Re-inventing the wheel for snow rendering

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Santa Monica Studio

Hello!

10+ years Engine/Rendering Engineer

Deadpool (360, PS3, PC)
Call of Duty: Advanced Warfare (360, PS3, PC, XOne, PS4)
Firewatch (PC, PS4)
God of War (PS4)
God of War: Ragnarök (PS4, PS5)

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Goal of talk

How we write technology
to support high quality custom setups
by creating reusable toolset

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Goal of talk

Look at re-write of height field system in God of War: Ragnarök
(no game spoilers)

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Keep in mind

Less about tech details, more about why of each choice

Take-aways during the talk

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How we do things at SMS

Art and design have lots of manual control

We work in Maya as our main level editor, run on kit

We use automation, but it's in service of creators control

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Engineering challenge

Support creator team for the long term

Details are for our workflows/requirements, lessons are for all

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Let's paint a scene

April 2018, God of War has shipped

Sequel is PS4/PS5, high quality on both

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God of War: Ragnarök requirements

Good part of game is Midgard -> lots of snow

Fimbulvetr (Old Norse) ‘awful, mighty winter’

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We already have that

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Can't we re-use that? *Narrator voice: they couldn't*

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GoW 2018 Snow: rendering

Surface is rendered with ss-parallax mapping
All manual custom rendering different per material

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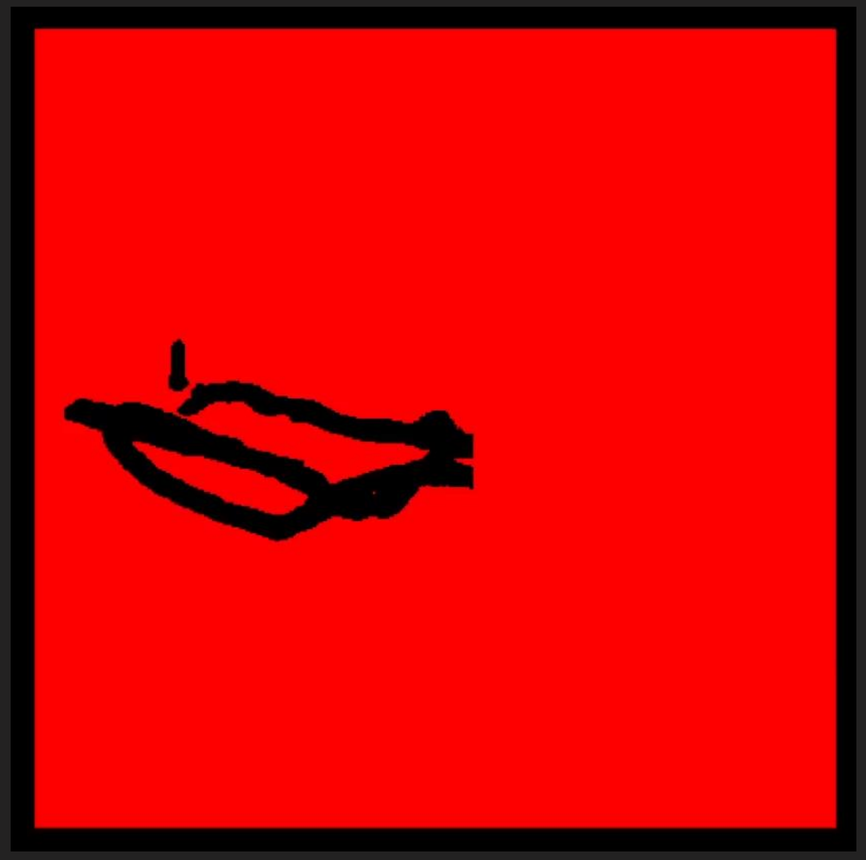
GoW 2018 Snow: heights and details

Carving shapes/VFX rendered into persistent top-down texture



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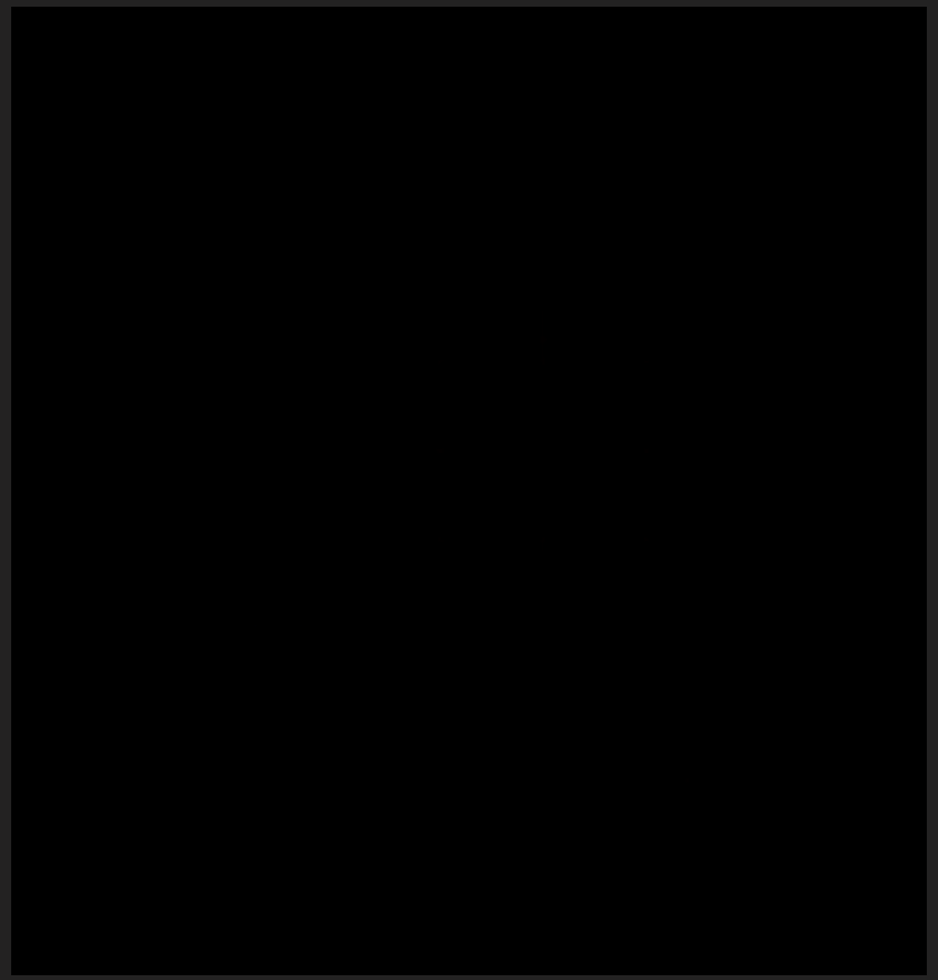
GoW 2018 Snow: heights and details

