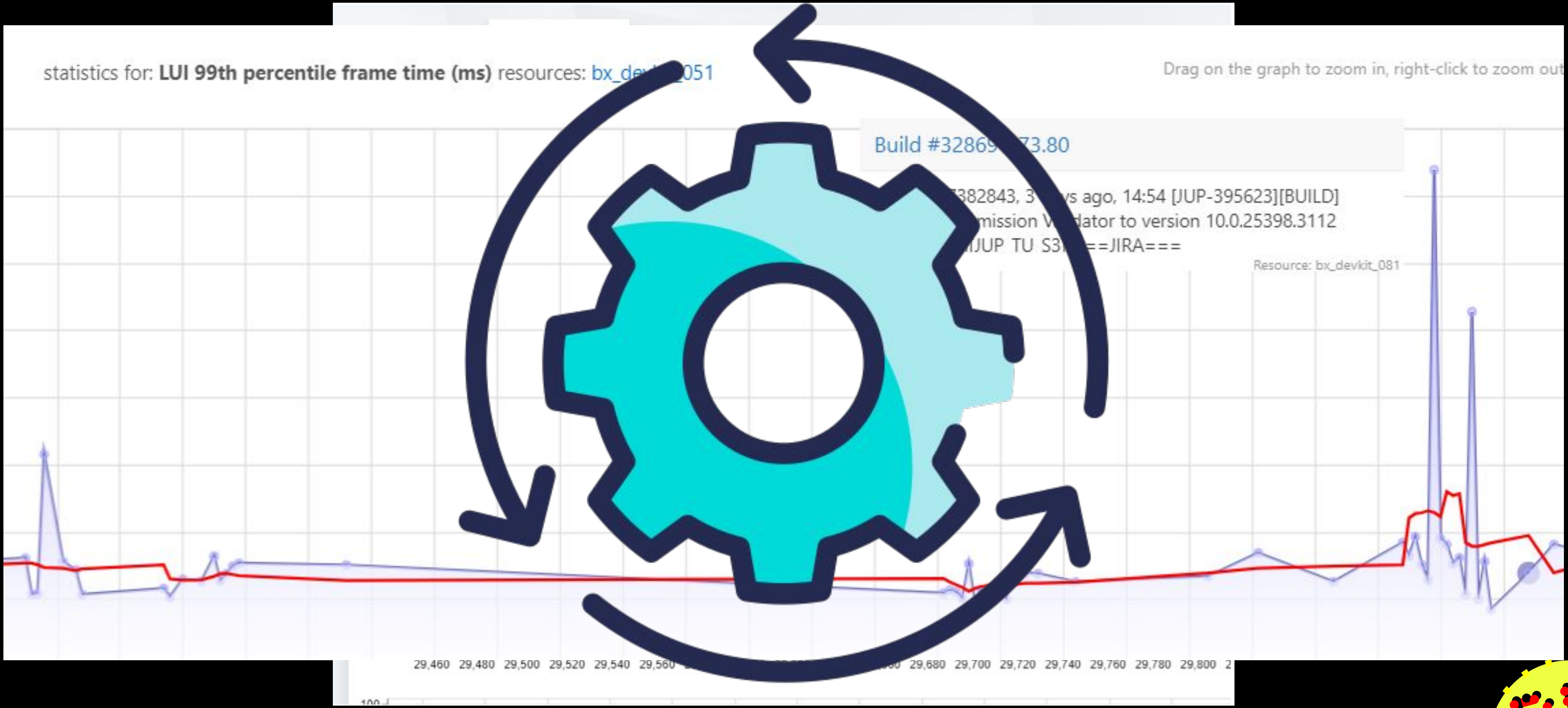


```
2,000 ms   2,500 ms   3,000 ms   3,500 ms   4,000 ms   4,500 ms   5,000 ms   5,500 ms   6,000 ms   6,500 ms   7,000 ms
                                                 9,090.22 ms / 9,090.22 ms (11.76 ms selected)
Frame - 201737
Com_Frame
Update Client Screen
CL_Screen_DrawGame
CL_ScreenMP_CGameRendering
R_RenderScene
R_GenerateSortedDrawSurfs
LUI_CoD_UpdateFrame
ui/luiroot.lua:480
run_frame
LUI.UIRoot.ProcessEventNow for event run_frame
LUIRoot:run_frame
event: @ui/luiroot.lua:1975
LUI.UIRoot.Frame
LUI.UIRoot.ProcessInputs
mouseup
LUI.UIRoot.ProcessEventNow for event mouseup
GenericPanelButtonWithIcon2:mouseup
GenericPanelButtonWithIcon2:button_action
event: @ui/generated/widgets/globalpanelpl
addmenu
LUI.UIRoot.ProcessEventNow for event ad
LUIRoot:addmenu
event: @ui/eventcatcher.lua:168
@ui/flowmanager.lua:1191
leavem   Clo OpenMenuInfo: Emblem                                   Embl
LUI.UI        Build widget type                                     even
LUIRoo        Exec widget const
event:                                                     ui/l
@ui/fl
  MPM
  eve
  Mai
  eve
```

Time Range:

```
                                                          read          Start          Inc. D
addmenu                                                   Main (109304)  2,955,843,600
  LUI.UIRoot.ProcessEventNow for event                    Main (109304)  2,955,847,000
    LUIRoot:addmenu                                       ain (109304)   2,955,887,500
      event: @ui/eventcatcher.lua:168                     ain (109304)   2,955,944,300
        @ui/flowm      lua:1191                           in (109304)    2,956,023,600
          OpenMe        mSelectMenu                       in (109304)    3,339,660,300
            Bu          mSelectMenu                       in (109304)    3,339,725,100
              E         blemSelectMenu                    in (109304)    3,339,818,500
                DB_F              /emblem_1142            in (109304)    4,792,069,500
                DB_FindX          em_1077                 ain (109304)   4,792,131,900
                DB_FindXAsset        42                   ain (109304)   4,792,144,400
                DB_FindXAssetHeader        element119_ma  lain (109304)  4,792,206,500
                DB_FindXAssetHeader - em                  Main (109304)  4,792,211,300
                      Header - emblems/                   Main (109304)  4,792,272,900
                             - emblems/emb                Main (109304)  4,792,277,600
                               blems/emblem_90            Main (109304)  4,792,339,100
                                ms/emblem_1142            Main (109304)  4,792,344,300
                DB              ems/emblem_108            Main (109304)  4,792,413,200
                DB              lems/emblem_1             Main (109304)  4,792,418,400
                DB         eader - emblems/emble          Main (109304)  4,792,488,000
                DB         der - emblems/em               n (109304)     4,792,493,100
                                                                         4,792,554,900
                                                                         4,792,559,600
                                                                         4,792,622,200
                                                                         4,792,627,200
                                                                         4,792,698,700
                                                                         4,792,703,600
```

AUTOMATED PERFORMANCE TESTING



statistics for: **LUI 99th percentile frame time (ms)** resources: bx_dev 051

Drag on the graph to zoom in, right-click to zoom out

Build #32869 73.80

382843, 3 s ago, 14:54 [JUP-395623][BUILD]
mission V dator to version 10.0.25398.3112
JUP TU S3 ==JIRA===

Resource: bx_devkit_081

RESULTS – PS4 BASE PLATFORM

SINGLEPLAYER:	1.2ms
MULTIPLAYER:	2.1ms
GROUND WAR:	3.1ms
WARZONE:	3.9ms

THANK-YOU!

Sound: Mike Tornabene

Voice Over: Dan Nelson

Photoshop: Carl Prescott & Kyle Turchik