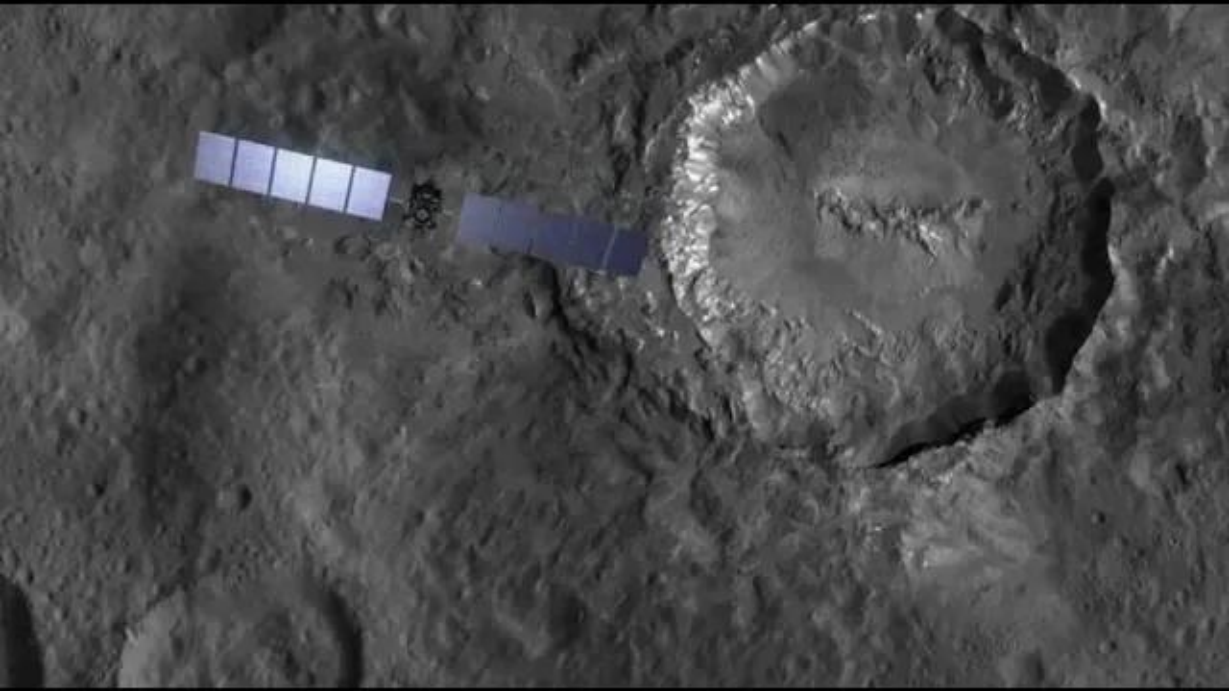

1
00:08:48,093 --> 00:08:50,663
[gentle music]

2
00:09:06,011 --> 00:09:08,380
- Hello everyone, my
name is Gay Yee Hill,

3
00:09:08,413 --> 00:09:12,551
and welcome to this NASA
science chat on Dawn.

4
00:09:12,584 --> 00:09:16,755
I am sitting in the control
room, mission control,

5
00:09:16,788 --> 00:09:18,724
of JPL, which is
home of the DSN,

6
00:09:18,757 --> 00:09:20,826
and right now, I don't
know if you can actually

7
00:09:20,859 --> 00:09:23,862
see it on the screen,
but the DSN is talking

8
00:09:23,895 --> 00:09:26,532
to the Dawn spacecraft right now

9
00:09:26,565 --> 00:09:31,537
on the Goldstone antenna like
it has for the past 11 years.

10
00:09:32,471 --> 00:09:34,340
It calls home every week.

11
00:09:34,373 --> 00:09:37,876
Well, the situation is

going to change after awhile

12
00:09:37,909 --> 00:09:41,780
because the spacecraft
is running out of fuel,

13
00:09:41,813 --> 00:09:45,317
which actually affects
its orientation

14
00:09:45,350 --> 00:09:48,921
so that it no longer can
point to earth and talk to us.

15
00:09:48,954 --> 00:09:52,891
So that means the mission
is coming to an end soon,

16
00:09:52,924 --> 00:09:55,661
and we thought that this
might be a great opportunity

17
00:09:55,694 --> 00:09:58,297
to talk to you and
have you talk to us

18
00:09:58,330 --> 00:10:00,232
about some of the great things

19
00:10:00,265 --> 00:10:02,234
this mission has accomplished.

20
00:10:02,267 --> 00:10:05,337
Let's take a look back, I
have some animation for you

21
00:10:05,370 --> 00:10:08,240
and we can look at what
this mission has done.

22
00:10:08,273 --> 00:10:12,144
It started in 2007,
it launched that year,

23
00:10:12,177 --> 00:10:15,447
and it was a mission to
the main asteroid belt.

24
00:10:15,480 --> 00:10:18,651
It was headed for the
two largest bodies

25
00:10:18,684 --> 00:10:21,787
in the asteroid belt,
Vesta and Ceres,

26
00:10:21,820 --> 00:10:23,589
and the reason why
they were going there

27
00:10:23,622 --> 00:10:28,027
was because these two places
are sort of like time capsules

28
00:10:28,060 --> 00:10:30,963
of the early solar system.

29
00:10:30,996 --> 00:10:34,600
Now, this is your opportunity
to ask us questions,

30
00:10:34,633 --> 00:10:36,935
so if you're a reporter
and you're dialed in,

31
00:10:36,968 --> 00:10:40,973
hit Star One, when you're
ready to ask a question,

32

00:10:41,006 --> 00:10:43,108
and if you're on social media,

33
00:10:43,141 --> 00:10:47,379
go ahead and use
the hashtag askNASA,

34
00:10:47,412 --> 00:10:50,015
and we'll put your
question in the queue.

35
00:10:50,048 --> 00:10:52,017
All right, let's
take a moment now

36
00:10:52,050 --> 00:10:53,786
and get some perspective.

37
00:10:53,819 --> 00:10:58,257
Before Dawn, this was
the only image we had

38
00:10:58,290 --> 00:11:03,362
of Vesta, it was an
image given to us

39
00:11:04,229 --> 00:11:05,864
by the Hubble Space Telescope,

40
00:11:05,897 --> 00:11:09,702
and then post-Dawn,
after Dawn arrived,

41
00:11:09,735 --> 00:11:13,972
we get a much better image,
and a better understanding

42
00:11:14,005 --> 00:11:18,043
after this spacecraft mapped
and orbited this body.

43
00:11:18,076 --> 00:11:20,779
Same goes for
Ceres, Ceres, again,

44
00:11:20,812 --> 00:11:25,617
the only image we had was from
the Hubble Space Telescope,

45
00:11:25,650 --> 00:11:29,254
just the fuzzy ball, and again,

46
00:11:29,287 --> 00:11:33,025
post-Dawn, you see
a whole lot more.

47
00:11:33,058 --> 00:11:35,728
So it's your opportunity
to ask questions,

48
00:11:35,761 --> 00:11:38,764
please do, use the
hashtag askNASA,

49
00:11:38,797 --> 00:11:42,301
and now, let's go ahead
and do an overview

50
00:11:42,334 --> 00:11:45,738
of this Mission to Small Worlds.

51
00:11:45,771 --> 00:11:48,474
[soft music]

52
00:11:48,507 --> 00:11:50,943
- You know, when you work
on a mission this long,

53
00:11:50,976 --> 00:11:52,478

it feels like a part of you.

54
00:11:53,912 --> 00:11:56,215
I've been a space enthusiast
since I was four years old.

55
00:11:57,616 --> 00:11:59,618
Getting to work on
a mission like this,

56
00:11:59,651 --> 00:12:01,887
it's a dream come true.

57
00:12:02,988 --> 00:12:05,991
To me, Dawn is
truly earth's first

58
00:12:06,024 --> 00:12:07,693
inter-planetary spaceship.

59
00:12:09,261 --> 00:12:13,132
No other spacecraft has
gone to a distant body,

60
00:12:13,165 --> 00:12:16,468
gone into orbit around
it, maneuvered there,

61
00:12:16,501 --> 00:12:19,571
then broken out of
orbit, traveled elsewhere

62
00:12:19,604 --> 00:12:22,341
in the solar system to
another alien world,

63
00:12:22,374 --> 00:12:23,976
and gone into orbit around it,

64

00:12:25,110 --> 00:12:26,779
and it does that
with ion propulsion,

65
00:12:26,812 --> 00:12:29,115
which I first heard of
on a Star Trek episode.

66
00:12:30,115 --> 00:12:31,617
We've turned ion propulsion

67
00:12:31,650 --> 00:12:34,186
from science fiction
into science fact.

68
00:12:35,353 --> 00:12:37,623
- The Dawn mission
really is a journey

69
00:12:37,656 --> 00:12:39,191
back to the beginning
of the solar system,

70
00:12:39,224 --> 00:12:41,127
and that's why we call it Dawn.

71
00:12:42,494 --> 00:12:45,063
We chose two time capsules
from the beginning

72
00:12:45,096 --> 00:12:47,733
of the solar system,
Vesta and Ceres,

73
00:12:47,766 --> 00:12:50,035
which are the most
massive and largest bodies

74
00:12:50,068 --> 00:12:51,370
in the main asteroid belt.

75
00:12:52,737 --> 00:12:54,573
They both formed very
early, when the solar system

76
00:12:54,606 --> 00:12:57,442
was forming out of the
protoplanetary disk,

77
00:12:57,475 --> 00:13:00,646
and yet they ended up in these
two very different states.

78
00:13:00,679 --> 00:13:05,751
Vesta is a dry, rocky body
that looks a lot like our moon.

79
00:13:06,351 --> 00:13:07,853
[soft music]

80
00:13:07,886 --> 00:13:10,856
Whereas Ceres had a lot of
water, and it looks much more

81
00:13:10,889 --> 00:13:13,792
like the icy moons of
the outer solar system.

82
00:13:13,825 --> 00:13:16,895
- And it seems like
what determined

83
00:13:16,928 --> 00:13:21,633
their eventual fate was the
location where they started,

84
00:13:21,666 --> 00:13:23,802
and we now believe
that Ceres formed

85
00:13:23,835 --> 00:13:27,039
much farther from the
sun than it is now.

86
00:13:27,072 --> 00:13:31,143
- [Carol] When Dawn found
the bright material on Ceres,

87
00:13:31,176 --> 00:13:34,079
what we saw was
completely mind blowing.

88
00:13:34,112 --> 00:13:37,082
It was made of sodium carbonate.

89
00:13:37,115 --> 00:13:41,386
Sodium carbonate is not
common in the solar system,

90
00:13:41,419 --> 00:13:45,324
but we see it coming out
of the plumes of Enceladus,

91
00:13:45,357 --> 00:13:49,194
we see it in lakes on
Earth, and here it was

92
00:13:49,227 --> 00:13:50,663
on the surface of Ceres.

93
00:13:53,031 --> 00:13:55,234
[soft music]

94
00:13:55,267 --> 00:13:56,501
- [Narrator] The mission
will end when Dawn runs out

95
00:13:56,534 --> 00:13:58,837
of the conventional

chemical propellant

96
00:13:58,870 --> 00:14:03,809
that it uses to orient itself
in the zero gravity of space.

97
00:14:03,842 --> 00:14:07,913
Dawn'll become this
inert celestial monument

98
00:14:07,946 --> 00:14:12,117
in orbit around the dwarf
planet that it unveiled.

99
00:14:12,150 --> 00:14:14,553
[soft music]

100
00:14:14,586 --> 00:14:16,822
Dawn serves as a
lasting reminder

101
00:14:16,855 --> 00:14:20,025
that the passion
for bold adventures

102
00:14:20,058 --> 00:14:25,064
and our noble aspirations
to reach out into the cosmos

103
00:14:26,197 --> 00:14:28,700
take us far far
beyond the confines

104
00:14:28,733 --> 00:14:31,837
of our humble home
here on planet earth.

105
00:14:31,870 --> 00:14:34,874
[soft string music]

106
00:14:47,886 --> 00:14:50,022
- All right, so we
know you're anxious

107
00:14:50,055 --> 00:14:53,225
to speak to our panel,
so let me introduce them.

108
00:14:53,258 --> 00:14:56,128
Let's start here at
JPL, Carol Raymond

109
00:14:56,161 --> 00:14:59,631
is the principal
investigator for Dawn,

110
00:14:59,664 --> 00:15:01,733
and then next to
her is Marc Rayman,

111
00:15:01,766 --> 00:15:05,704
different spelling, and
he is the mission director

112
00:15:05,737 --> 00:15:08,007
as well as the chief engineer.

