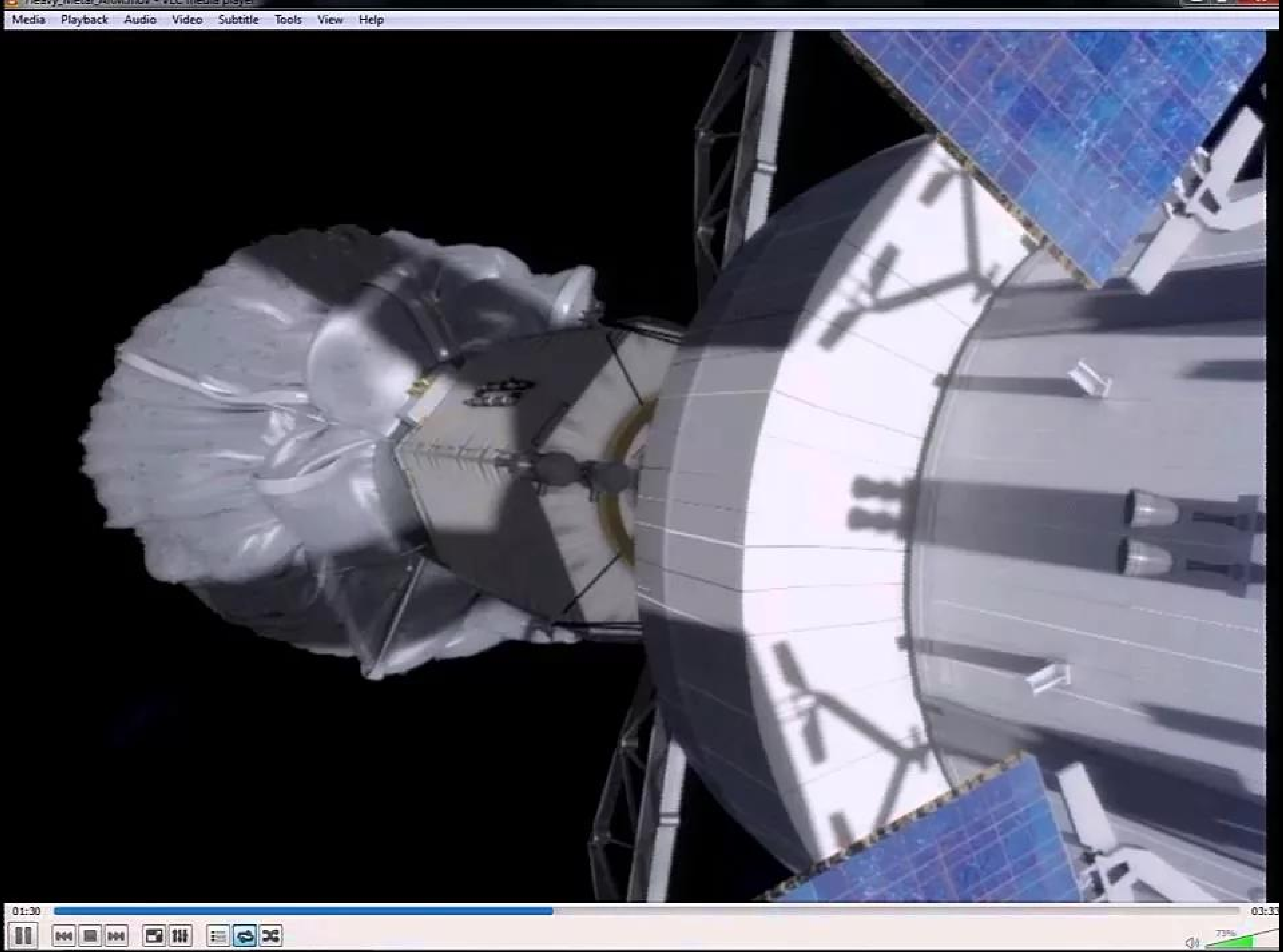
Media
Playback
Audio
Video
Subtitle
Tools
View
Help
01:30

