Extending In-Game Textures using CDNs for Call of Duty:MWII

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Sledgehammer Games

Talk Overview

- The problem we need to solve

- Modern Warfare's Proof of Concept

- Vanguard fully implemented approach

- Modern Warfare 2's improvements

- Questions
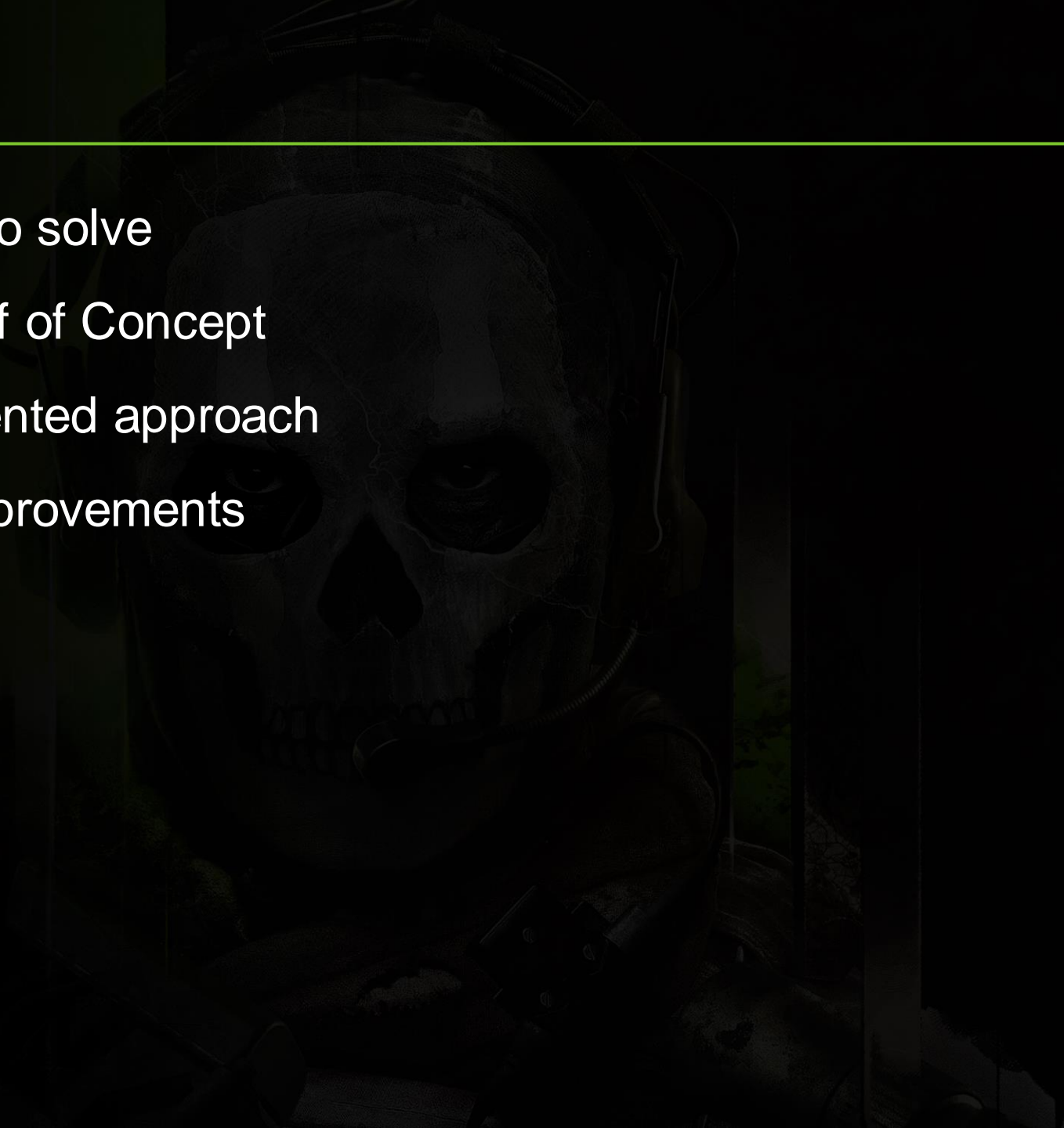
About Me

- Principal Engineer at Sledgehammer Games

- Over 20 years in the games industry

- Notable titles include:
  - Star Wars – The Force Unleashed
  - Bioshock Infinite
  - Borderlands
  - Rainbow Six
  - Call Of Duty
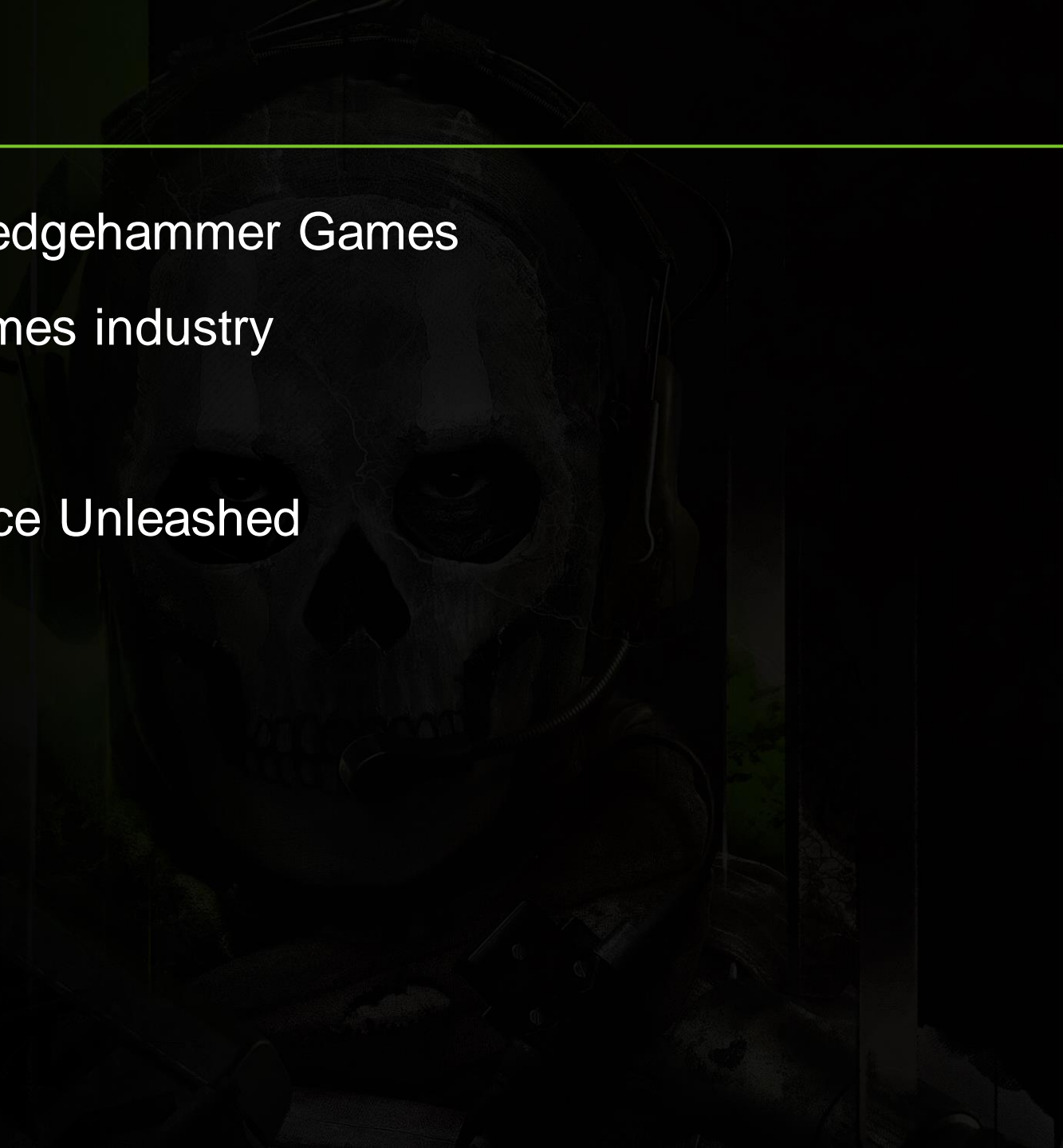
Term Explanations

- Gen 8 is the 8th Generation consoles

- Gen 9 refers to the 9th Generation of Consoles

- Fast Files - Resident Binary Blobs of data

- Xpaks – Streamed Binary Blobs of data

- MB – 1,048,576 bytes

- GB – 1024 MB

- PB – 1,048,576 GB

The Problem

The Problem
Usable Hard Drive Space

PlayStation 4

407 GiB

PlayStation 5

667 GiB

XBOX One

362 GiB

XBOX Series S

364 GiB

XBOX Series X

802 GiB

Install Size

As of July 2021

WARZONE MODERN WARFARE	190 GB
BLACK OPS COLD WAR	102 GB
VANGUARD	~102GB?
	392 GB

Hard Drive Space
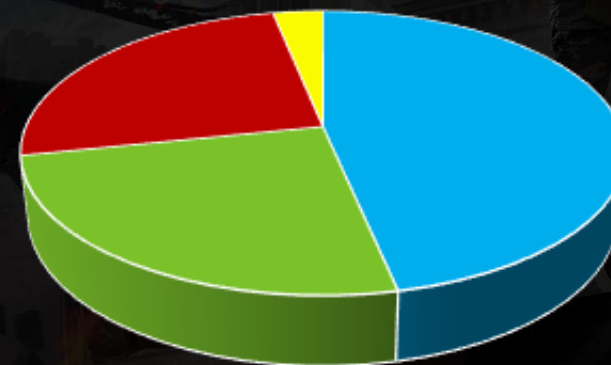
WZ   CW   Van   Remaining

- What takes up space in a typical COD game?
  - Executable
  - Resident Binary Files
  - Movies
  - Streamed Binary Files