113
00:15:09,174 --> 00:15:11,143
And then let's jump over
to NASA headquarters,

114
00:15:12,577 --> 00:15:16,481
there's Jim Green, and he is
the chief scientist for NASA.

115
00:15:16,514 --> 00:15:18,717
Jim, let's go ahead
and start with you.

116

00:15:18,750 --> 00:15:22,120
Tell us why NASA decided
to have this mission

117
00:15:22,153 --> 00:15:24,790
go to the main asteroid belt.

118
00:15:26,825 --> 00:15:29,594
- Well, you know, the asteroid
belt is a very unique area

119
00:15:29,627 --> 00:15:33,398
that surrounds our Sun
between Mars and Jupiter.

120
00:15:33,431 --> 00:15:36,101
It has hundreds of
thousands of objects

121
00:15:36,134 --> 00:15:39,304
that we know about, and
perhaps more than a million

122
00:15:39,337 --> 00:15:42,107
that are out there,
many yet to be found.

123
00:15:42,140 --> 00:15:45,077
But what's really unique
about this particular area

124
00:15:45,110 --> 00:15:49,614
is that it's really about
planetesimal material,

125
00:15:49,647 --> 00:15:54,653
small planetoid material
trying to become a planet,

126
00:15:55,720 --> 00:15:57,723

trying to get together,
but it's failed,

127
00:15:57,756 --> 00:16:01,493
and the reason why it's
failed is because of Jupiter.

128
00:16:01,526 --> 00:16:04,062
Jupiter's gravity is so immense

129
00:16:04,095 --> 00:16:06,999
and it pervades
the asteroid belt,

130
00:16:07,032 --> 00:16:09,901
that as objects collide
and then become,

131
00:16:09,934 --> 00:16:13,705
try to become one, and in a
process we call accretion,

132
00:16:13,738 --> 00:16:16,308
Jupiter's gravity
won't let that happen,

133
00:16:16,341 --> 00:16:18,377
kinda tugs 'em apart.

134
00:16:18,410 --> 00:16:23,281
This is what's kept this
region to be very primitive.

135
00:16:23,314 --> 00:16:26,685
Now, for Dawn, Dawn
is not an acronym.

136
00:16:26,718 --> 00:16:31,456
It's really going to the
beginning of our solar system,

137
00:16:31,489 --> 00:16:34,159
the dawn of our solar system,
which is one of the reasons

138
00:16:34,192 --> 00:16:38,030
why I really like the name,
and then interrogate two

139
00:16:38,063 --> 00:16:40,499
of the biggest bodies
that are there.

140
00:16:40,532 --> 00:16:42,901
You can't get much
better than that.

141
00:16:42,934 --> 00:16:44,136
- All right, thanks, Jim.

142
00:16:44,169 --> 00:16:47,739
So the two bodies
are Vesta and Ceres,

143
00:16:47,772 --> 00:16:49,975
and let's bring it
over to Marc Rayman.

144
00:16:50,008 --> 00:16:51,943
How did we get there?

145
00:16:51,976 --> 00:16:54,012
- Well, we took advantage
of ion propulsion,

146
00:16:54,045 --> 00:16:56,114
which I mentioned in
the video I first heard

147

00:16:56,147 --> 00:16:59,117
of in a Star Trek episode,
and ion propulsion

148
00:16:59,150 --> 00:17:01,486
has 10 times the efficiency

149
00:17:01,519 --> 00:17:03,488
of conventional
chemical propulsion,

150
00:17:03,521 --> 00:17:06,258
and that's really the key to
what allows us to undertake

151
00:17:06,291 --> 00:17:09,127
a truly uniquely
ambitious mission.

152
00:17:09,160 --> 00:17:11,196
So it would be like
having your car

153
00:17:11,229 --> 00:17:13,632
get 300 miles per
gallon, and without it,

154
00:17:13,665 --> 00:17:15,734
this mission would be
not just difficult,

155
00:17:15,767 --> 00:17:19,037
but impossible,
truly impossible.

156
00:17:19,070 --> 00:17:22,641
- So how does it work,
compared to what we're used to?

157
00:17:22,674 --> 00:17:25,577

- Well, again, it's just
fantastically efficient,

158
00:17:25,610 --> 00:17:27,345
and we can get into
the details later,

159
00:17:27,378 --> 00:17:30,482
perhaps of how it works, but
one of the interesting aspects

160
00:17:30,515 --> 00:17:32,884
of it is, although
it's very efficient,

161
00:17:32,917 --> 00:17:36,354
we only flow a very small
amount of propellant

162
00:17:36,387 --> 00:17:38,123
through the engine at a time,

163
00:17:38,156 --> 00:17:41,026
and so it's very efficient,
but it's very gentle,

164
00:17:41,059 --> 00:17:44,529
and in fact, the ion engine
pushes on the spacecraft

165
00:17:44,562 --> 00:17:47,966
as hard as this single piece
of paper pushes on my hand.

166
00:17:47,999 --> 00:17:49,901
I think we even
have an animation

167
00:17:49,934 --> 00:17:54,306
showing the use of

this remarkable system

168
00:17:54,339 --> 00:17:56,608
going into orbit around
Ceres, it really does produce

169
00:17:56,641 --> 00:17:59,744
this cool blue glow like
in science fiction movies,

170
00:17:59,777 --> 00:18:02,214
and you can see here
how maneuverable it is.

171
00:18:02,247 --> 00:18:06,218
And with this very gentle
thrust in the zero gravity,

172
00:18:06,251 --> 00:18:08,453
frictionless
conditions of space,

173
00:18:08,486 --> 00:18:11,189
gradually the
effect can build up.

174
00:18:11,222 --> 00:18:13,925
So it would take Dawn
four days to accelerate

175
00:18:13,958 --> 00:18:16,128
from zero to 60 miles per hour,

176
00:18:16,161 --> 00:18:18,763
which doesn't exactly make
you think of a drag racer,

177
00:18:18,796 --> 00:18:20,832
but instead of
thrusting for four days,

178
00:18:20,865 --> 00:18:25,003
if you thrust for a week
or a month or a year,

179
00:18:25,036 --> 00:18:27,772
or as Dawn now has,
for nearly six years,

180
00:18:27,805 --> 00:18:30,809
you can achieve
fantastically high velocity.

181
00:18:30,842 --> 00:18:35,848
In Dawn's case, more than
25,700 miles per hour.

182
00:18:36,981 --> 00:18:37,883
So this is what I
like to think of

183
00:18:37,916 --> 00:18:40,485
as acceleration with patience.

184
00:18:40,518 --> 00:18:42,721
- So it means you can go
to a whole lot more places,

185
00:18:42,754 --> 00:18:44,122
I would imagine.
- It opens up destinations

186
00:18:44,155 --> 00:18:47,659
in the solar system that
NASA would otherwise

187
00:18:47,692 --> 00:18:49,895
be completely unable to reach,

188

00:18:49,928 --> 00:18:53,999
and it allowed us, not only to
get to both Vesta and Ceres,

189
00:18:54,032 --> 00:18:58,036
but orbit them, linger there
for long periods of time,

190
00:18:58,069 --> 00:19:01,439
make detailed, comprehensive
investigations,

191
00:19:01,472 --> 00:19:04,276
really scrutinize them
and develop intimate,

192
00:19:04,309 --> 00:19:07,946
richly detailed portraits,
and that's what has

193
00:19:07,979 --> 00:19:11,216
produced the fabulous
scientific return that we have.

194
00:19:11,249 --> 00:19:13,051
- And speaking of the
scientific return,

195
00:19:13,084 --> 00:19:14,553
let's go to Carol now.

196
00:19:14,586 --> 00:19:19,591
I think a lot of people know
that these are two bodies

197
00:19:20,992 --> 00:19:23,695
in the main asteroid belt,
but they have no idea

198
00:19:23,728 --> 00:19:26,898

what they're like,
what they are,

199
00:19:26,931 --> 00:19:29,801
one is a dwarf planet,
the other is not,

200
00:19:29,834 --> 00:19:32,003
can you explain
these two bodies?

201
00:19:32,036 --> 00:19:35,707
- Sure, I think the
important thing to realize

202
00:19:35,740 --> 00:19:38,643
about these two bodies, is,
as was said in the video

203
00:19:38,676 --> 00:19:41,513
and Jim also repeated, that
these are time capsules

204
00:19:41,546 --> 00:19:43,315
from the very beginning
of the solar system.

205
00:19:43,348 --> 00:19:45,617
And what we're after
with the Dawn mission

206
00:19:45,650 --> 00:19:48,286
is to understand what
the conditions were like

207
00:19:48,319 --> 00:19:51,256
in the early solar
nebula, when the bodies

208
00:19:51,289 --> 00:19:54,459

started to accrete out of
the protoplanetary disk,

209
00:19:54,492 --> 00:19:57,329
and as these bodies
accreted, they incorporated

210
00:19:57,362 --> 00:20:00,332
the material that was native
to their neighborhoods,

211
00:20:00,365 --> 00:20:03,702
and then they kept
accreting into bigger

212
00:20:03,735 --> 00:20:06,638
and bigger bodies, but
these earliest blocks

213
00:20:06,671 --> 00:20:09,507
tell us an enormous
amount about the processes

214
00:20:09,540 --> 00:20:11,910
and the materials
that were available,

215
00:20:11,943 --> 00:20:13,812
and so we wanna answer questions

216
00:20:13,845 --> 00:20:16,681
of how and when did
these bodies form,

217
00:20:16,714 --> 00:20:20,185
and then how did that
material move around

218
00:20:20,218 --> 00:20:22,621
in the solar system as

the planets were forming

219
00:20:22,654 --> 00:20:25,957
and we're actually trying
to get at big questions

220
00:20:25,990 --> 00:20:28,460
like how and when did life arise

221
00:20:28,493 --> 00:20:32,330
and then was it distributed
within our solar system

222
00:20:32,363 --> 00:20:34,132
by these small bodies that may

223
00:20:34,165 --> 00:20:37,636
have incorporated
life within them.

224
00:20:37,669 --> 00:20:40,839
So Ceres and Vesta are
these two intact survivors

225
00:20:40,872 --> 00:20:43,541
from this era, and they're
very different objects,

226
00:20:43,574 --> 00:20:46,945
so they represent two
chapters, we could say,

227
00:20:46,978 --> 00:20:51,216
in solar system history,
and Vesta is a good example

228
00:20:51,249 --> 00:20:53,385
of the inner solar system,
that's on the right,

229
00:20:53,418 --> 00:20:57,022
it's a dry rocky body,
it underwent melting

230
00:20:57,055 --> 00:21:00,025
and formed a core,
kind of like the Earth,

231
00:21:00,058 --> 00:21:02,694
Mars and the Moon,
whereas Ceres,

232
00:21:02,727 --> 00:21:06,197
the large dwarf planet, a
thousand kilometers in diameter,

233
00:21:06,230 --> 00:21:09,834
this is really a small
world, and it formed

234
00:21:09,867 --> 00:21:14,439
with much more water, still
retaining a lot of water,

235
00:21:14,472 --> 00:21:16,241
and the processes that
went on inside of Ceres

236
00:21:16,274 --> 00:21:18,510
were very very
different than Vesta.

237
00:21:18,543 --> 00:21:21,146
So by understanding how
these two bodies formed

238
00:21:21,179 --> 00:21:23,248
and evolved, we're
getting a picture

239
00:21:23,281 --> 00:21:28,186
of the development of other
bodies in the solar system

240
00:21:28,219 --> 00:21:30,155
at that earliest epoch.

241
00:21:30,188 --> 00:21:32,057
- And how bodies
like Earth formed.

242
00:21:32,090 --> 00:21:36,928
- And those bodies came
together to form the Earth,

243
00:21:36,961 --> 00:21:39,998
and so it also tells
us about the materials

244
00:21:40,031 --> 00:21:43,401
that were available to form
the Earth and other planets.

245
00:21:43,434 --> 00:21:45,603
- And Marc, you wanted
to add something?

246
00:21:45,636 --> 00:21:47,105
- I was just gonna, just
add a little context

247
00:21:47,138 --> 00:21:49,007
for the size of Ceres,
that thousand kilometers,

248
00:21:49,040 --> 00:21:53,211
that's almost 600 miles
across, it's a big place,

249

00:21:53,244 --> 00:21:57,215
and Vesta has an average
diameter of 325 miles,

250
00:21:57,248 --> 00:21:58,917
very large.