Project from top-down to screen, add VFX and details



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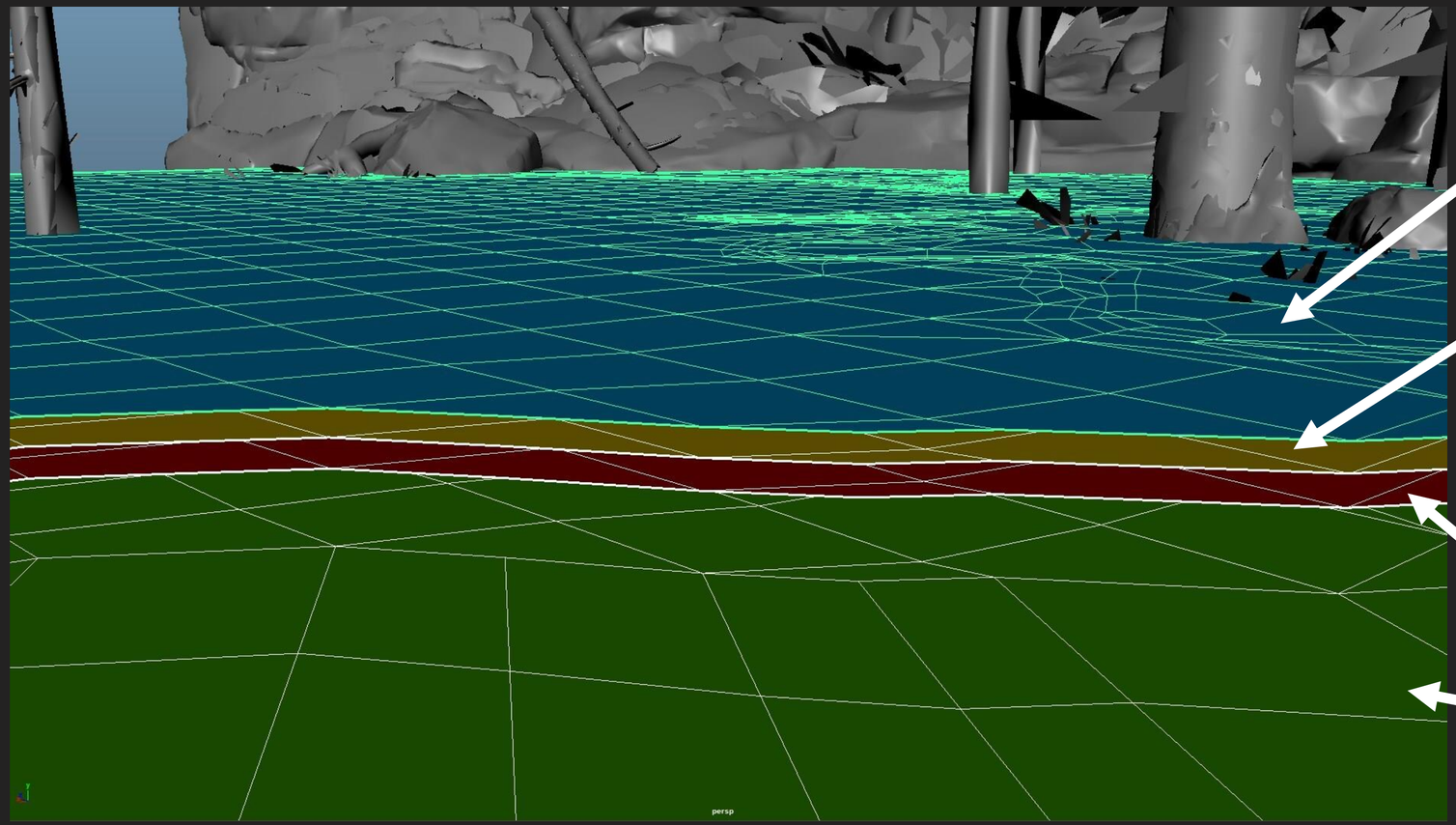
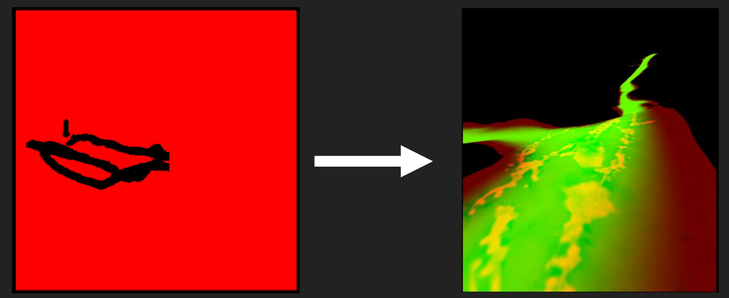
GoW 2018 Snow: Maya setup



Flat rendering surface

Projection surface



Max and min displacement

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Pros...

Very detailed

Cost proportional to use

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...and cons...