Gen8 Package
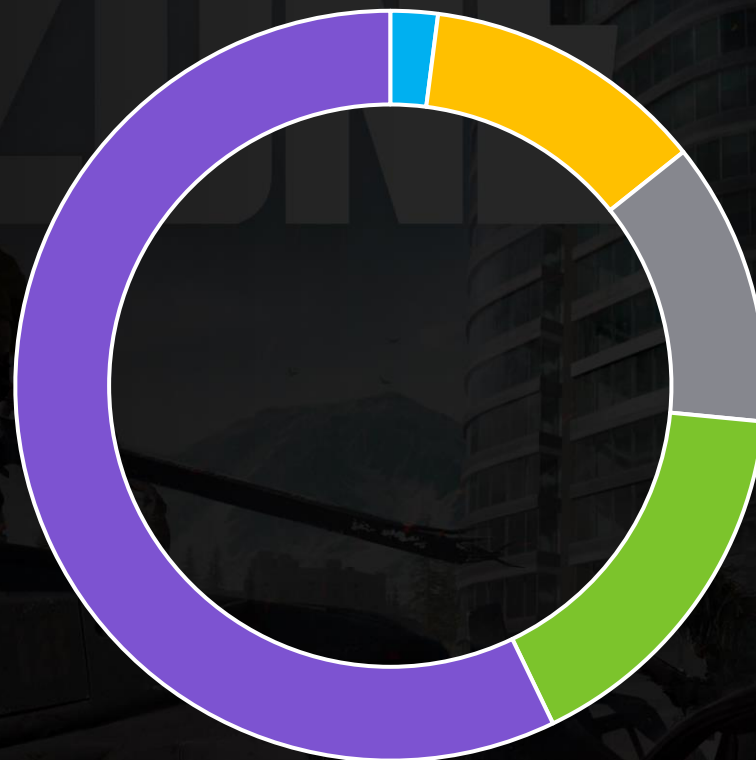
- Executable 2%
- Resident 12%
- Streamed (Movies) 12%
- Streamed (Sounds) 16%
- Streamed (Image) 58%
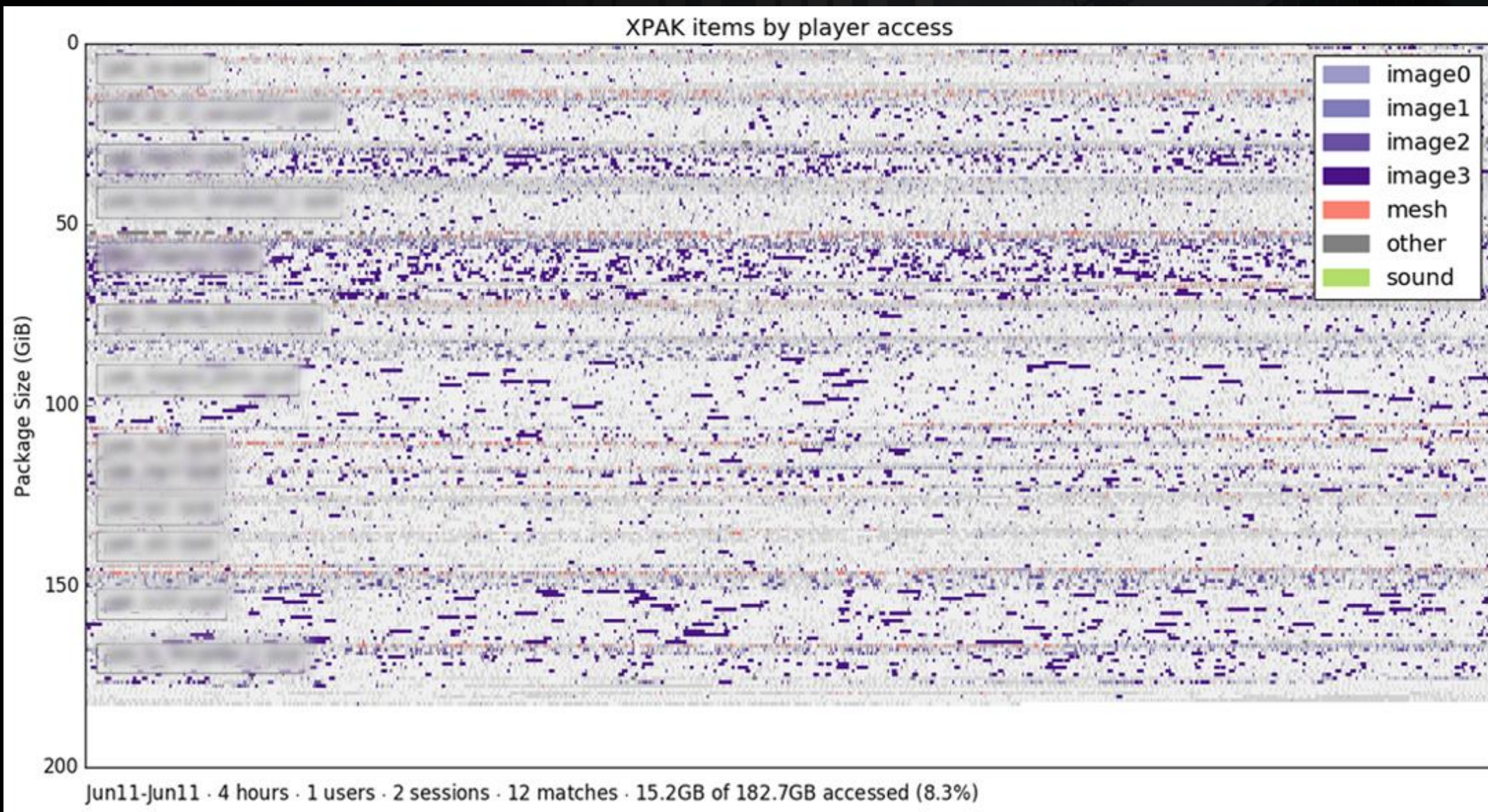
XPAK items by player access

Jun11-Jun13 · 4 hours · 1 users · 7 sessions · 70 matches · 45.9GB of 182.7GB accessed (25.1%)

XPAK items by player access

Jun11-Jun17 · 1 hours · 1 users · 12 sessions · 176 matches · 54.1GB of 182.7GB accessed (29.6%)

Proof of Concept

EBOSWORTH Texture Streaming?

- Originally developed by Eli Bosworth

  - Extended Binary Object Storage With Opportunistic Remote Transfer via Http

  - EBOSWORTH!

ebosworth committed this change 2 years ago into //iw8/main-dev under Review 7758590   👤 View Review

```
Allows streaming assets over HTTP.

[TU_Oscar] [PC Only]
The goal of these changes is to provide a proof of concept for the E.B.O.S.W.O.R.T.H feature, which stands for Extended Binary Object Storage With Opportunistic Remote Transfer via Http.
This feature would enable us to shrink the package size of the game by allowing assets to be downloaded as needed over HTTP rather than shipping everything with the game. At a high level the way
this works is that when the streamer attempts to load an asset, if it finds that the asset is not stored in local xpaks, it triggers a download of that asset. When the asset is downloaded it is
loaded into streamer memory and cached on disk. The cache is a set of xpak files that new assets are appended to.
```

- Sadly the name didn't stick…

CDN Texture Streaming

- We call it **On Demand Texture Streaming** or CDN Texture Streaming.

- CDN – Content Delivery Network
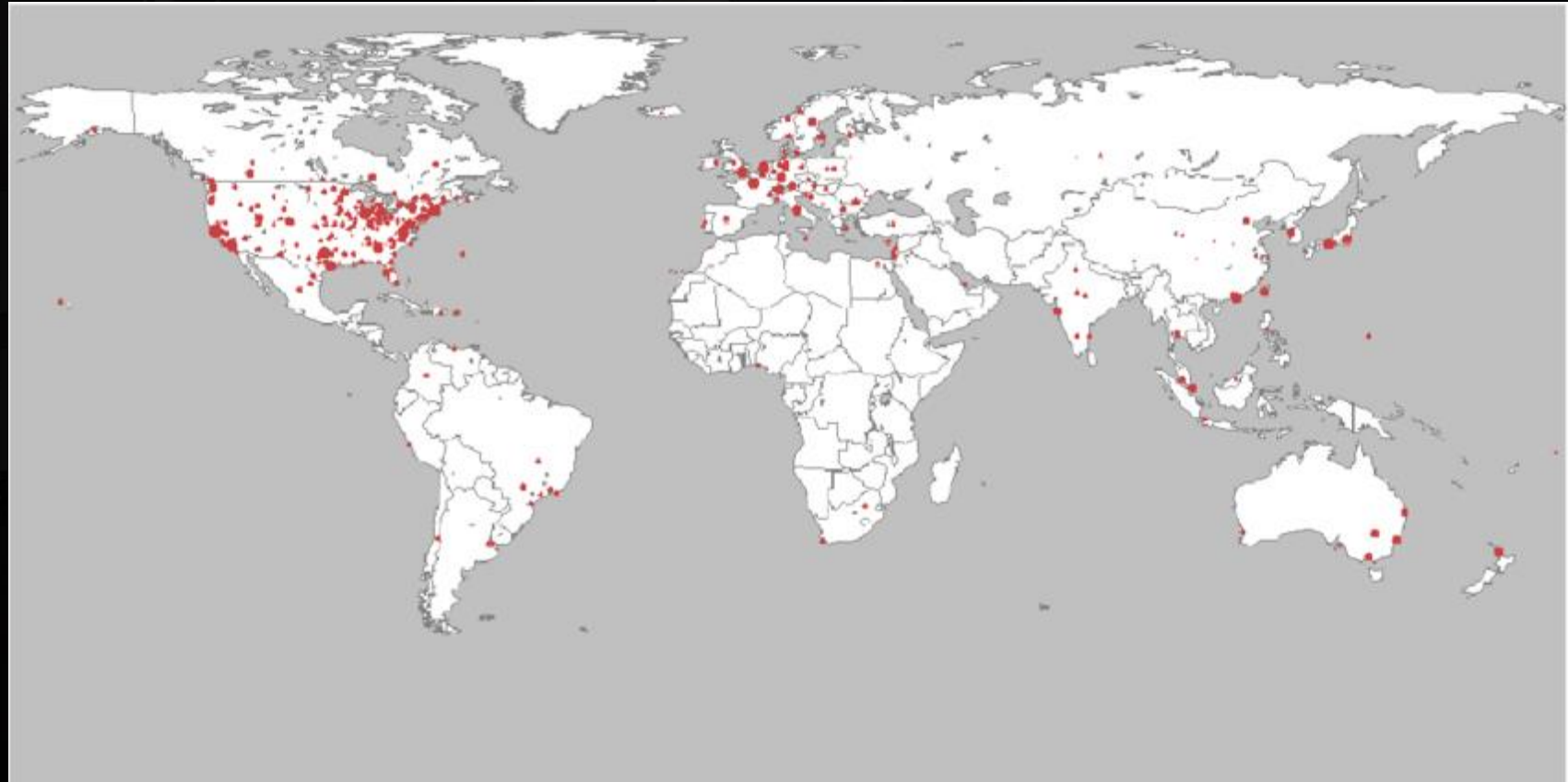
- Download on Demand

Weapons and Operators *per se* are not streamed
Component _textures_ are streamed

Customised Equipment

Every object made of up 10's or
100's of individual textures of
different size / popularity

Weapon skins

Operator Skins

Reminder - The Problem

Install Size

As of July 2021

CALL OF DUTY WARZONE MODERN WARFARE — 190 GB

CALL OF DUTY BLACK OPS COLD WAR — 102 GB

CALL OF DUTY VANGUARD — ~102GB?

392 GB

■ Package Size (GB) ■ Cache Size ■ Reduction
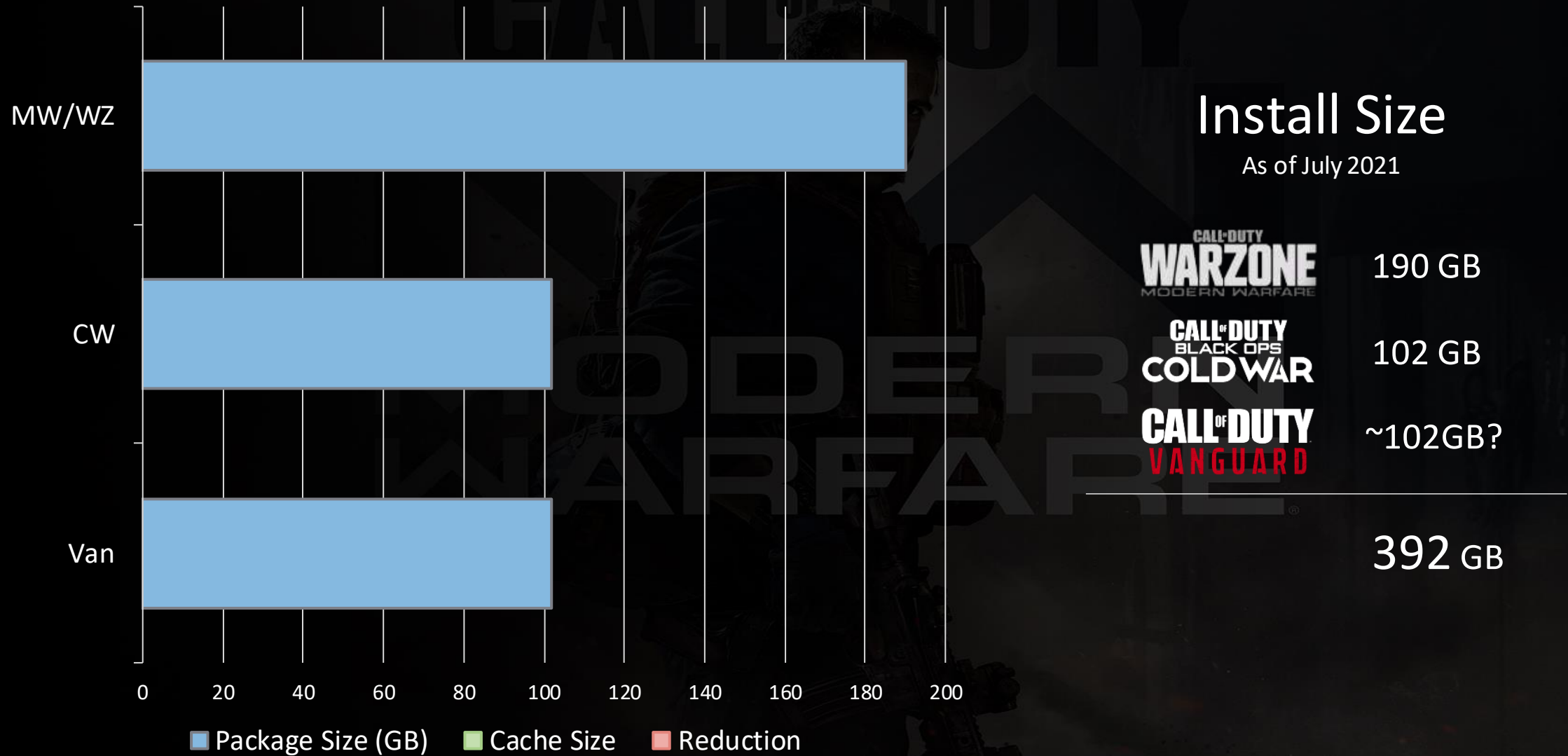
Proof Of Concept a good start

Install Size

As of July 2021

CALL OF DUTY
WARZONE
MODERN WARFARE

~~190 GB~~
150 GB + 12GB

CALL OF DUTY
BLACK OPS
COLD WAR

102 GB

CALL OF DUTY
VANGUARD

~102GB?