251
00:21:59,384 --> 00:22:01,486
- All three of you have
set a fantastic stage

252
00:22:01,519 --> 00:22:04,556
for our questions, again,
if you are a reporter,

253
00:22:04,589 --> 00:22:08,393
feel free to hit Star One,
and you will be placed

254
00:22:08,426 --> 00:22:10,228
into the queue
for your question,

255
00:22:10,261 --> 00:22:14,432
and if you are on social media
and you also have a question,

256
00:22:14,465 --> 00:22:17,969
go ahead and use
the hashtag askNASA.

257
00:22:19,404 --> 00:22:21,172
And we have some questions
already, let's get started.

258
00:22:21,205 --> 00:22:26,211
The first one is from James
Moore, and here's the question.

259
00:22:27,612 --> 00:22:30,281

Biggest difference, if any,
between Vesta and Ceres?

260
00:22:30,314 --> 00:22:33,385
And biggest surprise
in exploring these two?

261
00:22:33,418 --> 00:22:35,253
Who wants to get started?

262
00:22:35,286 --> 00:22:37,088
Go ahead, yeah.
- Yeah.

263
00:22:37,121 --> 00:22:38,323
- [Jim] Well, I'll be happy to.

264
00:22:38,356 --> 00:22:40,992
- Oh, all right, Jim.
- Go ahead, Jim.

265
00:22:41,025 --> 00:22:42,260
- Jim, take it away.

266
00:22:42,293 --> 00:22:45,563
- You know me, to me, as
a planetary scientist,

267
00:22:45,596 --> 00:22:49,334
but also not a specialist
in these bodies,

268
00:22:49,367 --> 00:22:51,669
this is almost
like night and day.

269
00:22:51,702 --> 00:22:55,407
I mean, the concept
that you had much more

270
00:22:55,440 --> 00:23:00,445
of an icy set of materials
that formed Ceres

271
00:23:01,712 --> 00:23:03,681
wasn't the environment
that we had for Vesta

272
00:23:03,714 --> 00:23:07,819
as we just talked about, and
that Vesta was big enough,

273
00:23:07,852 --> 00:23:10,388
that it, indeed, early
on in its history

274
00:23:10,421 --> 00:23:14,092
melted the material
and created a core.

275
00:23:14,125 --> 00:23:17,395
This is the basic process
of differentiation.

276
00:23:17,428 --> 00:23:20,498
This is what we call,
then, the devolvement

277
00:23:20,531 --> 00:23:23,134
of the beginning of planets.

278
00:23:23,167 --> 00:23:26,704
So it's like what we'd
call a planetesimal,

279
00:23:26,737 --> 00:23:29,808
a small body that's
starting that whole process,

280

00:23:29,841 --> 00:23:32,010
you got a whole collection
of these together,

281
00:23:32,043 --> 00:23:34,379
and you form things
like the Earth.

282
00:23:34,412 --> 00:23:37,849
But their contrast,
from one mission alone,

283
00:23:37,882 --> 00:23:40,084
is just, to me, so startling.

284
00:23:40,117 --> 00:23:42,454
- [Gay] Carol, do you
have something to add?

285
00:23:42,487 --> 00:23:45,890
- Well, I would say that
the biggest difference

286
00:23:45,923 --> 00:23:49,093
is clearly the interior
and the chemistry,

287
00:23:49,126 --> 00:23:51,863
as Jim's already talked about,

288
00:23:51,896 --> 00:23:54,966
but also the fact
that we now understand

289
00:23:54,999 --> 00:23:58,236
that Ceres must have
formed much farther out

290
00:23:58,269 --> 00:24:00,939
in the solar system,

it's more like bodies

291
00:24:00,972 --> 00:24:04,442
in the Kuiper Belt, in the
trans-Neptunian region,

292
00:24:04,475 --> 00:24:07,378
so that it was transported in

293
00:24:07,411 --> 00:24:09,280
during a dynamic reorganization

294
00:24:09,313 --> 00:24:13,218
in the early solar system,
so it's even more compelling

295
00:24:13,251 --> 00:24:15,553
because it represents
a class of objects

296
00:24:15,586 --> 00:24:19,090
that's very hard to
get to with spacecraft,

297
00:24:19,123 --> 00:24:21,526
and then we have Vesta
that's much more like

298
00:24:21,559 --> 00:24:24,963
the terrestrial planets,
and so we learn so much

299
00:24:24,996 --> 00:24:29,701
from learning about how this
early forming planetesimal

300
00:24:29,734 --> 00:24:31,803
formed and evolved.
- Which was so amazing

301
00:24:31,836 --> 00:24:34,506
about this mission,
it was a twofer.

302
00:24:34,539 --> 00:24:36,107
- It was, and in
fact, I was gonna say,

303
00:24:36,140 --> 00:24:39,010
their superficially similar
distances from the Sun

304
00:24:39,043 --> 00:24:43,114
really belie the fact that
they're very very different.

305
00:24:43,147 --> 00:24:44,782
I mean, the premise
of the question

306
00:24:44,815 --> 00:24:46,251
was maybe they're
similar, but what are some

307
00:24:46,284 --> 00:24:47,919
of the key differences,
but really,

308
00:24:47,952 --> 00:24:50,421
they're different
in myriad ways.

309
00:24:50,454 --> 00:24:53,791
- All right, well, we have
a reporter on the line.

310
00:24:53,824 --> 00:24:57,862
We have Dave Mosher
with Business Insider.

311
00:24:57,895 --> 00:24:59,264
Dave, what's your question?

312
00:25:00,698 --> 00:25:02,500
- [Dave] Thanks for doing
this, really appreciate it.

313
00:25:02,533 --> 00:25:04,969
I guess this is for
anyone who takes it,

314
00:25:05,002 --> 00:25:06,404
wants to take it.
- Okay.

315
00:25:06,437 --> 00:25:10,108
- [Dave] So, a couple questions,
do you have an exact date

316
00:25:10,141 --> 00:25:13,578
or approximate date for
when the mission will end,

317
00:25:13,611 --> 00:25:15,914
and then a followup to that,

318
00:25:15,947 --> 00:25:20,084
why is the cutoff 20 years
and what is, sort of,

319
00:25:20,117 --> 00:25:23,388
the planetary protection
explanation for that,

320
00:25:23,421 --> 00:25:26,457
is that when, sort of,
enough of the microbes

321
00:25:26,490 --> 00:25:29,260

that might be left
on there are croaked,

322
00:25:29,293 --> 00:25:30,995
[Gay laughs]
is that something

323
00:25:31,028 --> 00:25:33,798
of an arbitrary designation?

324
00:25:33,831 --> 00:25:36,734
- Okay, so the first
part of the question was,

325
00:25:36,767 --> 00:25:39,971
we don't have, I do
have an exact date

326
00:25:40,004 --> 00:25:42,340
for when the mission
will end, 2018.

327
00:25:44,241 --> 00:25:47,979
More to the point, we can't
predict it with perfect accuracy

328
00:25:48,012 --> 00:25:51,416
because the spacecraft relies
on hydrazine propellant,

329
00:25:51,449 --> 00:25:56,287
which we use to control
its orientation in space.

330
00:25:56,320 --> 00:25:57,522
That is, it doesn't
have anything to do

331
00:25:57,555 --> 00:26:00,558
with where it goes,

but how we orient it,

332
00:26:00,591 --> 00:26:02,660
and when it exhausts
this propellant,

333
00:26:02,693 --> 00:26:04,162
it will no longer
be able to point

334
00:26:04,195 --> 00:26:07,098
its solar arrays at the
sun or its antenna at earth

335
00:26:07,131 --> 00:26:10,768
or its sensors at Ceres,
and we can estimate

336
00:26:10,801 --> 00:26:12,937
that that will happen, most
likely, between the middle

337
00:26:12,970 --> 00:26:15,473
of this month and the
middle of October,

338
00:26:15,506 --> 00:26:17,942
but for various technical
reasons we could get into

339
00:26:17,975 --> 00:26:20,511
if we wanted to,
perhaps afterwards,

340
00:26:20,544 --> 00:26:23,848
we can't determine that
with exquisite accuracy.

341
00:26:23,881 --> 00:26:26,784
And so the spacecraft

will operate normally

342
00:26:26,817 --> 00:26:28,920
until it exhausts
this propellant

343
00:26:28,953 --> 00:26:30,755
and then it will no
longer be able to control

344
00:26:30,788 --> 00:26:33,925
its orientation and it won't
be able to communicate with us.

345
00:26:33,958 --> 00:26:36,127
- All right, we're going
to move on right now

346
00:26:36,160 --> 00:26:39,897
to another focus area,
and that is Ceres.

347
00:26:39,930 --> 00:26:41,933
That's where Dawn is right now,

348
00:26:41,966 --> 00:26:44,636
and one of the most
compelling things

349
00:26:44,669 --> 00:26:48,306
about being at Ceres
are these bright spots

350
00:26:48,339 --> 00:26:51,576
that we saw as we were
coming into Ceres,

351
00:26:51,609 --> 00:26:54,946
and here's a video we
call The Bright Stuff.

352
00:26:56,280 --> 00:26:57,415
[vibrant music]

353
00:26:57,448 --> 00:26:58,983
- Approaching Ceres,
we saw this very bright

354
00:26:59,016 --> 00:27:02,020
region on the surface,
and then as we got closer

355
00:27:02,053 --> 00:27:03,888
and closer, you
saw that there were

356
00:27:03,921 --> 00:27:06,290
multiple bright regions
in this one crater.

357
00:27:06,323 --> 00:27:07,959
- What we're seeing
is an indication

358
00:27:07,992 --> 00:27:09,527
that there are liquid brines,

359
00:27:10,895 --> 00:27:12,430
potentially in the subsurface,
even in the present day,

360
00:27:13,864 --> 00:27:15,700
rising to the surface and
becoming these bright spots,

361
00:27:15,733 --> 00:27:17,201
and that tells us that
there has to be a process

362

00:27:17,234 --> 00:27:21,005
providing energy to then drive
these fluids to the surface.

363
00:27:21,038 --> 00:27:22,640
We call them bright spots,

364
00:27:22,673 --> 00:27:24,809
but actually it's
a relative term.

365
00:27:24,842 --> 00:27:26,477
The brightest
bright spot on Ceres

366
00:27:26,510 --> 00:27:29,881
has an albedo of
around .5, which is

367
00:27:29,914 --> 00:27:32,583
about the same
brightness as dirty snow.

368
00:27:32,616 --> 00:27:34,886
We found that there are
over 300 bright spots

369
00:27:34,919 --> 00:27:36,954
all over the surface of Ceres,

370
00:27:36,987 --> 00:27:38,489
and that indicates that this

371
00:27:38,522 --> 00:27:40,858
is a relatively
widespread process.

372
00:27:40,891 --> 00:27:43,294
- [Jennifer] The salts that
we see in Occator Crater

373
00:27:43,327 --> 00:27:45,897
are a similar
composition to salts

374
00:27:45,930 --> 00:27:48,633
that we find in Mono
Lake, in California.

375
00:27:48,666 --> 00:27:50,735
- Ceres represents
something of a bridge

376
00:27:50,768 --> 00:27:52,837
between the bodies of
the inner solar system

377
00:27:52,870 --> 00:27:54,272
and the outer solar system.

378
00:27:54,305 --> 00:27:56,908
In the inner solar system
we see rocky bodies,

379
00:27:56,941 --> 00:27:59,577
in the outer solar system we
more broadly see icy bodies,

380
00:27:59,610 --> 00:28:01,813
and Ceres is sitting
somewhere in between,

381
00:28:02,947 --> 00:28:04,082
but we know now from
the bright spots

382
00:28:04,115 --> 00:28:06,084
that it is changing,
the bright spots

383
00:28:07,084 --> 00:28:08,553
that are already on the surface

384
00:28:08,586 --> 00:28:09,787
are darkening over time scales

385
00:28:09,820 --> 00:28:11,689
of hundreds of millions
of years or even less,

386
00:28:11,722 --> 00:28:13,691
but we also see that
the bright spots

387
00:28:13,724 --> 00:28:17,762
maybe are still forming, so
Ceres is still an active body

388
00:28:17,795 --> 00:28:19,230
and we still have
a lot of questions

389
00:28:19,263 --> 00:28:21,265
about what are the
processes that are modifying

390
00:28:21,298 --> 00:28:24,102
Ceres' surface over time,
and what that tells us

391
00:28:24,135 --> 00:28:26,604
about the internal
nature of Ceres

392
00:28:26,637 --> 00:28:28,006
and how it actually formed.