Variable cost, not good average/worst case

Tuning is hard, and error prone

Visual artifacts because of rendering technique

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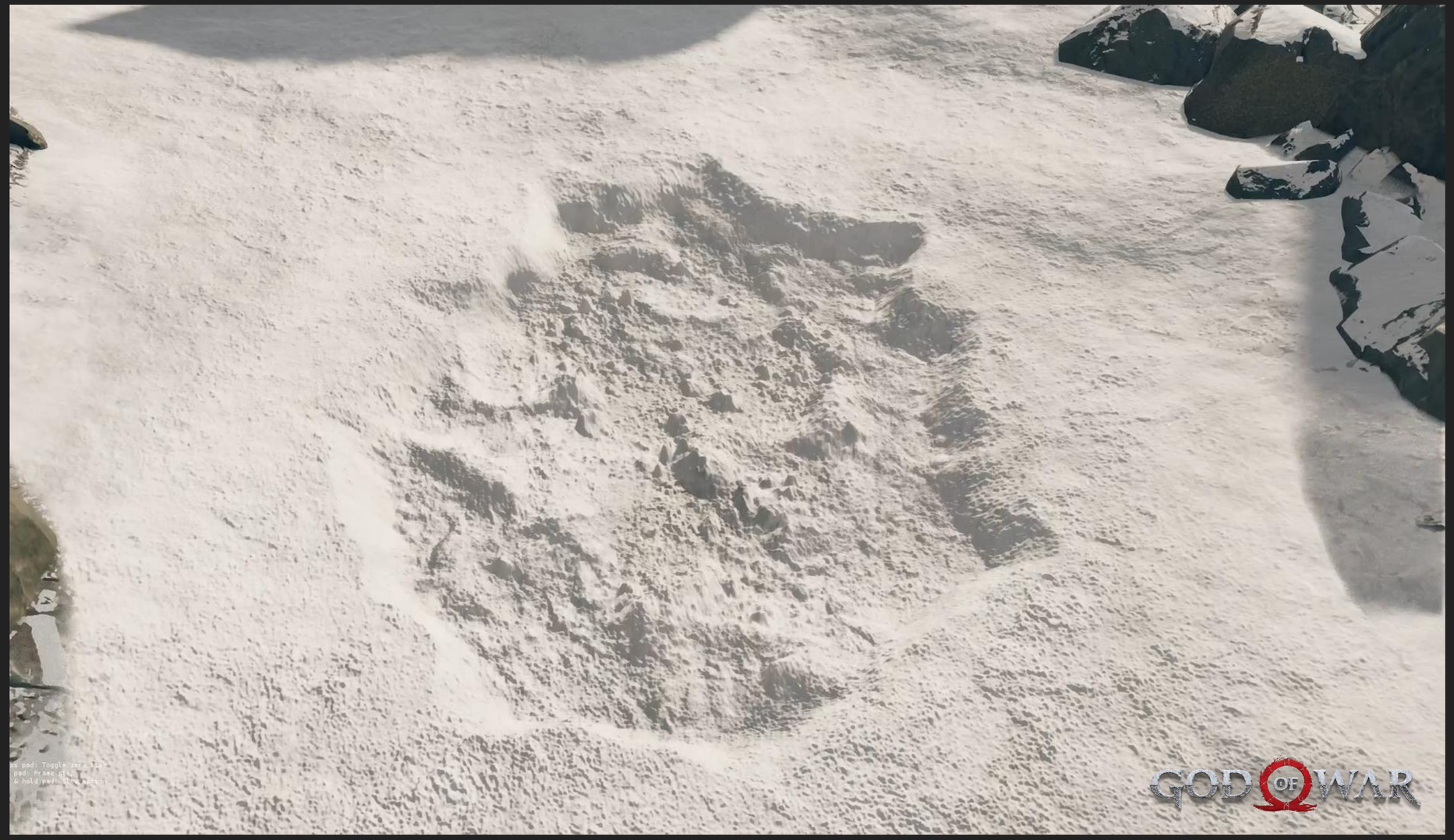
...and cons... (parallax and camera)



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...and cons... (detail shimmering)

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...and cons

Lots of limitations, lots of workarounds

Only flat terrains, camera always above

Art not making art (and not just them)

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Consequences: Limited use

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If all you have is a hammer...

Parallax itself is great

Great on water, still used it in Ragnarök

Not good for organic terrains

Good enough at the time given constraints

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Summary of issues

Too much control, not right reasons

Too much because of parallax

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A “Respectful Big Nope”

Art meeting with rendering:
current system won’t work

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Why?

Bigger game

Bigger team

More teams

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Game requirements

Snow is not an exception, it's the worst case

From 3 to ~50 areas 😐 (and more cases)

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What didn't work

Change workflow: more automatic

Change core: geometrical approach

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Our requirements

No terrain system; arbitrary meshes

Highly customizable with material features

Minimal setup

Aim for good average perf, no fixed memory cost

Must run well/look good on PS4, scale up on PS5

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Compromise

Not same pixel quality

Art team gave the thumbs up

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First step

Establish visual goal: get a spec from art

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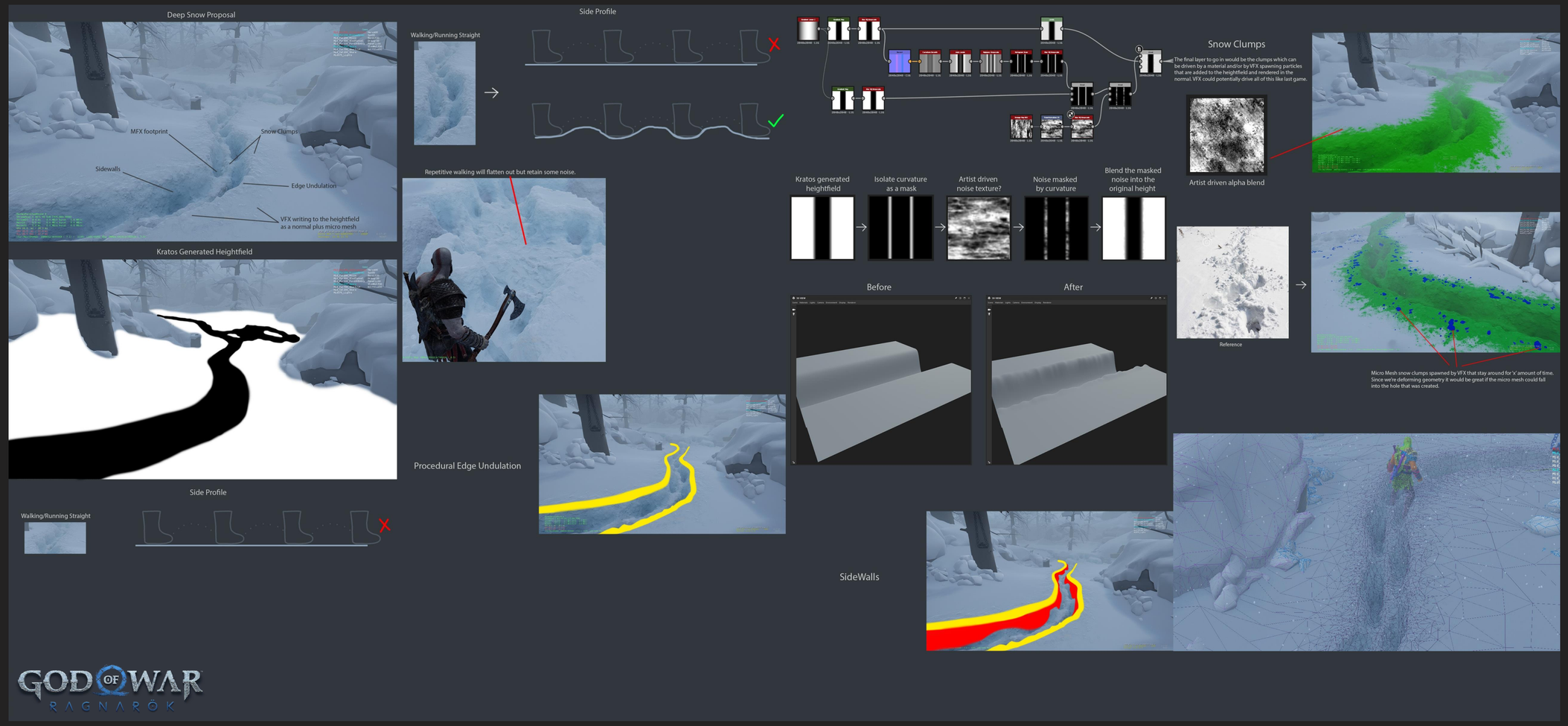
Oh, you want a spec?