~~392 GB~~ 366 GB

Chart axis: MW/WZ, CW, Van — 0 20 40 60 80 100 120 140 160 180 200

Legend: ■ Package Size (GB) ■ Cache Size ■ Reduction

CALL OF DUTY
VANGUARD

Complete High Res Streaming

MWII

Success Criteria

- No "low res" textures or missing images.

- Multiplayer must never be negatively affected by extra network traffic.

- Reduction of package size by at least 25%.

What is an image part?

Gen8

Image Part 4

Image Part 3

Image Part 2

Image Part 1

Image Part 0

512 x 512

Mip 0

256 x 256

Mip 1

128 x 128

Mip 2

Mip 3-6

Mip 7
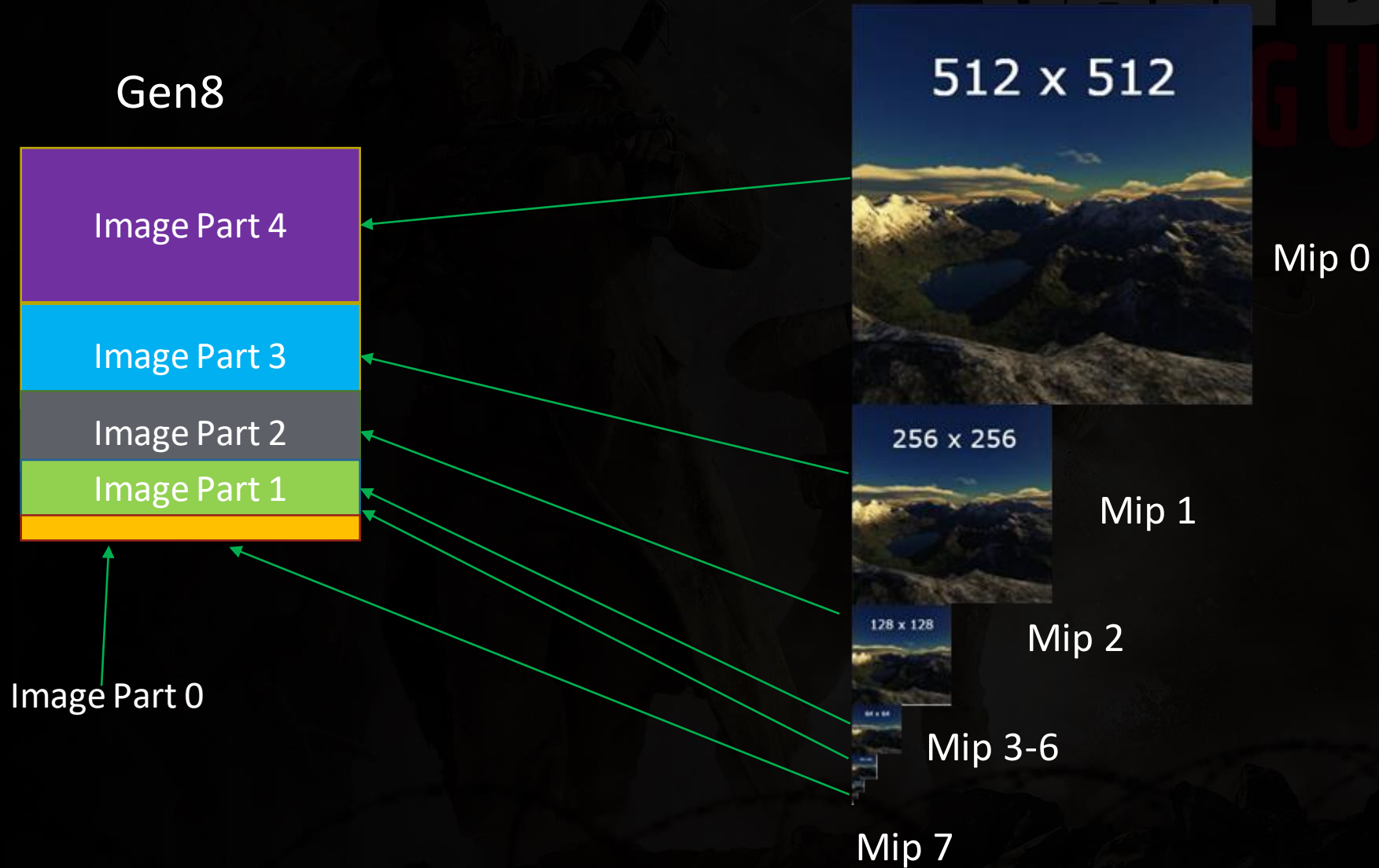
Frequency Bias

- We implemented Frequency Bias which analyses the "noise of an image"

  – Low Frequency images have less change in them
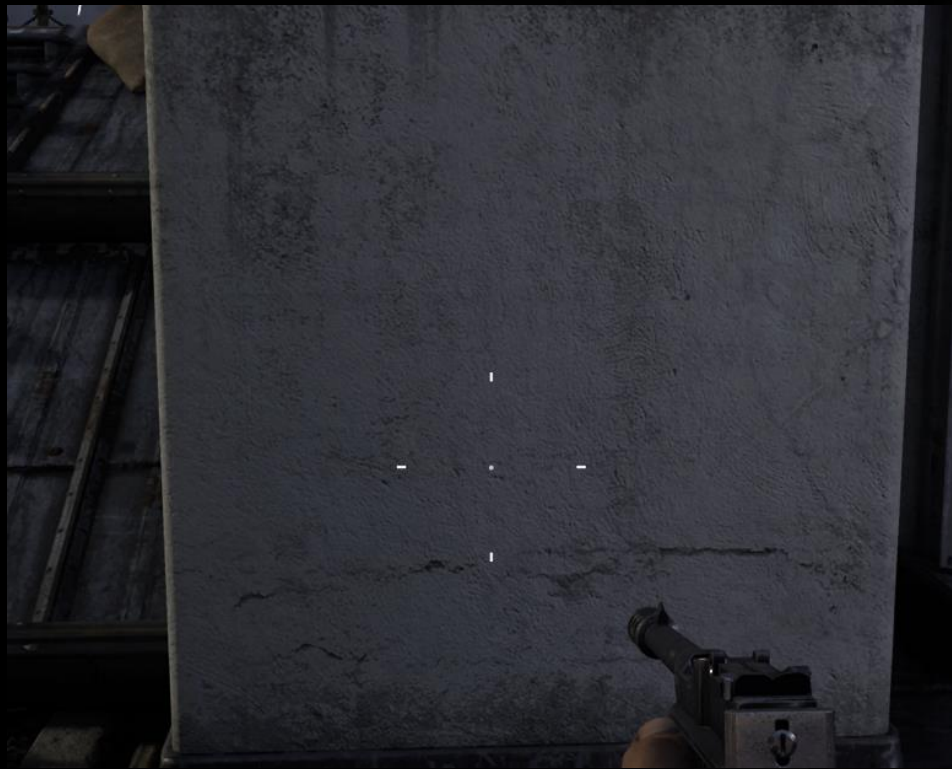
Low Frequency   High Frequency

Image Part breakdown

Gen9

Gen8

| Image Part 4 |
| Image Part 3 |
| Image Part 2 |
| Image Part 1 |

Image Part 0

| Image Part 7 |
| Image Part 6 |
| Image Part 5 |
| Image Part 4 |
| Image Part 3 |
| Image Part 2 |
| Image Part 1 |
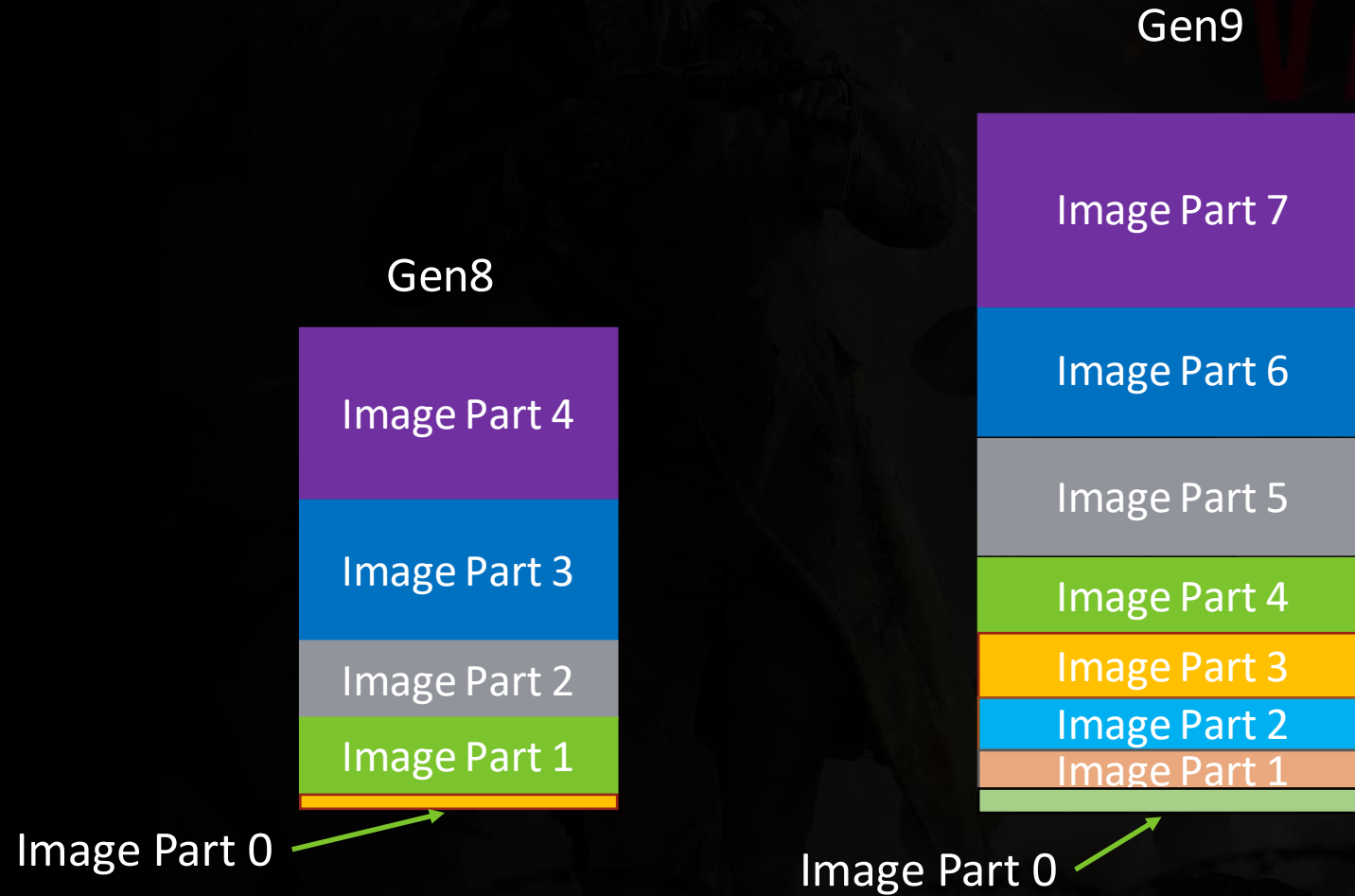
Image Part 0

Image Parts removed from Package

Gen8

| Image Part 4 |
| Image Part 3 |
| Image Part 2 |
| Image Part 1 |

Image Part 0

Gen9

| Image Part 7 |
| Image Part 6 |
| Image Part 5 |
| Image Part 4 |
| Image Part 3 |
| Image Part 2 |
| Image Part 1 |