393
00:28:31,175 --> 00:28:32,744
- All right, the subject matter

394
00:28:32,777 --> 00:28:34,879
is Ceres and the bright spots,

395
00:28:34,912 --> 00:28:38,282
and the intriguing
thing that you heard

396
00:28:38,315 --> 00:28:41,352
in that video is, still active.

397
00:28:41,385 --> 00:28:44,021
Things are still going on.
- That's right.

398
00:28:44,054 --> 00:28:45,456
- Can you talk about that?
- Sure.

399
00:28:45,489 --> 00:28:48,726
This was one of the
biggest surprises at Ceres

400
00:28:48,759 --> 00:28:53,765
was that we found features
that clearly are very young.

401
00:28:55,132 --> 00:28:58,569
We know that from the
brightness of the features,

402
00:28:58,602 --> 00:29:01,439
the types of materials and
the fact that they degrade

403
00:29:01,472 --> 00:29:03,541
over time, as Nathan
was talking about,

404

00:29:03,574 --> 00:29:08,580
but also these very young
looking shapes, morphology,

405
00:29:09,647 --> 00:29:12,383
and one of the real postcards

406
00:29:12,416 --> 00:29:15,386
for our Ceres activity
is Ahuna Mons.

407
00:29:15,419 --> 00:29:19,524
It is, Mons means mountain
in planetary nomenclature,

408
00:29:19,557 --> 00:29:23,361
and so this is a lonely
mountain, it's the only one

409
00:29:23,394 --> 00:29:25,496
on the surface of Ceres,
I think we have a picture

410
00:29:25,529 --> 00:29:30,101
of it, yah, and you can see
that the slopes are very steep

411
00:29:30,134 --> 00:29:32,703
and you can see that
that bright material

412
00:29:32,736 --> 00:29:34,405
which we know now
is sodium carbonate

413
00:29:34,438 --> 00:29:38,810
with ammonium chloride salt
is streaking down the sides,

414
00:29:38,843 --> 00:29:43,047

it's actually
starting to degrade

415
00:29:43,080 --> 00:29:47,852
and to become flatter,
really, over time.

416
00:29:47,885 --> 00:29:49,720
So we know that this
feature is very young

417
00:29:49,753 --> 00:29:52,824
and we believe that it formed
because there are pockets

418
00:29:52,857 --> 00:29:55,927
of brine in the subsurface,
leftover from the phase

419
00:29:55,960 --> 00:29:58,296
when we had a global
subsurface ocean.

420
00:29:58,329 --> 00:30:02,233
An so these briny, salty
fluids are being squeezed up,

421
00:30:02,266 --> 00:30:04,969
likely due to the pressure
of some freezing material

422
00:30:05,002 --> 00:30:08,105
in the subsurface, and they're
extruding on the surface

423
00:30:08,138 --> 00:30:11,976
and forming this beautiful
mountainous feature.

424
00:30:12,009 --> 00:30:13,544

- It is gorgeous.
- It's 13,000 feet high.

425
00:30:13,577 --> 00:30:16,814
I mean, this is an
impressive structure.

426
00:30:16,847 --> 00:30:19,951
- And it's the only one
on the entire surface.

427
00:30:19,984 --> 00:30:22,820
- Right, and so
what the thinking is

428
00:30:22,853 --> 00:30:27,024
is that it's not the only
one that's ever existed,

429
00:30:27,057 --> 00:30:28,860
but it's the one
that we see today

430
00:30:28,893 --> 00:30:30,895
preserved because it's so young.

431
00:30:30,928 --> 00:30:34,966
So over time, these features
will basically relax

432
00:30:34,999 --> 00:30:38,703
and degrade and they'll
become much flatter.

433
00:30:38,736 --> 00:30:41,072
So you can think about it
like erosion on the Earth,

434
00:30:41,105 --> 00:30:43,274
but erosion doesn't

take place on Ceres,

435
00:30:43,307 --> 00:30:46,210
but there are processes
which will degrade

436
00:30:46,243 --> 00:30:48,646
features over time, so
we think that this one

437
00:30:48,679 --> 00:30:50,915
is just very very young.
- Wow.

438
00:30:50,948 --> 00:30:54,218
- You can think of it just
as if you pinch your skin,

439
00:30:54,251 --> 00:30:56,354
after awhile it relaxes
back to its original shape,

440
00:30:56,387 --> 00:30:58,456
and the same processes
occur on Ceres,

441
00:30:58,489 --> 00:31:01,259
same kind of processes,
where, over time

442
00:31:01,292 --> 00:31:04,662
these features flatten out
and eventually disappear.

443
00:31:04,695 --> 00:31:07,465
- All right, well, we
have a caller on the line,

444
00:31:07,498 --> 00:31:11,402
Mike Wall with space.com,

Mike, what's your question?

445
00:31:12,903 --> 00:31:14,872
- [Mike] Thank you, guys
for especially doing this,

446
00:31:14,905 --> 00:31:18,242
first of all, and I
apologize if this question

447
00:31:18,275 --> 00:31:19,877
is a little redundant,
but I actually

448
00:31:19,910 --> 00:31:21,412
had to hop in a little late.

449
00:31:21,445 --> 00:31:25,049
Could you just, yeah, just
kinda walk through, Marc,

450
00:31:25,082 --> 00:31:27,885
what's the long term,
sort of, state of Dawn?

451
00:31:27,918 --> 00:31:31,522
I mean, it's going to
stay in orbit around Ceres

452
00:31:31,555 --> 00:31:34,492
for a number of years after
the fuel runs out, right,

453
00:31:34,525 --> 00:31:37,261
do you have an idea of how
long that's going to be,

454
00:31:37,294 --> 00:31:40,731
and when it's, gonna
eventually spiral down

455
00:31:40,764 --> 00:31:43,367
and actually crash
onto the surface?

456
00:31:43,400 --> 00:31:46,504
- Okay, well, were the listeners
able to hear that question

457
00:31:46,537 --> 00:31:48,472
as well?
- Yes.

458
00:31:48,505 --> 00:31:52,076
- Okay, so the reason
we're, first of all,

459
00:31:52,109 --> 00:31:54,278
let me remind you of the reason
we're leaving it in orbit,

460
00:31:54,311 --> 00:31:58,082
in fact, this relates to the
question that came in earlier.

461
00:31:58,115 --> 00:32:01,385
We're leaving it in
orbit to protect Ceres

462
00:32:01,418 --> 00:32:05,389
from the terrestrial
contamination of Dawn,

463
00:32:05,422 --> 00:32:07,925
and it's not because
of the microbes

464
00:32:07,958 --> 00:32:09,126
that were asked about earlier.

465
00:32:09,159 --> 00:32:10,428
There are microbes
that are hardy enough

466
00:32:10,461 --> 00:32:13,698
to last far far longer
than the few decades

467
00:32:13,731 --> 00:32:15,967
that we're concerned about.

468
00:32:16,000 --> 00:32:18,536
Rather, it's because,
with its combination

469
00:32:18,569 --> 00:32:22,139
of organic materials,
water, other chemicals,

470
00:32:22,172 --> 00:32:25,876
internal heat, Ceres represents
a place in the solar system

471
00:32:25,909 --> 00:32:27,878
that we're interested
in for future

472
00:32:27,911 --> 00:32:30,548
astrobiological exploration.

473
00:32:30,581 --> 00:32:32,616
And the idea of
leaving it in orbit

474
00:32:32,649 --> 00:32:35,553
for at least 20 years,
which is the requirement,

475
00:32:35,586 --> 00:32:38,389

is that that's long enough
that if NASA chooses

476
00:32:38,422 --> 00:32:42,660
to mount a follow on mission,
to conduct subsequent

477
00:32:42,693 --> 00:32:45,830
astrobiological exploration,
it's long enough

478
00:32:45,863 --> 00:32:49,834
to do that without it
being compromised by Dawn,

479
00:32:49,867 --> 00:32:53,237
and so, in answer to
your question, Mike,

480
00:32:53,270 --> 00:32:56,574
we are required to guarantee
that the spacecraft

481
00:32:56,607 --> 00:32:58,576
will remain in orbit
for at least 20 years,

482
00:32:58,609 --> 00:33:00,411
and that was part of
the basis upon which

483
00:33:00,444 --> 00:33:02,747
we chose the orbit
that it's in now.

484
00:33:02,780 --> 00:33:05,649
But our analyses give
us very high confidence,

485
00:33:05,682 --> 00:33:08,853

greater than 99%, that
it will stay in orbit

486
00:33:08,886 --> 00:33:13,891
for even half a century, and
most likely longer than that.

487
00:33:15,359 --> 00:33:17,261
- And Jim, do you have any
response to that as well?

488
00:33:19,963 --> 00:33:22,233
- Indeed, Marc's exactly right.

489
00:33:22,266 --> 00:33:27,271
The concept that we found of
the body still being active

490
00:33:29,106 --> 00:33:32,410
allows us the exciting
possibility of going back

491
00:33:32,443 --> 00:33:34,512
and studying it further.

492
00:33:34,545 --> 00:33:37,848
You know, if Ceres
was more like the Moon

493
00:33:37,881 --> 00:33:40,951
then we wouldn't
be so particular

494
00:33:40,984 --> 00:33:45,990
about finding a way to
keep Ceres more pristine,

495
00:33:47,157 --> 00:33:50,895
and so consequently, the
body is so intriguing

496
00:33:50,928 --> 00:33:53,731
in so many ways, we just
absolutely gotta go back.

497
00:33:53,764 --> 00:33:55,566
This is a dwarf planet.

498
00:33:55,599 --> 00:33:58,536
It is maintaining
a spherical shape.

499
00:33:58,569 --> 00:34:02,440
The gravity is allowing
the motion of the surfaces

500
00:34:02,473 --> 00:34:04,875
with other processes going on,

501
00:34:04,908 --> 00:34:09,914
and in, that's evolving, the
material that we see sometimes

502
00:34:11,248 --> 00:34:13,384
on the surface can be
actually fairly young.

503
00:34:13,417 --> 00:34:18,322
Tens of millions of years old,
and so there's upwellings,

504
00:34:18,355 --> 00:34:22,093
there's kind of processes
that we just don't understand,

505
00:34:22,126 --> 00:34:24,195
and that's what's
drawing us back.

506

00:34:24,228 --> 00:34:28,099
And so we wanna study those
in their natural form.

507
00:34:28,132 --> 00:34:30,835
- All right, well, we have
a social media question now,

508
00:34:30,868 --> 00:34:34,305
this is from Don
Sparrow, his question is,

509
00:34:34,338 --> 00:34:38,642
does the composition of
Ceres and Vesta vary much

510
00:34:38,675 --> 00:34:43,214
from Earth or the Moon?
- Yes, it does.

511
00:34:43,247 --> 00:34:47,017
Vesta actually has
a lot of affinity

512
00:34:47,050 --> 00:34:49,053
or similarities to the Moon,

513
00:34:49,086 --> 00:34:52,223
it's a dry rocky basaltic crust,

514
00:34:52,256 --> 00:34:56,861
has basaltic crust on the
surface, has an iron core.

515
00:34:56,894 --> 00:34:59,997
The density is similar to
the terrestrial planets,

516
00:35:00,030 --> 00:35:05,035
so yes, the moon has a

core, the moon has basalts

517
00:35:05,068 --> 00:35:07,938
on the surface, so it is
similar in that sense,

518
00:35:07,971 --> 00:35:11,909
but Ceres is a completely
different object,

519
00:35:11,942 --> 00:35:15,112
and it's interesting
that we knew there was

520
00:35:15,145 --> 00:35:16,914
a lot of ice on
Ceres, and we knew

521
00:35:16,947 --> 00:35:18,849
that it had been
liberated from the rock

522
00:35:18,882 --> 00:35:21,519
and formed a, we
predicted that it formed

523
00:35:21,552 --> 00:35:24,421
a subsurface ocean,
and we expected

524
00:35:24,454 --> 00:35:26,457
to see that ice
covering the surface,

525
00:35:26,490 --> 00:35:29,160
like we see on
Jupiter's moon, Europa.