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GOD OF WAR RAGNARÖK

Second step

Back of the napkin math for perf

Same area as before test with tessellated mesh by hand (25 m^2)

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Takeaway #1

Start from product, do back of napkin math

Make your knowledge “better”

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Next steps

How do we go about dynamic geometry displacement?

Standing on shoulders of giants

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What's out there

Terrain/fixed meshes/fixed tessellation

T-Junctions

High memory cost (or not flexible enough)

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Do It Yourself

Some RnD but production/team constraints

Idea: indirect draws of differently tessellated tris and skin to original mesh – only where needed

Didn't pan out. Was it wasted? *(narrator voice: it wasn't)*

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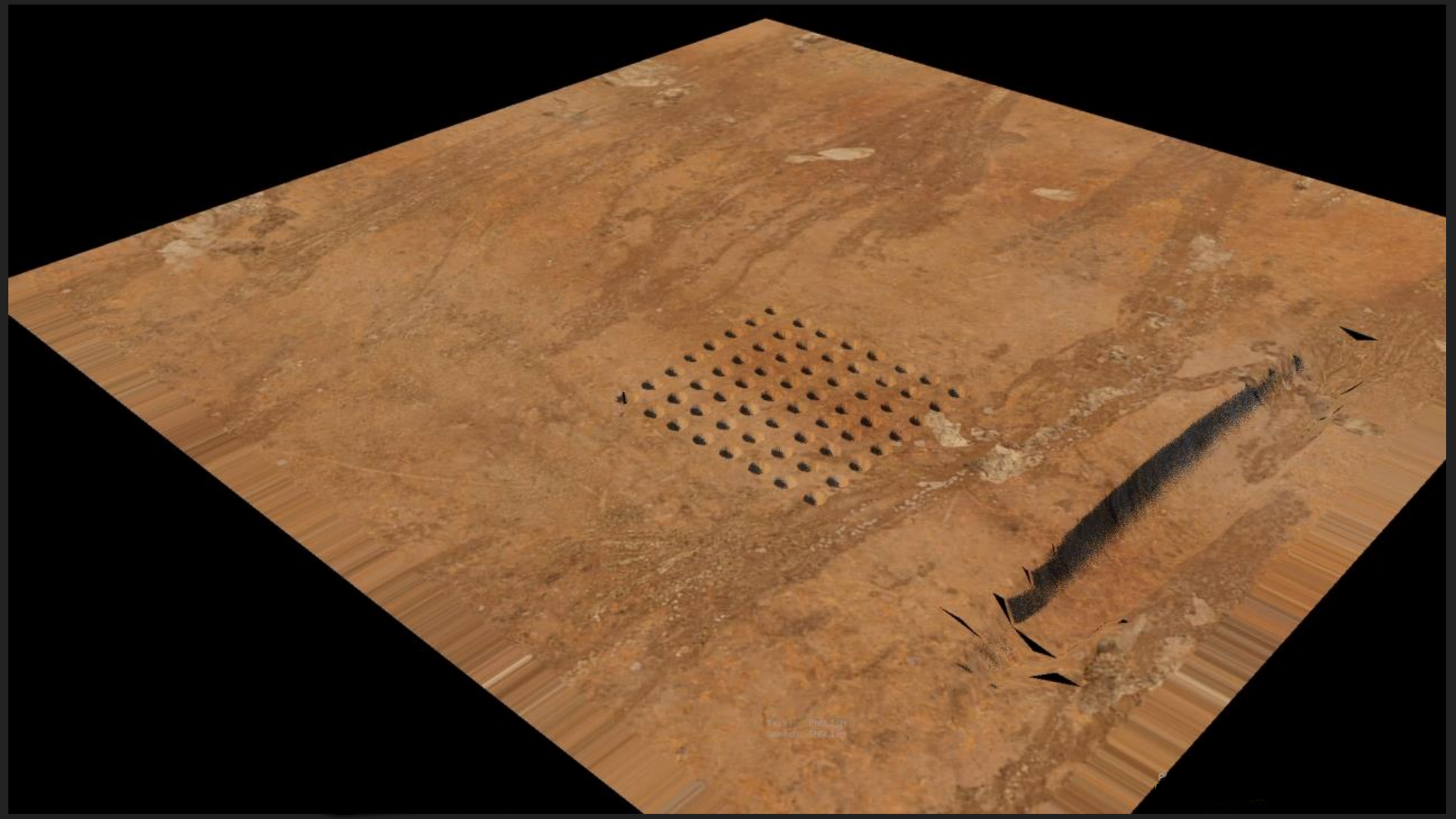
Do It Yourself: Programmer art edition



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Sometimes you get lucky

Another programmer was working on hardware tessellation pipeline

Has issues, but fits all our boxes

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Takeaway #2

Force yourself into a modular approach
(moral of the story)

"No Core Pillars"

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How it works – 1st pass

Any mesh in Maya: just a checkbox (limitation on topology)

Reuse what worked before

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How it works – 1st pass

Automated heights and carving

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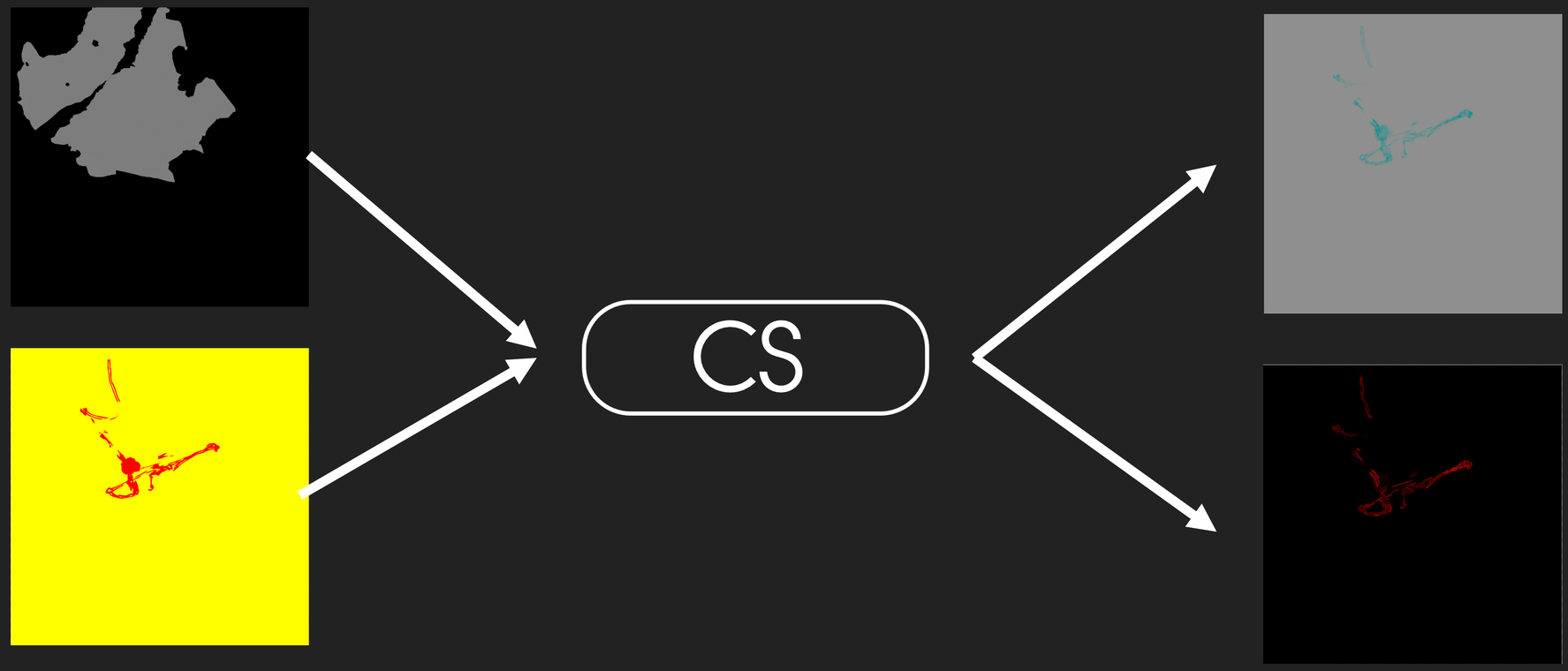
How it works – 1st pass

