1
00:00:00,000 --> 00:00:03,920
[MUSIC PLAYING]

2
00:00:03,920 --> 00:00:16,470

3
00:00:16,470 --> 00:00:17,470
COLTON OGDEN: All right.

4
00:00:17,470 --> 00:00:18,553
Good afternoon, everybody.

5
00:00:18,553 --> 00:00:20,490
Thank you so much for
coming to today's talk.

6
00:00:20,490 --> 00:00:21,510
My name is Colton Ogden.

7
00:00:21,510 --> 00:00:23,730
I'm the course instructor
for GD50, which

8
00:00:23,730 --> 00:00:26,105
is CS50's new Introduction
to Game Development course.

9
00:00:26,105 --> 00:00:28,980
We started this last spring and
we've been having lectures every week

10
00:00:28,980 --> 00:00:30,690
so far for the last semester.

11
00:00:30,690 --> 00:00:32,790
Last week we took a
look at Portal, which

12
00:00:32,790 --> 00:00:36,240
is a famous game by Valve, whereby
you get a gun that can essentially

13
00:00:36,240 --> 00:00:39,460
shoot these portals that
defy the laws of space

14
00:00:39,460 --> 00:00:41,010

onto different services in the game.

15
00:00:41,010 --> 00:00:44,820
Walk in and out of them and teleport
through them and see through them.

16
00:00:44,820 --> 00:00:47,340
And there are a host of
interesting challenges associated

17
00:00:47,340 --> 00:00:48,798
with implementing a game like this.

18
00:00:48,798 --> 00:00:51,450
Now last week we looked at a
simple version of it in Unity,

19
00:00:51,450 --> 00:00:55,961
but today we are joined by Dave Kircher
and Tejeev Kohli of Valve Software who

20
00:00:55,961 --> 00:00:57,960
actually were on the
Portal team and implemented

21
00:00:57,960 --> 00:01:00,570
all of the interesting sort of
design and technical decisions

22
00:01:00,570 --> 00:01:03,270
that went about making it work
and making it fun and believable.

23
00:01:03,270 --> 00:01:07,020
So without any further ado,
this is the "Portal Problems."

24
00:01:07,020 --> 00:01:07,769
Thank you.

25
00:01:07,769 --> 00:01:10,114
[APPLAUSE]

26
00:01:10,114 --> 00:01:13,866

27
00:01:13,866 --> 00:01:14,810
TEJEEV KOHLI: Hi.

28
00:01:14,810 --> 00:01:17,960
So we're just going to run through.

29
00:01:17,960 --> 00:01:22,850
Both me and Dave were actually
students when we were hired by Valve,

30
00:01:22,850 --> 00:01:29,630
and we were hired to recreate the work
we did as a student project for Valve

31
00:01:29,630 --> 00:01:32,480
for Portal 1 and for Portal 2.

32
00:01:32,480 --> 00:01:35,660
And today we just wanted
to talk to you about some

33
00:01:35,660 --> 00:01:41,900
of the issues we had trying to
create the mechanic for portals,

34
00:01:41,900 --> 00:01:45,380
and then also some of the design, both
the technical and some of the design

35
00:01:45,380 --> 00:01:53,880
issues that we had to tackle and work
on to make the mechanic work properly.

36
00:01:53,880 --> 00:01:56,915
So Dave is going to start off
and then I'll jump in later.

37
00:01:56,915 --> 00:01:58,670
DAVE KIRCHER: Hey, folks.

38
00:01:58,670 --> 00:02:01,130
As he mentioned, my name
is Dave Kircher I was hired

39
00:02:01,130 --> 00:02:03,960
on specifically to work for Portal.

40
00:02:03,960 --> 00:02:05,970
So I'm going to go ahead and preface.

41
00:02:05,970 --> 00:02:09,060

We're jumping through a lot of topics
today and jumping very quickly,

42
00:02:09,060 --> 00:02:11,119
so this is a very video
heavy presentation

43
00:02:11,119 --> 00:02:13,560
so that we can jump quickly in and out.

44
00:02:13,560 --> 00:02:16,260
And I'm sorry if I go a little too fast.

45
00:02:16,260 --> 00:02:18,350
I'm kind of optimizing for the stream.

46
00:02:18,350 --> 00:02:21,470
So hopefully, if I have gone
too quickly over something,

47
00:02:21,470 --> 00:02:25,230
you can review the stream
and see it a second time.

48
00:02:25,230 --> 00:02:28,280
So without further ado, let's
start off-- just quickly.

49
00:02:28,280 --> 00:02:30,620
I'm assuming that most
of the people here

50
00:02:30,620 --> 00:02:34,497
have played Portal or at least are
familiar with it in some sense.

51
00:02:34,497 --> 00:02:35,580
That's just an assumption.

52
00:02:35,580 --> 00:02:37,790
And that, for at least
the technical portions,

53
00:02:37,790 --> 00:02:41,300
that you are at least somewhat
familiarized with 3D rendering.

54
00:02:41,300 --> 00:02:44,300
If you're not, you may need to study

up a little bit and then come back.

55
00:02:44,300 --> 00:02:46,970
But let's start off with
just what is a portal?

56
00:02:46,970 --> 00:02:49,250
A portal is a discontinuity in 3D space.

57
00:02:49,250 --> 00:02:51,080
It's a 2D discontinuity
where we basically

58
00:02:51,080 --> 00:02:56,210
define a 2D rectangle somewhere in
space such that the front face-- sorry,

59
00:02:56,210 --> 00:02:59,960
the back face of the 2D rectangle is
defined as the front face of another 2D

60
00:02:59,960 --> 00:03:01,260
rectangle.

61
00:03:01,260 --> 00:03:04,252
So I've got my simple little
example here of this blue portal

62
00:03:04,252 --> 00:03:05,210
and this orange portal.

63
00:03:05,210 --> 00:03:09,420
We're defining them to be back to back,
which gets us this result over here.

64
00:03:09,420 --> 00:03:11,887
So from the perspective
of this little portal guy,

65
00:03:11,887 --> 00:03:14,720
it should look like there's another
room attached with a cube in it.

66
00:03:14,720 --> 00:03:17,197
But we're not actually
moving 3D space at all

67
00:03:17,197 --> 00:03:20,030
because otherwise we're trying to

make sure that this perspective is

68
00:03:20,030 --> 00:03:21,920
true for both this guy and the cube.

69
00:03:21,920 --> 00:03:23,919
And then you'd have this
weird overlapping space

70
00:03:23,919 --> 00:03:25,670
that doesn't make any sense to anybody.

71
00:03:25,670 --> 00:03:28,130
So we do a lot of hacks
to make it seem like space

72
00:03:28,130 --> 00:03:32,930
is folding in these interesting
ways without actually moving space.

73
00:03:32,930 --> 00:03:35,510
Another way to think of
it is that it's a door.

74
00:03:35,510 --> 00:03:38,690
If you look closely at this
doorway, it's a very standard door.

75
00:03:38,690 --> 00:03:41,760
It's a door like you walk through
it, different stuff happens.

76
00:03:41,760 --> 00:03:44,900
But what I'm not telling you initially
is that this actually isn't a door.

77
00:03:44,900 --> 00:03:47,540
For technical reasons, this
level required a portal here

78
00:03:47,540 --> 00:03:50,120
because we needed this room to move.

79
00:03:50,120 --> 00:03:53,000
So even though it looks like a
doorway, it's completely fake.

80
00:03:53,000 --> 00:03:55,190
And that it's a doorway

that actually takes you

81
00:03:55,190 --> 00:03:59,300
about a half mile across the level.

82
00:03:59,300 --> 00:04:02,090
But it looks like a door, and
so my job on the Portal series

83
00:04:02,090 --> 00:04:06,080
was to make sure that when
we're creating portals that they

84
00:04:06,080 --> 00:04:08,720
feel to the player like a doorway.

85
00:04:08,720 --> 00:04:11,390
And if you think of them
in terms of a doorway,

86
00:04:11,390 --> 00:04:14,600
all the interesting stuff for a portal
happens on the inside of the doorway

87
00:04:14,600 --> 00:04:17,089
and nothing interesting
happens on the outside.

88
00:04:17,089 --> 00:04:19,797
And it's my job to make sure that
all the interesting things that

89
00:04:19,797 --> 00:04:22,280
are happening outside
the door don't happen.

90
00:04:22,280 --> 00:04:26,101
Because that's all stuff
that doesn't make any sense.

91
00:04:26,101 --> 00:04:28,100
So as you can see, I just
flew across the level.

92
00:04:28,100 --> 00:04:30,320
And that's the other side of
that door that we just looked at.

93
00:04:30,320 --> 00:04:32,270

And I'm walking through
it and it's a doorway.

94
00:04:32,270 --> 00:04:34,250
So it's a door that doesn't
take you a couple of inches.

95
00:04:34,250 --> 00:04:36,249
It takes you about a half
mile across the level.

96
00:04:36,249 --> 00:04:40,319

97
00:04:40,319 --> 00:04:42,110
Now we're into our
rendering section, which

98
00:04:42,110 --> 00:04:47,207
is basically one of my main
expertises in the portal area.

99
00:04:47,207 --> 00:04:49,290
So we're going be talking
about quite a few things

100
00:04:49,290 --> 00:04:51,650
and I'm going to jump in
quickly, so hopefully I

101
00:04:51,650 --> 00:04:52,940
don't spew it out too quickly.

102
00:04:52,940 --> 00:04:55,920
That's kind of my problem.

103
00:04:55,920 --> 00:04:58,610
So there are primarily two layers
to render a portal of view.

104
00:04:58,610 --> 00:05:03,500
There might be more, but these are the
two that I am primarily familiar with.

105
00:05:03,500 --> 00:05:06,200
The preliminary way that we did
it with Narbacular Drop, which

106
00:05:06,200 --> 00:05:10,280

was the predecessor to Portal
was with rendered texture.

107
00:05:10,280 --> 00:05:12,682
And then when we got to working
on the Portal franchise,

108
00:05:12,682 --> 00:05:14,390
we switched to a method
where you draw it

109
00:05:14,390 --> 00:05:16,848
all in a single pass using
what's known as a stencil buffer

110
00:05:16,848 --> 00:05:19,230
and I'll be talking more
about that in a bit.

111
00:05:19,230 --> 00:05:21,600
But there are tradeoffs to each method.

112
00:05:21,600 --> 00:05:25,460
So with a texture, you have to have
separate textures per portal view.

113
00:05:25,460 --> 00:05:27,260
And if you have support
for recursion, you

114
00:05:27,260 --> 00:05:29,676
have to have many, many textures
pre-allocated to do this.

115
00:05:29,676 --> 00:05:32,570
So your memory growth
gets big very fast.

116
00:05:32,570 --> 00:05:35,270
You have to use the Painter's
Algorithm or something like it

117
00:05:35,270 --> 00:05:37,130
to render your portals.

118
00:05:37,130 --> 00:05:39,470
You basically have to figure
out the deepest portal you

119

00:05:39,470 --> 00:05:41,681
can see into and render that one first.

120
00:05:41,681 --> 00:05:43,430
And then any outward
ones from that you're

121
00:05:43,430 --> 00:05:44,510
going to render them
because they're going

122
00:05:44,510 --> 00:05:46,610
to contain a view of that first portal.

123
00:05:46,610 --> 00:05:48,500
So you have to render it in that order.

124
00:05:48,500 --> 00:05:50,240
And I don't know if it's true anymore.

125
00:05:50,240 --> 00:05:53,300
It definitely was when I originally
was working on the first portal.

126
00:05:53,300 --> 00:05:55,670
That you couldn't effectively
use anti-aliasing,

127
00:05:55,670 --> 00:05:58,391
so you get small visual artifacts
as you get close to a portal

128
00:05:58,391 --> 00:06:00,890
because it would be rendered
as a texture that doesn't quite

129
00:06:00,890 --> 00:06:04,730
render the same way as the
rest of the back buffer.

130
00:06:04,730 --> 00:06:06,837
But it is the simplest
to implement, especially

131
00:06:06,837 --> 00:06:08,420
if you don't support recursion at all.

132
00:06:08,420 --> 00:06:11,450
It is super simple to do because you

can ignore the Painter's Algorithm

133
00:06:11,450 --> 00:06:15,080
and just render all of them
before you of your main view.

134
00:06:15,080 --> 00:06:17,120
By contrast, when you
render with stencils,

135
00:06:17,120 --> 00:06:19,340
it renders the entire
frame to the back buffer

136
00:06:19,340 --> 00:06:21,673
so you don't have any extra
texture memory requirements.

137
00:06:21,673 --> 00:06:23,600
You're doing it all in a single pass.

138
00:06:23,600 --> 00:06:26,510
You're starting from your main
view and working your way in.

139
00:06:26,510 --> 00:06:29,234
You actually have to nest it a
little bit, so it's interesting.

140
00:06:29,234 --> 00:06:31,400
You are guaranteed to get
homogeneous visual quality

141
00:06:31,400 --> 00:06:32,570
because it's a single pass.

142
00:06:32,570 --> 00:06:35,450
The way you're rendering
the rest of your frame.

143
00:06:35,450 --> 00:06:39,200
But it has a lot of extra
complexity of when you render them

144
00:06:39,200 --> 00:06:41,840
and how you render them.

145
00:06:41,840 --> 00:06:46,640
So this rendering portion

is going to require

146
00:06:46,640 --> 00:06:48,390
quite a bit of spatial thinking.

147
00:06:48,390 --> 00:06:49,970
So I'm going to show you this video.

148
00:06:49,970 --> 00:06:52,590
Basically this is a layout I'm
going to use a couple of times.

149
00:06:52,590 --> 00:06:53,320
Does this play?

150
00:06:53,320 --> 00:06:55,280
Hopefully-- yes, OK.

151
00:06:55,280 --> 00:06:57,860
This is a room layout that I'm
going to use a couple of times

152
00:06:57,860 --> 00:06:59,990
where I've got an orange
portal and a blue portal.

153
00:06:59,990 --> 00:07:03,650
And behind each one is a thin
wall with some stuff behind it.

154
00:07:03,650 --> 00:07:07,460
But hopefully to help illustrate
what's in front of the blue portal,

155
00:07:07,460 --> 00:07:10,520
you can see there's a whole
bunch of blue stuff over there.

156
00:07:10,520 --> 00:07:13,550

157
00:07:13,550 --> 00:07:17,890
So yes, that is the example layout I
want you to kind of keep in your head

158
00:07:17,890 --> 00:07:21,451
because spatial thinking is
important to actually have reference.

159
00:07:21,451 --> 00:07:22,700
Let this finish one more time.

160
00:07:22,700 --> 00:07:26,850

161
00:07:26,850 --> 00:07:28,650
OK.

162
00:07:28,650 --> 00:07:33,550
Now this is something that pertains
to both rendering with textures

163
00:07:33,550 --> 00:07:35,550
and stencils and I'm going
to let this play once

164
00:07:35,550 --> 00:07:37,650
because I was advised that if
I front load this too much,

165
00:07:37,650 --> 00:07:38,490
it sounds confusing.

166
00:07:38,490 --> 00:07:40,865
So while I'm playing this, I
want you to look at the fact

167
00:07:40,865 --> 00:07:44,010
that when the orange portal is
on screen and when it's not,

168
00:07:44,010 --> 00:07:46,260
everything inside where
the orange oval is

169
00:07:46,260 --> 00:07:49,320
looks exactly the same for when
it is and when it is not there.

170
00:07:49,320 --> 00:07:52,270

171
00:07:52,270 --> 00:07:55,980
And so what I'm doing here is as
I'm toggling between the views

172
00:07:55,980 --> 00:07:58,410

is I am teleporting to
where the virtual camera is.

173
00:07:58,410 --> 00:08:01,070
That's rendering out
of the orange portal.

174
00:08:01,070 --> 00:08:03,665
Whoops-- come on, go back.

175
00:08:03,665 --> 00:08:06,480
Oh, God.

176
00:08:06,480 --> 00:08:07,924
OK.

177
00:08:07,924 --> 00:08:09,090
I'm toggling back and forth.

178
00:08:09,090 --> 00:08:10,881
I'm looking into the
orange portal, but I'm

179
00:08:10,881 --> 00:08:14,519
toggling to where the virtual
camera is behind the blue portal.

180
00:08:14,519 --> 00:08:16,560
So if you remember back
to when I said that we're

181
00:08:16,560 --> 00:08:18,780
defining the back face
of one rectangle to be

182
00:08:18,780 --> 00:08:20,910
the front face of
another rectangle, that

183
00:08:20,910 --> 00:08:24,100
means that they should
be coplanar at all times.

184
00:08:24,100 --> 00:08:27,720
And so if you think of
my player model in terms

185
00:08:27,720 --> 00:08:29,790
of walking it to the orange portal.