526
00:35:29,193 --> 00:35:31,595
But instead, we got to

Ceres and we saw this

527
00:35:31,628 --> 00:35:33,797
very heavily cratered surface,

528
00:35:33,830 --> 00:35:35,733
which made us scratch
our heads a little bit.

529
00:35:35,766 --> 00:35:37,801
Did this process really happen?

530
00:35:37,834 --> 00:35:39,036
What are we looking at?

531
00:35:39,069 --> 00:35:41,805
And it took awhile to
realize that the surface

532
00:35:41,838 --> 00:35:46,844
of Ceres is a mixture
of clays, salts and ice,

533
00:35:48,011 --> 00:35:51,048
and a very light strong
phase which is keeping

534
00:35:51,081 --> 00:35:54,185
it kind of as that,
looking like a crust

535
00:35:54,218 --> 00:35:56,687
and being able to
retain its craters.

536
00:35:56,720 --> 00:35:59,123
And that light phase
is a clathrate,

537

00:36:00,324 --> 00:36:03,394
it's a gas hydrate.
- It's low density,

538
00:36:03,427 --> 00:36:06,363
but very strong.
- Yeah, so we could not

539
00:36:06,396 --> 00:36:10,401
really have imagined what
the surface of Ceres,

540
00:36:11,635 --> 00:36:15,105
that it would look like
this, yet the chemistry

541
00:36:15,138 --> 00:36:16,874
and the materials
that make up Ceres

542
00:36:16,907 --> 00:36:19,577
are very very different
from the Moon.

543
00:36:19,610 --> 00:36:21,278
- All right, well,
we're going to move on

544
00:36:21,311 --> 00:36:23,447
to the next topic,
but just before,

545
00:36:23,480 --> 00:36:27,418
let's do one more call,
it is from Ken Kramer

546
00:36:27,451 --> 00:36:29,053
with, what was the?

547
00:36:30,687 --> 00:36:33,858

Space UpClose is the
publication, Ken?

548
00:36:34,992 --> 00:36:36,894
- [Ken] Thank you,
thanks for doing this.

549
00:36:36,927 --> 00:36:38,729
It's a pleasure
to be part of this

550
00:36:38,762 --> 00:36:40,064
as well, since the launch.

551
00:36:40,097 --> 00:36:42,099
My question, really,
is for all three,

552
00:36:42,132 --> 00:36:44,602
and it does pertain
to the bright spots.

553
00:36:44,635 --> 00:36:47,204
I'd like to know,
can one of you review

554
00:36:47,237 --> 00:36:49,540
what do we know about
subsurface oceans

555
00:36:49,573 --> 00:36:53,010
or lakes of Ceres in the
past and the present,

556
00:36:53,043 --> 00:36:55,713
and second, to go back
to the follow on mission.

557
00:36:55,746 --> 00:36:59,650
Would you consider,

what would you do?

558
00:36:59,683 --> 00:37:01,919
Would it be a sample
return mission, possibly,

559
00:37:01,952 --> 00:37:04,622
to the sodium carbonate
or Ahuna Mons,

560
00:37:04,655 --> 00:37:06,357
or elsewhere, thank you.

561
00:37:07,691 --> 00:37:10,394
- Whoo, some loaded
questions there. [laughing]

562
00:37:10,427 --> 00:37:13,831
So what do we know
about the activity,

563
00:37:13,864 --> 00:37:18,869
the gravity and topography
that we've mapped on Ceres

564
00:37:20,337 --> 00:37:22,807
have allowed us to infer the
properties of the interior,

565
00:37:23,840 --> 00:37:25,042
and the chemistry of the surface

566
00:37:25,075 --> 00:37:28,612
tells us a tremendous
amount about the process

567
00:37:28,645 --> 00:37:32,850
of the ice melting,
the interaction between

568
00:37:32,883 --> 00:37:37,554
the water and the rock
creating these salts

569
00:37:37,587 --> 00:37:41,392
and ice, and now we're
seeing those salts,

570
00:37:41,425 --> 00:37:43,627
the sodium carbonates,
aluminum chloride,

571
00:37:43,660 --> 00:37:45,296
on the surface of Ceres.

572
00:37:45,329 --> 00:37:46,997
How did they get there?

573
00:37:47,030 --> 00:37:51,702
We see them in these very
specific young deposits,

574
00:37:51,735 --> 00:37:56,140
so we know that there is a
process that's mobilizing

575
00:37:56,173 --> 00:37:58,809
those materials in the
subsurface and bringing them up,

576
00:37:58,842 --> 00:38:02,813
so there has to be some
liquid still inside of Ceres,

577
00:38:02,846 --> 00:38:05,349
some briny fluids,
likely very deep

578
00:38:05,382 --> 00:38:07,484

where it gets a
little bit warmer,

579
00:38:07,517 --> 00:38:11,221
and then the action
of, likely impact heat

580
00:38:11,254 --> 00:38:14,892
is causing those
fluids to further melt

581
00:38:14,925 --> 00:38:17,061
and get driven to the surface.

582
00:38:17,094 --> 00:38:19,930
So, as Jim talked about before,

583
00:38:19,963 --> 00:38:24,134
we know there is an
active geological cycle

584
00:38:24,167 --> 00:38:28,172
that's bringing material
from deep up to the surface,

585
00:38:28,205 --> 00:38:30,207
and that gives us an
opportunity to sample

586
00:38:30,240 --> 00:38:35,246
some of Ceres' interior material

587
00:38:36,380 --> 00:38:39,550
by sending a mission
to the surface.

588
00:38:39,583 --> 00:38:43,654
The Holy Grail of any planetary
science is sample return,

589
00:38:43,687 --> 00:38:46,256
we all know that, it's
also very difficult

590
00:38:46,289 --> 00:38:49,660
and to an object like
Ceres, you really wanna know

591
00:38:49,693 --> 00:38:51,428
where to sample, there's so many

592
00:38:51,461 --> 00:38:52,930
different interesting materials

593
00:38:52,963 --> 00:38:56,533
that I think the next step has
to be to explore the surface

594
00:38:56,566 --> 00:38:58,635
before we get to the sample.

595
00:38:58,668 --> 00:39:02,072
- Well, we are trying to cover
an awful lot of territory

596
00:39:02,105 --> 00:39:04,508
because the mission did so much,

597
00:39:04,541 --> 00:39:07,978
and let's not ignore
the other place

598
00:39:08,011 --> 00:39:10,547
that Dawn went to,
which was Vesta.

599
00:39:10,580 --> 00:39:13,417
And so here's a short
video to show you

600
00:39:13,450 --> 00:39:15,886
some of the greatest hits there.

601
00:39:15,919 --> 00:39:18,489
[upbeat music]

602
00:40:30,594 --> 00:40:32,396
So there you have
it, that is Vesta,

603
00:40:32,429 --> 00:40:34,531
and what's so
interesting about it is

604
00:40:34,564 --> 00:40:39,537
it's so similar, it has a
core, it has so many things

605
00:40:41,304 --> 00:40:44,308
that are so similar to
the rocky planets and--

606
00:40:44,341 --> 00:40:46,643
- Things that are familiar to us

607
00:40:46,676 --> 00:40:49,680
because it's similar to
the Earth and the Moon,

608
00:40:50,814 --> 00:40:52,816
but the other reason
we know Vesta very well

609
00:40:52,849 --> 00:40:55,452
is that pieces of it have
been falling on the Earth,

610
00:40:55,485 --> 00:40:58,856

a tremendous amount
of material from Vesta

611
00:40:58,889 --> 00:41:01,458
has been falling on the
Earth for a long time.

612
00:41:01,491 --> 00:41:03,494
So there's a certain
class of meteorites

613
00:41:03,527 --> 00:41:06,396
called the Howardite
Eucrite Diogenite series,

614
00:41:06,429 --> 00:41:10,501
that constitute about 6%
of the meteorites that fall

615
00:41:10,534 --> 00:41:12,636
to the Earth, and that's more

616
00:41:12,669 --> 00:41:14,671
than the Moon and Mars combined.

617
00:41:14,704 --> 00:41:18,308
So, here is one of
the pieces of Vesta

618
00:41:18,341 --> 00:41:20,511
that's fallen to the
Earth, this is a piece

619
00:41:20,544 --> 00:41:22,880
of the Millbillillie eucrite
that fell in Australia,

620
00:41:22,913 --> 00:41:27,918
and it's, properties
of these meteorites

621
00:41:29,252 --> 00:41:32,055
have been studied in
laboratories for decades,

622
00:41:32,088 --> 00:41:36,093
and it was recognized
as far back as 1969

623
00:41:36,126 --> 00:41:39,763
that the reflected
light from Vesta

624
00:41:39,796 --> 00:41:42,766
looked very much
like the measurements

625
00:41:42,799 --> 00:41:45,502
of the spectra of these
meteorites in the lab.

626
00:41:45,535 --> 00:41:47,838
- Sort of like a fingerprint?
- Like a fingerprint.

627
00:41:47,871 --> 00:41:50,741
And so that begged the question,

628
00:41:50,774 --> 00:41:53,644
did all of this material
actually come from Vesta?

629
00:41:53,677 --> 00:41:57,981
And the answer that
Dawn provided was yes,

630
00:41:58,014 --> 00:42:00,183
we believe that
the HED meteorites

631
00:42:00,216 --> 00:42:02,519
all came, all could
come from Vesta,

632
00:42:02,552 --> 00:42:06,156
and therefore, we have
executed the first

633
00:42:06,189 --> 00:42:08,292
reverse sample return mission,

634
00:42:08,325 --> 00:42:10,260
we studied the samples
and then we went

635
00:42:10,293 --> 00:42:11,895
and looked at where
they came from,

636
00:42:11,928 --> 00:42:15,766
and so this has made Vesta an
even more interesting object,

637
00:42:15,799 --> 00:42:17,768
and just one more
thing about that

638
00:42:17,801 --> 00:42:22,806
is that we don't know of any
other body in the solar system

639
00:42:23,940 --> 00:42:26,677
that really matches
these meteorites

640
00:42:26,710 --> 00:42:29,179
like Vesta does, so that
means that even though

641

00:42:29,212 --> 00:42:31,281
there's a couple
that look similar,

642
00:42:31,314 --> 00:42:35,052
Vesta is a singular and unique
body in our solar system,

643
00:42:35,085 --> 00:42:38,455
so again, we're learning
a lot about the diversity

644
00:42:38,488 --> 00:42:41,658
and about the early
evolution by being able

645
00:42:41,691 --> 00:42:46,396
to study this body in the
laboratory and out in space.

646
00:42:46,429 --> 00:42:48,832
- And we actually have far more
material in our laboratories

647
00:42:48,865 --> 00:42:51,001
from Vesta, thanks
to these meteorites,

648
00:42:51,034 --> 00:42:53,804
than we do even from the Moon
with the more than 840 pounds

649
00:42:53,837 --> 00:42:56,206
of material Apollo
astronauts brought back.

650
00:42:56,239 --> 00:42:58,175
- So you're kind of
ahead of the game

651

00:42:58,208 --> 00:43:01,311
because you have
samples right here.

652
00:43:01,344 --> 00:43:05,248
- Exactly, and the science
community has been studying

653
00:43:05,281 --> 00:43:08,552
these rocks in every
manner possible,

654
00:43:10,687 --> 00:43:12,856
so it does highlight
how important

655
00:43:12,889 --> 00:43:17,227
it is to link space exploration
with our robotic emissaries

656
00:43:17,260 --> 00:43:20,797
with the painstakingly
detailed work

657
00:43:20,830 --> 00:43:22,799
that occurs in the laboratories,

658
00:43:22,832 --> 00:43:24,334
to really understand
the chemistry

659
00:43:24,367 --> 00:43:27,270
and the processes which
are captured there.

660
00:43:27,303 --> 00:43:30,040
- All right, well, we have
a social media question.

661
00:43:30,073 --> 00:43:31,041

- [Jim] You know,
that's a fantastic--

662
00:43:31,074 --> 00:43:33,010
- Oh, I'm sorry, Jim, go ahead.

663
00:43:33,043 --> 00:43:34,911
- Oh, that's all right.

664
00:43:34,944 --> 00:43:39,316
Well, I just have to say
that section of a meteorite

665
00:43:39,349 --> 00:43:43,387
is spectacular, look
how large that is,

666
00:43:43,420 --> 00:43:47,457
and the uniformity of
it and then the details

667
00:43:47,490 --> 00:43:49,826
that we can tease out, I mean,

668
00:43:49,859 --> 00:43:53,363
the concept that we
can actually relate

669
00:43:53,396 --> 00:43:56,433
those pieces of rock
that fall from the sky

670
00:43:56,466 --> 00:44:00,570
with real objects is
the start of, I think,

671
00:44:00,603 --> 00:44:04,408
a lot more that we wanna
do relating these pieces

672
00:44:04,441 --> 00:44:06,543
as we go out, back
out to the asteroid,

673
00:44:06,576 --> 00:44:08,712
or to other asteroids.