Compositing pass:
smoothing heights & calculate tessellation factor



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How it works – 1st pass

Hardware tessellation for mesh

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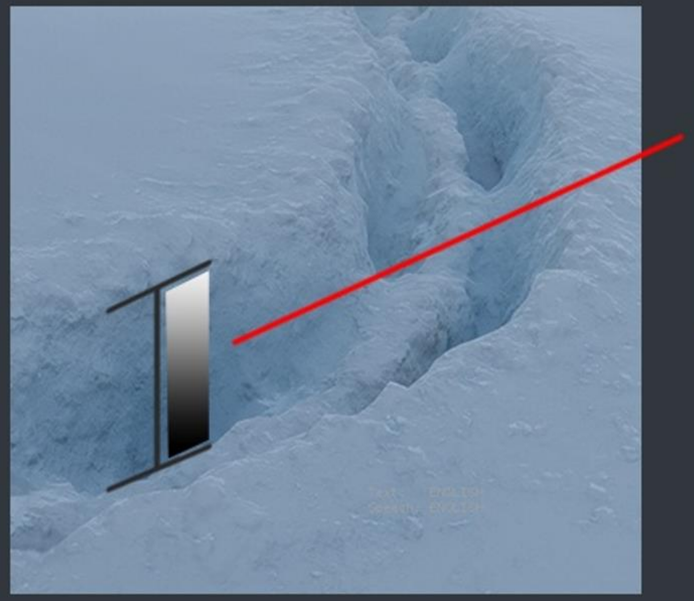
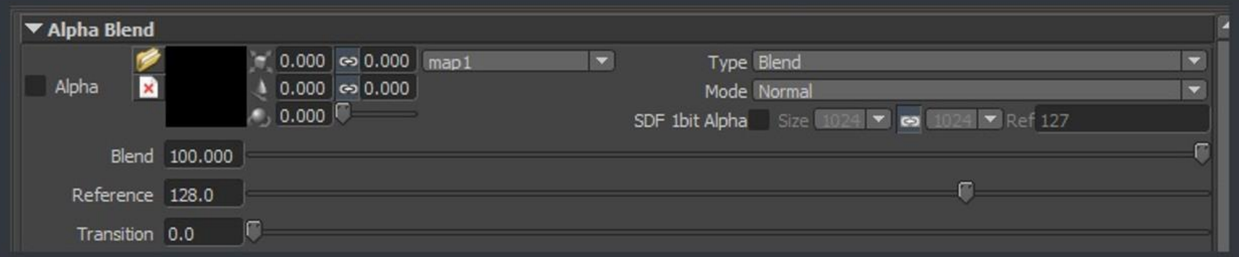
How it works – 2nd pass

Layers for blending



Using the depth of the geometry as an alpha will allow us to mask in the sidewall material and/or reveal materials underneath the snow



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How it works – 2nd pass

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How it works – 2nd pass

Art starts requesting masking feature: red flag?

You CAN use it, but you don't HAVE to

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How it works – 3rd pass

Detail Mask:

Persistent

Used as mask for detail normal map

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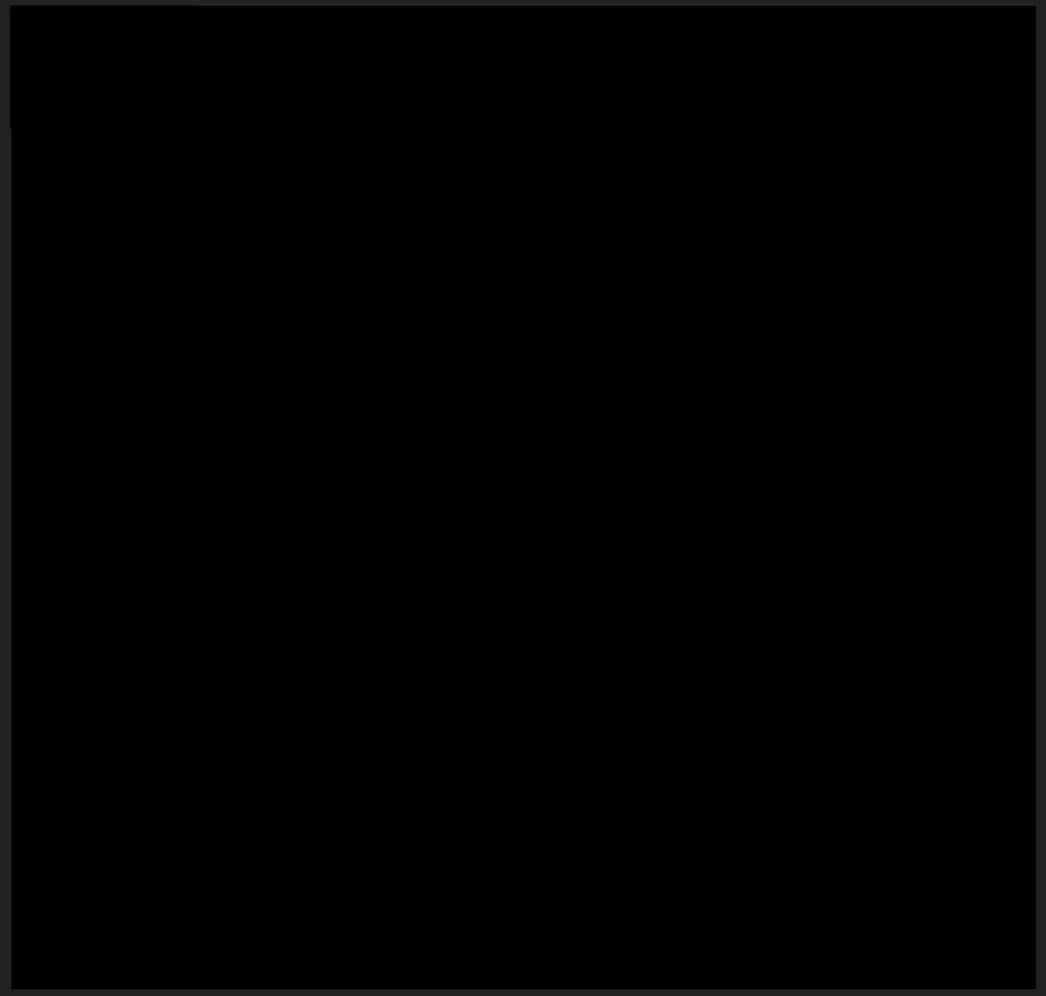
How it works – 3rd pass