186
00:08:29,790 --> 00:08:33,809
When I'm rendering my exit view, I
should end up behind the blue portal

187
00:08:33,809 --> 00:08:35,070
as I'm rendering out of it.

188
00:08:35,070 --> 00:08:39,060
So it's important to remember that
all the angles carry over from that.

189
00:08:39,060 --> 00:08:42,059
And most importantly that whether
you're rendering textures or rendering

190
00:08:42,059 --> 00:08:45,690
to stencil that nothing
inside ever moves

191
00:08:45,690 --> 00:08:47,850
because it should be the
exact same view angles,

192
00:08:47,850 --> 00:08:49,725
the pixels should be in
the exact same place.

193
00:08:49,725 --> 00:08:52,260
If they're not in the same
place, your math is wrong.

194
00:08:52,260 --> 00:08:54,801
And this is especially important
when rendering with textures

195
00:08:54,801 --> 00:08:57,480
because one of the first mistakes
I've seen several people do

196
00:08:57,480 --> 00:09:00,900
is that they render the
entire screen to a texture.

197
00:09:00,900 --> 00:09:05,790
And then they map the entire texture
to this little quadratic here

198
00:09:05,790 --> 00:09:09,760

and it looks all weird depending
on how close or far away you are.

199
00:09:09,760 --> 00:09:12,030
But as long as you project the--

200
00:09:12,030 --> 00:09:15,360

201
00:09:15,360 --> 00:09:17,190
sorry.

202
00:09:17,190 --> 00:09:19,260
Trying to work with
videos is not the easiest.

203
00:09:19,260 --> 00:09:22,860
So as long as you project
where the vertices of your mesh

204
00:09:22,860 --> 00:09:27,840
are in screen space, you can reuse those
coordinates as your texture coordinates

205
00:09:27,840 --> 00:09:29,797
and then it will line up perfectly.

206
00:09:29,797 --> 00:09:32,130
So that's the point of why
it's rendering as one-to-one.

207
00:09:32,130 --> 00:09:34,755
You just want to make sure that
you're rendering the same parts

208
00:09:34,755 --> 00:09:37,120
to the same part of the screen.

209
00:09:37,120 --> 00:09:39,287
Now I said I'd be using
that previous layout a bunch

210
00:09:39,287 --> 00:09:41,078
and I swear I'm going
to get back to there.

211
00:09:41,078 --> 00:09:43,800
But this is a much better layout
for rendering with stencils,

212
00:09:43,800 --> 00:09:46,299
and so now you need to learn a
new layout just for a minute.

213
00:09:46,299 --> 00:09:47,425
It's only used in stencils.

214
00:09:47,425 --> 00:09:49,632
But I've got these two
portals looking at each other.

215
00:09:49,632 --> 00:09:51,750
They're kind of-- one
stacked on top of the other,

216
00:09:51,750 --> 00:09:53,970
and they've got these
light bridges that are just

217
00:09:53,970 --> 00:09:56,960
serving to show you that transparencies
are kind of a special case.

218
00:09:56,960 --> 00:09:57,720
So I'm going to play it one more time.

219
00:09:57,720 --> 00:09:59,636
So you just got two
portals facing each other.

220
00:09:59,636 --> 00:10:03,210
And even though they're tiny, it
does make an infinite recursion down

221
00:10:03,210 --> 00:10:03,990
into the portals.

222
00:10:03,990 --> 00:10:06,750

223
00:10:06,750 --> 00:10:10,500
So rendering with stencils.

224
00:10:10,500 --> 00:10:13,290
I'm kind of assuming that
for this part of the talk

225

00:10:13,290 --> 00:10:16,830
that you have some idea
what a depth buffer is.

226
00:10:16,830 --> 00:10:18,900
You may need to read up
on that if you don't.

227
00:10:18,900 --> 00:10:21,600
The stencil buffer is very
similar to the depth buffer

228
00:10:21,600 --> 00:10:27,330
in that it defines rules and operations
for when we can wholesale just not

229
00:10:27,330 --> 00:10:29,130
draw a pixel or when
we do want to draw it.

230
00:10:29,130 --> 00:10:31,810
And then also while
we are drawing pixels,

231
00:10:31,810 --> 00:10:34,950
you can define several operations
of how to modify the depth buffer.

232
00:10:34,950 --> 00:10:37,680
But for all intents and purposes,
it's invisible to the user

233
00:10:37,680 --> 00:10:42,430
except for the end result. So stencil
buffer, a lot like a depth buffer,

234
00:10:42,430 --> 00:10:48,870
but you're controlling the values
in code instead of by vertex depth.

235
00:10:48,870 --> 00:10:52,770
So before we render any scene using
stencils, what we're going to do

236
00:10:52,770 --> 00:10:55,290
is we're going to clear our
stencil buffer at the same time

237
00:10:55,290 --> 00:10:56,498
as we clear our depth buffer.

238
00:10:56,498 --> 00:10:58,320
We're going to clear
it to all zero values.

239
00:10:58,320 --> 00:11:02,190
And the stencil buffer we were
working with with Portal 1--

240
00:11:02,190 --> 00:11:03,990
I believe it only had two bits.

241
00:11:03,990 --> 00:11:04,750
I could be wrong.

242
00:11:04,750 --> 00:11:07,125
It might be up to eight bits,
but it's not a lot of bits.

243
00:11:07,125 --> 00:11:10,162
So we need to be very conservative
with the values we put in there.

244
00:11:10,162 --> 00:11:11,620
So we're going to clear it to zero.

245
00:11:11,620 --> 00:11:14,590
So everything in it is zero.

246
00:11:14,590 --> 00:11:17,400
And then we're going to render all
of the OPEC objects in our scene

247
00:11:17,400 --> 00:11:19,840
and that's where we get to the
visual I'm showing you here.

248
00:11:19,840 --> 00:11:22,214
So you'll notice that none of
the light bridges are here.

249
00:11:22,214 --> 00:11:24,660
None of the cool fancy
window stuff is here.

250
00:11:24,660 --> 00:11:27,390
So all we've done is draw
in all the opaque objects.

251
00:11:27,390 --> 00:11:31,020
And then we take a special
detour to render a portal.

252
00:11:31,020 --> 00:11:33,430
At this point, we've
rendered this oval here.

253
00:11:33,430 --> 00:11:36,990
And while we're rendering the
oval, we tell the rendering system

254
00:11:36,990 --> 00:11:41,220
to increment the stencil buffer
wherever we render a pixel.

255
00:11:41,220 --> 00:11:45,420
So while we're rendering, all of
the pixels here go from 0 to 1

256
00:11:45,420 --> 00:11:47,370
and that's an important bit.

257
00:11:47,370 --> 00:11:49,780
So we're going to be able to
use that to tell the depth--

258
00:11:49,780 --> 00:11:53,940
to tell draw operations
where to draw from then on.

259
00:11:53,940 --> 00:11:58,110
And then as soon as we've drawn the
incrementing of the stencil buffer,

260
00:11:58,110 --> 00:12:01,882
we tell all draw operations
from then on to only draw

261
00:12:01,882 --> 00:12:03,090
where the stencil value is 1.

262
00:12:03,090 --> 00:12:04,673
And we tell it to not modify anything.

263
00:12:04,673 --> 00:12:06,780
We're only drawing where there's a 1.

264

00:12:06,780 --> 00:12:09,630
And then we can basically just
forget all about stencil buffers

265
00:12:09,630 --> 00:12:12,582
for a little bit and keep drawing.

266
00:12:12,582 --> 00:12:15,540
But at this point if you've been
following along with the depth buffer,

267
00:12:15,540 --> 00:12:18,510
we've already drawn this nice
little wall behind the portal.

268
00:12:18,510 --> 00:12:22,432
So the depth is the same
as this little quad here.

269
00:12:22,432 --> 00:12:25,390
And so the first thing we do is we
render a full screen quad with depth

270
00:12:25,390 --> 00:12:27,980
at maximum value, which
does really effectively

271
00:12:27,980 --> 00:12:29,560
make this a hole at this point.

272
00:12:29,560 --> 00:12:32,518
And if we were to continue drawing
opaque objects and things like that,

273
00:12:32,518 --> 00:12:34,760
they would just show up in this hole.

274
00:12:34,760 --> 00:12:37,490
So then we start--

275
00:12:37,490 --> 00:12:40,220
after we have drawn, after we
have punched our hole in depth

276
00:12:40,220 --> 00:12:44,060
and we've required that all draw
operations have this matching

277
00:12:44,060 --> 00:12:48,140

stencil value of 1, then what we do is
we just start over in our main scene

278
00:12:48,140 --> 00:12:49,490
again and just draw it again.

279
00:12:49,490 --> 00:12:51,855
But this time we move
our virtual camera.

280
00:12:51,855 --> 00:12:54,230
Just the same operation as I
showed you in the rendering.

281
00:12:54,230 --> 00:12:57,500
It's one-to-one, we just have
to do a matrix transform such

282
00:12:57,500 --> 00:13:00,530
that we're behind the blue
portal and we draw it again.

283
00:13:00,530 --> 00:13:02,130
And so, let's see here.

284
00:13:02,130 --> 00:13:05,460
I think I have a magnifying glass.

285
00:13:05,460 --> 00:13:08,216
So you may notice that we're in--

286
00:13:08,216 --> 00:13:09,840
whoops.

287
00:13:09,840 --> 00:13:12,619
OK, I can't apparently zoom
and use a laser pointer.

288
00:13:12,619 --> 00:13:14,660
So you may notice that
the player model is there,

289
00:13:14,660 --> 00:13:17,240
and then the exact same setup
as I had shown you before.

290
00:13:17,240 --> 00:13:20,859
It's the same set of
quads and the oval again.

291
00:13:20,859 --> 00:13:22,400
And we do the exact same thing again.

292
00:13:22,400 --> 00:13:25,730
We tell it to increment so all the
values in this tiny little oval

293
00:13:25,730 --> 00:13:27,320
here are now 2.

294
00:13:27,320 --> 00:13:32,257
And then at that point we tell, OK, only
render pixels with a stencil value of 2

295
00:13:32,257 --> 00:13:34,340
and then we can just ignore
stencil buffers again.

296
00:13:34,340 --> 00:13:37,710
We punch the hole again,
and then we recurse again.

297
00:13:37,710 --> 00:13:39,860
And we go into a value of 3.

298
00:13:39,860 --> 00:13:41,154
At this point--

299
00:13:41,154 --> 00:13:43,070
I'm going to get more
into detail on it later,

300
00:13:43,070 --> 00:13:46,405
but we stop recursively
rendering to stencil buffers

301
00:13:46,405 --> 00:13:48,530
because otherwise we'd draw
a whole bunch of scenes

302
00:13:48,530 --> 00:13:50,300
that we're not going to actually see.

303
00:13:50,300 --> 00:13:53,360
We pull a little trick
that I'm going to get into.

304

00:13:53,360 --> 00:13:56,850
So as we've drawn all of our opaques,
we would theoretically do our detour.

305
00:13:56,850 --> 00:13:57,830
We don't.

306
00:13:57,830 --> 00:14:01,630
And then we finish by drawing
all of our translucent objects.

307
00:14:01,630 --> 00:14:04,100
And I know it's very
tiny to see them there,

308
00:14:04,100 --> 00:14:06,550
but it will become more apparent later.

309
00:14:06,550 --> 00:14:08,967
I think that-- sorry, that's
actually our rendering trick.

310
00:14:08,967 --> 00:14:11,716
And there, now we've actually drawn
the translucence in that view.

311
00:14:11,716 --> 00:14:14,990
And I know this is very small, but it'll
make more sense at recursion level 1.

312
00:14:14,990 --> 00:14:16,823
So as we draw our
translucent objects, we're

313
00:14:16,823 --> 00:14:20,360
still all confined to drawing
where stencil value is 2.

314
00:14:20,360 --> 00:14:24,410
And then once we are done drawing
all of our translucent objects,

315
00:14:24,410 --> 00:14:27,120
we render the portal oval--

316
00:14:27,120 --> 00:14:29,720
whoops, sorry, sorry.

317
00:14:29,720 --> 00:14:32,540

I'm going to pretend that
we're drawing to the big oval

318
00:14:32,540 --> 00:14:34,800
here because it's easier to see.

319
00:14:34,800 --> 00:14:38,750
We would draw another quad at
this level, sort of like a window,

320
00:14:38,750 --> 00:14:45,597
telling it to decrement the
stencil value back to 1.

321
00:14:45,597 --> 00:14:47,180
I'm sorry, I need to take a step back.

322
00:14:47,180 --> 00:14:50,630
We need to replace depth so that
there's no longer a hole there.

323
00:14:50,630 --> 00:14:54,440
So we draw the full screen quad
with depth equal to the portal plane

324
00:14:54,440 --> 00:14:57,560
while still restricting to the
nested view and then we decrement.

325
00:14:57,560 --> 00:14:58,370
Sorry.

326
00:14:58,370 --> 00:15:01,160
So by the time we've
done decrementing, that

327
00:15:01,160 --> 00:15:05,600
means all of these pixels inside
this first recursion are now 1 again.

328
00:15:05,600 --> 00:15:08,180
Every single one of them is
a 1 on the stencil value.

329
00:15:08,180 --> 00:15:11,514
So we can continue rendering the
translucence from the first recursion

330
00:15:11,514 --> 00:15:13,430

just like we did when
we're doing the opaques.

331
00:15:13,430 --> 00:15:18,550
We can say just restrict your
drawing to all stencil value 1.

332
00:15:18,550 --> 00:15:20,300
And then we finish our
translucence there.

333
00:15:20,300 --> 00:15:23,660
We do the exact same thing again while
we're going back to the main view.

334
00:15:23,660 --> 00:15:28,329
We fix up our depth and then we
decrement the stencil values again.

335
00:15:28,329 --> 00:15:30,120
And then we just finish
out our main scene,

336
00:15:30,120 --> 00:15:33,860
and now you have portals
drawn using stencils.

337
00:15:33,860 --> 00:15:37,970
They required no extra
texture memory whatsoever.

338
00:15:37,970 --> 00:15:41,060
So bouncing back to
the scene that we had

339
00:15:41,060 --> 00:15:45,020
shown before this, one of the things
that we had to solve pretty quickly

340
00:15:45,020 --> 00:15:48,584
is when you have some object
in the middle of a portal,

341
00:15:48,584 --> 00:15:50,750
you have to be able to see
it in two places at once.

342
00:15:50,750 --> 00:15:53,150
And the way that we do this
is we literally just look up

343
00:15:53,150 --> 00:15:55,010
every piece and rendering geometry.

344
00:15:55,010 --> 00:15:58,940
It uses every texture and replicate
it and teleport it every single frame

345
00:15:58,940 --> 00:16:01,040
to wherever the original is.

346
00:16:01,040 --> 00:16:03,860
And while we're replicating,
this object over here.

347
00:16:03,860 --> 00:16:07,010
You can see that it's slightly
more in front of the orange portal.

348
00:16:07,010 --> 00:16:10,070
So basically the rules are defined
such that whichever object--

349
00:16:10,070 --> 00:16:15,530
whichever side of the object has
its origin in front of the portal

350
00:16:15,530 --> 00:16:16,460
is the master.

351
00:16:16,460 --> 00:16:18,980
And the origin for this
cube is right in its middle,

352
00:16:18,980 --> 00:16:23,510
and origin is just a term that we use
to define the one point in space that

353
00:16:23,510 --> 00:16:25,259
defines where this object is.

354
00:16:25,259 --> 00:16:27,050
So usually it's in the
center of an object.

355
00:16:27,050 --> 00:16:30,350
Not always, but that means
this is the real one.

356
00:16:30,350 --> 00:16:33,080
And this is our complete
and utter fake one

357
00:16:33,080 --> 00:16:37,700
that we have to do for every single
object that is penetrating the portal.

358
00:16:37,700 --> 00:16:39,620
Now when we duplicate
geometry and whether we

359
00:16:39,620 --> 00:16:42,650
not-- whether we duplicate or not,
we have another problem to solve.

360
00:16:42,650 --> 00:16:44,025
I'm going to let this video play.

361
00:16:44,025 --> 00:16:47,360
I'm going to be toggling
a broken part on and off.

362
00:16:47,360 --> 00:16:51,690
So when the cube is not behind the
wall, that's the fixed version.

363
00:16:51,690 --> 00:16:54,630
And when you can see it behind the
wall, that's the broken version.

364
00:16:54,630 --> 00:16:57,110
So if you think about
replicating geometry,

365
00:16:57,110 --> 00:17:00,260
we have replicated the entire
model to this orange portal.