674
00:44:08,745 --> 00:44:11,381
It's just really spectacular.

675
00:44:11,414 --> 00:44:14,518
Dawn has been that
first spacecraft

676
00:44:14,551 --> 00:44:17,187
that's allowed us to
make that connection.

677
00:44:17,220 --> 00:44:19,489
You know, we have
teams of people

678
00:44:19,522 --> 00:44:23,260
that go down to the
Antarctic every summer

679
00:44:23,293 --> 00:44:26,830
to be able, in snowmobiles,
crossing the snows,

680
00:44:26,863 --> 00:44:29,866
looking for falls, fresh
falls, also looking for

681
00:44:29,899 --> 00:44:32,869
meteorites that have
been on the ice shelf

682
00:44:32,902 --> 00:44:35,605

for long periods of time
that have now surfaced.

683
00:44:35,638 --> 00:44:38,842
We bring 600 to 900 of
'em back every season,

684
00:44:38,875 --> 00:44:42,879
cull through them,
and we only understand

685
00:44:42,912 --> 00:44:47,317
a small fraction of them, and
so it's these kind of things

686
00:44:47,350 --> 00:44:50,087
that are just spectacular
progress that we're making.

687
00:44:50,120 --> 00:44:54,925
Dawn has just made a
wonderful connection for us.

688
00:44:54,958 --> 00:44:58,061
- Well, this question might
be a little repetitious,

689
00:44:58,094 --> 00:45:01,298
but maybe you can give your
personal nugget on this.

690
00:45:01,331 --> 00:45:05,268
What's the importance
of understanding Vesta?

691
00:45:05,301 --> 00:45:10,307
- Well, Vesta represents one
of the very earliest forming

692
00:45:11,174 --> 00:45:13,410

bodies in our solar system.

693
00:45:13,443 --> 00:45:17,147
We can trace it back
to the first solids

694
00:45:17,180 --> 00:45:19,716
that were condensing
that contained a lot

695
00:45:19,749 --> 00:45:22,819
of this short lived,
radioactive material,

696
00:45:22,852 --> 00:45:26,556
aluminum 26, and we know
because of the size of Vesta

697
00:45:26,589 --> 00:45:28,291
and the fact that it
melted completely,

698
00:45:28,324 --> 00:45:31,928
we can peg when it
formed to be between

699
00:45:31,961 --> 00:45:36,767
one and 1.5 million years
after the first grains

700
00:45:36,800 --> 00:45:38,702
were forming out of
our solar nebula.

701
00:45:38,735 --> 00:45:42,439
- Which was a little more than
4.5, six billion years ago.

702
00:45:43,606 --> 00:45:48,211
- So Vesta, we have

our bronze model here,

703
00:45:48,244 --> 00:45:53,250
is really such a time
capsule, and is telling us

704
00:45:54,684 --> 00:45:59,690
about the fact that this
body could come together

705
00:46:00,790 --> 00:46:02,325
very very quickly,
and we learned

706
00:46:02,358 --> 00:46:05,495
from looking at the
pattern of the craters

707
00:46:05,528 --> 00:46:07,831
that hit Vesta, because
it's been around

708
00:46:07,864 --> 00:46:11,568
for a very long time in the
middle of our solar system,

709
00:46:11,601 --> 00:46:14,971
we could find out that
the other planetesimals

710
00:46:15,004 --> 00:46:17,674
forming at that time likely
grew, also, very quickly

711
00:46:17,707 --> 00:46:22,512
because of the number and the
size of the craters on Vesta.

712
00:46:22,545 --> 00:46:25,749
So we've learned,

not only how quickly

713
00:46:25,782 --> 00:46:30,788
and the kind of evolution
that Vesta underwent

714
00:46:32,155 --> 00:46:34,057
at that very earliest
time, but we're also able

715
00:46:34,090 --> 00:46:37,427
to understand the bigger picture

716
00:46:37,460 --> 00:46:40,597
of how these objects were
kind of like popping up

717
00:46:40,630 --> 00:46:45,636
out of the nebula and
growing very big very fast.

718
00:46:46,836 --> 00:46:48,004
- All right, well,
we're gonna go on

719
00:46:48,037 --> 00:46:49,639
to another section,
but before that,

720
00:46:49,672 --> 00:46:52,108
let's take a phone
call from Dave Mosher

721
00:46:52,141 --> 00:46:54,144
and Business Insider, Dave?

722
00:46:54,177 --> 00:46:56,813
- [Dave] Thanks
again for doing this.

723
00:46:56,846 --> 00:46:59,216
Just wanted to follow
up on the sample return

724
00:46:59,249 --> 00:47:01,985
mission question, what would
that mission look like?

725
00:47:02,018 --> 00:47:05,055
Would the primary
goal be to look for,

726
00:47:05,088 --> 00:47:10,093
look into the geology or
the astrobiological signs,

727
00:47:11,527 --> 00:47:13,430
either past or present, or
would you try to do both

728
00:47:13,463 --> 00:47:16,233
at the same time, and then
a quick followup to that

729
00:47:16,266 --> 00:47:19,002
would be, could that same
mission also determine

730
00:47:19,035 --> 00:47:22,372
whether or not there is a
subsurface ocean, thank you.

731
00:47:22,405 --> 00:47:25,375
- All right, well we're gonna
lob that over to you, Jim.

732
00:47:25,408 --> 00:47:30,414
[laughing] Well,
indeed, many months ago

733
00:47:31,614 --> 00:47:33,850
we started to form a
group of scientists

734
00:47:33,883 --> 00:47:37,287
to really be able to
tease the architecture

735
00:47:37,320 --> 00:47:38,889
of a new mission out.

736
00:47:38,922 --> 00:47:41,091
This is so important
for us to do

737
00:47:41,124 --> 00:47:46,129
so that we can determine how
we would make major progress,

738
00:47:47,630 --> 00:47:50,267
the questions we would answer,
the type of instruments

739
00:47:50,300 --> 00:47:52,669
that we would take
that would enable us

740
00:47:52,702 --> 00:47:55,872
to probe below the surface,
that would enable us

741
00:47:55,905 --> 00:48:00,043
to make specific
measurements in great detail

742
00:48:00,076 --> 00:48:03,179
of the variations of
the surface material

743

00:48:03,212 --> 00:48:07,217
and the salts, and then
how we're gonna get there,

744
00:48:07,250 --> 00:48:09,085
you know, how do we land?

745
00:48:09,118 --> 00:48:12,822
One of the reasons that's
really important to recognize

746
00:48:12,855 --> 00:48:16,693
that Dawn is in such a
highly elliptical orbit,

747
00:48:16,726 --> 00:48:18,395
is it has the ability, then,

748
00:48:18,428 --> 00:48:20,864
to give us high
resolution imaging.

749
00:48:20,897 --> 00:48:25,903
This is absolutely essential,
as a way for us in the future

750
00:48:26,769 --> 00:48:28,071
to be able to leverage that data

751
00:48:28,104 --> 00:48:30,340
such that we can land safely.

752
00:48:30,373 --> 00:48:33,476
So those things are
all coming together,

753
00:48:33,509 --> 00:48:35,712
the science team has
been talking about this

754
00:48:35,745 --> 00:48:37,480
and meeting, they're
trying to construct

755
00:48:37,513 --> 00:48:40,317
the best way to go, and
we'll get the results,

756
00:48:40,350 --> 00:48:43,119
probably in another
nine months or so,

757
00:48:43,152 --> 00:48:45,722
and then that'll feed
into a larger process

758
00:48:45,755 --> 00:48:48,325
as more studies are being done

759
00:48:48,358 --> 00:48:52,462
and we'll work in the next,
we'll work out the next decade

760
00:48:52,495 --> 00:48:54,864
and whether one of those
missions would indeed

761
00:48:54,897 --> 00:48:56,633
being going back to Ceres.

762
00:48:56,666 --> 00:48:59,169
- All right, we have still
another phone question,

763
00:48:59,202 --> 00:49:03,807
this is from Leo Enright
from The Irish Times, Leo?

764
00:49:03,840 --> 00:49:07,043

- [Leo] Thanks very
much, Irish Television.

765
00:49:07,076 --> 00:49:11,281
- Ah, I thought that
was wrong, okay, hi Leo.

766
00:49:11,314 --> 00:49:13,750
- [Leo] Indeed, I'm
going to feel young.

767
00:49:13,783 --> 00:49:16,353
I always research with Jennifer
Scully on this briefing,

768
00:49:16,386 --> 00:49:20,256
it's great to see
her get videoed in.

769
00:49:20,289 --> 00:49:23,493
But my question, going
back to the comments

770
00:49:23,526 --> 00:49:26,830
about Vesta and
how cratered it is,

771
00:49:26,863 --> 00:49:31,835
I'm wondering how come
Ceres is not so cratered,

772
00:49:32,969 --> 00:49:36,039
or is there something
that I'm missing

773
00:49:36,072 --> 00:49:37,907
or is more what's to be done?

774
00:49:37,940 --> 00:49:41,611
I mean, we look at Pluto,

several huge craters

775
00:49:41,644 --> 00:49:45,882
on Pluto, notably, of
course, the heart feature,

776
00:49:47,483 --> 00:49:51,021
and so I just wondered,
what is the theory?

777
00:49:51,054 --> 00:49:53,857
Was Ceres just not bombarded,

778
00:49:53,890 --> 00:49:56,593
or are we not
seeing the evidence?

779
00:49:56,626 --> 00:49:58,461
- Okay, great question.

780
00:49:58,494 --> 00:50:01,798
We do see a lot of
craters on Ceres

781
00:50:01,831 --> 00:50:04,701
up to about 100
kilometers in diameter.

782
00:50:04,734 --> 00:50:08,405
The population that's
smaller than that

783
00:50:08,438 --> 00:50:13,443
is what would be expected for
a body in Ceres' neighborhood.

784
00:50:15,178 --> 00:50:17,914
Based on the models of
the asteroid flocks,

785
00:50:17,947 --> 00:50:19,916
which have been developed
from cratering records

786
00:50:19,949 --> 00:50:21,985
on myriad solar system bodies,

787
00:50:22,018 --> 00:50:26,756
so clearly there is a deficit
of large craters on Ceres.

788
00:50:26,789 --> 00:50:30,927
There are three that
are fairly large,

789
00:50:30,960 --> 00:50:33,196
the Urvara, Yalode in
the southern hemisphere,

790
00:50:33,229 --> 00:50:37,500
and then the large Kerwan
crater closer to the equator.

791
00:50:37,533 --> 00:50:42,472
And they clearly have
cratering characteristics,

792
00:50:42,505 --> 00:50:46,676
the characteristics of a
classical impact crater,

793
00:50:46,709 --> 00:50:49,179
and then after that,
there's really nothing.

794
00:50:49,212 --> 00:50:54,217
So we speculate
that the properties

795

00:50:55,685 --> 00:50:58,188
of the subsurface are such
that these larger craters

796
00:50:58,221 --> 00:51:01,958
will relax over time,
not that they didn't,

797
00:51:01,991 --> 00:51:03,993
not that these
impacts didn't occur,

798
00:51:04,026 --> 00:51:07,030
but that the record of them
has been largely erased.

799
00:51:07,063 --> 00:51:12,069
There are several crypto
basins, meaning hidden.

800
00:51:12,935 --> 00:51:14,904
We kind of can see the outline

801
00:51:14,937 --> 00:51:19,309
in a rim topography, and
they're very deep excavations,

802
00:51:19,342 --> 00:51:21,544
and we've identified
three of those,

803
00:51:21,577 --> 00:51:23,446
and that would be
consistent with what

804
00:51:23,479 --> 00:51:26,483
we would have expected in
terms of the largest impacts

805
00:51:26,516 --> 00:51:29,819

hitting Ceres, so the conclusion

806
00:51:29,852 --> 00:51:32,122
that was reached by the
studies of science team

807
00:51:32,155 --> 00:51:37,160
is yes, Ceres experienced
the same impact history

808
00:51:38,628 --> 00:51:41,631
as other objects, or that
would be expected there,

809
00:51:41,664 --> 00:51:45,835
but the surface has, it's
not so much resurfaced

810
00:51:45,868 --> 00:51:48,438
as the surface has
been modified over time

811
00:51:48,471 --> 00:51:51,441
such that you can't recognize
those signatures anymore.