1
00:00:07,369 --> 00:00:03,169
NASA's Jet Propulsion Laboratory

2
00:00:09,799 --> 00:00:07,379
presents the von Karman lecture a series

3
00:00:12,169 --> 00:00:09,809
of talks by scientists and engineers who

4
00:00:24,500 --> 00:00:12,179
are exploring our planet our solar

5
00:00:28,099 --> 00:00:26,609
hey good evening ladies and gentlemen

6
00:00:30,839 --> 00:00:28,109
how's everyone tonight

7
00:00:33,150 --> 00:00:30,849
yeah good excellent well thanks for

8
00:00:35,520 --> 00:00:33,160
coming up to join us again the asteroid

9
00:00:38,460 --> 00:00:35,530
redirect a robotic mission concept seeks

10
00:00:42,240 --> 00:00:38,470
to rendezvous with capture and redirect

11
00:00:44,939 --> 00:00:42,250
a trans lunar space an entire small

12
00:00:46,590 --> 00:00:44,949
near-earth asteroid it would focus the

13
00:00:48,750 --> 00:00:46,600

capabilities of the science technology

14
00:00:51,030 --> 00:00:48,760
and human exploration communities on a

15
00:00:52,770 --> 00:00:51,040
grand challenge creating a new synergy

16
00:00:55,170 --> 00:00:52,780
between robotic and human missions to

17
00:00:57,840 --> 00:00:55,180
advance human space exploration beyond

18
00:01:00,119 --> 00:00:57,850
low Earth orbit for the first time in 50

19
00:01:02,820 --> 00:01:00,129
years this talk addresses the key

20
00:01:04,829 --> 00:01:02,830
aspects of the concept and the options

21
00:01:07,380 --> 00:01:04,839
studied to assess its technical

22
00:01:09,780 --> 00:01:07,390
feasibility including evaluations of the

23
00:01:11,550 --> 00:01:09,790
expected number of potential targets the

24
00:01:14,039 --> 00:01:11,560
necessity to adequately characterize

25
00:01:17,039 --> 00:01:14,049
candidate targets the spacecraft design

26
00:01:19,800 --> 00:01:17,049
the process to capture a non-cooperative

27
00:01:21,480 --> 00:01:19,810
asteroid in deep space and the power and

28
00:01:24,060 --> 00:01:21,490
propulsion technologies required for

29
00:01:25,410 --> 00:01:24,070
such an endeavor tonight's guest has

30
00:01:27,499 --> 00:01:25,420
worked on numerous spacecraft and

31
00:01:30,179 --> 00:01:27,509
Technology projects since joining JPL in

32
00:01:32,130 --> 00:01:30,189
1977 including the Galileo mission to

33
00:01:34,859 --> 00:01:32,140
Jupiter and the shuttle imaging radar

34
00:01:37,560 --> 00:01:34,869
sea he was also responsible for the

35
00:01:39,569 --> 00:01:37,570
design development test and launch of

36
00:01:41,849 --> 00:01:39,579
the Mars Pathfinder spacecraft that

37
00:01:44,910 --> 00:01:41,859
landed successfully on Mars on July 4th

38
00:01:46,919 --> 00:01:44,920

1997 he was a project manager of the

39
00:01:48,539 --> 00:01:46,929
deep impact project from formulation

40
00:01:51,059 --> 00:01:48,549
through the critical design review in

41
00:01:53,760 --> 00:01:51,069
2002 then worked as the chief engineer

42
00:01:56,039 --> 00:01:53,770
of the Mars Science Laboratory in until

43
00:01:59,039 --> 00:01:56,049
August of 2004 when he was appointed

44
00:02:01,709 --> 00:01:59,049
chief engineer of JPL in February of

45
00:02:03,989 --> 00:02:01,719
2007 he was named NASA's chief architect

46
00:02:06,270 --> 00:02:03,999
and program systems engineer for the

47
00:02:08,430 --> 00:02:06,280
constellation program which included

48
00:02:10,620 --> 00:02:08,440