Low Frequency Bias Only

Image Part 0
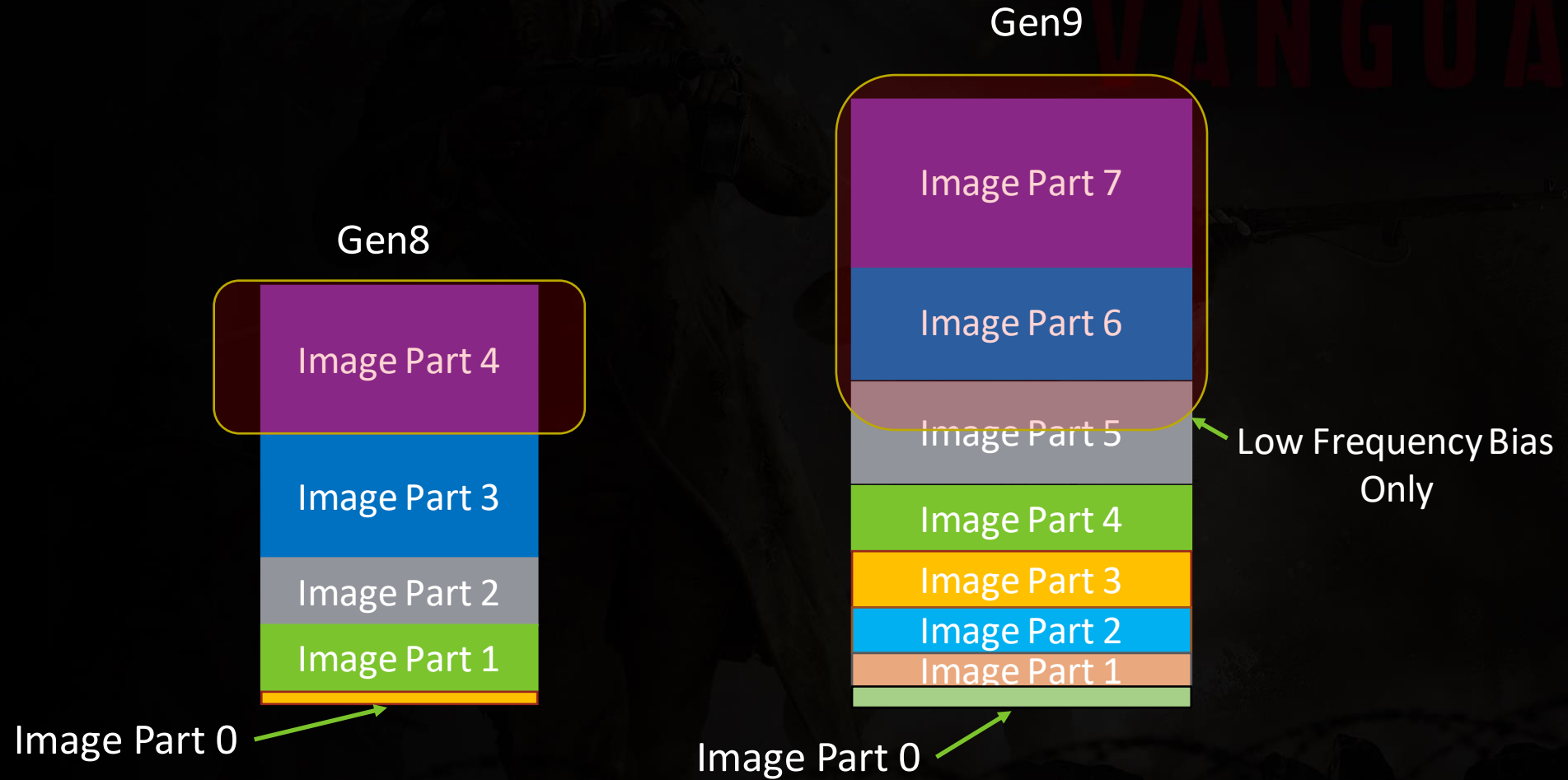
So Where do we store this data?

- Reserve space on the consoles
  - 12 GB by default
  - Grows over time
- When full, discard LRU slice

```
Slice sizes (MB):
0:100%  1:100%  2:100%  3:100%  4:100%  5:100%  6:100%  7:100%  8:100%  9:100%  10:69%  11:57%
 1024    1024    1024    1024    1024    1024    1024    1024    1024    1024     710     586
```

```
Slice sizes (MB):
0:100%  1:100%  2:100%  3:100%  4:100%  5:100%  6:100%  7:100%  8:100%  9:100%  10:99%  11:88%  12: 0%  13: 0%
 1024    1024    1024    1024    1024    1024    1024    1024    1024    1024    1023     909      1       0
```

How do we tell the game to use them?

- Every map generates its own streaming data it requires

- Qualified Image parts are tagged with CDN.

- We combine the maps into groups and run deduplication over them

- The game loads the cdn stub xpaks so it knows what data can be downloaded

	0x000a27a115a2a2bf		8214	1048576	742456448	0	1	0
	0x000a27a115a2a2bf		8214	1048576		0	1	0

This helps Development too!

- All stub xpaks are used by devs during development as well.

- Also means locally developed content will interact as CDN content.

- All images are hashed based on name size and compression type.

- Content creators can opt out of using CDN stubs as well.

How do we select what to download?

Streamer
- Streamer encounters a CDN Image Part it hasn't downloaded yet

CDN Check
- Send Request to download from the CDN

Download
- Once Download is complete, verify the data is okay
  - Never trust the client
    - We had bad data from a library login service!

Update Xpak
- Once we verify the data is the correct size and is a valid image
  - We update the Xpak entries to reference this new image part

Streamer
- Streamer will load the new image part next update.

Challenge – Save Game

- We had a random crash during single player.

- We were able to discover the issue was that save games were not given priority on the HDD.

- To resolve this, we pause all CDN downloads while saves are active.

- The bug was resolved in a future release of the platforms SDK.

HOURLY % CHANGE IN PACKET BURSTS
VG

- Red vertical lines show when the test ran from: **1/21/2022 12:00 – 1/22/2022 12:00 PST**

- We clearly see an effect on packet bursts as the test begins, and the effect fades to zero quickly at test end.

Percent Change of Packet Bursts Treatment vs. Control
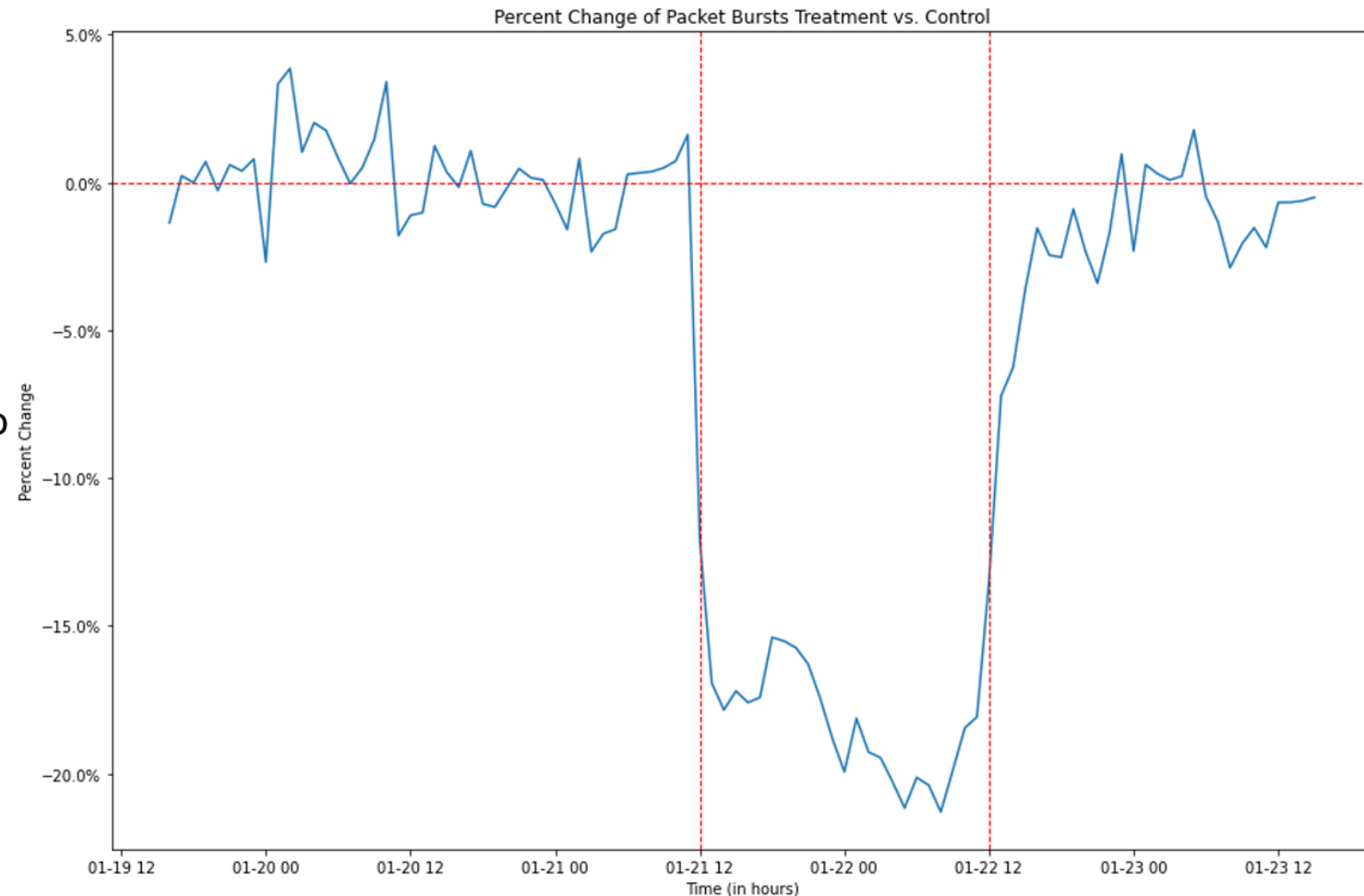
HOURLY% CHANGE IN PACKET BURSTS

- Red vertical lines show when the test ran from: **3/10/2022 12:00 – 2/11/2022 12:00 PST**

- Slight decline during test period when comparing treatment vs. control.

- However, this decline is insignificant based on our testing, and can be observed in periods preceding the test.
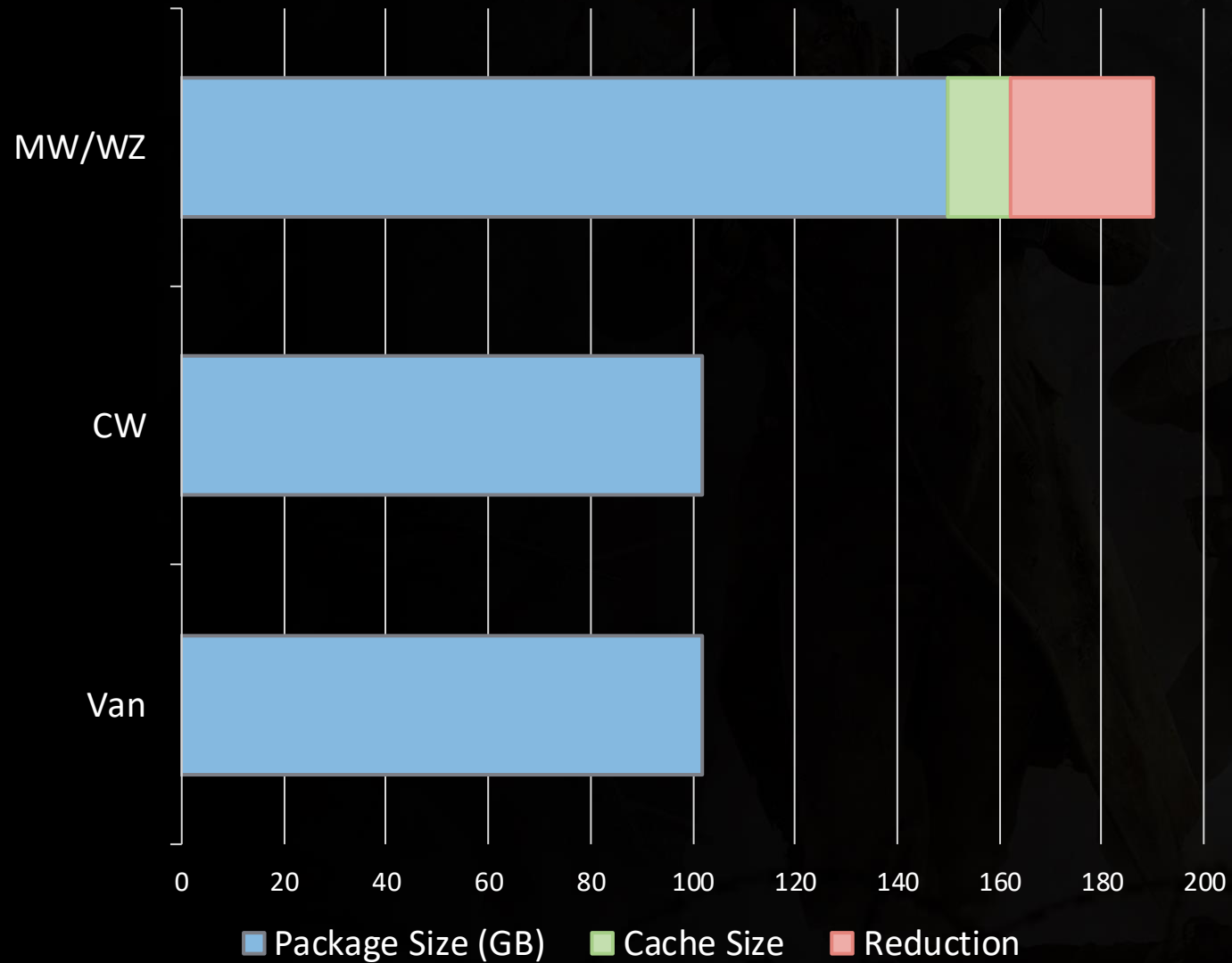
Percent Change of Packet Bursts Treatment vs. Control

So How did we do?