812
00:51:51,474 --> 00:51:53,109
- In some ways, it's similar
to what we were talking

813
00:51:53,142 --> 00:51:56,279
about earlier with the
Ahuna Mons volcano,

814
00:51:56,312 --> 00:52:01,318
over time the ground relaxes
back to its original shape.

815
00:52:02,518 --> 00:52:04,053
- All right, well

speaking of time,

816
00:52:04,086 --> 00:52:07,524
we're going to move on to a
look at the end of the mission

817
00:52:07,557 --> 00:52:09,392
and what's going to take place.

818
00:52:09,425 --> 00:52:14,431
I have a video here
that is taken by a DLR--

819
00:52:16,132 --> 00:52:18,101
- Our partners in Germany.
- Our German partners,

820
00:52:18,134 --> 00:52:22,005
and it's a view from
the two lowest orbits

821
00:52:22,038 --> 00:52:26,376
and the final orbit is the
orbit that Dawn will be in

822
00:52:26,409 --> 00:52:29,479
for decades to come.
- For decades to come.

823
00:52:29,512 --> 00:52:31,081
And the one before,
the orbit before that

824
00:52:32,281 --> 00:52:33,183
was about the same
height above Ceres

825
00:52:34,450 --> 00:52:35,518
as the International
Space Station

826
00:52:35,551 --> 00:52:37,020
is above Earth, about 240 miles.

827
00:52:37,053 --> 00:52:38,288
- All right, well
let's take a look.

828
00:52:38,321 --> 00:52:40,891
[dreamy music]

829
00:53:45,087 --> 00:53:49,559
And those are spectacular
images, they really are.

830
00:53:49,592 --> 00:53:51,027
- The lowest ones, we
should've clarified,

831
00:53:51,060 --> 00:53:53,296
were taken from an altitude
of only about 22 miles.

832
00:53:53,329 --> 00:53:55,265
That's three times
higher than you are

833
00:53:55,298 --> 00:53:57,567
when you fly cross country
on a commercial aircraft.

834
00:53:57,600 --> 00:53:59,068
- And let's talk about that.

835
00:53:59,101 --> 00:54:03,373
That is Dawn's final orbit,
and we've got the actual view

836
00:54:03,406 --> 00:54:06,075

of the ellipse to
give people an idea.

837
00:54:06,108 --> 00:54:09,879
That is the final orbit
that Dawn will be locked in

838
00:54:09,912 --> 00:54:11,914
from here on out.
- Right.

839
00:54:11,947 --> 00:54:14,050
That's the orbit that it's
been in since June 9th,

840
00:54:14,083 --> 00:54:19,089
and every 27 hours it swoops
down to just 22 miles,

841
00:54:20,289 --> 00:54:24,494
and then it flies out,
soars up to 2,500 miles,

842
00:54:24,527 --> 00:54:26,262
and then comes back down again.

843
00:54:26,295 --> 00:54:28,731
- Let's talk about that,
how the mission will end.

844
00:54:28,764 --> 00:54:33,169
It'll stay in that orbit, but
why did we pick that method?

845
00:54:33,202 --> 00:54:35,305
- Because, as we
discussed earlier,

846
00:54:35,338 --> 00:54:39,175
we wanna protect Ceres from

the terrestrial contamination,

847
00:54:39,208 --> 00:54:42,211
the organic materials that
are onboard the spacecraft,

848
00:54:42,244 --> 00:54:44,614
but at the same time,
we wanted to get

849
00:54:44,647 --> 00:54:47,216
as low as we possibly
could in this final phase

850
00:54:47,249 --> 00:54:49,552
of the mission to get
the highest resolution,

851
00:54:49,585 --> 00:54:51,888
the coolest, most
spectacular views,

852
00:54:51,921 --> 00:54:56,059
and other rich science
data that are not pictures,

853
00:54:56,092 --> 00:54:58,194
but spectrometry

854
00:54:58,227 --> 00:55:00,263
and measurements of
nuclear radiation

855
00:55:00,296 --> 00:55:04,167
that emanates from Ceres,
and so we found this orbit

856
00:55:04,200 --> 00:55:07,904
that allowed us to come
down to very low altitude

857
00:55:07,937 --> 00:55:11,140
about once a day, and yet
the orbit would remain

858
00:55:11,173 --> 00:55:13,676
relatively stable
for decades to come,

859
00:55:13,709 --> 00:55:16,179
and so that's why
we're leaving it there.

860
00:55:16,212 --> 00:55:18,448
- Carol, anything
regarding this?

861
00:55:18,481 --> 00:55:21,517
- Well, I just
wanted to mention,

862
00:55:21,550 --> 00:55:24,454
you could see clearly
from that animation

863
00:55:24,487 --> 00:55:29,292
that this orbit was like
putting your glasses on,

864
00:55:29,325 --> 00:55:32,395
if you don't see very
well, and all of a sudden

865
00:55:32,428 --> 00:55:34,230
all these rich
details popping out,

866
00:55:34,263 --> 00:55:37,367
and it's really given
us a lot to work with

867
00:55:37,400 --> 00:55:39,669
and try to understand
the geologic processes

868
00:55:39,702 --> 00:55:42,839
which are placing these
bright deposits on the surface

869
00:55:42,872 --> 00:55:46,209
and giving us some
insights as to what kind of

870
00:55:46,242 --> 00:55:48,511
plumbing system is going
on under the surface.

871
00:55:48,544 --> 00:55:52,515
So it's just been, just a
fabulous end to the mission.

872
00:55:52,548 --> 00:55:55,051
- All right, well, we have
some social media questions,

873
00:55:55,084 --> 00:55:57,153
in fact, we have a lot of
social media questions.

874
00:55:57,186 --> 00:56:00,823
Here's one from Facebook,
from Paul Higgins.

875
00:56:00,856 --> 00:56:04,327
The Expanse imagines a
future in which humans live

876
00:56:04,360 --> 00:56:08,131
on Ceres and mine
in the asteroid belt

877
00:56:08,164 --> 00:56:09,932
for water, ice and minerals.

878
00:56:09,965 --> 00:56:11,768
This is a TV show.

879
00:56:11,801 --> 00:56:14,137
Do you see anything
plausible in that?

880
00:56:14,170 --> 00:56:17,874
- Well, so I'll mention, I
haven't seen the TV show,

881
00:56:17,907 --> 00:56:20,977
but I've read the novels,
which I find very entertaining.

882
00:56:21,010 --> 00:56:23,413
I will mention that
their depiction of Ceres

883
00:56:23,446 --> 00:56:27,917
is entirely different, not
at all like the actual Ceres,

884
00:56:27,950 --> 00:56:32,221
but I'm sure at some
point, as humankind expands

885
00:56:32,254 --> 00:56:34,290
farther and farther
into the solar system,

886
00:56:34,323 --> 00:56:37,059
far in the future,
sure it's credible

887

00:56:37,092 --> 00:56:40,396
that people will be there,
and because a substantial

888
00:56:40,429 --> 00:56:45,301
fraction of Ceres mass is
water ice, it's a resource

889
00:56:45,334 --> 00:56:47,570
that future explorers
could use at some point,

890
00:56:47,603 --> 00:56:51,407
but Ceres is farther than
Mars, it's not easy to get to.

891
00:56:51,440 --> 00:56:54,143
That's one of the reasons
we needed ion propulsion,

892
00:56:54,176 --> 00:56:58,981
and so I think that
future is pretty far away.

893
00:56:59,014 --> 00:57:02,852
- All right, here is
a second question.

894
00:57:02,885 --> 00:57:06,656
What's the next step
for ion propulsion?

895
00:57:06,689 --> 00:57:08,791
Jim, do you wanna
take that first?

896
00:57:08,824 --> 00:57:11,194
Next step for ion propulsion.

897
00:57:11,227 --> 00:57:12,962

- Sure, in fact, right.

898
00:57:12,995 --> 00:57:18,001
So indeed, many of our
technologists are developing

899
00:57:19,535 --> 00:57:24,541
a capability that leverages
the same basic physics,

900
00:57:25,941 --> 00:57:28,578
the same basic concept
but make it more efficient

901
00:57:28,611 --> 00:57:33,282
and make it a larger
thrust associated with it.

902
00:57:33,315 --> 00:57:37,620
So we've been investing into
that for many many years,

903
00:57:38,954 --> 00:57:41,524
and in fact, human
exploration is now starting

904
00:57:41,557 --> 00:57:44,460
to pick up the idea that indeed,

905
00:57:44,493 --> 00:57:47,563
as we go back to the
Moon and have a system

906
00:57:47,596 --> 00:57:49,465
called The Gateway,
this will be in

907
00:57:49,498 --> 00:57:51,968
what we call cislunar
space, in the vicinity

908
00:57:52,001 --> 00:57:54,337
of the Moon and the
Earth, enabling us

909
00:57:54,370 --> 00:57:57,707
to do all kinds of new
research on the Moon.

910
00:57:57,740 --> 00:58:02,345
That that will also
have these ion engines,

911
00:58:02,378 --> 00:58:04,347
so I think we're just seeing now

912
00:58:04,380 --> 00:58:07,517
the start of how they can
be applied in many missions.

913
00:58:07,550 --> 00:58:10,620
I would like to see
more planetary missions

914
00:58:10,653 --> 00:58:14,090
have this capability, it's
becoming more available.

915
00:58:14,123 --> 00:58:16,092
- What do you think, Marc?

916
00:58:16,125 --> 00:58:17,527
- I agree with Jim.

917
00:58:17,560 --> 00:58:19,529
I mean, the way
I think of it is,

918
00:58:20,930 --> 00:58:22,932

ion propulsion is a tool in the
toolbox of mission designers

919
00:58:22,965 --> 00:58:26,335
and so for each mission,
the question to ask

920
00:58:26,368 --> 00:58:28,738
is what's the most
effective way for NASA

921
00:58:28,771 --> 00:58:32,041
to get the science,
given the constraints

922
00:58:32,074 --> 00:58:36,546
that we have of physics
and the responsible use

923
00:58:36,579 --> 00:58:39,081
of taxpayer dollars that we're
privileged enough to use.

924
00:58:39,114 --> 00:58:42,919
I think we'll find many many
future exciting missions,

925
00:58:42,952 --> 00:58:45,521
destinations that we
couldn't otherwise reach,

926
00:58:45,554 --> 00:58:49,091
and missions that we
couldn't otherwise undertake

927
00:58:49,124 --> 00:58:51,761
that will take advantage
of ion propulsion.

928
00:58:51,794 --> 00:58:55,698

- And we're coming close to
the final 10 minutes here.

929
00:58:55,731 --> 00:58:59,468
Your thoughts as this
mission is coming to a close,

930
00:58:59,501 --> 00:59:03,005
your personal feelings
about this mission,

931
00:59:03,038 --> 00:59:04,540
what are your thoughts?

932
00:59:04,573 --> 00:59:07,376
Do you focus on the fact
that it's coming to an end,

933
00:59:07,409 --> 00:59:10,479
or all the great stuff you got?

934
00:59:10,512 --> 00:59:13,115
- Absolutely all the
great stuff that we got.

935
00:59:13,148 --> 00:59:16,218
We have so much data that we've,

936
00:59:16,251 --> 00:59:18,654
I won't say we've just
scratched the surface,

937
00:59:18,687 --> 00:59:23,693
but we really haven't done
all of the deep analysis

938
00:59:24,760 --> 00:59:28,397
and put things
together in comparison

939
00:59:28,430 --> 00:59:31,367
with other bodies that we
know of in the solar system,

940
00:59:31,400 --> 00:59:36,305
and so I'm really looking
forward to working on these data

941
00:59:36,338 --> 00:59:38,374
with the community,
working on these data

942
00:59:39,842 --> 00:59:42,511
and really see how far we
can go in understanding

943
00:59:42,544 --> 00:59:45,047
that comes from this
nebulous mission,

944
00:59:45,080 --> 00:59:49,352
which has taken up a large
portion of my career.

945
00:59:49,385 --> 00:59:53,522
It was selected
in the year 2000,

946
00:59:53,555 --> 00:59:58,561
and it's just been a
long and awesome journey.

947
01:00:00,496 --> 01:00:02,298
- Marc, how about you?