responsibility for the architecture of a

49
00:02:11,940 --> 00:02:10,630
new human exploration spaceflight system

50
00:02:13,980 --> 00:02:11,950
to the moon and beyond

51
00:02:16,800 --> 00:02:13,990
he returned to JPL as the chief engineer

52
00:02:18,900 --> 00:02:16,810
in December 2009 and currently is the

53
00:02:21,540 --> 00:02:18,910
pre project manager for the conceptual

54
00:02:24,150 --> 00:02:21,550
design of the cross agency study of the

55
00:02:25,500 --> 00:02:24,160
asteroid redirect robotic mission he

56
00:02:26,820 --> 00:02:25,510
received his BS in mechanical

57
00:02:29,490 --> 00:02:26,830
engineering from the University of New

58
00:02:31,320 --> 00:02:29,500
Mexico in 1977 and an MS and

59
00:02:34,559 --> 00:02:31,330
aeronautical engineering from Caltech in

60
00:02:36,360 --> 00:02:34,569
1982 additionally he is the recipient of

61
00:02:37,130 --> 00:02:36,370
two of NASA's outstanding leadership

62
00:02:38,860 --> 00:02:37,140
medals

63
00:02:40,970 --> 00:02:38,870

for his work on Mars Pathfinder and

64
00:02:42,440 --> 00:02:40,980
constellation ladies and gentlemen

65
00:02:53,980 --> 00:02:42,450
please help me welcome tonight's guest

66
00:02:58,250 --> 00:02:56,420
so what would you say to somebody who

67
00:03:00,500 --> 00:02:58,260
said they were working on a mission to

68
00:03:03,110 --> 00:03:00,510
go out into deep space rendezvous with

69
00:03:05,710 --> 00:03:03,120
an asteroid capture it bring it back to

70
00:03:06,860 --> 00:03:05,720
and put it in orbit around the moon

71
00:03:08,030 --> 00:03:06,870
crazy

72
00:03:09,380 --> 00:03:08,040
exactly right do you think they were

73
00:03:12,410 --> 00:03:09,390
crazy yeah you'd say that sounds

74
00:03:14,510 --> 00:03:12,420
impossible well as all of us here at JPL

75
00:03:16,460 --> 00:03:14,520
know that's what we do at NASA we love

76
00:03:18,830 --> 00:03:16,470
the impossible and this has got a great

77
00:03:19,790 --> 00:03:18,840
flavor of the impossible and I'm going

78
00:03:23,270 --> 00:03:19,800
to share that with you tonight

79
00:03:25,850 --> 00:03:23,280
so the asteroid redirect mission is

80
00:03:27,590 --> 00:03:25,860
actually two missions it is a robotic

81
00:03:29,540 --> 00:03:27,600
mission which is the mission that I'm

82
00:03:30,790 --> 00:03:29,550
primarily responsible for that is a

83
00:03:35,380 --> 00:03:30,800
cross-agency

84
00:03:37,790 --> 00:03:35,390
project team of JPL Glenn Langley

85
00:03:39,979 --> 00:03:37,800
Goddard Space Flight Center as well as

86
00:03:41,539 --> 00:03:39,989
Johnson Space Center and the crewed

87
00:03:44,780 --> 00:03:41,549
mission which is primarily the

88
00:03:47,000 --> 00:03:44,790

responsibility of JSC so I'm going to

89
00:03:50,449 --> 00:03:47,010
describe for you tonight the the basic

90
00:03:53,360 --> 00:03:50,459
elements of this project but I want to

91
00:03:55,009 --> 00:03:53,370
start with a with where is NASA what is

92
00:03:58,430 --> 00:03:55,019
NASA thinking today in human spaceflight

93
00:04:00,350 --> 00:03:58,440
well we're not just thinking about where

94
00:04:02,270 --> 00:04:00,360
are we going we're thinking about how

95
00:04:04,250 --> 00:04:02,280
we're gonna get there we're not just

96
00:04:05,990 --> 00:04:04,260
thinking what's the destination we're

97
00:04:07,250 --> 00:04:06,000