366
00:17:00,260 --> 00:17:03,367
Which means all the
stuff that is supposed

367
00:17:03,367 --> 00:17:06,200
to be in front of the blue portal
is also sticking behind this wall.

368
00:17:06,200 --> 00:17:10,940
Because once again, we have defined

the two faces to be coplanar.

369
00:17:10,940 --> 00:17:13,996
So what we have to do is we have
to use what's known as a clip plane

370
00:17:13,996 --> 00:17:15,829
to tell the rendering
system, you know what?

371
00:17:15,829 --> 00:17:20,869
Just don't draw any pixels if the mesh
is on this half of this half space.

372
00:17:20,869 --> 00:17:23,640
And we define the half space
to be the portal plane.

373
00:17:23,640 --> 00:17:25,390
And we can turn this
clip plane on and off

374
00:17:25,390 --> 00:17:27,400
as we're drawing objects
inside the portal plane

375
00:17:27,400 --> 00:17:28,369
and that's what makes it work.

376
00:17:28,369 --> 00:17:30,290
Otherwise it would clip the whole world.

377
00:17:30,290 --> 00:17:32,110
I'm going to play the video again.

378
00:17:32,110 --> 00:17:32,742
It happens.

379
00:17:32,742 --> 00:17:34,450
So, yeah, we're just
telling it, hey, you

380
00:17:34,450 --> 00:17:38,740
need to just ignore every single pixel
that's on that half of all of space.

381
00:17:38,740 --> 00:17:40,034
Don't draw them.

382
00:17:40,034 --> 00:17:41,950
And that makes it so it
doesn't seem like it's

383
00:17:41,950 --> 00:17:46,170
sticking out the back in weird
ways that people don't understand.

384
00:17:46,170 --> 00:17:50,200
OK, now this is a very similar concept.

385
00:17:50,200 --> 00:17:53,080
Something that we coined
the term "banana juice" for.

386
00:17:53,080 --> 00:17:56,040
Even back in Narbacular Drop
because it's just confusing.

387
00:17:56,040 --> 00:17:58,960
And I know you're asking yourself,
what in the heck is "banana juice?"

388
00:17:58,960 --> 00:18:00,260
That doesn't make any sense.

389
00:18:00,260 --> 00:18:04,270
So we decided to use a
completely insane term for it.

390
00:18:04,270 --> 00:18:07,450
Because even our technical
shorthand for describing the problem

391
00:18:07,450 --> 00:18:10,270
didn't accurately describe what it was.

392
00:18:10,270 --> 00:18:12,790
So we decided to use a term that--

393
00:18:12,790 --> 00:18:15,320
it was obvious that
explanation was needed.

394
00:18:15,320 --> 00:18:20,050
So what we've got here is
I've got my orange camera

395

00:18:20,050 --> 00:18:22,381
and I'm looking into
the orange portal here.

396
00:18:22,381 --> 00:18:24,880
And that means I've got my blue
camera, virtual camera here,

397
00:18:24,880 --> 00:18:27,340
looking out of the blue portal.

398
00:18:27,340 --> 00:18:29,290
And if you remember back
to my example, we've

399
00:18:29,290 --> 00:18:31,690
got this geometry that's
behind the blue portal.

400
00:18:31,690 --> 00:18:35,200
And it's between the blue
virtual camera and the portal,

401
00:18:35,200 --> 00:18:38,410
and if we render that, it's
going to look completely broken.

402
00:18:38,410 --> 00:18:42,280
So "banana juice" is a term
to define this broken stuff

403
00:18:42,280 --> 00:18:45,370
that you would see if you were
looking behind the thin wall.

404
00:18:45,370 --> 00:18:48,100
And I have a video of it here.

405
00:18:48,100 --> 00:18:50,980
I believe I'm toggling back and
forth between views just like when

406
00:18:50,980 --> 00:18:52,060
I showed you rendering as one-to-one.

407
00:18:52,060 --> 00:18:53,860
And that's me turning
off the clip plane.

408

00:18:53,860 --> 00:18:57,026
This is what it would look like if we
were in the virtual space and the clip

409
00:18:57,026 --> 00:19:00,700
planes were not enabled and
then I go back to our main view.

410
00:19:00,700 --> 00:19:04,030
And you'll see as I move around in a
second that it looks completely broken

411
00:19:04,030 --> 00:19:07,870
and it kind of breaks your brain if
you don't understand what's going on.

412
00:19:07,870 --> 00:19:11,770
So that is "banana juice," and
you fix it exactly the same way

413
00:19:11,770 --> 00:19:14,110
as with the entity clipping.

414
00:19:14,110 --> 00:19:19,600
You have clip models, but what we do
is I'm going to replay the video here.

415
00:19:19,600 --> 00:19:24,370
If you're watching, this entire
part of the level is now clipped.

416
00:19:24,370 --> 00:19:27,760
So what we do is while we're
rendering a virtual camera,

417
00:19:27,760 --> 00:19:31,851
we just clip the entire world
behind the portal plane.

418
00:19:31,851 --> 00:19:32,350
All of it.

419
00:19:32,350 --> 00:19:35,382
Everything that's back there.

420
00:19:35,382 --> 00:19:37,090
So that's how you fix
"banana juice" too.

421

00:19:37,090 --> 00:19:39,090
It's not super difficult
once you understand it,

422
00:19:39,090 --> 00:19:41,140
but I can tell you it
took me about two days

423
00:19:41,140 --> 00:19:43,848
to figure out exactly what was
going on when I originally saw it.

424
00:19:43,848 --> 00:19:46,010
It just didn't make any sense.

425
00:19:46,010 --> 00:19:49,150
So moving on again, I know we're
jumping a lot and I'm sorry.

426
00:19:49,150 --> 00:19:51,580
We're just going to keep
moving on at a quick pace.

427
00:19:51,580 --> 00:19:54,299
So infinite recursion is something
that people kind of expected

428
00:19:54,299 --> 00:19:55,840
to see when they were playing portal.

429
00:19:55,840 --> 00:19:57,839
If you ever played the
original Narbacular Drop,

430
00:19:57,839 --> 00:20:01,090
we didn't support any form of
recursion and it was kind of a letdown.

431
00:20:01,090 --> 00:20:03,470
So I'm going to go into how this works.

432
00:20:03,470 --> 00:20:06,910
So in this view, you can see
that we have this blue portal.

433
00:20:06,910 --> 00:20:10,810
That's our first recursion right here
and it's taking up most of the screen.

434

00:20:10,810 --> 00:20:14,230
And then we've got this blue portal
that you can see the entirety of it.

435
00:20:14,230 --> 00:20:16,150
That's our second recursion.

436
00:20:16,150 --> 00:20:20,170
And this one in here is
completely and totally fake.

437
00:20:20,170 --> 00:20:23,170
So that one, there is no
portal there whatsoever.

438
00:20:23,170 --> 00:20:26,500
What we're doing is we're
taking whatever we see

439
00:20:26,500 --> 00:20:28,570
of this portal, the second recursion.

440
00:20:28,570 --> 00:20:31,720
We're taking that exact view
from the previous frame.

441
00:20:31,720 --> 00:20:35,470
We're taking those pixels and then
we're basically doing a fix up

442
00:20:35,470 --> 00:20:37,600
in case you moved your camera around.

443
00:20:37,600 --> 00:20:43,000
And we're applying the texture
coordinates from the second portal

444
00:20:43,000 --> 00:20:45,070
to where the third portal would be.

445
00:20:45,070 --> 00:20:48,000
And by a completely fake, I mean we
didn't even render this blue oval.

446
00:20:48,000 --> 00:20:51,310
That's just a copy of
this oval right here.

447
00:20:51,310 --> 00:20:56,890

So it's the exact same thing as if you
point a video camera at a video monitor

448
00:20:56,890 --> 00:20:58,600
that's showing what it's recording.

449
00:20:58,600 --> 00:21:00,290
You get that feedback loop.

450
00:21:00,290 --> 00:21:02,665
But we have access to a little
bit of extra special math.

451
00:21:02,665 --> 00:21:04,623
That means that we don't
get that weird snaking

452
00:21:04,623 --> 00:21:06,380
effect if you move it back and forth.

453
00:21:06,380 --> 00:21:08,620
We can fix it up quickly.

454
00:21:08,620 --> 00:21:12,229
But this video is actually going to show
you about how this quickly breaks down.

455
00:21:12,229 --> 00:21:14,020
Because if you're
thinking ahead, you might

456
00:21:14,020 --> 00:21:17,680
be wondering what happens if you
can't see all the second portal.

457
00:21:17,680 --> 00:21:20,620
And the answer is that we stretch it.

458
00:21:20,620 --> 00:21:24,610
So as you watch the third one, it just
kind of stretches off in weird ways.

459
00:21:24,610 --> 00:21:26,892
Which is a problem that, if
we spend a bunch of time,

460
00:21:26,892 --> 00:21:28,100
we probably could have fixed.

461
00:21:28,100 --> 00:21:31,600
But in game development, sometimes
you just call it good enough

462
00:21:31,600 --> 00:21:34,660
and move on because I bet anybody
that played the original Portal never

463
00:21:34,660 --> 00:21:36,096
noticed this whatsoever.

464
00:21:36,096 --> 00:21:37,434
[LAUGHING]

465
00:21:37,434 --> 00:21:40,300

466
00:21:40,300 --> 00:21:44,830
So another breakdown of it, which I
find personally annoying and interesting

467
00:21:44,830 --> 00:21:45,570
at the same time.

468
00:21:45,570 --> 00:21:47,519
I'm just going to show
the video of it first.

469
00:21:47,519 --> 00:21:50,560
As I'm walking, you'll notice at the
third recursion, which is completely

470
00:21:50,560 --> 00:21:52,320
fake, you're going to see a pop.

471
00:21:52,320 --> 00:21:56,860
You're going to see every single time I
walk through a portal, it pops around.

472
00:21:56,860 --> 00:22:00,610
So this is actually fairly easy
to explain once you understand--

473
00:22:00,610 --> 00:22:02,950
really understand how the hack works.

474
00:22:02,950 --> 00:22:05,530
So if you look at my

visualization here, this

475
00:22:05,530 --> 00:22:08,840
is what the actual recursion would
look like if we actually did it.

476
00:22:08,840 --> 00:22:12,040
So we've got a couple of portals
here at these blue lines.

477
00:22:12,040 --> 00:22:15,130
And so inside our first portal
that we're fairly close to,

478
00:22:15,130 --> 00:22:17,590
our field of view is really wide.

479
00:22:17,590 --> 00:22:21,970
And then as we get to our second portal,
it gets really narrow really fast.

480
00:22:21,970 --> 00:22:24,220
But then as we get to the
third, it narrows even more.

481
00:22:24,220 --> 00:22:26,260
And then the fourth,
it narrows even more.

482
00:22:26,260 --> 00:22:29,110
But since we're cutting and
pasting, the second recursion,

483
00:22:29,110 --> 00:22:32,260
if you look down here on this
visualization, this is the hack.

484
00:22:32,260 --> 00:22:34,701
So we take this one, the
second visualization, and copy

485
00:22:34,701 --> 00:22:36,700
and paste it onto the
third and onto the fourth.

486
00:22:36,700 --> 00:22:38,680
And you can notice that this
doesn't converge at all.

487

00:22:38,680 --> 00:22:39,610
It doesn't narrow.

488
00:22:39,610 --> 00:22:42,400
So we're seeing the same
amount of wall around each

489
00:22:42,400 --> 00:22:50,050
of the recursions no matter what, no
matter how narrow this magenta cone is.

490
00:22:50,050 --> 00:22:53,620
So as we walk through a
portal, the magenta cone,

491
00:22:53,620 --> 00:22:56,110
we're picking a portal that's
further off because now

492
00:22:56,110 --> 00:22:58,568
that's the second recursion
after we walk through a portal.

493
00:22:58,568 --> 00:23:00,760
So it starts off narrow,
which is closer to what

494
00:23:00,760 --> 00:23:02,920
it should look like at infinity.

495
00:23:02,920 --> 00:23:06,070
It should narrow to basically
where you're seeing a blue tube.

496
00:23:06,070 --> 00:23:10,626
But then as we walk closer
and closer to the main portal,

497
00:23:10,626 --> 00:23:12,500
then it's going to widen
and widen and widen.

498
00:23:12,500 --> 00:23:17,702
And so there's just a pop
where it snaps into place.

499
00:23:17,702 --> 00:23:18,910
So hopefully that made sense.

500

00:23:18,910 --> 00:23:21,250
And once again, completely
changing topics because we

501
00:23:21,250 --> 00:23:23,560
got so many things to cover.

502
00:23:23,560 --> 00:23:27,280
So when we're rendering
portals, we have to have

503
00:23:27,280 --> 00:23:30,470
a mix of rendering first
person and third person.

504
00:23:30,470 --> 00:23:33,700
So in this case, you can see I've
got my third-person model over here

505
00:23:33,700 --> 00:23:34,750
through this portal.

506
00:23:34,750 --> 00:23:36,580
Another third person model over here.

507
00:23:36,580 --> 00:23:39,880
And then we don't see it in the main
view because I'm about to turn it on.

508
00:23:39,880 --> 00:23:43,870
It would look really weird if you saw
the third-person view in the main view.

509
00:23:43,870 --> 00:23:46,570
Yeah.

510
00:23:46,570 --> 00:23:50,620
I mean, some games do try to fix this
with very special representations.

511
00:23:50,620 --> 00:23:53,640
They'll try to draw just the
legs or something like that.

512
00:23:53,640 --> 00:23:58,360
But, yes, so we have to
have a complicated system

513
00:23:58,360 --> 00:24:02,200

to figure out when to draw third
person and when to draw first person.

514
00:24:02,200 --> 00:24:05,320
And if you were to guess, I
bet you would say, well, just

515
00:24:05,320 --> 00:24:08,020
render a third person every
time you look through a portal.

516
00:24:08,020 --> 00:24:09,940
And it turns out it's slightly
more complicated than that.

517
00:24:09,940 --> 00:24:11,960
I'm not actually going to get
into the complicated version,

518
00:24:11,960 --> 00:24:13,668
but I'm going to show
you how it's broken

519
00:24:13,668 --> 00:24:16,420
if you use that simple rule
because why would life be easy

520
00:24:16,420 --> 00:24:18,295
and we would just be
able to render just when

521
00:24:18,295 --> 00:24:20,380
we're on the other side of a portal.

522
00:24:20,380 --> 00:24:21,640
So in this case--

523
00:24:21,640 --> 00:24:22,280
let me look up.

524
00:24:22,280 --> 00:24:25,090
So you'll notice in this
case, I'm on a tilted angle.

525
00:24:25,090 --> 00:24:27,710
And this is a case where my feet
are on one side of the portal

526
00:24:27,710 --> 00:24:29,710

and my eyes are on the
other side of the portal.

527
00:24:29,710 --> 00:24:31,960
So it kind of breaks
the original system that

528
00:24:31,960 --> 00:24:35,830
would say, oh, just render if you're
on the other side of a portal.

529
00:24:35,830 --> 00:24:38,079
And so, yeah, it's a
little more complicated.

530
00:24:38,079 --> 00:24:38,620
Not terribly.

531
00:24:38,620 --> 00:24:40,703
It should actually look
way more broken than this,

532
00:24:40,703 --> 00:24:42,649
but we actually had the
fix in several places.

533
00:24:42,649 --> 00:24:45,440
And this is a special build where
I had to go back and break things

534
00:24:45,440 --> 00:24:49,030
and only broken it in one place.

535
00:24:49,030 --> 00:24:50,560
Yeah, OK.

536
00:24:50,560 --> 00:24:54,430
And then the last on
our rendering portion.

537
00:24:54,430 --> 00:24:56,680
So earlier I had talked about
how we need to duplicate

538
00:24:56,680 --> 00:24:59,235
geometry that is mid-portal.

539
00:24:59,235 --> 00:25:01,610
But there's also another thing

that we need to duplicate,

540
00:25:01,610 --> 00:25:05,050
which there are screen space
affects where we can query

541
00:25:05,050 --> 00:25:06,940
draw operations and things like that.

542
00:25:06,940 --> 00:25:11,320
And so one way that we use these draw
operations that are in screen space

543
00:25:11,320 --> 00:25:15,850
is to determine how much light
glare to use around these lights.

544
00:25:15,850 --> 00:25:21,130
And so how these work are
basically we draw a quad

545
00:25:21,130 --> 00:25:22,420
while we're drawing the light.

546
00:25:22,420 --> 00:25:24,904
And then we say, OK,
in a couple of frames

547
00:25:24,904 --> 00:25:27,070
I want you to tell me how
many pixels actually drew.

548
00:25:27,070 --> 00:25:30,320
And we're not allowed to actually query
this immediately because of pipeline

549
00:25:30,320 --> 00:25:30,820
reasons.