948
01:00:02,331 --> 01:00:04,834
- Well, I of course agree
with what Carol said.

949

01:00:04,867 --> 01:00:06,702
I mean, the spacecraft
and the mission

950
01:00:06,735 --> 01:00:11,607
are coming to an end, but
the advancement of knowledge

951
01:00:11,640 --> 01:00:14,477
is gonna continue and
probably even accelerate

952
01:00:14,510 --> 01:00:17,413
as there are more and more
analyses applied to the data

953
01:00:17,446 --> 01:00:20,483
but with regard to
the mission itself,

954
01:00:20,516 --> 01:00:23,886
as we said in the video and
Carol said, it's a part of you.

955
01:00:23,919 --> 01:00:27,757
I mean, it's something,
it's really exciting

956
01:00:27,790 --> 01:00:31,027
to work on a mission
that's so far away,

957
01:00:31,060 --> 01:00:33,329
and Dawn is, it's more
than a million times

958
01:00:33,362 --> 01:00:35,564
farther away than
the space station,

959

01:00:35,597 --> 01:00:39,201
well over a thousand times
farther than the Moon.

960
01:00:39,234 --> 01:00:41,671
Farther than the Sun, I
think it's really exciting,

961
01:00:41,704 --> 01:00:45,741
personally, to be
able to work on that,

962
01:00:45,774 --> 01:00:47,810
and I think it should be
exciting for everybody.

963
01:00:47,843 --> 01:00:50,980
This is as mission of
humankind, as are other

964
01:00:51,013 --> 01:00:54,984
inter-planetary missions,
and I just think it's,

965
01:00:55,017 --> 01:00:58,487
it should be exciting
for everybody to look up

966
01:00:58,520 --> 01:01:01,924
at the night sky and think,
Gosh, we have spacecraft

967
01:01:01,957 --> 01:01:04,126
out there, it's, I
think it's really--

968
01:01:04,159 --> 01:01:07,997
- It's pretty amazing.
- It is, it is really amazing.

969

01:01:08,030 --> 01:01:10,066
And when it comes to an end,

970
01:01:10,099 --> 01:01:15,104
it's, I'm both sad
that it's ending

971
01:01:17,639 --> 01:01:20,209
and yet I couldn't
be more thrilled

972
01:01:20,242 --> 01:01:22,378
with how successful it's been.

973
01:01:22,411 --> 01:01:25,881
- You could not possibly
be any more proud

974
01:01:25,914 --> 01:01:30,219
of what you've accomplished,
and when you had adversity,

975
01:01:30,252 --> 01:01:33,489
you guys figured a
way out of the box

976
01:01:33,522 --> 01:01:34,990
to make it still work.

977
01:01:35,023 --> 01:01:36,392
- And when you say you
guys, it's not us sitting

978
01:01:36,425 --> 01:01:39,762
at the table, it's a
large team of committed,

979
01:01:39,795 --> 01:01:44,767
capable, diligent,
passionate expert engineers

980
01:01:46,001 --> 01:01:47,470
and scientists who
really worked hard

981
01:01:47,503 --> 01:01:50,172
to make this mission
successful, and I could not

982
01:01:50,205 --> 01:01:52,742
be more proud of them,
and the opportunity

983
01:01:52,775 --> 01:01:55,878
to work with them, it's
been a wonderful experience

984
01:01:55,911 --> 01:01:59,048
to make this mission a reality.

985
01:01:59,081 --> 01:02:01,917
- Well, Jim, do you have
anything to add to that?

986
01:02:01,950 --> 01:02:04,653
- Oh, yes, I do, I do,

987
01:02:04,686 --> 01:02:07,323
because, you know,
as head of planetary

988
01:02:07,356 --> 01:02:11,494
for a number of years,
I saw the dedication

989
01:02:11,527 --> 01:02:16,532
in many planetary teams
and it is absolutely

990

01:02:19,301 --> 01:02:21,470
so remarkable, they
are so dedicated

991
01:02:21,503 --> 01:02:23,506
and they work so hard.

992
01:02:23,539 --> 01:02:27,710
They literally, this is
really a major element

993
01:02:27,743 --> 01:02:32,214
of their life, and these
missions are not easy.

994
01:02:32,247 --> 01:02:33,716
They're incredibly difficult.

995
01:02:33,749 --> 01:02:36,619
Each and every one are special

996
01:02:36,652 --> 01:02:39,655
in the way it's put together,
the way it is implemented,

997
01:02:39,688 --> 01:02:43,325
the science that it
obtains, no one spacecraft

998
01:02:43,358 --> 01:02:45,294
is identical to the other.

999
01:02:45,327 --> 01:02:46,962
I mean, they go to far reaches,

1000
01:02:46,995 --> 01:02:49,665
from Mercury, where
it's so incredibly hot

1001

01:02:49,698 --> 01:02:53,102
to Pluto, where it's
so incredibly cold,

1002
01:02:53,135 --> 01:02:55,437
and all the systems
that have to be designed

1003
01:02:55,470 --> 01:02:58,574
and developed to do that,
you just pour your heart

1004
01:02:58,607 --> 01:03:03,613
out into this, and it's
tough when these things end.

1005
01:03:04,847 --> 01:03:06,348
But the legacy of the
mission, of course,

1006
01:03:06,381 --> 01:03:09,652
is the data, the ability
to be able to go back,

1007
01:03:09,685 --> 01:03:12,054
find new things,
new discoveries.

1008
01:03:12,087 --> 01:03:15,357
And there's many things, I
know, that our scientists

1009
01:03:15,390 --> 01:03:18,494
have seen, recognized,
they can't explain it,

1010
01:03:18,527 --> 01:03:21,230
and sorta put that in
the back of their mind

1011

01:03:21,263 --> 01:03:24,834
until something else clicks
and they can put it together

1012
01:03:24,867 --> 01:03:26,502
and make other discoveries.

1013
01:03:26,535 --> 01:03:29,839
This happens throughout
our solar system

1014
01:03:29,872 --> 01:03:34,210
which makes the planetary
community so important to us

1015
01:03:34,243 --> 01:03:37,913
to continue to fund and
work in these areas,

1016
01:03:37,946 --> 01:03:40,182
find great missions
for the next one,

1017
01:03:40,215 --> 01:03:43,185
the next generation
to get involved in,

1018
01:03:43,218 --> 01:03:47,423
but I too will feel
sad about Dawn.

1019
01:03:47,456 --> 01:03:52,395
I watched it launch, I helped
it through some tough times

1020
01:03:53,528 --> 01:03:56,432
and from a number of
ways, financially,

1021
01:03:56,465 --> 01:03:59,869

you know, I remember the
time we were gonna launch it

1022
01:03:59,902 --> 01:04:03,205
and we kept getting storm
after storm after storm,

1023
01:04:03,238 --> 01:04:05,274
and I had to make the decision,

1024
01:04:05,307 --> 01:04:07,409
we're gonna
disassemble the rocket,

1025
01:04:07,442 --> 01:04:09,111
we're then gonna launch Phoenix,

1026
01:04:09,144 --> 01:04:12,214
and then we're gonna put
Dawn back on the launchpad.

1027
01:04:12,247 --> 01:04:17,253
That and those kinda
things really endear me

1028
01:04:18,553 --> 01:04:22,124
to being part of that challenge
and part of overcoming

1029
01:04:22,157 --> 01:04:25,694
the major difficulties
that occur,

1030
01:04:25,727 --> 01:04:28,998
and so I have that
same feeling, Marc.

1031
01:04:29,031 --> 01:04:31,934
And I'm with you on
that one, and Carol,

1032
01:04:31,967 --> 01:04:34,103
I know we're gonna
continue to analyze data,

1033
01:04:34,136 --> 01:04:35,905
and I'm with you
on that one too.

1034
01:04:35,938 --> 01:04:37,539
[all laughing]

1035
01:04:37,572 --> 01:04:40,542
- All right, well,
while we have you, Jim,

1036
01:04:40,575 --> 01:04:45,214
give us an idea of what's coming
up for NASA with asteroids.

1037
01:04:45,247 --> 01:04:49,818
- Well, this is another
spectacular time

1038
01:04:49,851 --> 01:04:53,022
that we are in, for which
we have small body missions,

1039
01:04:53,055 --> 01:04:56,725
and the very next one,
OSIRIS-REx is going to go

1040
01:04:56,758 --> 01:05:01,764
to another small world, it's
an asteroid called Bennu.

1041
01:05:03,165 --> 01:05:07,002
This particular body is
unlike Vesta, unlike Ceres,

1042
01:05:07,035 --> 01:05:10,205
it's what we believe is
a carbonaceous chondrite.

1043
01:05:10,238 --> 01:05:13,475
It's about 500 meters in size,

1044
01:05:13,508 --> 01:05:16,812
whereas Vesta is 500
kilometers in size.

1045
01:05:16,845 --> 01:05:20,616
This is much different,
but its material

1046
01:05:20,649 --> 01:05:24,119
is very important for
us to be able to return.

1047
01:05:24,152 --> 01:05:28,257
So the concept is, this is
a sample return mission.

1048
01:05:28,290 --> 01:05:31,894
We will go to Bennu, which
we've already started to see,

1049
01:05:34,129 --> 01:05:36,265
by December, early December,
we will be getting into

1050
01:05:36,298 --> 01:05:38,701
the vicinity to the point
where we'll be mapping

1051
01:05:38,734 --> 01:05:41,670
in high resolution, we'll
go down to the surface,

1052

01:05:41,703 --> 01:05:46,342
acquire material and then
bring that material back,

1053
01:05:46,375 --> 01:05:50,946
put it in another capsule and
return that capsule to earth.

1054
01:05:50,979 --> 01:05:53,248
So not only will we
study that object

1055
01:05:53,281 --> 01:05:56,819
for more than a year, but
flying in its vicinity,

1056
01:05:56,852 --> 01:06:00,422
we'll be acquiring a sample
and bringing it back.

1057
01:06:00,455 --> 01:06:02,758
And what do we expect
in this sample?

1058
01:06:02,791 --> 01:06:05,394
Well, carbonaceous
chondrite means it has

1059
01:06:05,427 --> 01:06:08,764
all kinds of carbon compounds

1060
01:06:08,797 --> 01:06:11,233
and perhaps complex
carbon compounds,

1061
01:06:11,266 --> 01:06:13,302
maybe even amino acids.

1062
01:06:13,335 --> 01:06:16,038
This object, which

bombarded the Earth,

1063
01:06:16,071 --> 01:06:18,507
in particular, these
type of objects,

1064
01:06:18,540 --> 01:06:22,177
after the Earth was formed,
perhaps brought ingredients

1065
01:06:22,210 --> 01:06:25,881
like that to earth that
help seeded the top layer

1066
01:06:25,914 --> 01:06:29,351
of the Earth that may
have, in some way,

1067
01:06:29,384 --> 01:06:31,320
been used to start life.

1068
01:06:31,353 --> 01:06:33,722
Another series of
questions we wanna know

1069
01:06:33,755 --> 01:06:36,792
about this particular body
we'll start to answer.

1070
01:06:36,825 --> 01:06:40,162
So that's coming up in December,
so hang on to your seats,

1071
01:06:40,195 --> 01:06:43,399
here comes another small
body to investigate.

1072
01:06:43,432 --> 01:06:46,335
- Well, we'll be looking
forward to it in December.

1073
01:06:46,368 --> 01:06:48,504
That wraps things up for us.

1074
01:06:48,537 --> 01:06:52,641
Carol, thank you so much,
Marc and Jim, you too.

1075
01:06:52,674 --> 01:06:55,077
If we did not get
to your questions,

1076
01:06:55,110 --> 01:06:59,681
do not fret, just go ahead,
we'll be staying on the line,

1077
01:06:59,714 --> 01:07:03,118
we will still be answering
the askNASA questions

1078
01:07:03,151 --> 01:07:05,554
for another good
half hour, in fact,

1079
01:07:05,587 --> 01:07:08,524
our experts are gonna
hang around for you,

1080
01:07:08,557 --> 01:07:12,394
so if you would like to
learn more about Dawn,

1081
01:07:12,427 --> 01:07:15,664
there is a website for
you that you can peruse

1082
01:07:15,697 --> 01:07:20,703
to your heart's content,
that is nasa.gov/dawn.

1083
01:07:21,870 --> 01:07:23,772
I hope you had a lotta
fun, I know we did.

1084
01:07:23,805 --> 01:07:25,941
Thanks for joining
us, and we hope