Install Size

As of July 2021

WARZONE ~~190 GB~~ 150 GB + 12GB

CALL OF DUTY BLACK OPS COLD WAR 102 GB

CALL OF DUTY VANGUARD ~102GB?

~~392 GB~~ 366 GB

Legend:
- Package Size (GB)
- Cache Size
- Reduction

Chart categories: MW/WZ, CW, Van

X-axis: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200

50% reduction in package size!
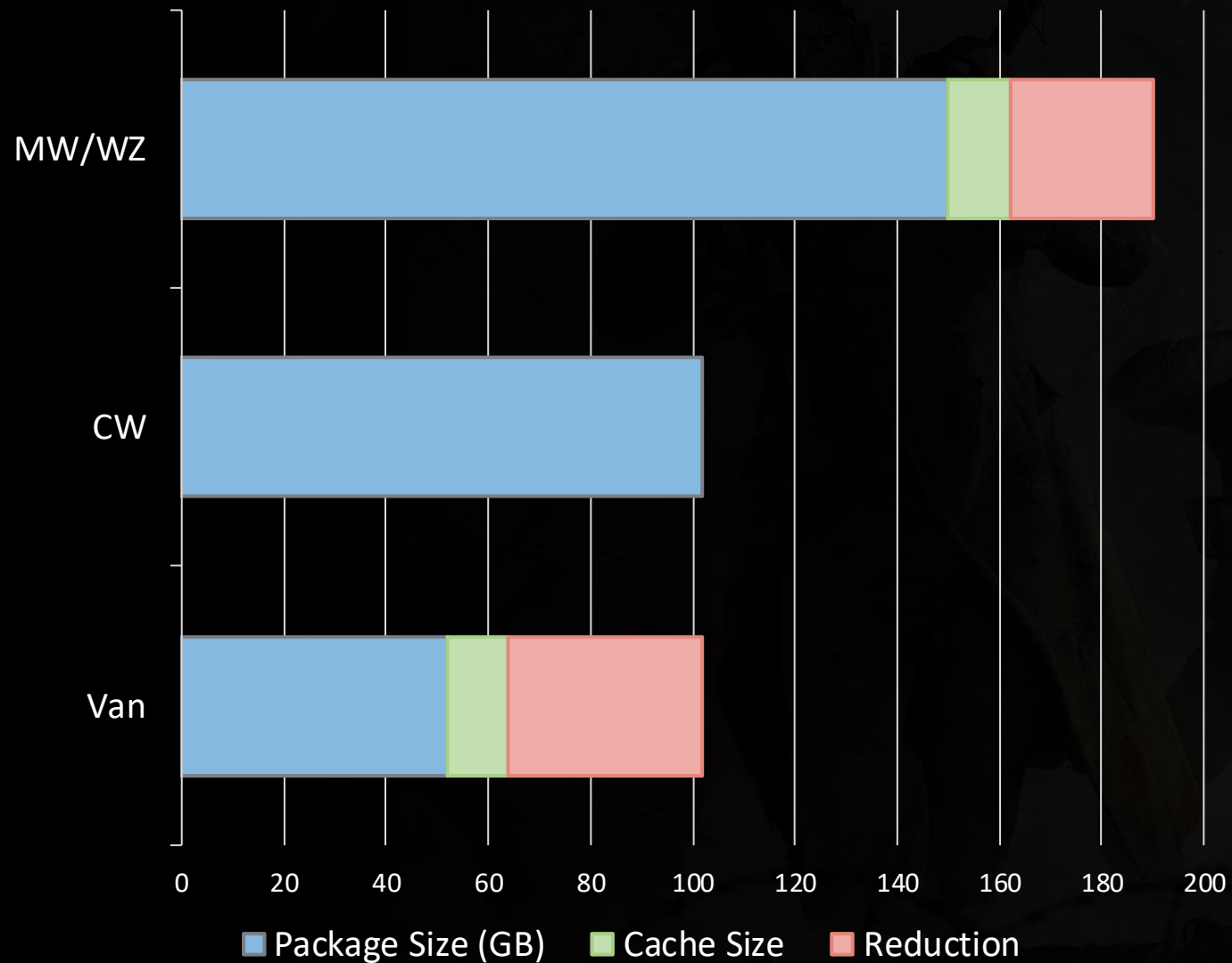
MW/WZ

CW

Van

| 0 | 20 | 40 | 60 | 80 | 100 | 120 | 140 | 160 | 180 | 200 |

■ Package Size (GB) ■ Cache Size ■ Reduction

Install Size

As of July 2021

WARZONE MODERN WARFARE

~~190 GB~~
150 GB + 12GB

CALL OF DUTY BLACK OPS COLD WAR

102 GB

CALL OF DUTY VANGUARD

~~~102GB?~~
52GB + 12GB

~~392 GB~~ 326 GB

Where we are today

Multiplayer Speed Limiting

- Constantly monitor Latency and packet loss.

```
Streamer Quality: 1.0000 Transient Pressure: false
Throttle speed:   1280  Safe max speed: 1228,
Network Health Stats Active/Inactive (Ping: 37 / 37) (PacketLoss: 0 / 0) (Speed: 1305 KB/S)

Kill switch: false  Soft kill switch: false
Image Parts: [5] 164 = 100.5MB (1KB < 627KB > 1918KB)    [6] 88 = 180.8MB (731KB < 2103KB > 4094K
```

```
Stream HTTP Debug Info: Got 122 assets, Failed 0 assets. Ignored 0 assets. Total Ignore Size: 0 MB
CDN URL:
Network Health State  Disabled  Stream http Activity: Idle
Current Recv Buffer:   Normal Speed  (128 KB)
Network Health Stats Active/Inactive (Ping: 0 / 0) (PacketLoss: 0 / 0) (Speed: 0 KB/S)

Kill-switch: 0  SoftKillSwitch: false
Image Parts: [5] 75 = 46.9MB (2KB < 640KB > 1679KB)    [6] 47 = 112.0MB (3040KB < 2439KB > 4089KB)
Version: 1. Max slice size: 1024 MB. 29.82 GB of free disk space.

Items: 2. Next Download Time: 203234, Data Cap: 157.4MB/0.0MB (0.0%), Avg Download Speed: 0.83MB/s

Current slice sizes (MB):
0: 8%  1: 7%  2: 0%  3: 0%  4: 0%  5: 0%  6: 0%  7: 0%  8: 0%  9: 0%  10: 0%  11: 0%  12: 0%  13: 0%  14: 0%  15: 0%
  82    74     0      0      0      0      0      0      0      0       0       0       0       0       0       0
24: 0% 25: 0% 26: 0% 27: 0% 28: 0%
  0      0      0      0      0

status        name                                                                                              part  ke
Interrupted   mtl_stango44_stock_00_n&mtl_stango44_stock_00_o&mtl_stango44_stock_00_g~1532993840885              6    0x
Interrupted   mtl_stango44_rec_bottom_00_n&mtl_stango44_rec_bottom_00_o&mtl_stango44_rec_bottom_00_              6    0x
Complete      c_s4_vm_mp_eng_solange_bracelet_01_n&c_s4_vm_mp_eng_solange_bracelet_01_g~1317455056               6    0x
Complete      c_s4_vm_mp_eng_solange_sleeve_01_c&c_s4_vm_mp_eng_solange_sleeve_01_s~130164865823663              6    0x
Complete      mtl_stango44_stock_00_c&mtl_stango44_stock_00_s~559834176240185719                                 6    0x
Complete      micro_ger_leather2_n&white~6484712368195182394                                                     6    0x
Complete      mtl_stango44_mag_00_c&mtl_stango44_mag_00_s~2686688246621541548                                    6    0x
Complete      mtl_ach_sandbag_cover_01_nml&mtl_ach_sandbag_cover_01_wet_cos~8910583458789149306                  6    0x
Complete      c_s4_vm_mp_eng_solange_bracelet_01_c&c_s4_vm_mp_eng_solange_bracelet_01_s~16467894238              6    0x
Complete      s4_vm_base_female_arms_n&s4_vm_base_female_arms_g~184173133512984277823                            6    0x
```

- Download speeds set using a trickle approach

- We Monitor with 50ms intervals and adjust over time.

- If burst detected, interrupt the users downloads and put the CDN into a rest mode.

Multiplayer Debugging

Network state →

Slices →

Image part progress →

```
▼ Stream HTTP
Summary

                                                          Swap To Monitor   Force Fill Cache   Transparent Toggle

Network Health State: Active    Stream http Activity: Downloading
Streamer Quality: 1.0000 Transient Pressure: false
Throttle speed:   1280 Safe max speed: 1228,
Network Health Stats Active/Inactive (Ping: 37 / 37) (PacketLoss: 0 / 0) (Speed: 1305 KB/S)

Kill switch: false  Soft kill switch: false
Image Parts: [5] 164 = 100.5MB (1KB < 627KB > 1918KB)   [6] 88 = 180.8MB (731KB < 2103KB > 4094KB)   [7] 8 = 40.3MB (1208KB < 5154KB > 13278KB)
Version: 2. Max slice size: 1024 MB. 37.74 GB of free disk space.
Stream HTTP Debug Info: Got 260 assets, Failed 1 assets.
LRU entries: 0 in file, 697 pending
Discard: None

Items: 2. Next Download Time: 355084, Data Cap: 10704.8MB/0.0MB (0.0%), Avg Download Speed: 1.09MB/s


Slice sizes (MB):
0:100% 1:100% 2:100% 3:100% 4:100% 5:100% 6:100% 7:100% 8:100% 9:100% 10:99% 11:100% 12:15%  13: 4%
1024   1024   1024   1024   1024   1024   1024   1024   1024   1024   1023   1024   157     49

status       name                                                                          part key                 recv'ed   time     MB/sec  distance
Downloading  #x413fb1b210bf1b7a1                                                            6    0x4352abc758212311  201   KB  0.5 sec  0.45    11.9849
Downloading  #x4b1e70e2e67fff62                                                             6    0x14e27e513245ce21  1343  KB  2.1 sec  0.67    11.6538
Complete     #x4d42f9b9fa7b07ad                                                             6    0x63b73dc95788ab7d  1789  KB  2.7 sec  0.67    11.6538
Complete     tarp_white_clean_no_logo_01_c~2444739444846487909                             5    0x272d6158810cd255  4     KB  0.2 sec  0.02    11.6538
Complete     tarp_white_clean_no_logo_01_c&tarp_white_clean_01_s~14794982828154243020      6    0x20e9bbfcfd42dbd7  1184  KB  1.8 sec  0.68    11.2167
Complete     decor_plastic_wrap_money_stack_02_c&decor_plastic_wrap_money_stack_02_s~25138335526751 6 0x583fabdec1cb5f8e 1331 KB 1.9 sec 0.70 10.5066
Complete     white&metal_painted_rust_01_r~1230159294281079333                             5    0x1fb2ffa308db9971  1186  KB  1.8 sec  0.66    10.3373
Complete     #x415f5a8d1fd8fbc75                                                            5    0x3abb7c7c454af008  860   KB  1.4 sec  0.63    9.2926
Complete     #x46adbb71c5bce1a92                                                            5    0x728a76728aa096f2  287   KB  0.5 sec  0.65    9.1115
Complete     #x446d3b18faa9d973c                                                            5    0xc428d6b6c544f8c   582   KB  0.9 sec  0.63    8.7697
Complete     #x45a0479d56216798c                                                            5    0x57c3fffa1019b0e9  606   KB  0.9 sec  0.66    8.7270
Complete     #x4728121729a906d85                                                            5    0xbbddfafc1c87b86   236   KB  0.4 sec  0.63    8.3271
Complete     #x4b7ee32dc8327a3                                                              5    0x57a019066da71bfa  739   KB  1.2 sec  0.64    8.2945
Complete     #x464bc14ecebd48fdb                                                            6    0x533a49807cf41a35  3919  KB  5.7 sec  0.70    8.1669
Complete     #x47ad9be765e0e284c                                                            5    0x1de9adc9b1708a98  410   KB  0.7 sec  0.57    7.9840
Complete     #x43f4631e8fb3f2cab                                                            6    0x39185c978a05c31c  1945  KB  2.9 sec  0.70    7.4487
```

Increasing the CDN Speeds

- Increase the CDN speeds for single player content.

- By specifying the receive buffer sizes explicitly.

- Implemented our own socket interface between CDN and the console.

- On Gen8 the limiting factor was I/O pressure.

- On Gen9 the only limiting factor was SSD write limits.

Write speed limiting for Gen9

- Gen9 SSD's have write caps.

- Both have limits to how much you can write.

- We track these limits and adjust our single player speeds accordingly.

File I/O Control for Gen8

- Track the "Streamer Quality" metric.

- If it goes below an acceptable value we pause the CDN downloads.

- We also monitor "Transient Pressure".