550
00:25:30,820 --> 00:25:33,086
We don't have the results
for several frames.

551
00:25:33,086 --> 00:25:34,960
So we have to cache off
that handle that says

552
00:25:34,960 --> 00:25:38,125
how many pixels did you draw and we'll

get the result at some point later.

553
00:25:38,125 --> 00:25:40,750
Sometimes you're lucky and it's
just one frame, but usually two

554
00:25:40,750 --> 00:25:43,015
or three frames-- you have
to save it for a while.

555
00:25:43,015 --> 00:25:44,890
But you may notice that
even though we're not

556
00:25:44,890 --> 00:25:48,820
replicating the geometry of the
light, we're drawing two of them

557
00:25:48,820 --> 00:25:50,210
because they're in screen space.

558
00:25:50,210 --> 00:25:53,380
So that means that this query
system had to be smart about it

559
00:25:53,380 --> 00:25:57,340
and I'm going to show how we
have two separate results.

560
00:25:57,340 --> 00:26:00,490
Now if we had used the engine
as it was originally written,

561
00:26:00,490 --> 00:26:03,380
there would be just one
query for one light.

562
00:26:03,380 --> 00:26:06,410
But then that would mean that
these lights would dim in unison.

563
00:26:06,410 --> 00:26:09,370
So we need to have separate
buckets for each view of portals.

564
00:26:09,370 --> 00:26:11,200
And every view query that portal--

565
00:26:11,200 --> 00:26:15,190

any view query that is issued
while in that recursion,

566
00:26:15,190 --> 00:26:18,670
we have to keep it in a totally
separate bucket and call it back later.

567
00:26:18,670 --> 00:26:22,070
And then as we walk through portals,
we have to transfer those buckets.

568
00:26:22,070 --> 00:26:25,360
So if I were to walk into the blue
portal at this point, all of those

569
00:26:25,360 --> 00:26:27,250
handles we have to
transfer to the main view.

570
00:26:27,250 --> 00:26:30,610
And then all the ones that are from the
main view we transfer into what was now

571
00:26:30,610 --> 00:26:32,985
orange because we would be
walking out of this orange one

572
00:26:32,985 --> 00:26:35,260
if we walked into the blue.

573
00:26:35,260 --> 00:26:39,340
So, yeah, that is the quick set of
rendering things I wanted to cover.

574
00:26:39,340 --> 00:26:42,610
So now I'm going to hand it
off to my colleague, Tejeev,

575
00:26:42,610 --> 00:26:44,190
to talk a bit about design.

576
00:26:44,190 --> 00:26:47,308
Give your spatial
thinking a bit of a rest.

577
00:26:47,308 --> 00:26:48,286
[CHUCKLES]

578
00:26:48,286 --> 00:26:51,220

579
00:26:51,220 --> 00:26:53,450
TEJEEV KOHLI: So that was
a lot of technical stuff

580
00:26:53,450 --> 00:26:55,810
about rendering of portals.

581
00:26:55,810 --> 00:27:00,020
And you can see it's more
complex than it seems at first.

582
00:27:00,020 --> 00:27:03,130
The naive solution seems like we'll
get you most of the way there,

583
00:27:03,130 --> 00:27:07,250
but then as you start putting in
more things in the game and more ways

584
00:27:07,250 --> 00:27:09,139
to play a game, to
interact with the game,

585
00:27:09,139 --> 00:27:11,180
you see there's a bunch
of different complexities

586
00:27:11,180 --> 00:27:13,060
that you have to account for.

587
00:27:13,060 --> 00:27:16,580
And a lot of those complexities
are not just in a technical sense,

588
00:27:16,580 --> 00:27:18,770
but also from a design sense.

589
00:27:18,770 --> 00:27:21,440
So I just want to talk
through some of the issues

590
00:27:21,440 --> 00:27:25,460
that we came up with as we were making
Portal 1 and 2 and some of the ways

591
00:27:25,460 --> 00:27:27,179
we tried to solve them.

592
00:27:27,179 --> 00:27:28,970
One of the first things
I wanted to mention

593
00:27:28,970 --> 00:27:33,740
was when first coming up
with the idea for portals,

594
00:27:33,740 --> 00:27:38,210
before figuring out if we
should spend a bunch of time

595
00:27:38,210 --> 00:27:45,400
making this idea, this new game mechanic
that most people haven't seen before.

596
00:27:45,400 --> 00:27:48,920
What we did was--

597
00:27:48,920 --> 00:27:53,930
Dave and his team made
a prototype of Portal

598
00:27:53,930 --> 00:28:00,710
in a 2D game engine that is used in
DigiPen while they were students.

599
00:28:00,710 --> 00:28:05,390
And it was made in-house
DigiPen 2D engine.

600
00:28:05,390 --> 00:28:08,810
And you can see here that
it's a 2D version of Portal,

601
00:28:08,810 --> 00:28:14,200
but it's still got all the basic game
mechanics that are used in Portal.

602
00:28:14,200 --> 00:28:20,510
And the main goal of doing something
like this is to vet out the mechanics

603
00:28:20,510 --> 00:28:23,980
and see if they're
still fun at their core.

604
00:28:23,980 --> 00:28:28,070

And part of what you do
here is you playtest, right?

605
00:28:28,070 --> 00:28:30,890
You make this simple
prototype, and you get

606
00:28:30,890 --> 00:28:33,710
other people to try it out and
play it and say, hey, is this fun?

607
00:28:33,710 --> 00:28:38,240
Is this something that we should
spend our next year working on

608
00:28:38,240 --> 00:28:40,092
as a proper 3D game?

609
00:28:40,092 --> 00:28:42,800
And the prototype you can see had
most of the basic functionality

610
00:28:42,800 --> 00:28:50,840
there and kind of vetted out the idea
of the mechanics to take it forward.

611
00:28:50,840 --> 00:28:53,360
And as we take the
mechanics forward, one

612
00:28:53,360 --> 00:28:56,120
of the first things
that you realize is this

613
00:28:56,120 --> 00:28:58,760
is a brand new mechanic that
people don't really understand

614
00:28:58,760 --> 00:29:01,080
and you have a train them.

615
00:29:01,080 --> 00:29:04,397
Train them with how the
mechanic works and also

616
00:29:04,397 --> 00:29:06,230
train them with sufficient
knowledge so they

617

00:29:06,230 --> 00:29:10,310
can use that mechanic to solve
puzzles, which is the core of the game.

618
00:29:10,310 --> 00:29:14,060
And one of the things
that we did is you have

619
00:29:14,060 --> 00:29:17,390
to have certain sections
of the game where

620
00:29:17,390 --> 00:29:22,470
you can be sure that the player has the
knowledge that they need to progress.

621
00:29:22,470 --> 00:29:28,670
So a lot of this is about making
sure that the levels you're designing

622
00:29:28,670 --> 00:29:32,330
are done in such a way that when
the player finishes that level,

623
00:29:32,330 --> 00:29:35,330
they have that knowledge
that you want them to have.

624
00:29:35,330 --> 00:29:41,060
And one of the ways we ensure that is
through doing a lot of play testing,

625
00:29:41,060 --> 00:29:44,810
and play testing is something I'll talk
about a little more as the talk goes

626
00:29:44,810 --> 00:29:45,990
on.

627
00:29:45,990 --> 00:29:48,847
But the basic idea of
play testing is just

628
00:29:48,847 --> 00:29:50,430
getting someone else to play the game.

629
00:29:50,430 --> 00:29:52,138
And that someone else
could be a coworker

630
00:29:52,138 --> 00:29:54,920
who sits next to you, your friend--

631
00:29:54,920 --> 00:29:57,050
anyone else really.

632
00:29:57,050 --> 00:30:00,320
Someone you get especially to come
play the game from outside the company,

633
00:30:00,320 --> 00:30:03,560
but usually it's just your coworkers,
people that sit next to you.

634
00:30:03,560 --> 00:30:07,460
People that see you work on the game but
don't know exactly what you're doing.

635
00:30:07,460 --> 00:30:10,250
And you can observe them
and see what they're doing,

636
00:30:10,250 --> 00:30:13,490
get some feedback from
them, and then use that data

637
00:30:13,490 --> 00:30:15,390
and iterate on the mechanic.

638
00:30:15,390 --> 00:30:21,680
And you can see here, this
was a level in Portal 1.

639
00:30:21,680 --> 00:30:25,250
It was pretty early on, this level,
and you could see the portals here.

640
00:30:25,250 --> 00:30:28,070
The blue portal here
is moving on a timer.

641
00:30:28,070 --> 00:30:30,740
It moves from one to
the next to the next.

642
00:30:30,740 --> 00:30:34,170
And the idea of this level was
by the time players solve this,

643
00:30:34,170 --> 00:30:37,980
they understand that I go in one
portal and come out the other.

644
00:30:37,980 --> 00:30:40,430
That's the basic idea here.

645
00:30:40,430 --> 00:30:44,970
And in Portal 1, this level did a pretty
good job of teaching players that.

646
00:30:44,970 --> 00:30:48,650
For Portal 2, we have
a very similar puzzle.

647
00:30:48,650 --> 00:30:50,750
I'm going to just try and play here.

648
00:30:50,750 --> 00:30:52,280
It's a pretty similar puzzle.

649
00:30:52,280 --> 00:30:54,440
The idea is the same thing.

650
00:30:54,440 --> 00:30:57,260
You have the three sections
that the portal can go.

651
00:30:57,260 --> 00:31:01,839
The one change we made here was we
move the portal away from a timer

652
00:31:01,839 --> 00:31:02,880
and moved it to a button.

653
00:31:02,880 --> 00:31:07,240
So this way the player has more control
of where the portals are opening.

654
00:31:07,240 --> 00:31:09,110
There are a few reasons for this.

655
00:31:09,110 --> 00:31:13,970
The main one here is like the level in
Portal 2 has a lot more visual noise.

656
00:31:13,970 --> 00:31:15,210
There's a lot more like--

657
00:31:15,210 --> 00:31:18,870
it's an old level, a lot of
foliage, a lot of destroyed stuff.

658
00:31:18,870 --> 00:31:21,590
So it's not as clean as Portal 1.

659
00:31:21,590 --> 00:31:24,860
And also, there's a case
of Portal 2, there's

660
00:31:24,860 --> 00:31:27,980
a lot of people that have
already played Portal 1

661
00:31:27,980 --> 00:31:30,620
and are probably already
familiar with the mechanics.

662
00:31:30,620 --> 00:31:33,770
So we don't want them to
have to go through the timers

663
00:31:33,770 --> 00:31:36,960
and wait for all the things to happen,
even though they know how it works.

664
00:31:36,960 --> 00:31:42,080
So this way they can
just go in and show us

665
00:31:42,080 --> 00:31:44,180
that they know how the
portals work without having

666
00:31:44,180 --> 00:31:46,090
to wait through all the timers.

667
00:31:46,090 --> 00:31:48,170
And the basic goal is the same thing.

668
00:31:48,170 --> 00:31:51,582
That by the end of this level, we're
confident that the players understand

669
00:31:51,582 --> 00:31:52,290
how portals work.

670
00:31:52,290 --> 00:31:56,210

671
00:31:56,210 --> 00:31:59,190
One of the other things that
you learn through play testing

672
00:31:59,190 --> 00:32:02,390
is you learn what you
need to teach the player.

673
00:32:02,390 --> 00:32:04,680
There's sometimes when
you'll be making the game

674
00:32:04,680 --> 00:32:08,010
and there's certain things that
you as a designer or as a creator

675
00:32:08,010 --> 00:32:12,540
won't think are challenging
concepts or are things that need

676
00:32:12,540 --> 00:32:15,240
to be talked to players explicitly.

677
00:32:15,240 --> 00:32:17,910
One of those things
that we noticed early on

678
00:32:17,910 --> 00:32:23,550
is this concept here where a lot
of players kind of thought portals

679
00:32:23,550 --> 00:32:24,810
were one way.

680
00:32:24,810 --> 00:32:28,290
That you go in one and you come
out the other and that's it.

681
00:32:28,290 --> 00:32:32,645
But they have to be taught that
you can actually go in both ways.

682
00:32:32,645 --> 00:32:34,770
You can go in the blue one
and come out the orange,

683
00:32:34,770 --> 00:32:37,200
or you can go in the orange
one and come out the blue one.

684
00:32:37,200 --> 00:32:40,925
And so this puzzle specifically
does that, where the blue one

685
00:32:40,925 --> 00:32:42,300
is the only one that'd be moving.

686
00:32:42,300 --> 00:32:44,220
The orange one stays stationary.

687
00:32:44,220 --> 00:32:47,550
First you go in the blue one, you come
out the orange one, replace the blue,

688
00:32:47,550 --> 00:32:52,310
and then you go in the orange
one and come out the blue one.

689
00:32:52,310 --> 00:32:57,890
The idea with this again is you
have to figure through play testing

690
00:32:57,890 --> 00:33:00,580
is how you figure out
the different things.

691
00:33:00,580 --> 00:33:04,110
The different discrete small things
that you need to teach the player.

692
00:33:04,110 --> 00:33:06,750
And also try to figure out
how to teach them in a way

693
00:33:06,750 --> 00:33:10,210
where they're figuring it out
instead of you telling it to them.

694
00:33:10,210 --> 00:33:13,316
So for the most part in
Portal 1 and 2, there's

695
00:33:13,316 --> 00:33:14,940
certain things that we tell the player.

696
00:33:14,940 --> 00:33:17,880
But for the most part we
want them to figure it

697
00:33:17,880 --> 00:33:21,280
out and have that epiphany themselves.

698
00:33:21,280 --> 00:33:23,170
Because then they really learn it.

699
00:33:23,170 --> 00:33:28,860
If you just tell it to them, they
might not take in the exact knowledge.

700
00:33:28,860 --> 00:33:33,340
Another thing here is this
was a level in Portal 2,

701
00:33:33,340 --> 00:33:37,570
but we noticed through
one of our play tests--

702
00:33:37,570 --> 00:33:40,980
I looked through a few of our
play tests that players were super

703
00:33:40,980 --> 00:33:44,520
hesitant to place portals on the floor.

704
00:33:44,520 --> 00:33:48,000
Even though this level is probably
the fifth or sixth one in the game,

705
00:33:48,000 --> 00:33:50,580
and you've done that a few
times in the game before this.

706
00:33:50,580 --> 00:33:52,670
But usually you are
doing it way down there

707
00:33:52,670 --> 00:33:57,510
and doing a fling mechanic where you
fly through the portal and come out.

708
00:33:57,510 --> 00:34:00,180
So players have placed
portal on the floor before,

709
00:34:00,180 --> 00:34:03,270
but they haven't done
it right at their feet.

710
00:34:03,270 --> 00:34:07,790
So we had to design a scenario
here where the only way forward--

711
00:34:07,790 --> 00:34:10,090
you're trapped in this
black room with nothing else

712
00:34:10,090 --> 00:34:13,260
and the only thing you can do is
place a portal on the floor there.

713
00:34:13,260 --> 00:34:18,300
And that's one of the things that
you realize as you keep testing.

714
00:34:18,300 --> 00:34:21,147
You'll come across players
of different skill levels

715
00:34:21,147 --> 00:34:23,730
and different knowledge of video
games and different knowledge

716
00:34:23,730 --> 00:34:25,330
of how controls work.

717
00:34:25,330 --> 00:34:29,070
And typically you want to make
sure that you're not only catering

718
00:34:29,070 --> 00:34:30,850
to the low end or the high end.

719
00:34:30,850 --> 00:34:35,080
You want to make sure that both of them
can have a good time with your game.

720
00:34:35,080 --> 00:34:39,870
So you want to design puzzle games
in a way that aren't super intrusive.

721
00:34:39,870 --> 00:34:42,960
If a player that sees
this get here already

722
00:34:42,960 --> 00:34:45,473
knows that I can place
portals on floor and go by.

723
00:34:45,473 --> 00:34:47,639
This doesn't seem like
anything that's stopping him.

724
00:34:47,639 --> 00:34:49,290
This just seems like part of the level.

725
00:34:49,290 --> 00:34:52,080
But to a new player that
comes in here and is

726
00:34:52,080 --> 00:34:55,920
like I don't know how to proceed, it
takes them a while to figure it out.

727
00:34:55,920 --> 00:34:59,260
And then when they have that aha
moment, they feel pretty smart about it.

728
00:34:59,260 --> 00:35:01,860
So you want to make sure
that you're designing stuff

729
00:35:01,860 --> 00:35:07,000
in a way that isn't frustrating players
that already understand the mechanics,

730
00:35:07,000 --> 00:35:12,780
but also isn't making players that
don't understand the mechanics have

731
00:35:12,780 --> 00:35:14,310
to be super frustrated as well.