Dynamic Details:

Non-Persistent

Generate dynamic normals in shader



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How it works – 3rd pass

Addressed mesh topology limitation

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What does it look like so far

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How does it run

As we start using it everywhere, cost creeps up

We expected it, but not as much

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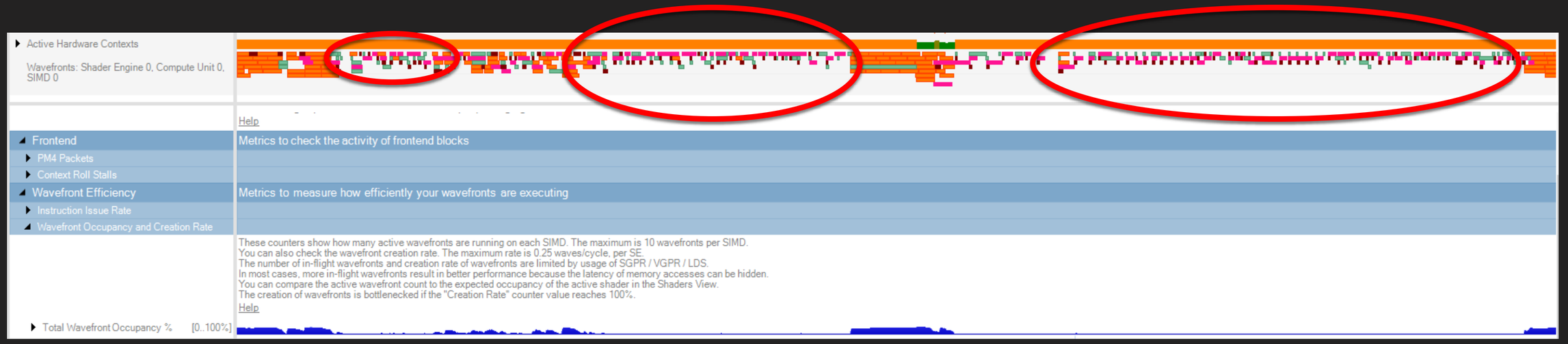
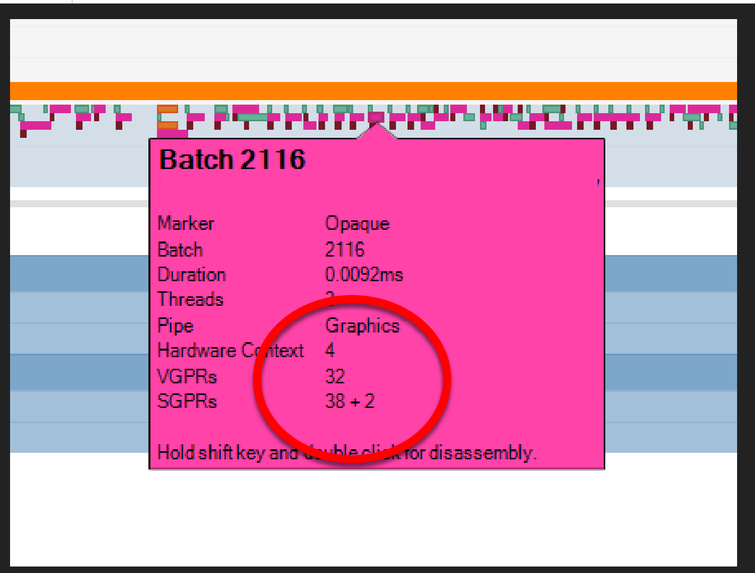
Performance: PS4 capture



Occupancy ☹



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Takeaway #3

Be prepared

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How did we address it?

Problem is tessellated tri count

Our use case is worst case scenario

Artist are nice people, tried to offer help

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Solution overview - Summary

Inspired by GPU driven rendering

Partition the mesh and only render what's needed

Saved a lot, thanks to research done before

Solved a specific problem, gained knowledge

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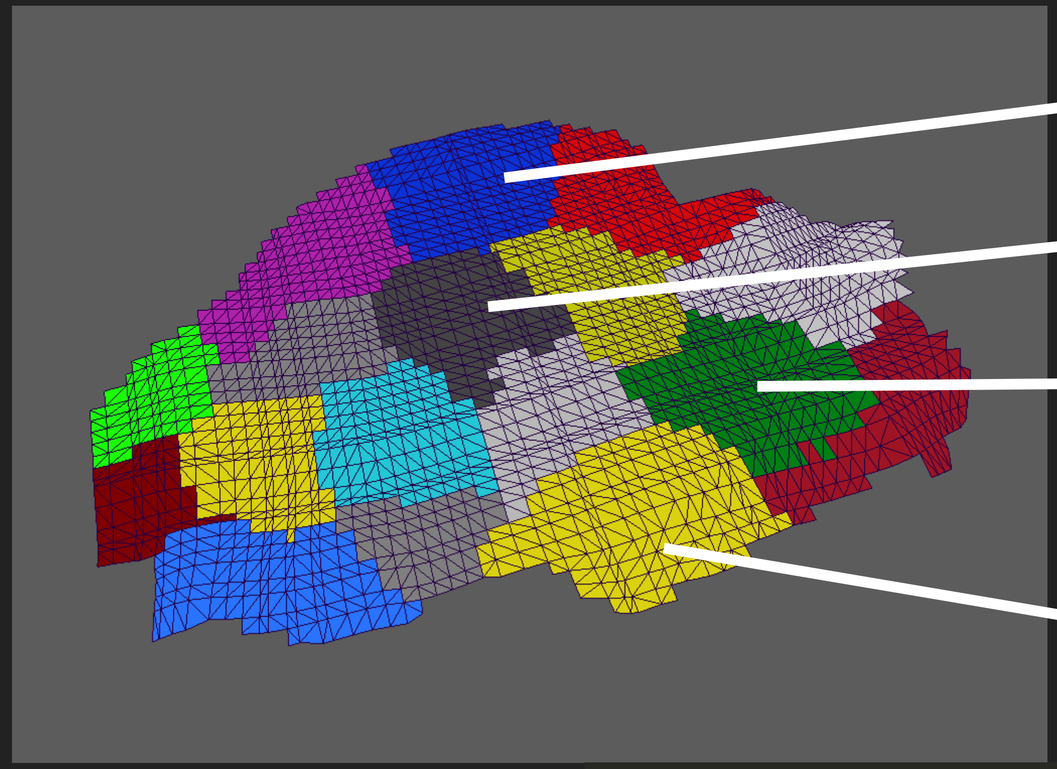
How: Data