```
HDD Cooldown Active For : 1 seconds
Streamer Quality: 0.9563  Transient Pressure: true
Throttle speed:    128  Safe max speed: 1228,
Network Health Stats Active/Inactive (Ping: 0 / 0) (PacketLoss: 0 / 0) (Speed: 0 KB/S)
```

Single Player Debugger

Write speed target

Slices

Image part progress

▼ Stream HTTP

Summary

Swap To Monitor   Force Fill Cache   Transparent Toggle

Network Health State: None   Stream http Activity: Downloading
Streamer Quality: 1.0000 Transient Pressure: false
Throttle speed: 3348 Safe max speed: 4096,
Write Speeds, Current/Average/Target: (2933/3365/3363) KB/Sec

Kill switch: false Soft kill switch: false
Image Parts: [5] 1160 = 630.1MB (0KB < 556KB > 1628KB)   [6] 586 = 1122.6MB (2KB < 1961KB > 5526KB)   [7] 68 = 436.0MB (543KB < 6565KB > 13577KB)
Version: 2. Max slice size: 1024 MB. 41.45 GB of free disk space.
Stream HTTP Debug Info: Got 1814 assets, Failed 31 assets.
LRU entries: 6526 in file, 540 pending
Discard: None

Items: 2. Next Download Time: 2000463. Data Cap: 6917.7MB/0.0MB (0.0%). Avg Download Speed: 1.68MB/s

Slice sizes (MB):

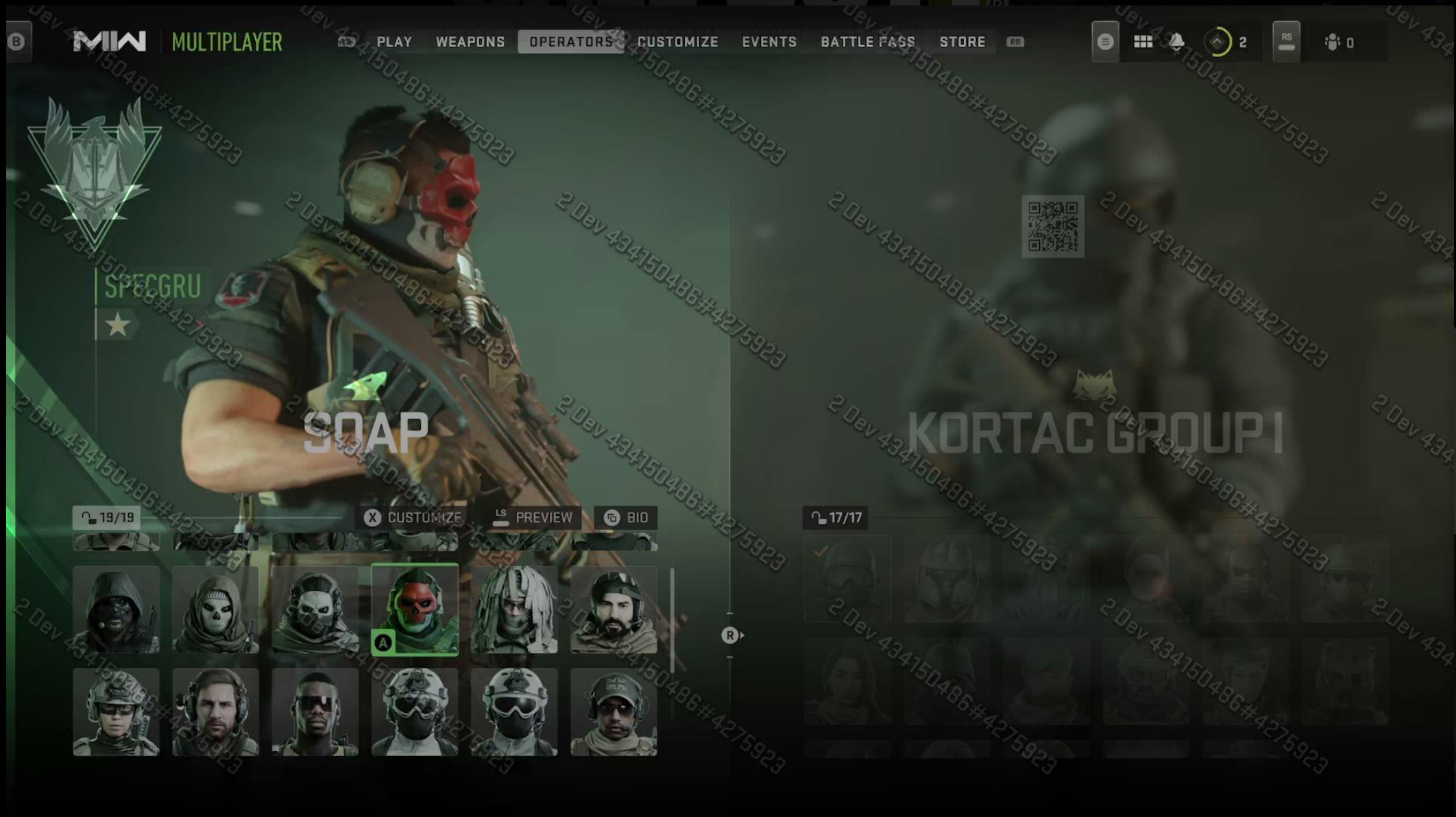| 0:100%	1:100%	2:100%	3:100%	4:100%	5:100%	6:99%	7:99%	8:27%	9:22%	10: 0%	11: 0%
1024	1024	1024	1024	1024	1024	1023	1023	283	228	0	0

status	name	part	key	recv'ed		time	MB/sec	distance
Downloading	veh9_civ_lnd_motorhome_glass_n&veh9_civ_lnd_motorhome_glass_g~12996136447583177819	5	0x4bd9ad83800ea006	141	KB	0.3 sec	0.56	8.7382
Complete	veh9_civ_lnd_sedan_2009_police_texas_n&veh9_civ_lnd_sedan_2009_police_texas_g~55763065	5	0x4badbdd4bbc482af	490	KB	0.4 sec	1.22	8.4896
Downloading	ee_furniture_club_couch_n&ee_furniture_club_couch_g~15331467052656930125	6	0x5b3966365b5fe67f	965	KB	0.7 sec	1.44	8.0885
Complete	sp_opforce_cartel_grunt_lmg_1_1_polo_shirt_m~12086074706908833411	5	0x23c6925b30e818ec	170	KB	0.2 sec	0.81	12.7449
Complete	attachment_vm_drummag_eastern_c&attachment_vm_drummag_eastern_s~11555873281561442157	6	0x2802e7cd50e47214	372	KB	0.2 sec	1.07	12.5498
Complete	sp_opforce_cartel_grunt_lmg_1_1_shirt_a_c&defaultspec~11613460194439712190	5	0x2c71fe2ea74e4c65	1148	KB	0.8 sec	1.55	11.7874
Complete	un_foliage_cactus_myrtle_01_n&un_foliage_cactus_myrtle_01_ao&un_foliage_cactus_myrtle_	5	0x3a8f9e37634f29ca	1059	KB	0.7 sec	1.46	4.3915
Complete	head_sc_m_bansal_cartel_grunt_ar_1_1_tattoo_m~13809176085161875140	5	0x4c6b6aaebbf290ed	46	KB	0.2 sec	0.27	9.7005
Complete	balaclava_a_n&balaclava_a_o&balaclava_a_g~10124925836614151976	6	0x768e95f8bce5d4b9	1973	KB	1.2 sec	1.67	7.5164
Complete	sp_opforce_cartel_grunt_lmg_1_1_lmg_pouch_c&sp_opforce_cartel_tier_2_lmg_pouch_5_1_s~6	5	0x3c06699ebb8817dd	229	KB	0.2 sec	1.18	8.9773
Complete	sp_opforce_cartel_grunt_lmg_1_1_belt_a_brown_c&ctsfo_belt_a_s~13476468120960965831	5	0x7bf8a26def832fd0	154	KB	0.2 sec	0.67	8.9329
Complete	balaclava_a_gray_c&balaclava_a_s~17153117294735875765	6	0x22855abd02e75e64	1537	KB	0.9 sec	1.69	7.5164
Complete	sp_opforce_cartel_grunt_lmg_1_1_polo_shirt_n&parts_polo_shirt_unbuttoned_g~17407824167	6	0x77824e476eafe398	3232	KB	1.9 sec	1.73	7.0760
Complete	sp_opforce_cartel_grunt_lmg_1_1_jeans_black_c&defaultspec~18332540124338183488	5	0x5e9a5f26fbae6c6f	951	KB	0.7 sec	1.35	6.3564
Complete	sp_opforce_cartel_grunt_lmg_1_1_shirt_longsleeve_c&defaultspec~14211562408160091164	5	0x66fe3418384d602f	989	KB	0.7 sec	1.40	6.2221
Complete	sp_opforce_cartel_grunt_lmg_1_1_shirt_longsleeve_m~13241923290035389907	5	0x5f8862ea6e237f2f	588	KB	0.4 sec	1.48	6.2221

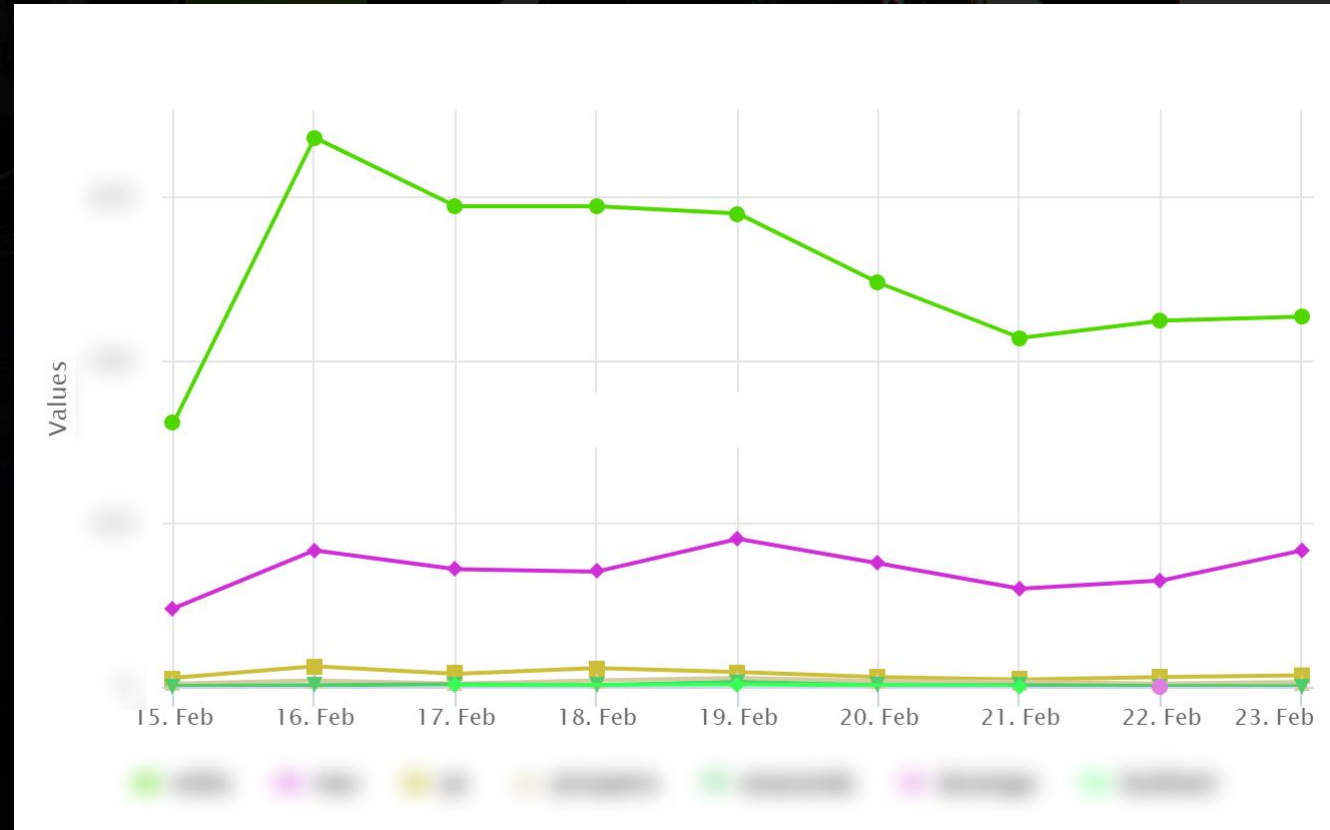"Winning is not everything, but wanting to win is."
– Vince Lombardi

Handle Read errors

- We track read errors to the CDN Binary Data in the Cache.

- We record these events to study the causes.

CDN In Action! (Modern Warfare 2)