732
00:35:14,310 --> 00:35:19,440

733
00:35:19,440 --> 00:35:20,870
Another thing that we had to do--

734
00:35:20,870 --> 00:35:27,680
Portal 1 and 2 both have this mechanic
where you go into a portal on the floor

735
00:35:27,680 --> 00:35:31,220
and come out one on the wall and
it keeps your momentum and velocity

736
00:35:31,220 --> 00:35:33,290
and flings you forward.

737
00:35:33,290 --> 00:35:37,520
One of the things we noticed while
we were working on this mechanic

738
00:35:37,520 --> 00:35:42,680
is that there's a lot of times when
players don't exactly quite line up

739
00:35:42,680 --> 00:35:44,690
as they're falling through the portal.

740
00:35:44,690 --> 00:35:47,570
Which means that when they fall
in, they're going to fall out--

741
00:35:47,570 --> 00:35:51,860
they're not going to come out of the
portal on the wall in the correct way.

742
00:35:51,860 --> 00:35:57,950
And a lot of times players won't know
that they had the right solution,

743
00:35:57,950 --> 00:36:00,440
they just kind of messed up
the execution a little bit.

744
00:36:00,440 --> 00:36:04,680
And we want to try and help
the players in these cases,

745
00:36:04,680 --> 00:36:06,950
but again try to be
not intrusive about it.

746
00:36:06,950 --> 00:36:10,170
Because you want to make
sure that the players--

747
00:36:10,170 --> 00:36:12,620
as they're solving puzzles,
they're not thinking

748
00:36:12,620 --> 00:36:17,060
that they had the right solution but it
didn't work the first time I tried it.

749
00:36:17,060 --> 00:36:20,060
So now I have to rethink the whole
solution even though the solution was

750
00:36:20,060 --> 00:36:21,419
correct the first time.

751
00:36:21,419 --> 00:36:23,960
So one of the things we used--
we used a few different things

752
00:36:23,960 --> 00:36:25,890
to help the players out in this way.

753
00:36:25,890 --> 00:36:30,650
And again, with the idea of them
being mostly invisible to the player.

754
00:36:30,650 --> 00:36:33,410
They're not always completely
invisible and in some cases

755
00:36:33,410 --> 00:36:35,690
we have ways to opt out of them.

756
00:36:35,690 --> 00:36:38,670
But this is one of the
things that we used.

757
00:36:38,670 --> 00:36:40,700
So if you notice here,
the player's going

758
00:36:40,700 --> 00:36:43,730
to drop through the orange portal.

759
00:36:43,730 --> 00:36:46,160
But as you notice as I walk through--

760
00:36:46,160 --> 00:36:50,660
walk forward here, I'm purposely
not going to fall exactly straight.

761

00:36:50,660 --> 00:36:54,570
And one of the mechanics
we had in the game was--

762
00:36:54,570 --> 00:36:57,499
it was pretty subtle there,
but I'm going to do it again.

763
00:36:57,499 --> 00:37:00,290
You'll see I'm walking to the side
and the game kind of funnels you

764
00:37:00,290 --> 00:37:01,640
into the portal.

765
00:37:01,640 --> 00:37:06,770
So we had the special thing we
used in portals, for portals

766
00:37:06,770 --> 00:37:09,980
that are on the floor facing mostly up.

767
00:37:09,980 --> 00:37:12,710
Imagine there's a cone
coming out of the portal,

768
00:37:12,710 --> 00:37:16,100
and if you're falling from
some height and if you're

769
00:37:16,100 --> 00:37:17,640
within that cone and the cone--

770
00:37:17,640 --> 00:37:18,710
it's not super wide.

771
00:37:18,710 --> 00:37:20,090
It's pretty narrow.

772
00:37:20,090 --> 00:37:22,490
If you're within that
cone, then we kind of

773
00:37:22,490 --> 00:37:24,680
funnel you into the
center of the portal.

774
00:37:24,680 --> 00:37:26,513
So that when you're

coming out of it, you're

775
00:37:26,513 --> 00:37:28,330
going to be lined up perfectly with it.

776
00:37:28,330 --> 00:37:31,280
And as you can see, the third time
I did it there, it didn't happen.

777
00:37:31,280 --> 00:37:33,830
Because the way this
works is that it only

778
00:37:33,830 --> 00:37:36,450
works if you're looking at a portal.

779
00:37:36,450 --> 00:37:38,780
So it works the second
time, but the third time I'm

780
00:37:38,780 --> 00:37:43,480
going to go mostly in the same
direction and it's not going to work.

781
00:37:43,480 --> 00:37:48,130
So that's our way of trying to
make these things be non-intrusive.

782
00:37:48,130 --> 00:37:51,626
To where if players don't expect to go
in that portal, it's not going to work.

783
00:37:51,626 --> 00:37:54,500
But if the player is looking at a
portal and they expect to go in it,

784
00:37:54,500 --> 00:37:58,240
we kind of nudge them
along a little bit.

785
00:37:58,240 --> 00:38:01,634
And you can see it here,
and this is a second case

786
00:38:01,634 --> 00:38:04,550
of the same thing where there's a
portal on the floor and the ceiling.

787
00:38:04,550 --> 00:38:06,710

And you can see as
the funnel is working,

788
00:38:06,710 --> 00:38:08,750
the play is perfectly
in the center of it.

789
00:38:08,750 --> 00:38:11,499
But I'm going to look forward a
little bit and disable the funnel.

790
00:38:11,499 --> 00:38:13,574
And you can see the player's
going to go off axis

791
00:38:13,574 --> 00:38:16,490
because the funnels are disabled and
the player slowly went out of it.

792
00:38:16,490 --> 00:38:19,060

793
00:38:19,060 --> 00:38:20,630
Yeah, the funnel is disabled now.

794
00:38:20,630 --> 00:38:23,810

795
00:38:23,810 --> 00:38:28,280
And again, the idea of this is to
reduce a bunch of the player frustration

796
00:38:28,280 --> 00:38:31,940
and to reduce a bunch of the
false negatives that players get.

797
00:38:31,940 --> 00:38:35,300
You want to make sure that players
that think they've got the solution,

798
00:38:35,300 --> 00:38:37,490
and if it was the correct
solution, you want

799
00:38:37,490 --> 00:38:38,700
to kind of help them out a little bit.

800
00:38:38,700 --> 00:38:40,325
You don't to solve the puzzle for them.

801
00:38:40,325 --> 00:38:42,770
You don't want to give them,
like, here's the answer.

802
00:38:42,770 --> 00:38:44,978
But you do want to try and
help them out a little bit

803
00:38:44,978 --> 00:38:48,140
because that helps that makes
the game a little bit more fun

804
00:38:48,140 --> 00:38:49,942
and reduces the frustration.

805
00:38:49,942 --> 00:38:52,660

806
00:38:52,660 --> 00:38:56,960
So that was the help that we had
for when you're entering portals.

807
00:38:56,960 --> 00:39:00,630
We also have the opposite and
that was there in Portal 1.

808
00:39:00,630 --> 00:39:03,380
And in Portal 2, we
introduced something that

809
00:39:03,380 --> 00:39:08,000
was the opposite of a helper, which we
used when you're coming out of portals.

810
00:39:08,000 --> 00:39:11,750
So Portal 2 had this mechanic
called Aerial Faith Plates,

811
00:39:11,750 --> 00:39:13,950
which is pretty straightforward.

812
00:39:13,950 --> 00:39:18,110
You step on this faith plate
and it propels you to the air.

813
00:39:18,110 --> 00:39:23,660
And the level designers can
place the faith plate on a level

814
00:39:23,660 --> 00:39:26,960
and can kind of control
the trajectory of the arc

815
00:39:26,960 --> 00:39:29,650
of where the player is going to fly.

816
00:39:29,650 --> 00:39:32,690
And this arc is not really
visible to the player,

817
00:39:32,690 --> 00:39:35,730
but it's pretty apparent
based on the level design.

818
00:39:35,730 --> 00:39:40,220
So you can see in this one, I'm going
to play the video as I'm talking

819
00:39:40,220 --> 00:39:42,930
and then maybe play
it a couple of times.

820
00:39:42,930 --> 00:39:46,490
So the tech that was developed
for these Aerial Faith Plates

821
00:39:46,490 --> 00:39:51,466
is something that we
reuse for a fling helper.

822
00:39:51,466 --> 00:39:53,090
So you can see here there's all these--

823
00:39:53,090 --> 00:39:55,070
I'm going to turn on some debug draw.

824
00:39:55,070 --> 00:39:58,140
And you can see right here.

825
00:39:58,140 --> 00:40:02,150
So this green arc here is the
arc that's on the faith plates,

826
00:40:02,150 --> 00:40:06,150
but you can see there's some stuff
coming out of the walls there as well.

827
00:40:06,150 --> 00:40:10,610
So this is a part of the level where
the player is going to fling out of.

828
00:40:10,610 --> 00:40:13,800

829
00:40:13,800 --> 00:40:17,330
He's going to fling a box out of that
actually because he wanted this to work

830
00:40:17,330 --> 00:40:20,410
for objects as well as the player.

831
00:40:20,410 --> 00:40:23,840
So you can see as the
box goes through here

832
00:40:23,840 --> 00:40:27,050
and then here, these
are those faith plates.

833
00:40:27,050 --> 00:40:29,270
And then when the box
comes out of that, we

834
00:40:29,270 --> 00:40:34,111
have the box follow the arc
that's kind of predetermined.

835
00:40:34,111 --> 00:40:36,860
Because that's I think what the
player is expecting at that point.

836
00:40:36,860 --> 00:40:40,550
They expected to have solved
the solution-- solve the puzzle.

837
00:40:40,550 --> 00:40:43,630
But the funnel, the trigger here--

838
00:40:43,630 --> 00:40:46,370
this kind of corrects the arc to
make sure that it's always going

839
00:40:46,370 --> 00:40:50,480
to go in the place the player expects.

840

00:40:50,480 --> 00:40:55,435
And we also have a case of the
same things working for the player.

841
00:40:55,435 --> 00:40:57,560
So you can see here there's
two different arcs that

842
00:40:57,560 --> 00:41:01,520
are coming out because we doubled
up the triggers over here.

843
00:41:01,520 --> 00:41:03,590
The way these triggers
worked in the game

844
00:41:03,590 --> 00:41:06,800
is they won't always enable
when the player touches them.

845
00:41:06,800 --> 00:41:09,270
They require a minimum
velocity threshold.

846
00:41:09,270 --> 00:41:11,550
So the player has to be
doing most of the work.

847
00:41:11,550 --> 00:41:14,570
So the player has to have
figured out a way in the level

848
00:41:14,570 --> 00:41:17,990
through the puzzle design
to get that velocity.

849
00:41:17,990 --> 00:41:21,260
But we know that there's some
differences in physics and differences

850
00:41:21,260 --> 00:41:23,570
in the exact mechanism you might use.

851
00:41:23,570 --> 00:41:26,930
So we're just saying if you got the
minimum velocity that we acquire,

852
00:41:26,930 --> 00:41:29,310
we're going to take
it all the way there.

853
00:41:29,310 --> 00:41:33,870
So in this one, you can see
we have two different cases.

854
00:41:33,870 --> 00:41:37,790
So if I just fall out of the portal,
it's not going to activate any of them.

855
00:41:37,790 --> 00:41:40,300
If I somehow manage
to get some velocity,

856
00:41:40,300 --> 00:41:45,350
is going to activate the fail
case one and take me there.

857
00:41:45,350 --> 00:41:47,780
And the reason we have
the fail case one is

858
00:41:47,780 --> 00:41:51,920
because we want to make sure
that if players somehow get

859
00:41:51,920 --> 00:41:55,069
most of the velocity
but bonk on the wall,

860
00:41:55,069 --> 00:41:58,110
they don't keep thinking that they
can-- that's the correct way to do it.

861
00:41:58,110 --> 00:42:00,300
So we want to make it
obvious that you failed.

862
00:42:00,300 --> 00:42:01,425
So again it's the same way.

863
00:42:01,425 --> 00:42:04,383
We have to help-- you're helping the
players out but not by giving them

864
00:42:04,383 --> 00:42:05,060
the solution.

865
00:42:05,060 --> 00:42:08,979
Just by making it obvious that the

thing you did was correct or wrong.

866
00:42:08,979 --> 00:42:11,270
And then if you do the correct
way in this level, which

867
00:42:11,270 --> 00:42:16,730
is to get philosophy doing that,
and then you make a portal there,

868
00:42:16,730 --> 00:42:21,040
you're going to do the correct
thing and swing out of it.

869
00:42:21,040 --> 00:42:27,410
And again, the main idea here is to
get rid of those false negatives.

870
00:42:27,410 --> 00:42:30,380
Especially here because there's
a few different spots on the wall

871
00:42:30,380 --> 00:42:31,777
that you can put a portal.

872
00:42:31,777 --> 00:42:33,860
And we don't really want
to restrict a lot of that

873
00:42:33,860 --> 00:42:35,526
and just put the one square on the wall.

874
00:42:35,526 --> 00:42:37,490
That is the solution square.

875
00:42:37,490 --> 00:42:41,330
Because again, if you put the portal
down here or put the portal up here,

876
00:42:41,330 --> 00:42:43,470
the arc is going to
be slightly different.

877
00:42:43,470 --> 00:42:47,120
So this mechanism we had
just kind of corrects

878
00:42:47,120 --> 00:42:51,320
those arcs and makes sure that it goes

in the one or two ways that we want.

879
00:42:51,320 --> 00:42:55,440

880
00:42:55,440 --> 00:42:57,080
Another thing we added in--

881
00:42:57,080 --> 00:42:58,730
this we added in Portal 2--

882
00:42:58,730 --> 00:43:02,210
was highlights for your
portals so you can see where

883
00:43:02,210 --> 00:43:04,340
your portals are placed through walls.

884
00:43:04,340 --> 00:43:07,550
And this is something that's
super useful in levels

885
00:43:07,550 --> 00:43:12,410
where you have to keep track of
which portal you placed over there.

886
00:43:12,410 --> 00:43:14,300
So you know which one
to place over here.

887
00:43:14,300 --> 00:43:17,107
Because sometimes it's like, OK,
I just got out of the blue one

888
00:43:17,107 --> 00:43:18,440
and the orange one's over there.

889
00:43:18,440 --> 00:43:19,797
So if I place the blue one--

890
00:43:19,797 --> 00:43:22,880
oh, I got to do the whole puzzle again
now because I placed the wrong one.

891
00:43:22,880 --> 00:43:27,317
So this helps a lot in just making sure
that you know where your portals are

892

00:43:27,317 --> 00:43:29,400
so you can be like I want
to come out of that one,

893
00:43:29,400 --> 00:43:31,585
so I'm going to place the other one.

894
00:43:31,585 --> 00:43:34,460
And this is something we added in
Portal 2 and it was pretty helpful.

895
00:43:34,460 --> 00:43:37,730
And it's also helpful in the
co-op version of the game.

896
00:43:37,730 --> 00:43:40,020
Because in the co-op
one, you want to see

897
00:43:40,020 --> 00:43:42,800
where both the players'
portals are at all times

898
00:43:42,800 --> 00:43:46,100
and this kind mechanic helps in that.

899
00:43:46,100 --> 00:43:49,160
Another thing we added to kind
of help the player a little bit

900
00:43:49,160 --> 00:43:52,180
is a thing we call the placement helper.

901
00:43:52,180 --> 00:43:55,220
And this does not use a
whole lot in the game,

902
00:43:55,220 --> 00:43:57,830
but there's a few
sections in the game where

903
00:43:57,830 --> 00:44:01,760
we want to encourage
the players to come out

904
00:44:01,760 --> 00:44:05,250
of a portal in a particular direction.

905
00:44:05,250 --> 00:44:10,010

So we have these things that we place
in the level with a certain radius.

906
00:44:10,010 --> 00:44:13,100
And if you place a portal
within that radius,

907
00:44:13,100 --> 00:44:15,640
we just kind of snap
it to the direction--

908
00:44:15,640 --> 00:44:17,452
to the center of it.

909
00:44:17,452 --> 00:44:18,410
But they don't a timer.

910
00:44:18,410 --> 00:44:22,610
So if you place one
portal and you're like,

911
00:44:22,610 --> 00:44:25,790
oh, I actually want to place it over
here, you can always opt out of it.

912
00:44:25,790 --> 00:44:27,800
And that's again what
I was talking earlier.

913
00:44:27,800 --> 00:44:31,160
You want to add something-- excuse me.

914
00:44:31,160 --> 00:44:36,800
You want to add these helpers in a
way that, for players, they're mostly

915
00:44:36,800 --> 00:44:39,180
invisible to most of the players.

916
00:44:39,180 --> 00:44:42,590
But the players that want to opt out of
them have a way of opting out of them.