Divide mesh in chunks/meshlets
Create offset and culling info buffers



```
[
    {
        indexOffset = 0;
        indexCount = 315;
    },
    {
        indexOffset = 800;
        indexCount = 300;
    },
    {
        indexOffset = 1400;
        indexCount = 303;
    },

    ...

    {
        indexOffset = 15000;
        indexCount = 297;
    }
]
```

```
maxMeshletIndexCount = 315
```

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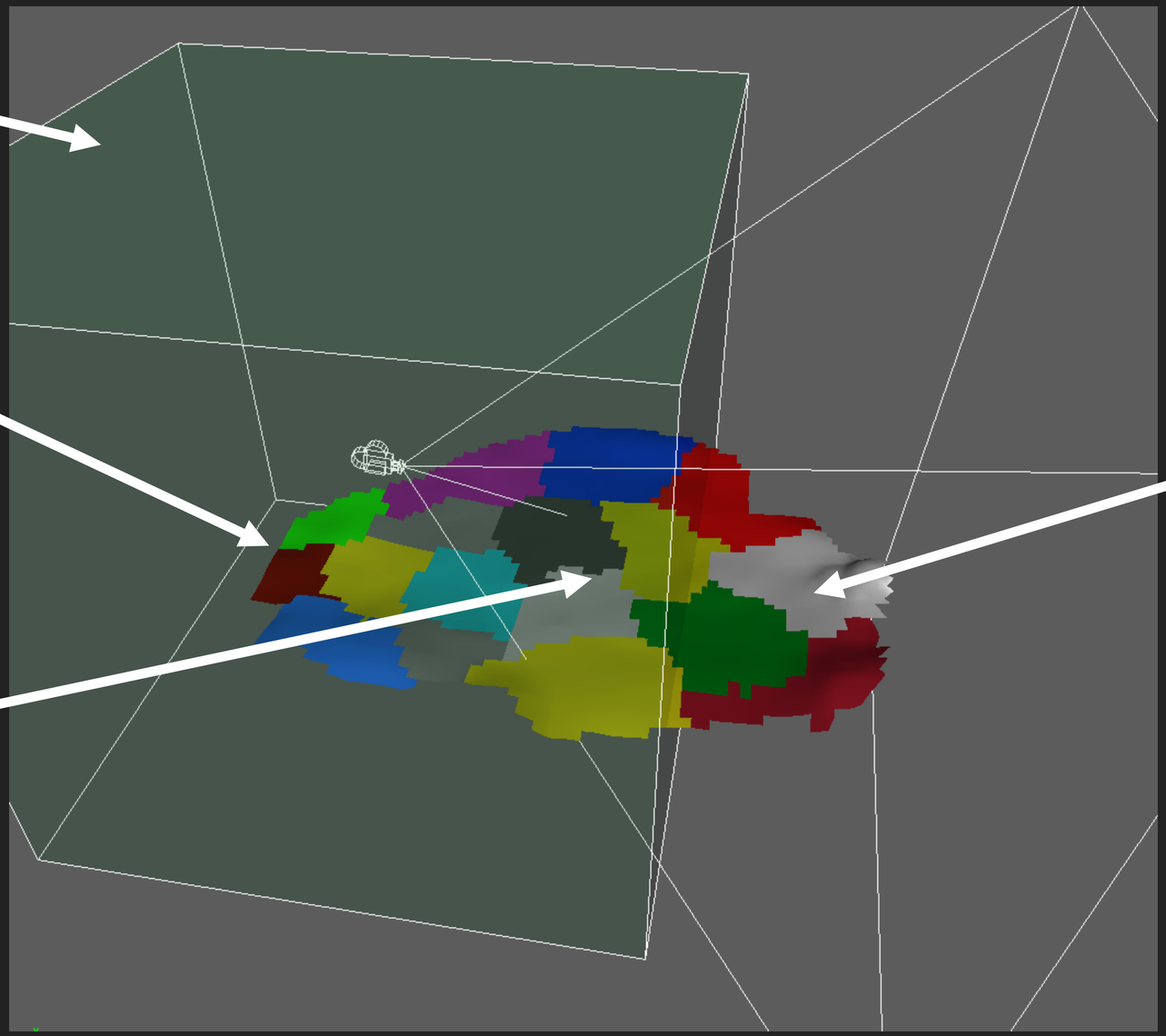
How: Culling and Draw Args



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How: Draw Call

CS

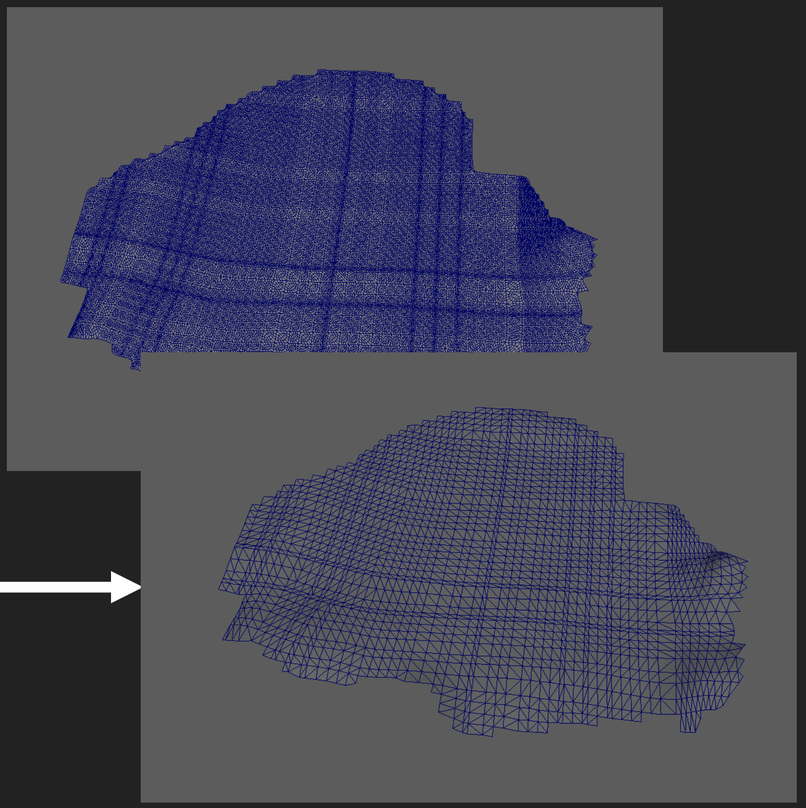
```
maxMeshletIndexCount * validMeshletCount
```

```
struct DrawIndirectArgs
{
    uint m_vertexCountPerInstance;
    uint m_instanceCount;
    uint m_startVertexLocation;
    uint m_startInstanceLocation;
};
```