```
▼ Stream HTTP
 Summary

                                                          Swap To Monitor   Force Fill Cache   Transparent Toggle

 Network Health State: None    Stream http Activity: Downloading
 Streamer Quality: 1.0000 Transient Pressure: false
 Throttle speed:   4096 Safe max speed: 4096,
 Write Speeds, Current/Average/Target: (0/0/3495) KB/Sec

 Kill switch: false   Soft kill switch: false
 Image Parts: [5] 205 = 130.8MB (1KB < 653KB > 1651KB)    [6] 187 = 458.9MB (6KB < 2512KB > 6385KB)    [7] 30 = 273.9MB (2084KB < 9349KB > 15513KB)
 Version: 2. Max slice size: 1024 MB. 49.04 GB of free disk space.
 Stream HTTP Debug Info: Got 422 assets, Failed 6 assets.
 LRU entries: 0 in file, 420 pending
 Discard: None

 Items: 2. Next Download Time: 441211, Data Cap: 881.0MB/0.0MB (0.0%), Avg Download Speed: 1.91MB/s

 Slice sizes (MB):
 0:43%  1:46%  2: 0%  3: 0%  4: 0%  5: 0%  6: 0%  7: 0%  8: 0%  9: 0%  10: 0%  11: 0%
  450    471     0      0      0      0      0      0      0      0      0       0
```
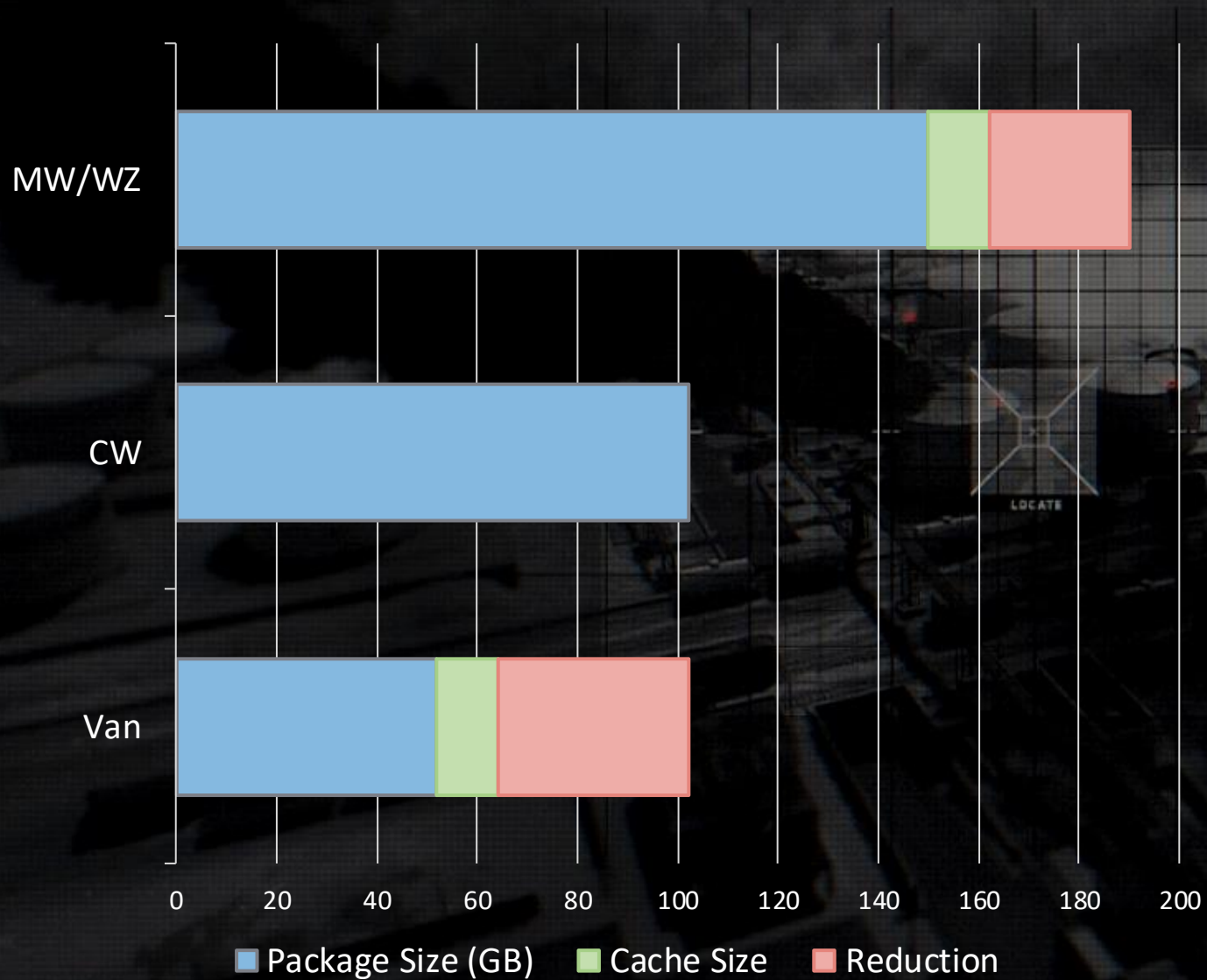
status	name	part	key	recv'ed	time	MB/sec	distance
Downloading	veh9_mil_lnd_apc_8x8_turret_n&veh9_mil_lnd_apc_8x8_turret_g~7002172996741316146	7	0x5e2328fd3344db4c	4617 KB	2.3 sec	2.04	2.3638
Complete	veh9_mil_lnd_apc_8x8_bottom_c&veh9_mil_lnd_apc_8x8_bottom_s~9519545595526736512	7	0x2d683676053fcac4	5833 KB	2.9 sec	2.07	2.2972
Downloading	veh9_mil_lnd_apc_8x8_bottom_n&veh9_mil_lnd_apc_8x8_bottom_g~4011681518983774717	7	0x30eb09964d6f5324	12116 KB	6.0 sec	2.08	2.0458
Complete	veh8_mil_lnd_mkilo23_skud_leg_n&veh8_mil_lnd_mkilo23_skud_leg_o&veh8_mil_lnd_mkilo23_s	5	0x50b50118c96ccb5b	598 KB	0.4 sec	1.48	2.2223
Complete	body_russian_helicopter_pilot_lod1_c&body_russian_helicopter_pilot_lod1_s~159517042439	5	0x4304006390b0ff59	339 KB	0.3 sec	1.34	38.9607
Complete	veh9_mil_lnd_jltv_platform_m~1839936505081608471	6	0x43d27035022790d2	101 KB	0.2 sec	0.51	31.7833
Complete	veh9_mil_lnd_jltv_platform_c&veh9_mil_lnd_jltv_platform_s~1855050123596561350	7	0x65d4a6ea566a4822	2084 KB	1.1 sec	1.89	31.7833
Complete	veh9_mil_lnd_jltv_body_n&veh9_mil_lnd_jltv_body_u&veh9_mil_lnd_jltv_body_g~4529082525	7	0x4886fbe535415e31	9279 KB	4.4 sec	2.15	31.5614
Complete	uk_shipping_crate_woodl_n&uk_shipping_crate_wood_g~14106047439537452224	6	0x515138013b6cbae3	3603 KB	1.7 sec	2.12	3.2021
Complete	li_i_mtl_un_foliage_tree_juniper_large_01_dry_proxy_albedo	5	0x70b78551bf9dae84	406 KB	0.2 sec	1.84	30.4218
Complete	rock_stone_ruins_wall_light_c&defaultspec~15516795721748651176	5	0x7b9524969b47aa65	1349 KB	0.7 sec	2.06	29.8801
Complete	veh8_mil_lnd_umike_body_01_c&veh8_mil_lnd_umike_body_01_s~6252526092796845593	6	0x4cb762958b834bcc	1575 KB	0.8 sec	2.00	29.3876
Complete	veh9_mil_lnd_jltv_cargo_n&veh9_mil_lnd_jltv_cargo_u&veh9_mil_lnd_jltv_cargo_g~70674815	7	0x539a7f9cf97a5550	4309 KB	2.1 sec	2.11	28.4281
Complete	veh9_mil_lnd_jltv_wheel_flat_n&veh9_mil_lnd_jltv_wheel_flat_g~5517169401171130290	5	0x4a37296d14f53db1	828 KB	0.5 sec	1.60	27.8601
Complete	veh9_mil_lnd_jltv_body_m~1157786100354892606	6	0x3654d80866435f11	3424 KB	1.8 sec	1.98	26.6087
Complete	veh8_mil_lnd_umike_body_01_allied_camo_c&veh8_mil_lnd_umike_body_01_s~1727003927810695	6	0x23a0d98ae338db11	1854 KB	1.0 sec	1.95	26.0051

So while we did good….

Install Size

As of July 2021

CALL OF DUTY WARZONE MODERN WARFARE — ~~190 GB~~ 150 GB + 12GB
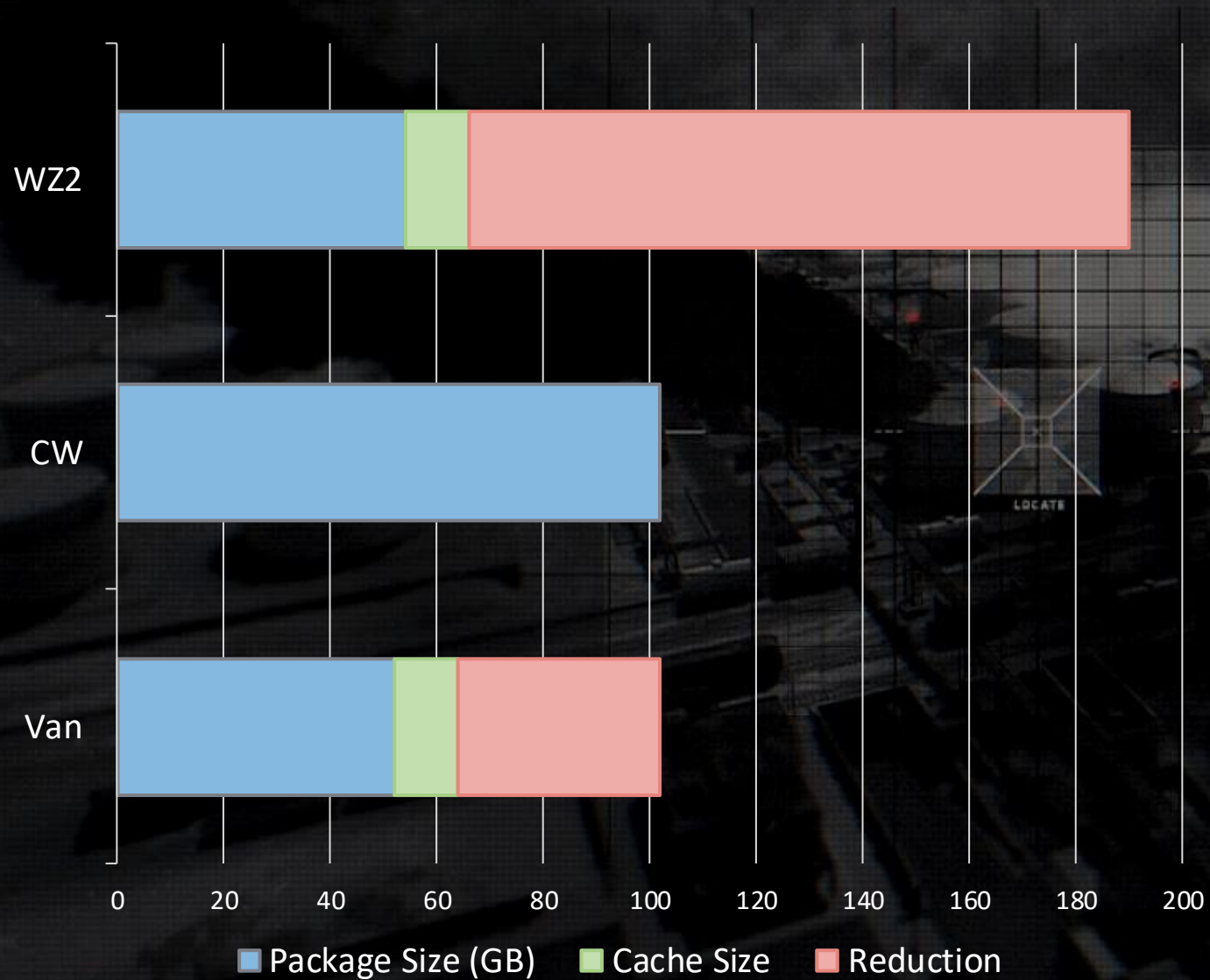
CALL OF DUTY BLACK OPS COLD WAR — 102 GB

CALL OF DUTY VANGUARD — ~~~102GB?~~ 52GB + 12GB

~~392 GB~~ **326** GB

Chart legend: ■ Package Size (GB) ■ Cache Size ■ Reduction

Chart categories (y-axis): MW/WZ, CW, Van
Chart x-axis: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200

MWII really emphasises the wins

Install Size

As of July 2021

CALL of DUTY WARZONE 2.0
~~190 GB~~
54 GB + 12GB

CALL of DUTY BLACK OPS COLD WAR
102 GB

CALL of DUTY VANGUARD
~~~102GB?~~
52GB + 12GB

~~392 GB~~ **232** GB

Legend: ■ Package Size (GB) ■ Cache Size ■ Reduction

HOLD ⟳ TO WALK FORWARD.