917
00:44:42,590 --> 00:44:43,766
[COUGHS]

918
00:44:43,766 --> 00:44:44,672

919
00:44:44,672 --> 00:44:46,031
Excuse me.

920
00:44:46,031 --> 00:44:49,090
So you can see the first portal
that's placed does get snapped,

921
00:44:49,090 --> 00:44:53,260
but the second one that's placed
is exactly where the player wanted.

922
00:44:53,260 --> 00:44:55,640
And we use these in a
few spots in the game,

923
00:44:55,640 --> 00:44:58,430
but they weren't used a whole
lot because for the most part

924
00:44:58,430 --> 00:45:00,380
you want to have-- you want
to make sure the player feels

925
00:45:00,380 --> 00:45:01,379
like they're in control.

926
00:45:01,379 --> 00:45:05,400

927
00:45:05,400 --> 00:45:08,990
And one of the other things
that was a lot of fun

928
00:45:08,990 --> 00:45:12,070
while making Portal, and Dave
will talk a lot about this--

929
00:45:12,070 --> 00:45:17,120
excuse me-- will talk a lot about
this later is the physics of portals,

930
00:45:17,120 --> 00:45:20,380
or physics of objects
interacting with portals.

931
00:45:20,380 --> 00:45:23,440
And for the most part we're trying
to be super accurate with it, right?

932
00:45:23,440 --> 00:45:27,234
We're trying to make stuff work
the way players expect in real life

933
00:45:27,234 --> 00:45:29,650
because that's kind of what
we're trying to simulate here.

934
00:45:29,650 --> 00:45:34,600
But one of the things that we thought
that we added here-- that we thought

935
00:45:34,600 --> 00:45:36,910
was more fun than accurate.

936
00:45:36,910 --> 00:45:37,820
So you can see the--

937
00:45:37,820 --> 00:45:39,464
[COUGHING]

938
00:45:39,464 --> 00:45:41,860

939
00:45:41,860 --> 00:45:44,170
Sorry, I'm a little bit sick.

940
00:45:44,170 --> 00:45:47,140
You can see here that
when the box starts off,

941
00:45:47,140 --> 00:45:48,850
it's just resting on the floor.

942
00:45:48,850 --> 00:45:50,960
So it's got no initial
velocity whatsoever.

943
00:45:50,960 --> 00:45:53,830
So when you place the blue
portal down, the expectation

944
00:45:53,830 --> 00:45:56,550
is probably that it keeps
resting there or maybe it

945
00:45:56,550 --> 00:45:59,440
goes in the center of the

portal and just stands there.

946
00:45:59,440 --> 00:46:02,140
But that's not a super
fun game mechanic.

947
00:46:02,140 --> 00:46:05,350
So here we just have it be so
that objects coming out of portals

948
00:46:05,350 --> 00:46:06,910
have some minimum velocity.

949
00:46:06,910 --> 00:46:09,860
So they always have
some minimum velocity.

950
00:46:09,860 --> 00:46:14,590
And this works in lots of other
parts of the game like the paint.

951
00:46:14,590 --> 00:46:17,090
And you can see here
that there is some air

952
00:46:17,090 --> 00:46:21,920
resistance that takes place and
the paint does slowly come down.

953
00:46:21,920 --> 00:46:25,330
But once it comes down to this
minimum velocity, it just stays there.

954
00:46:25,330 --> 00:46:29,890
And this is-- it's like
completely fabricated fiction.

955
00:46:29,890 --> 00:46:32,110
I guess there's no
real physics for this.

956
00:46:32,110 --> 00:46:37,120
It's just kind of like this is more fun
than trying to simulate real physics.

957
00:46:37,120 --> 00:46:39,370
So you can see here air
resistance is making

958

00:46:39,370 --> 00:46:41,024
it go down, like they're slowing down.

959
00:46:41,024 --> 00:46:43,690
But once they get to the minimum
velocity, they just stay there.

960
00:46:43,690 --> 00:46:46,342

961
00:46:46,342 --> 00:46:47,180
This is about it.

962
00:46:47,180 --> 00:46:49,700
So once it gets here, it's
just going to stay here.

963
00:46:49,700 --> 00:46:51,033
It's not going to go below that.

964
00:46:51,033 --> 00:46:55,350

965
00:46:55,350 --> 00:46:59,920
And speaking of gels, the
gels actually came up--

966
00:46:59,920 --> 00:47:02,800
were an idea that we
had for our student game

967
00:47:02,800 --> 00:47:05,057
that we made while we were in DigiPen.

968
00:47:05,057 --> 00:47:05,890
It was called "Tag--

969
00:47:05,890 --> 00:47:08,830
The Power of Paint."

970
00:47:08,830 --> 00:47:15,040
And in Tag, you had a paint gun that
you used to shoot the different colors.

971
00:47:15,040 --> 00:47:20,560
And the Portal 2 mechanic was adapted
from this and it's pretty similar.

972

00:47:20,560 --> 00:47:23,350
But one of the things we
did get rid of for Portal 2

973
00:47:23,350 --> 00:47:26,770
was the idea of having the paint gun.

974
00:47:26,770 --> 00:47:31,840
Because one of the core ideas
we had while working on Portal 2

975
00:47:31,840 --> 00:47:36,760
was that any mechanics we add to the
game should really work with portals

976
00:47:36,760 --> 00:47:41,980
and should really interact
at a core level with portals.

977
00:47:41,980 --> 00:47:45,400
So we thought instead of using
a gun to move the paint around,

978
00:47:45,400 --> 00:47:49,610
it will made much more sense to use
the portals to move the paint around.

979
00:47:49,610 --> 00:47:53,230
And that was kind of core not just with
the gels, but with any new mechanic

980
00:47:53,230 --> 00:47:54,370
we added to the game.

981
00:47:54,370 --> 00:47:57,470
Was that portals is the
core idea of the games.

982
00:47:57,470 --> 00:48:00,340
Everything we do should kind of
center around how portals work.

983
00:48:00,340 --> 00:48:03,140

984
00:48:03,140 --> 00:48:06,650
I'm just showing you the
different colors we had in Tag.

985

00:48:06,650 --> 00:48:10,670

986
00:48:10,670 --> 00:48:14,240
One of the colors that we added
in Portal that wasn't there in Tag

987
00:48:14,240 --> 00:48:16,370
was the portal gel.

988
00:48:16,370 --> 00:48:18,710
And this was again going
with the idea of how

989
00:48:18,710 --> 00:48:21,920
do we make the gels and the
portals interact better.

990
00:48:21,920 --> 00:48:24,780
So this one just lets you
spread around white paint

991
00:48:24,780 --> 00:48:27,281
so you can put portals
anywhere that the paint can go.

992
00:48:27,281 --> 00:48:29,030
And this is a pretty
cool mechanic in that

993
00:48:29,030 --> 00:48:32,810
it allows for a lot more open-ended
level design and a lot more player

994
00:48:32,810 --> 00:48:33,650
freedom.

995
00:48:33,650 --> 00:48:36,050
Because you can play portals
essentially anywhere now.

996
00:48:36,050 --> 00:48:38,240
Because for a lot of the
game we're restricting

997
00:48:38,240 --> 00:48:41,570
where the players can put portals on
the black surface or the white surface.

998

00:48:41,570 --> 00:48:42,920
And this just allows--

999
00:48:42,920 --> 00:48:46,730
you can just put white anywhere
and put portals anywhere.

1000
00:48:46,730 --> 00:48:50,000
We didn't use this a whole lot
because it is pretty open-ended

1001
00:48:50,000 --> 00:48:52,500
and it does break a
lot of puzzle designs.

1002
00:48:52,500 --> 00:48:56,180
But there are a few cases where we
use it in a pretty open-ended way

1003
00:48:56,180 --> 00:48:57,960
and have the player
just kind of have fun.

1004
00:48:57,960 --> 00:49:01,880
Spend some time painting the whole
level and then figuring out what to do.

1005
00:49:01,880 --> 00:49:04,755
And these kind of levels usually
have a couple of different solutions

1006
00:49:04,755 --> 00:49:07,213
because we don't know where
the players are going to paint.

1007
00:49:07,213 --> 00:49:10,627
So we just put a bunch of different
ways to get to the exit and players.

1008
00:49:10,627 --> 00:49:12,210
Some players figure out all the knobs.

1009
00:49:12,210 --> 00:49:14,750
Some players find the first
one and just go there.

1010
00:49:14,750 --> 00:49:20,030
And it helps to break up the pacing a
little bit from the conventional puzzle

1011
00:49:20,030 --> 00:49:23,330
design with the specific spots where
here are some white spots, here

1012
00:49:23,330 --> 00:49:24,970
are some black spots.

1013
00:49:24,970 --> 00:49:28,260
So it helps break that up a little bit.

1014
00:49:28,260 --> 00:49:32,450
One of the things that didn't make
it through from our student game

1015
00:49:32,450 --> 00:49:36,860
was the sticky gel that you
saw in the student version.

1016
00:49:36,860 --> 00:49:38,960
So this is going to
look a little bit broken

1017
00:49:38,960 --> 00:49:41,960
because this is from a really
old version of Portal 2

1018
00:49:41,960 --> 00:49:45,230
because the sticky gel
got cut pretty early on.

1019
00:49:45,230 --> 00:49:47,810
And you're going to see some
stuff here that doesn't really

1020
00:49:47,810 --> 00:49:50,120
make sense, but just go with it.

1021
00:49:50,120 --> 00:49:52,910

1022
00:49:52,910 --> 00:49:56,600
So you can see we used
purple instead of blue here.

1023
00:49:56,600 --> 00:50:00,350
So you can jump on-- you can walk on
walls and stuff, which is pretty cool.

1024

00:50:00,350 --> 00:50:03,720
So here you can see there's
blue paint coming out of there

1025
00:50:03,720 --> 00:50:06,110
but you can't see the actual
paint blobs because there

1026
00:50:06,110 --> 00:50:07,610
are invisible for some reason.

1027
00:50:07,610 --> 00:50:09,230
I couldn't figure it out.

1028
00:50:09,230 --> 00:50:12,744
But you can see the actual paint
on the walls, on the floor.

1029
00:50:12,744 --> 00:50:14,660
So this is just an idea
of the kind of puzzles

1030
00:50:14,660 --> 00:50:18,094
we were trying to come up
with using sticky paint.

1031
00:50:18,094 --> 00:50:20,010
There's an extra portal
there for some reason.

1032
00:50:20,010 --> 00:50:21,960
Ignore it.

1033
00:50:21,960 --> 00:50:24,119
This is a really old
version of the game.

1034
00:50:24,119 --> 00:50:26,660
So this is the kind of puzzles
we are trying to come up with.

1035
00:50:26,660 --> 00:50:32,870
Of combining the different paint
colors and portals together.

1036
00:50:32,870 --> 00:50:35,810
But we did end up cutting
this feature though.

1037

00:50:35,810 --> 00:50:37,860
There were a few different reasons.

1038
00:50:37,860 --> 00:50:41,060
One of them was obviously
it is quite disorienting.

1039
00:50:41,060 --> 00:50:43,970
You can see going up a wall
and trying to figure out where

1040
00:50:43,970 --> 00:50:45,950
the ceiling is, where the floor is.

1041
00:50:45,950 --> 00:50:48,640
Especially in a lot
of these levels where

1042
00:50:48,640 --> 00:50:50,270
they're mostly just black and white.

1043
00:50:50,270 --> 00:50:53,795
It gets pretty disorienting
and we had more than a few play

1044
00:50:53,795 --> 00:50:55,970
testers complain about that.

1045
00:50:55,970 --> 00:51:00,710
But the other big reason that we
cut it is because it didn't really

1046
00:51:00,710 --> 00:51:02,470
interact well with portals.

1047
00:51:02,470 --> 00:51:04,220
You don't really want
to walk into a level

1048
00:51:04,220 --> 00:51:07,130
and have the pots
already placed for you.

1049
00:51:07,130 --> 00:51:11,540
And there's no real good way
to make pots on the entire wall

1050
00:51:11,540 --> 00:51:15,740
without having to place

the portal like 50 times.

1051
00:51:15,740 --> 00:51:20,150
And also it didn't really interact
well with the portal player

1052
00:51:20,150 --> 00:51:24,080
physics and portal physics, and Dave
will talk some more about the player

1053
00:51:24,080 --> 00:51:25,730
physics through portals.

1054
00:51:25,730 --> 00:51:30,020
And this is one of the
things that you can see.

1055
00:51:30,020 --> 00:51:33,250
We had a paint gun for a little
bit, but we ended up cutting it.

1056
00:51:33,250 --> 00:51:36,050
So you can see I'm
painting the wall over here

1057
00:51:36,050 --> 00:51:39,140
and I'm going to walk on the wall.

1058
00:51:39,140 --> 00:51:41,690
But as I enter the blue
portal, you can see oh, it's

1059
00:51:41,690 --> 00:51:43,020
not going to let me go through.

1060
00:51:43,020 --> 00:51:45,020
But if I go through this way, it works.

1061
00:51:45,020 --> 00:51:47,720
And that's just one of the things that's
like, well, we've got to solve this.

1062
00:51:47,720 --> 00:51:48,620
We've got to ship like this.

1063
00:51:48,620 --> 00:51:50,030
We've got to solve the problems.

1064

00:51:50,030 --> 00:51:53,310
And we spent some time trying
to work on these issues.

1065
00:51:53,310 --> 00:51:56,060
But at some point, you
realize that you're not

1066
00:51:56,060 --> 00:51:59,190
guaranteed to solve these problems
no matter how long you spend on them.

1067
00:51:59,190 --> 00:52:01,190
So at some point you've
got to just be like, OK,

1068
00:52:01,190 --> 00:52:03,350
I don't want to spend
an extra month or two

1069
00:52:03,350 --> 00:52:06,610
trying to fix these problems
not knowing if you'll get there.

1070
00:52:06,610 --> 00:52:09,360
And plus there's other reasons why
the mechanic isn't working out.

1071
00:52:09,360 --> 00:52:13,790
So let's just stop working on this
and work on other stuff instead.

1072
00:52:13,790 --> 00:52:15,980
Another thing we ended up cutting--

1073
00:52:15,980 --> 00:52:20,360
this is from Portal 1 that was present
in Narbacular Drop was the ability

1074
00:52:20,360 --> 00:52:23,780
to place portals through portals.

1075
00:52:23,780 --> 00:52:26,660
And it's a pretty
confusing thing and that

1076
00:52:26,660 --> 00:52:29,090
was the main reason we cut
it because most players just

1077
00:52:29,090 --> 00:52:30,890
thought it was way too confusing.

1078
00:52:30,890 --> 00:52:33,723
Because you're placing the blue
portal by looking through the orange

1079
00:52:33,723 --> 00:52:34,250
portal here.

1080
00:52:34,250 --> 00:52:35,974
So the blue portal is--

1081
00:52:35,974 --> 00:52:39,140
he's pointing through the orange portal
here and facing the blue portal over

1082
00:52:39,140 --> 00:52:42,630
here because the other
blue portal is behind them.

1083
00:52:42,630 --> 00:52:44,780
It's just like-- it's too confusing.

1084
00:52:44,780 --> 00:52:46,790
And also it doesn't--

1085
00:52:46,790 --> 00:52:53,000
there's not a lot of puzzle design that
you lose by disabling this feature.

1086
00:52:53,000 --> 00:52:56,480
The thing you do gain is players
aren't getting super confused

1087
00:52:56,480 --> 00:52:59,450
and also you're not necessarily
cutting a bunch of puzzles

1088
00:52:59,450 --> 00:53:01,220
that you can't make now.

1089
00:53:01,220 --> 00:53:03,800
So this feature got cut as well.

1090
00:53:03,800 --> 00:53:07,410
And this is something
that we didn't really cut,

1091
00:53:07,410 --> 00:53:11,980
but we stopped using in Portal 2 that
was used a little bit in Portal 1

1092
00:53:11,980 --> 00:53:14,062
was the idea of a double fling.

1093
00:53:14,062 --> 00:53:16,230
And I'm going to show it here.

1094
00:53:16,230 --> 00:53:19,190
So double fling is
basically placing a portal

1095
00:53:19,190 --> 00:53:21,860
while you're falling out of a portal.

1096
00:53:21,860 --> 00:53:25,190
And it's one of those things
that it works pretty well.

1097
00:53:25,190 --> 00:53:26,450
It's a pretty cool mechanic.

1098
00:53:26,450 --> 00:53:29,090
And it was used in a
few spots in Portal 1.

1099
00:53:29,090 --> 00:53:32,210
A couple of puzzles required it,
like this puzzle here required you

1100
00:53:32,210 --> 00:53:33,890
to do this double fling.