HW Tess

```
struct DrawIndirectArgs
{
    uint m_vertexCountPerInstance;
    uint m_instanceCount;
    uint m_startVertexLocation;
    uint m_startInstanceLocation;
};
```

VS



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How: Mesh VS

```
// Returns true if the given Input Assembler Index ID in a meshlet draw corresponds to a valid
// meshlet index, and in that case replaces it with the meshlet Index ID that can be used
// to read from the index buffer.
bool FetchMeshletIndexID(..., const bool isTessellatedDraw, inout uint indexID)
{
    uint maxMeshletIndexCount = constantBuffer.heightFieldMaxMeshletIndexCount;

    const uint indexIDInMeshlet = indexID % maxMeshletIndexCount;
    const uint meshletIDInDraw  = indexID / maxMeshletIndexCount;

    // Get meshlet ID, and base index offset
    uint meshletID, baseIndexOffset;
    if (isTessellatedDraw)
    {
        meshletID = meshletIDInDraw;
        baseIndexOffset = constantBuffer.tessellatedIndexOffset;
    }
    else
    {
        meshletID = constantBuffer.heightFieldMeshletCount - 1 - meshletIDInDraw;
        baseIndexOffset = 0;
    }

    const uint meshletIndex = constantBuffer.heightFieldMeshletIndices[meshletID];
    const uint2 fetchedMeshletInfo = constantBuffer.heightFieldMeshletInfo[meshletIndex];

    HeightFieldMeshletInfo meshletInfo;
    meshletInfo.indexOffset = fetchedMeshletInfo.x;
    meshletInfo.indexCount = fetchedMeshletInfo.y;

    // We use the maximum meshlet index count as index stride between meshlets
    // while the vertex buffers are compacted so the surplus indices must be discarded
    if (indexIDInMeshlet >= meshletInfo.indexCount)
        return false;

    indexID = indexIDInMeshlet + meshletInfo.indexOffset + baseIndexOffset;

    return true;
}
```

Draw index count is
meshletMax * validChunksCount

Not “real” index

Clip invalid vertices

```
// We use the maximum meshlet index count as index stride between meshlets
// while the vertex buffers are compacted so the surplus indices must be discarded
if (indexIDInMeshlet >= meshletInfo.indexCount)
    return false;

indexID = indexIDInMeshlet + meshletInfo.indexOffset + baseIndexOffset;

return true;
```

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How: result

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Art very happy

No need of user optimization -> better game

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Be ready for more

New lead, more people
more wiggle room in schedule

Core is shippable

Go back to visual goal: add more details

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More polish

Opaque particles/geo collision

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More polish

Added dynamic model spawning around displacement

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Art even happier

Very simple parameter driven system around height displacement

Art gets taste of in-game no-authoring pipeline

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Greater than the sum of its parts

All thanks to reusable components

You have to ship it!

Height field tech, not just snow

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Concept vs In-Game

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We didn’t forget about Ps5

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In Closing - Requirements

No terrain system; arbitrary meshes ✓

Highly customizable with material features ✓

Minimal setup ✓

Aim for good average perf, no fixed memory cost ✓

Must run well/look good on PS4, scale up on PS5 ✓

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In Closing – The Process

We shipped on features on time

We were able to expand and reuse

No major re-writes/issues

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In Closing – The Future

We have tech that solved a problem,
but can/will change easily

Code can change, but we won't re-invent the wheel since the wheel ~~is the friends we made~~ is the knowledge we gained along the way

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In Closing – Takeaways

Start from product, back of napkin math

No “Core Pillar”

Be prepared

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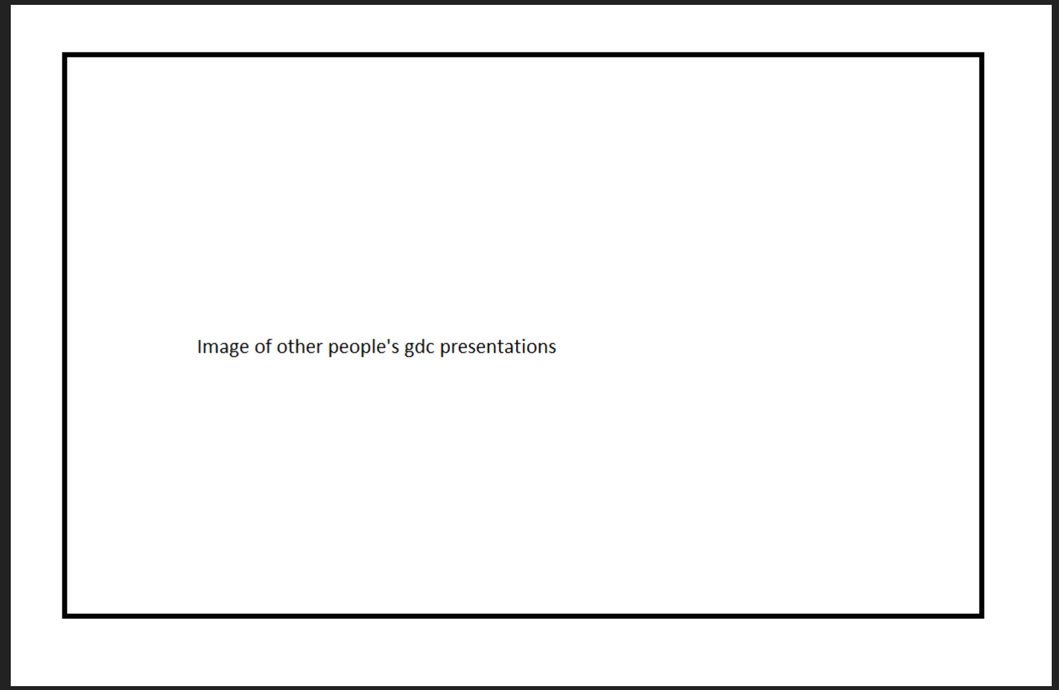
Thank you!



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Thank you!

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We are hiring: https://sms.playstation.com/careers

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