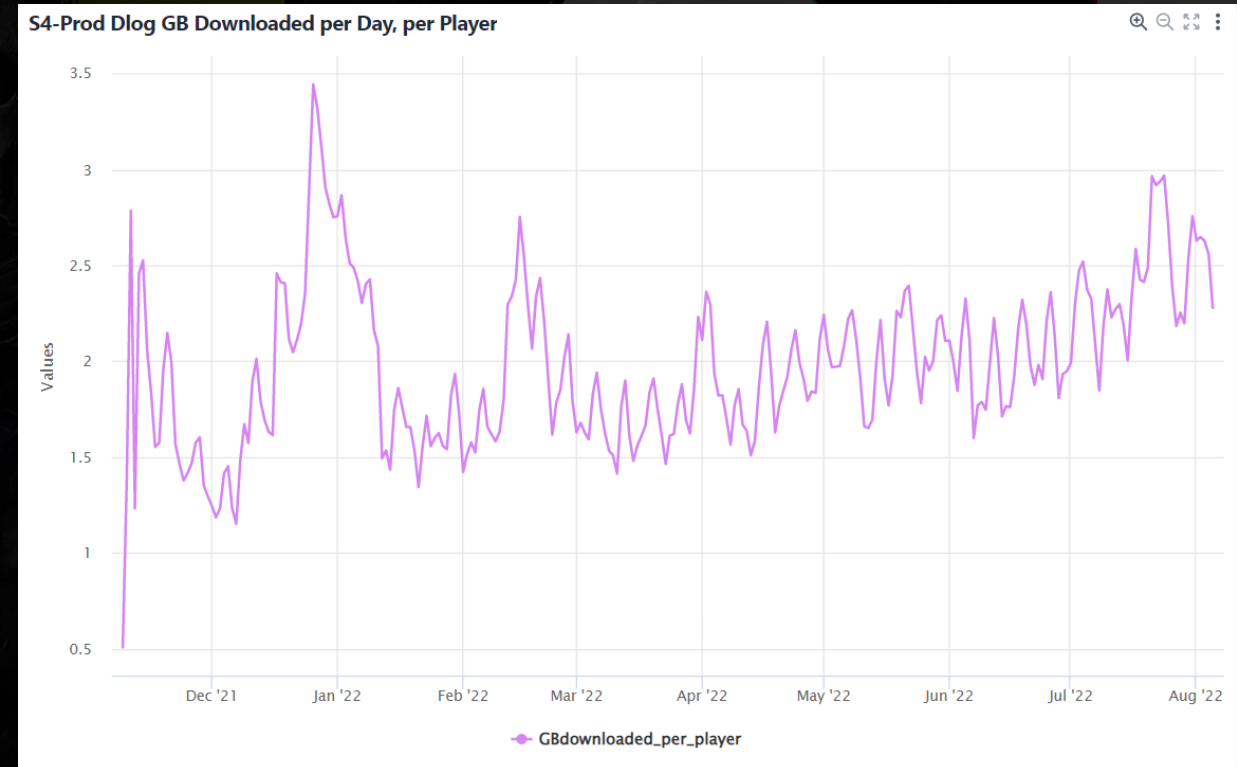# Fully downloaded scene
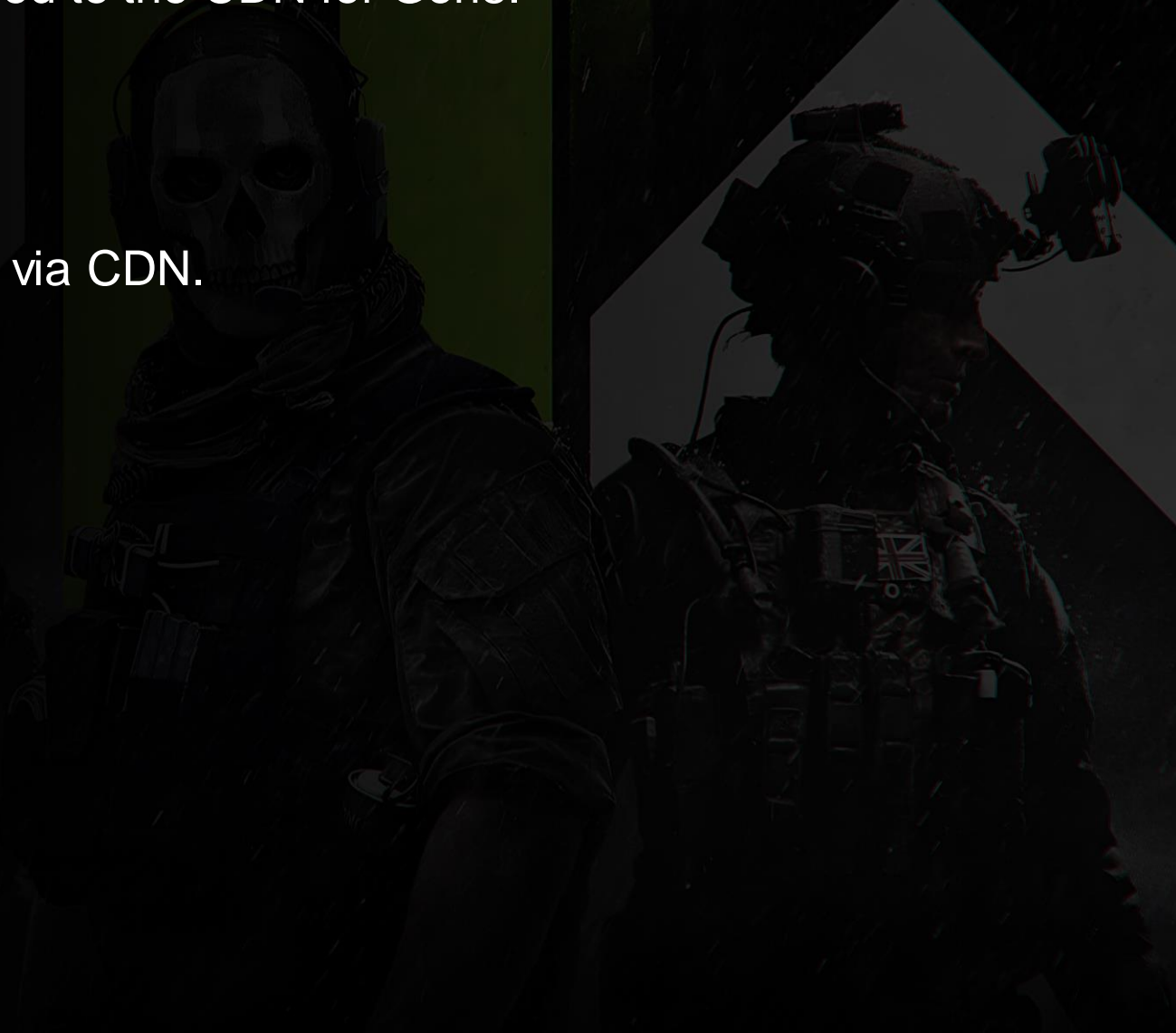
Stats

- Modern Warfare

  - Total Data downloaded to date: 220PB

  - ~5GB average downloaded per user total

- Vanguard

  - 31GB average downloaded per user total

  - Total data downloaded to date: 628PB

- Modern Warfare 2

  - 14.5GB average downloaded per user total

  - Total data downloaded to date: 812.5PB

S4-Prod Dlog GB Downloaded per Day, per Player

GBdownloaded_per_player

Potential Areas to explore

- Increasing the Image Parts dropped to the CDN for Gen8.

- HTTP2 Implementation.

- Prime your CDN cache.

- High Resolution Movie streaming via CDN.

- Improve Cache discarding.
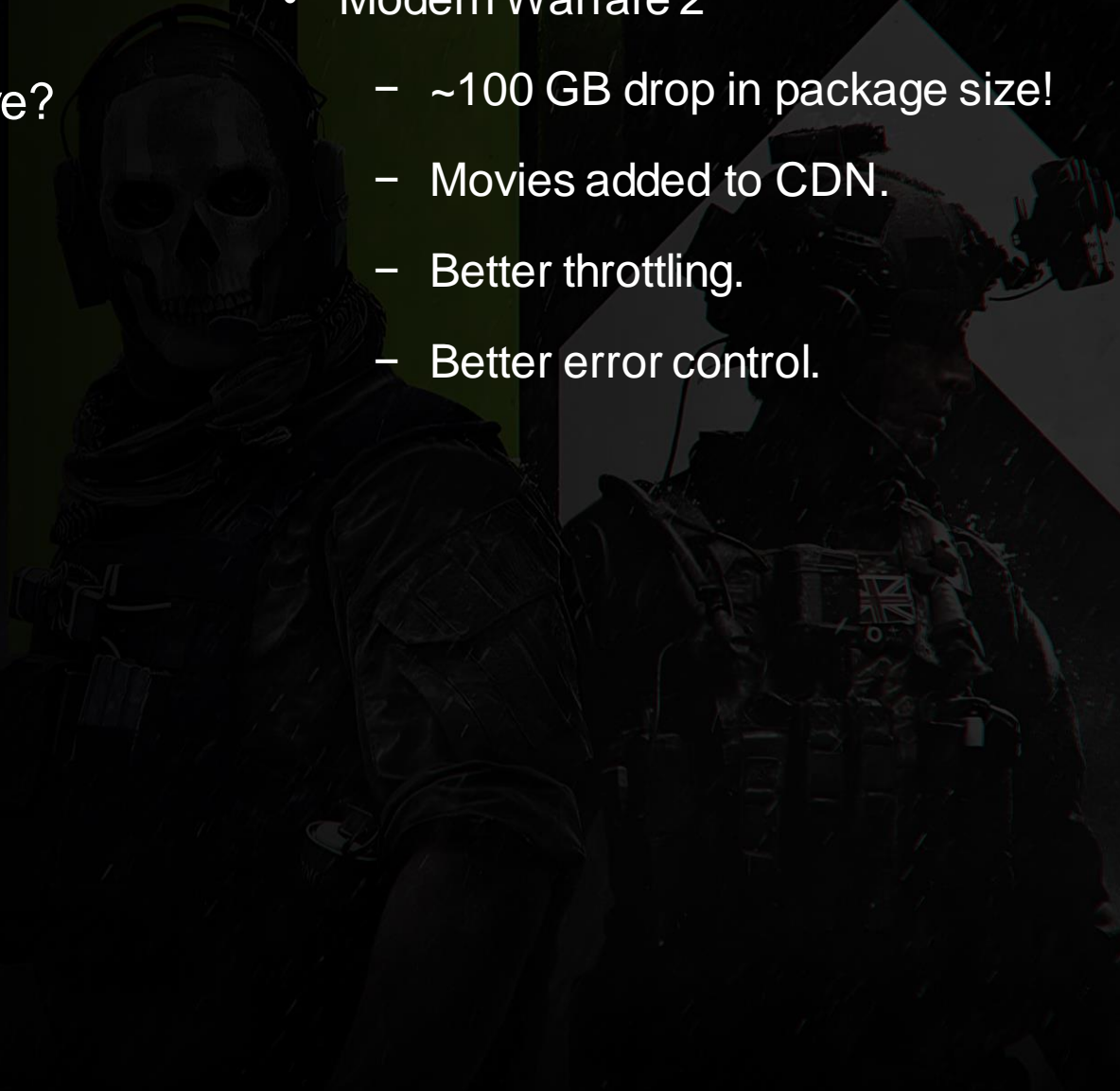
- Always open to new ideas?

Summary

- Discussed how CDN works
  - What was it supposed to achieve?

- Modern Warfare
  - Proof of concept successful.

- Vanguard
  - 50% package size achieved!
  - Save game issue resolved.
  - Packet Burst issues addressed.

- Modern Warfare 2
  - ~100 GB drop in package size!
  - Movies added to CDN.
  - Better throttling.
  - Better error control.

Major Contributors

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Questions?