1101
00:53:33,890 --> 00:53:37,610
But one of the things we
noticed was a lot of players

1102
00:53:37,610 --> 00:53:42,380
have difficulty in executing a
lot of these super hyper-sized,

1103
00:53:42,380 --> 00:53:44,630
high-precision movements
even though they know

1104

00:53:44,630 --> 00:53:46,190
what the solution of the puzzle is.

1105
00:53:46,190 --> 00:53:49,820
So players will walk in this room and
figure out, OK, I've got to do this,

1106
00:53:49,820 --> 00:53:51,890
I've got to do that, and
this is going to work.

1107
00:53:51,890 --> 00:53:54,590
But then a lot of players have
trouble walking out of a portal,

1108
00:53:54,590 --> 00:53:58,040
making a portal as quickly,
and it adds a lot of stress.

1109
00:53:58,040 --> 00:54:01,940
And we wanted to move away from a lot
of the twitch movement based stuff

1110
00:54:01,940 --> 00:54:05,239
and towards more of a
kind of, aha, I got it.

1111
00:54:05,239 --> 00:54:06,030
That kind of stuff.

1112
00:54:06,030 --> 00:54:09,720
And once you get it, we don't
want you to spend a bunch of time

1113
00:54:09,720 --> 00:54:13,144
in making sure you get the
precise movements right.

1114
00:54:13,144 --> 00:54:14,810
So this feature we didn't really cut it.

1115
00:54:14,810 --> 00:54:16,850
It's still a mechanic
that works in Portal 2,

1116
00:54:16,850 --> 00:54:19,370
but none of the puzzles in
Portal 2 required it anymore.

1117

00:54:19,370 --> 00:54:22,460
And once we added the level
editor, a lot of the puzzles people

1118
00:54:22,460 --> 00:54:26,100
are making do require it and
a lot of players like it.

1119
00:54:26,100 --> 00:54:31,100
But it's not something that we thought
we wanted to make everyone have to do.

1120
00:54:31,100 --> 00:54:33,870

1121
00:54:33,870 --> 00:54:38,360
Another thing that we changed
from Portal 1 to Portal 2

1122
00:54:38,360 --> 00:54:41,735
was these energy balls.

1123
00:54:41,735 --> 00:54:45,140
These energy balls at the time--

1124
00:54:45,140 --> 00:54:47,510
part of the reason we
used them in Portal 1

1125
00:54:47,510 --> 00:54:51,410
was because they were
there in Half-Life and it

1126
00:54:51,410 --> 00:54:56,760
was an already created mechanic that we
had that we could just keep from them.

1127
00:54:56,760 --> 00:55:00,610
But the basic mechanic
is these things fire--

1128
00:55:00,610 --> 00:55:03,890
these things fire this
ball that bounces around

1129
00:55:03,890 --> 00:55:07,794
and it needs to go in this receptacle
here under my gun right now.

1130

00:55:07,794 --> 00:55:10,460
And it should go in this receptacle
here and once it goes there,

1131
00:55:10,460 --> 00:55:12,507
it finishes the puzzle.

1132
00:55:12,507 --> 00:55:14,590
There are a few issues
with this mechanic, though,

1133
00:55:14,590 --> 00:55:17,720
in that there's a bunch of
timing element involved here.

1134
00:55:17,720 --> 00:55:19,760
Because the ball takes time to travel.

1135
00:55:19,760 --> 00:55:23,340
And also if you get hit by it, you die.

1136
00:55:23,340 --> 00:55:25,500
Which, I mean, it's fine.

1137
00:55:25,500 --> 00:55:26,900
It's a game mechanic

1138
00:55:26,900 --> 00:55:31,050
But for Portal 2, we just thought,
how can we improve on this idea?

1139
00:55:31,050 --> 00:55:37,480
And the thing we came up with was using
lasers instead of the energy balls.

1140
00:55:37,480 --> 00:55:40,820
Lower the volume a little bit.

1141
00:55:40,820 --> 00:55:43,190
So here you can see it it's
the same level from Portal 1

1142
00:55:43,190 --> 00:55:46,400
and you can even see the energy ball
dispenser going away and being replaced

1143
00:55:46,400 --> 00:55:49,025
by a laser because we want
to make sure the player is

1144
00:55:49,025 --> 00:55:51,320
like, GLaDOS is improving
these mechanics now

1145
00:55:51,320 --> 00:55:54,000
and got better versions of it.

1146
00:55:54,000 --> 00:55:58,280
So the laser effectively is
very similar to the energy ball.

1147
00:55:58,280 --> 00:56:00,470
It goes in one and you want it--

1148
00:56:00,470 --> 00:56:04,850
it goes in over here and you want it
to go to the receptacle over there.

1149
00:56:04,850 --> 00:56:10,950
The big advantage here is
that the reaction is instant.

1150
00:56:10,950 --> 00:56:14,040
So if the player got the solution
or not, it's instantaneous.

1151
00:56:14,040 --> 00:56:17,380
You don't have to have situations
where you place the exit portal

1152
00:56:17,380 --> 00:56:20,690
and now you have to wait for the ball
to go all the way across the level

1153
00:56:20,690 --> 00:56:22,220
and see if it lines up or not.

1154
00:56:22,220 --> 00:56:24,140
This way it just instantly does it.

1155
00:56:24,140 --> 00:56:28,280
Plus it also opens up a bunch of
different game play opportunities

1156
00:56:28,280 --> 00:56:31,040
because now you can use multiple
relays in the same level.

1157
00:56:31,040 --> 00:56:33,440
You can have the cube
that redirects the laser.

1158
00:56:33,440 --> 00:56:37,110
So overall it felt like an
improvement over the energy ball.

1159
00:56:37,110 --> 00:56:39,840

1160
00:56:39,840 --> 00:56:44,380
And talking about
lasers, so far we've been

1161
00:56:44,380 --> 00:56:46,630
talking about a bunch of
these smaller decisions we've

1162
00:56:46,630 --> 00:56:51,640
made to solve these smaller problems
as they kept coming up, like entering

1163
00:56:51,640 --> 00:56:55,330
exiting portals, making sure
things are lined up or not,

1164
00:56:55,330 --> 00:56:57,792
improving on the
specific game mechanics.

1165
00:56:57,792 --> 00:56:59,500
But one of the things
that you need to do

1166
00:56:59,500 --> 00:57:01,810
when you're trying to
make a whole game is

1167
00:57:01,810 --> 00:57:07,900
to see how these mechanics come together
and how you can combine them together

1168
00:57:07,900 --> 00:57:09,160
to make a whole game.

1169
00:57:09,160 --> 00:57:13,480
To make a few puzzles that increase
into difficulty, complexity,

1170
00:57:13,480 --> 00:57:15,760
and go towards some crescendo.

1171
00:57:15,760 --> 00:57:21,510
And one of the ways we did that is
by kind of using this kind of process

1172
00:57:21,510 --> 00:57:23,290
that I'm going to go through.

1173
00:57:23,290 --> 00:57:26,800
And we used it a couple of times
both in Portal 1 and in Portal 2.

1174
00:57:26,800 --> 00:57:30,280
And there's a few different mechanics
that we used the cycle over and over

1175
00:57:30,280 --> 00:57:31,030
for.

1176
00:57:31,030 --> 00:57:35,770
And that's kind of how the
entire game track is designed.

1177
00:57:35,770 --> 00:57:39,220
So it starts off with an
introduction, and the introduction

1178
00:57:39,220 --> 00:57:40,740
is the puzzle we just showed you.

1179
00:57:40,740 --> 00:57:43,739
That's the intro puzzle for lasers
and it's really straightforward.

1180
00:57:43,739 --> 00:57:45,030
It just shows you the mechanic.

1181
00:57:45,030 --> 00:57:48,344
You go through one portal, come out
the other, goes into the receptacle.

1182
00:57:48,344 --> 00:57:49,510
It's really straightforward.

1183
00:57:49,510 --> 00:57:50,860

Introduces the mechanic.

1184
00:57:50,860 --> 00:57:53,080
Most people would get
tripped up on this.

1185
00:57:53,080 --> 00:57:56,620
From there, we then try to saturate
the player with that same mechanic.

1186
00:57:56,620 --> 00:57:59,920
We introduce different
twists on that same--

1187
00:57:59,920 --> 00:58:01,630
without introducing
a whole new mechanic,

1188
00:58:01,630 --> 00:58:06,250
we just introduce different versions,
different tweaks on that same idea.

1189
00:58:06,250 --> 00:58:08,450
So this room still only has lasers.

1190
00:58:08,450 --> 00:58:11,260
But now we've introduced
relays and cubes.

1191
00:58:11,260 --> 00:58:17,389
And you can experiment, figure out how
to connect the three lasers together.

1192
00:58:17,389 --> 00:58:19,180
Figure out how to move
the cube, figure out

1193
00:58:19,180 --> 00:58:22,000
how to move the laser
through the portals.

1194
00:58:22,000 --> 00:58:23,490
But still it's only lasers.

1195
00:58:23,490 --> 00:58:25,630
Nothing super complex yet.

1196
00:58:25,630 --> 00:58:26,920
Then we give you more of that.

1197
00:58:26,920 --> 00:58:29,330
We give you more of
just the same mechanic.

1198
00:58:29,330 --> 00:58:33,930
Here there's two things firing lasers
and two things you've got to connect.

1199
00:58:33,930 --> 00:58:35,150
And so it's the same idea.

1200
00:58:35,150 --> 00:58:38,710
It's like just using lasers,
but not super complex.

1201
00:58:38,710 --> 00:58:42,010
Just building on the
complexity little by little.

1202
00:58:42,010 --> 00:58:44,069
Followed by a puzzle
that's like, OK, this

1203
00:58:44,069 --> 00:58:46,360
is a puzzle that's going to
teach you all about lasers.

1204
00:58:46,360 --> 00:58:49,570
By now you've seen lasers
in a few different ways.

1205
00:58:49,570 --> 00:58:52,810
This one, once you get this,
you understand how lasers work.

1206
00:58:52,810 --> 00:58:56,620
You know everything there is
to know about how lasers work.

1207
00:58:56,620 --> 00:58:57,990
So this puzzle here--

1208
00:58:57,990 --> 00:59:01,280
excuse me-- that's two cubes
and three things firing lasers,

1209
00:59:01,280 --> 00:59:04,051
and on the other side

of the puzzle there's

1210
00:59:04,051 --> 00:59:05,800
three things-- you've
got to connect them.

1211
00:59:05,800 --> 00:59:09,680
And this puzzle is very
difficult, but by this point,

1212
00:59:09,680 --> 00:59:11,830
you've been slowly
introduced to different ideas

1213
00:59:11,830 --> 00:59:15,410
of how lasers work and this one
is taking them all together.

1214
00:59:15,410 --> 00:59:18,640
And then once we've done that,
then we start combining them.

1215
00:59:18,640 --> 00:59:20,700
Then we start taking, OK,
now you've got a laser

1216
00:59:20,700 --> 00:59:22,790
and a different cube and a bridge.

1217
00:59:22,790 --> 00:59:25,700
And by this point you've
seen a whole separate--

1218
00:59:25,700 --> 00:59:28,770
we've done the whole introduction,
saturation, graduation track

1219
00:59:28,770 --> 00:59:30,410
with bridges as well.

1220
00:59:30,410 --> 00:59:32,980
So by this point, you
go in there and, OK, I

1221
00:59:32,980 --> 00:59:34,910
know how bridges, I
know how lasers work.

1222
00:59:34,910 --> 00:59:36,290

How do they work together?

1223
00:59:36,290 --> 00:59:38,830
How do I combine them together?

1224
00:59:38,830 --> 00:59:41,740
And then we start escalating from there.

1225
00:59:41,740 --> 00:59:45,340
And then you go into this puzzle
that has a bridge, has a laser,

1226
00:59:45,340 --> 00:59:48,490
has a turret, has some cubes
coming out, has a catapult,

1227
00:59:48,490 --> 00:59:49,736
has a bunch of this stuff.

1228
00:59:49,736 --> 00:59:51,610
But by the time the
player gets here, they're

1229
00:59:51,610 --> 00:59:53,800
not really overwhelmed
by it because they

1230
00:59:53,800 --> 00:59:56,650
have been introduced to all these
mechanics separately and also

1231
00:59:56,650 --> 00:59:58,370
smaller combinations of them.

1232
00:59:58,370 --> 01:00:00,277
So that when they get
to this point where

1233
01:00:00,277 --> 01:00:02,110
there's a bunch of
different mechanics, they

1234
01:00:02,110 --> 01:00:04,340
know how they all work individually.

1235
01:00:04,340 --> 01:00:08,020
And that's kind of the process
that we use of slowly ramping up

1236
01:00:08,020 --> 01:00:12,220
the difficulty, first with a single
mechanic, then combining them.

1237
01:00:12,220 --> 01:00:15,961
And then that's kind of how we take
the individual smaller design elements

1238
01:00:15,961 --> 01:00:18,460
and combine them together and
turn them into the whole game.

1239
01:00:18,460 --> 01:00:20,934

1240
01:00:20,934 --> 01:00:24,100
And now I think Dave is going to come
back and talk some more about physics.

1241
01:00:24,100 --> 01:00:29,320

1242
01:00:29,320 --> 01:00:32,780
DAVE KIRCHER: And after I cover
these last four bits of physics,

1243
01:00:32,780 --> 01:00:34,540
we're going to open up for questions.

1244
01:00:34,540 --> 01:00:37,480
I know we have a whole miscellaneous
section that we've outlined here,

1245
01:00:37,480 --> 01:00:39,520
but that's more just buffer material.

1246
01:00:39,520 --> 01:00:44,260
So I'm hoping you're going to put
your spatial thinking caps back on.

1247
01:00:44,260 --> 01:00:50,930
So how we handle portal transitions
is there's two distinct methods.

1248
01:00:50,930 --> 01:00:54,670
One is that we've got volumes here,
which we call touch volumes or trigger

1249

01:00:54,670 --> 01:00:55,570
volumes.

1250
01:00:55,570 --> 01:00:58,690
And those are centered
around the portal.

1251
01:00:58,690 --> 01:01:02,177
So I've got my blue portal here
and that was green volumes here.

1252
01:01:02,177 --> 01:01:04,510
And you'll notice it's entirely
in front of the portal--

1253
01:01:04,510 --> 01:01:05,620
that's important.

1254
01:01:05,620 --> 01:01:07,780
And then we've got this
yellow volume here.

1255
01:01:07,780 --> 01:01:10,840
So the yellow volume is--

1256
01:01:10,840 --> 01:01:13,960
it's whole job is to tell us
which objects in the world

1257
01:01:13,960 --> 01:01:16,997
are just kind of close to a
portal, and I'll come back

1258
01:01:16,997 --> 01:01:18,580
to why that's important to the minute.

1259
01:01:18,580 --> 01:01:21,490
But it separates us from
having to think about objects

1260
01:01:21,490 --> 01:01:25,204
that are way out in the world all
over in the white space around here.

1261
01:01:25,204 --> 01:01:26,620
We don't have to think about them.

1262
01:01:26,620 --> 01:01:29,020
And we also know they're not

objects behind the portal

1263
01:01:29,020 --> 01:01:32,690
because we're only interested in stuff
that happens in front of the portal.

1264
01:01:32,690 --> 01:01:36,500
And this green volume here is
where most of the magic happens.

1265
01:01:36,500 --> 01:01:40,349
This volume says the objects
in it are so close to a portal

1266
01:01:40,349 --> 01:01:43,390
we need to think very hard about what
they can do and what they can't do.

1267
01:01:43,390 --> 01:01:47,260
We're going to let those objects
start passing through the portal.

1268
01:01:47,260 --> 01:01:50,650
And so we keep these objects
in two separate lists.

1269
01:01:50,650 --> 01:01:55,270
Objects that are in this green volume
no longer intersect with any objects

1270
01:01:55,270 --> 01:01:56,620
out in the white space out here.

1271
01:01:56,620 --> 01:01:58,119
They don't have to think about them.

1272
01:01:58,119 --> 01:01:59,890
They're kept in a
completely separate list

1273
01:01:59,890 --> 01:02:02,230
and they don't collide with them at all.

1274
01:02:02,230 --> 01:02:04,720
They also don't collide
with world geometry.

1275
01:02:04,720 --> 01:02:05,960
I'll get to that in a bit.

1276
01:02:05,960 --> 01:02:07,720
And then objects in
this yellow volume are

1277
01:02:07,720 --> 01:02:10,780
the only ones that the objects in
the green volume have to worry about.

1278
01:02:10,780 --> 01:02:14,370
So these are objects that are
just kind of close to a portal.

1279
01:02:14,370 --> 01:02:18,430
And so another important interaction
with portals is ray casting.

1280
01:02:18,430 --> 01:02:22,660
So we're only interested in rays
that pass through the portal quad.

1281
01:02:22,660 --> 01:02:25,445
So if a ray happens to
just pass the portal plane,

1282
01:02:25,445 --> 01:02:27,820
but not intersect the quad,
we don't do anything with it.

1283
01:02:27,820 --> 01:02:28,690
It's not special.

1284
01:02:28,690 --> 01:02:30,689
We just treat it like any
other ray in the world

1285
01:02:30,689 --> 01:02:32,234
and let it do its merry thing.

1286
01:02:32,234 --> 01:02:33,400
But we got this magenta guy.

1287
01:02:33,400 --> 01:02:35,050
It intersects with the portal.

1288
01:02:35,050 --> 01:02:39,400
So now we have to recast a new ray
out the other orange portal which

1289
01:02:39,400 --> 01:02:41,620
essentially gives us two ray segments.

1290
01:02:41,620 --> 01:02:44,710
And if you think about that, if you
were to write any piece of code that

1291
01:02:44,710 --> 01:02:48,014
just did the ray casting and
hand back two ray segments

1292
01:02:48,014 --> 01:02:51,180
when somebody was expecting one, you're
probably going to get weird results.

1293
01:02:51,180 --> 01:02:53,551
So this means, the fact
that this is happening,

1294
01:02:53,551 --> 01:02:56,800
means that we have to go through every
single system in the game that possibly

1295
01:02:56,800 --> 01:03:00,380
casts a ray through a portal and
fix every single one to understand.

1296
01:03:00,380 --> 01:03:04,060
But if we give you back multiple
segments, different things happen.

1297
01:03:04,060 --> 01:03:06,755
Instead of assuming that this
starting point goes directly

1298
01:03:06,755 --> 01:03:09,130
to this end point, which
doesn't even go in the direction

1299
01:03:09,130 --> 01:03:12,070
it wanted to in the first place.

1300
01:03:12,070 --> 01:03:14,950
And so at its core,
remember how I told you

1301
01:03:14,950 --> 01:03:17,590
every object had an
origin, a single point that

1302
01:03:17,590 --> 01:03:20,110
defines where it is in space.

1303
01:03:20,110 --> 01:03:23,170
We use the ray casting to
determine if an object that's

1304
01:03:23,170 --> 01:03:25,700
in this green volume and
just kind of moving around.

1305
01:03:25,700 --> 01:03:27,699
We use a recast from
one point where it was

1306
01:03:27,699 --> 01:03:29,740
one frame to one point
where it was another frame

1307
01:03:29,740 --> 01:03:33,160
to see if it either passed through
a portal or outside the portal

1308
01:03:33,160 --> 01:03:36,070
because if it went over this
way, we do nothing at all.

1309
01:03:36,070 --> 01:03:38,020
If we went this way,
we need to teleport it.

1310
01:03:38,020 --> 01:03:39,970
So that's the basics of our handling.

1311
01:03:39,970 --> 01:03:44,860

1312
01:03:44,860 --> 01:03:48,430
So how do we let objects
pass through walls?

1313
01:03:48,430 --> 01:03:51,040
This is one of the things
I spent a whole lot of time

1314
01:03:51,040 --> 01:03:54,141
on because we wanted our portal
transitions to be very seamless.

1315
01:03:54,141 --> 01:03:56,140
Remember in one of my
first slides I showed you.

1316
01:03:56,140 --> 01:03:57,181
It should be like a door.

1317
01:03:57,181 --> 01:04:00,070
People expect to walk halfway through
the door and just stand there.

1318
01:04:00,070 --> 01:04:01,830
And how we do this is--

1319
01:04:01,830 --> 01:04:04,330
I'm going to talk about it a bit first.

1320
01:04:04,330 --> 01:04:07,630
Whenever you place a portal, we take
a snapshot of all the world geometry

1321
01:04:07,630 --> 01:04:11,110
around you and create a very
small representation of that

1322
01:04:11,110 --> 01:04:12,790
and carve a hole in it.

1323
01:04:12,790 --> 01:04:16,360
And we don't do this for the entire
world because that takes way too long.

1324
01:04:16,360 --> 01:04:19,780
And by way too long, I
mean a quarter of a second.

1325
01:04:19,780 --> 01:04:23,345
And in game terms,
that's just way too long.

1326
01:04:23,345 --> 01:04:25,220
I don't know if it was
a quarter of a second.

1327
01:04:25,220 --> 01:04:27,430
I remember originally that
we had a problem where

1328
01:04:27,430 --> 01:04:29,320
I think carving the mini-version
took a quarter of a second,

1329
01:04:29,320 --> 01:04:31,250
so it probably took several seconds.

1330
01:04:31,250 --> 01:04:34,570
So I'm going to show you a scenario
here where I've got a portal

1331
01:04:34,570 --> 01:04:35,740
and it's going into--

1332
01:04:35,740 --> 01:04:40,510
it's going along this corridor
gateway, gangplank thing.

1333
01:04:40,510 --> 01:04:43,939
And it's going to go into
this little classroom area.

1334
01:04:43,939 --> 01:04:45,730
And as I go back around
the wall, I'm going

1335
01:04:45,730 --> 01:04:51,130
to show you a debug mesh of
our collision representation.

1336
01:04:51,130 --> 01:04:54,430
So in this debug representation,
we've got these green lines.

1337
01:04:54,430 --> 01:04:57,460
These green lines and then
also these cyan lines--

1338
01:04:57,460 --> 01:04:58,960
or I'm probably mispronouncing that.

1339
01:04:58,960 --> 01:05:02,020
I call them bluish, but my colleague
has told me I need to call him cyan.

1340
01:05:02,020 --> 01:05:03,370
[CHUCKLING]

1341

01:05:03,370 --> 01:05:04,529

1342
01:05:04,529 --> 01:05:06,070
So I'm going to call them bluish now.

1343
01:05:06,070 --> 01:05:11,420
So these green lines and the
blue lines are in local space.

1344
01:05:11,420 --> 01:05:13,990
So they're with the blue
portal that we placed locally.

1345
01:05:13,990 --> 01:05:15,910
And I know it's super
hard to see, but there

1346
01:05:15,910 --> 01:05:18,910
are a bunch of red lines over
here and some magenta ones.

1347
01:05:18,910 --> 01:05:23,140
Those are from the other portal
that's in the classroom that

1348
01:05:23,140 --> 01:05:26,420
are flipped and glued to the
back of our local portal.

1349
01:05:26,420 --> 01:05:28,960
So it's all in this local space
and around this blue portal.

1350
01:05:28,960 --> 01:05:33,470
We put some new stuff behind it
and some new stuff in front of it.

1351
01:05:33,470 --> 01:05:36,220
And so you may be asking yourself
what the colors actually mean?

1352
01:05:36,220 --> 01:05:42,670
Green here is representing a brush
geometry, which most level editors, you

1353
01:05:42,670 --> 01:05:47,050
can create walls and various shapes
directly in the level editor.

1354
01:05:47,050 --> 01:05:50,950
And at least in our terminology,
we refer to these as brushes.

1355
01:05:50,950 --> 01:05:55,920
So they're usually very simple convex
shapes and super easy to deal with.

1356
01:05:55,920 --> 01:05:58,660
And this bluish geometry
is from what's known

1357
01:05:58,660 --> 01:06:02,650
as a static prop, which is a model that
somebody modeled in a model editor.

1358
01:06:02,650 --> 01:06:04,690
So it's going to be
arbitrarily complex, but it

1359
01:06:04,690 --> 01:06:07,360
has to be made up of convex shapes.

1360
01:06:07,360 --> 01:06:11,195
But we take a small snapshot
of that and then carve it up.

1361
01:06:11,195 --> 01:06:12,320
Sorry, I forgot to mention.

1362
01:06:12,320 --> 01:06:15,640
So we call it a static prop because
we are guaranteed it does not move.

1363
01:06:15,640 --> 01:06:18,160
And that's very important because it's
really easy to simulate things that

1364
01:06:18,160 --> 01:06:18,600
don't move.

1365
01:06:18,600 --> 01:06:19,266
They don't move.

1366
01:06:19,266 --> 01:06:22,860

1367
01:06:22,860 --> 01:06:26,530

And the same is true of
the red and magenta here.

1368
01:06:26,530 --> 01:06:29,680
The red is the brush geometry
on the paired portal side

1369
01:06:29,680 --> 01:06:35,470
and the magenta is static props on the
other side, which is mainly the desks.

1370
01:06:35,470 --> 01:06:37,100
And as I'm looking through here.

1371
01:06:37,100 --> 01:06:43,090
You can see just a small
snapshot, and then you

1372
01:06:43,090 --> 01:06:47,650
can see this magenta outline here
of the desk mesh on the other side.

1373
01:06:47,650 --> 01:06:50,860
It's important to know that
that's not me looking at the mesh

1374
01:06:50,860 --> 01:06:51,960
through the portal.

1375
01:06:51,960 --> 01:06:53,710
That's the local space
version and it just

1376
01:06:53,710 --> 01:06:56,950
happens to line up the desk because we
have to make sure everything lines up.

1377
01:06:56,950 --> 01:06:59,116
Otherwise your physical
interactions will seem weird

1378
01:06:59,116 --> 01:07:01,000
if something is halfway
in a portal and it's

1379
01:07:01,000 --> 01:07:03,902
kind of not colliding with something
or it's colliding with it wrong.

1380

01:07:03,902 --> 01:07:05,860
As I walk through, you'll
notice all the colors

1381
01:07:05,860 --> 01:07:09,650
change because we switched spaces
when I walk through in a second.

1382
01:07:09,650 --> 01:07:13,720
So now all the colors are
local space for this side.

1383
01:07:13,720 --> 01:07:15,770
So, yeah, that is how we carve a hole.

1384
01:07:15,770 --> 01:07:20,530
It's a very, very small area of
the level that we carve a hole in.

1385
01:07:20,530 --> 01:07:24,730
And so we're getting back to the
volumes I showed you two slides ago.

1386
01:07:24,730 --> 01:07:27,697
If we carve a small
representation of the world,

1387
01:07:27,697 --> 01:07:29,530
we have to know when
the player is colliding

1388
01:07:29,530 --> 01:07:31,540
with that versus the regular world.

1389
01:07:31,540 --> 01:07:34,180
Because if they're colliding
with the regular world,

1390
01:07:34,180 --> 01:07:36,070
they're going to collide with
the wall that's behind the portal

1391
01:07:36,070 --> 01:07:37,695
and they're not going to go through it.

1392
01:07:37,695 --> 01:07:40,599
So we have to use exclusively
that carved version

1393

01:07:40,599 --> 01:07:41,890
when they're close to a portal.

1394
01:07:41,890 --> 01:07:44,680
And we do that-- we're using the same
volumes I was talking about earlier.

1395
01:07:44,680 --> 01:07:46,180
This is a 3D representation of them.

1396
01:07:46,180 --> 01:07:48,195
And you'll notice that they have space--

1397
01:07:48,195 --> 01:07:50,320
a large amount of space
above and below the portal.

1398
01:07:50,320 --> 01:07:54,460
That's important because it's a
3D space instead of a 2D space.

1399
01:07:54,460 --> 01:07:59,030
So as I enter the yellow space,
I still collide with the world.

1400
01:07:59,030 --> 01:08:03,010
I still collide with all
the desks and things.

1401
01:08:03,010 --> 01:08:06,010
Because I'm still-- while I'm
exclusively in the yellow volume,

1402
01:08:06,010 --> 01:08:07,814
I'm still colliding with the world.

1403
01:08:07,814 --> 01:08:08,730
I'm going to show you.

1404
01:08:08,730 --> 01:08:10,730
It's a bad example, but
it's the video I've got.

1405
01:08:10,730 --> 01:08:12,880
I'm going to hit this
chair behind this desk

1406
01:08:12,880 --> 01:08:14,620
because it's still in the real world.

1407
01:08:14,620 --> 01:08:17,350
And then as I transition
into the green volume,

1408
01:08:17,350 --> 01:08:21,590
I am exclusively colliding
with our carved version of it.

1409
01:08:21,590 --> 01:08:24,880
Which-- that was a bad frame to cut.

1410
01:08:24,880 --> 01:08:27,220
If I happen to look back in the portal--

1411
01:08:27,220 --> 01:08:28,990
which side is scrubbing?

1412
01:08:28,990 --> 01:08:31,750
OK.

1413
01:08:31,750 --> 01:08:34,510
Sorry.

1414
01:08:34,510 --> 01:08:37,720
So if you happen to look inside the
portal, you might be able to see it.

1415
01:08:37,720 --> 01:08:39,886
There is-- I know it's super
hard to see, I'm sorry.

1416
01:08:39,886 --> 01:08:40,930
But we did carve a hole.

1417
01:08:40,930 --> 01:08:43,730
There's no there's no geometry
right here to stop us going in.

1418
01:08:43,730 --> 01:08:45,729
And since we're exclusively
using this new mesh,

1419
01:08:45,729 --> 01:08:47,770
we're allowed to just
go through that space.

1420
01:08:47,770 --> 01:08:51,020

1421
01:08:51,020 --> 01:08:54,939
OK, so more importantly
than static geometry, which

1422
01:08:54,939 --> 01:08:57,189
doesn't move and is super
easy to physically simulate,

1423
01:08:57,189 --> 01:09:00,130
we have dynamic props
and things that move.

1424
01:09:00,130 --> 01:09:02,830
Specifically in this case, boxes.

1425
01:09:02,830 --> 01:09:07,260
So the way we model this is very
similar to how we did with geometry.

1426
01:09:07,260 --> 01:09:09,310
We're going to be duplicating
everything and I'm

1427
01:09:09,310 --> 01:09:11,018
going to show you by
walking in a portal.

1428
01:09:11,018 --> 01:09:15,040
So this blue box that just
appeared is my player.

1429
01:09:15,040 --> 01:09:19,240
My player of physics object that's
replicated from this orange portal

1430
01:09:19,240 --> 01:09:21,649
to the backside of the blue portal.

1431
01:09:21,649 --> 01:09:24,231
And this is using a system
known as a physics shadow.

1432
01:09:24,231 --> 01:09:25,689
At least that's what our system is.

1433
01:09:25,689 --> 01:09:26,814
I'm not really a physicist.

1434
01:09:26,814 --> 01:09:29,060
That's just what we call
our representation of it.

1435
01:09:29,060 --> 01:09:33,069
So I mean, I haven't dealt with many
physics systems when I talk about that.

1436
01:09:33,069 --> 01:09:36,220
So what a physics shadow
does that's different

1437
01:09:36,220 --> 01:09:39,700
than our rendering geometry is we're
not allowed to actually teleport it

1438
01:09:39,700 --> 01:09:42,220
from one frame to the next
because if you teleport a physics

1439
01:09:42,220 --> 01:09:44,700
object, then all sorts of
interactions that intersect,

1440
01:09:44,700 --> 01:09:46,410
they have no previous basis to go from.

1441
01:09:46,410 --> 01:09:47,590
Of like how to solve that.

1442
01:09:47,590 --> 01:09:50,950
They can't rewind time because
they've suddenly teleported

1443
01:09:50,950 --> 01:09:52,340
into an interpenetrating space.

1444
01:09:52,340 --> 01:09:54,160
So all of our physics objects--

1445
01:09:54,160 --> 01:09:56,800
we give them a target of
where they need to go.

1446
01:09:56,800 --> 01:09:59,930
Sorry not all of our
physics options are shadows.

1447
01:09:59,930 --> 01:10:03,739
So just like the player volume and just
the examples I'm about to give you.

1448
01:10:03,739 --> 01:10:06,280
We told them where we want them
to go and they try their best

1449
01:10:06,280 --> 01:10:09,650
to apply forces and rotations to
go there, but if it doesn't work,

1450
01:10:09,650 --> 01:10:13,330
we're kind of SOL and
they do their best.

1451
01:10:13,330 --> 01:10:15,830
So I'm replicating that
for the player over there.

1452
01:10:15,830 --> 01:10:18,680
And we're also going to replicate
it for the cubes in a second

1453
01:10:18,680 --> 01:10:22,010
once I get around to placing them.

1454
01:10:22,010 --> 01:10:24,760
And so it's important to
note that we're not really

1455
01:10:24,760 --> 01:10:27,910
solving the discontinuity
in space because that

1456
01:10:27,910 --> 01:10:31,000
would be way too hard, at least
for a person of my skill level.

1457
01:10:31,000 --> 01:10:34,240
What we're doing is we're
saying each side has--

1458
01:10:34,240 --> 01:10:37,810
this cube over here is the master of
it's physics and this cube over here

1459
01:10:37,810 --> 01:10:39,550
is the master of its own physics.