thinking about what capabilities do we

98
00:04:09,860 --> 00:04:07,260
need what capabilities are we going to

99
00:04:12,259 --> 00:04:09,870
develop that'll become the elements that

100
00:04:13,400 --> 00:04:12,269
we can use as we go from low-earth orbit

101
00:04:14,930 --> 00:04:13,410
out to Mars

102
00:04:16,039 --> 00:04:14,940
the thing I really love about this

103
00:04:18,170 --> 00:04:16,049
picture and this is one that bill

104
00:04:19,849 --> 00:04:18,180
Gerstenmaier the director of the human

105
00:04:22,460 --> 00:04:19,859
space exploration or human exploration

106
00:04:25,820 --> 00:04:22,470
and operations directorate used at a

107
00:04:29,150 --> 00:04:25,830
recent von braun symposium it's a

108
00:04:32,480 --> 00:04:29,160
picture that shows two armed robotic

109
00:04:36,290 --> 00:04:32,490
spacecraft with additional liquid

110
00:04:39,409 --> 00:04:36,300
propulsion carrying a human habitat into

111
00:04:41,690 --> 00:04:39,419
orbit around the moon or on Mars so this

112
00:04:44,180 --> 00:04:41,700
is showing we're worth what we're

113
00:04:46,190 --> 00:04:44,190

thinking about how arm itself has become

114
00:04:48,710 --> 00:04:46,200
such an integral part of the human

115
00:04:53,879 --> 00:04:48,720
exploration program strategy

116
00:04:55,980 --> 00:04:53,889
so what is arm well it's about capturing

117
00:04:58,860 --> 00:04:55,990
a whole asteroid rendezvous with

118
00:05:00,990 --> 00:04:58,870
capturing a whole asteroid and bringing

119
00:05:02,670 --> 00:05:01,000
it back and putting in orbit around the

120
00:05:05,550 --> 00:05:02,680
moon there's another option we're also

121
00:05:08,790 --> 00:05:05,560
looking at which is going to a large

122
00:05:11,249 --> 00:05:08,800
asteroid hundreds of meters in size and

123
00:05:13,350 --> 00:05:11,259
picking up a boulder that's on the order

124
00:05:15,029 --> 00:05:13,360
of two to four meters and bringing that

125
00:05:16,980 --> 00:05:15,039
and putting that in orbit for the

126
00:05:19,200 --> 00:05:16,990
individual asteroid we're talking about

127
00:05:23,189 --> 00:05:19,210
something that's 10 meters in diameter

128
00:05:24,480 --> 00:05:23,199
and as much as a thousand tons by the

129
00:05:25,800 --> 00:05:24,490
way I'm going to do metric tonight

130
00:05:30,450 --> 00:05:25,810
because I know all you JPL errs

131
00:05:31,950 --> 00:05:30,460
understand that so and then once we're

132
00:05:33,779 --> 00:05:31,960
in orbit around the moon in what we call

133
00:05:36,210 --> 00:05:33,789
a distant retrograde orbit which is a

134
00:05:38,309 --> 00:05:36,220
very stable orbit then the crew will

135
00:05:41,430 --> 00:05:38,319
come visit sometime in the 2020s early

136
00:05:42,899 --> 00:05:41,440
20s as maybe as early as 2023 so let's

137
00:05:45,809 --> 00:05:42,909
go into a little bit more detail about

138
00:05:48,360 --> 00:05:45,819

why is NASA doing this what's what's

139
00:05:50,129 --> 00:05:48,370
NASA get out of this well it really

140
00:05:52,589 --> 00:05:50,139
addresses a number of very important

141
00:05:54,270 --> 00:05:52,599
objectives for the agency first up it

142
00:05:56,700 --> 00:05:54,280
demonstrates high-power

143
00:05:58,860 --> 00:05:56,710
solar electric propulsion we're talking

144
00:06:00,959 --> 00:05:58,870
about solar arrays that can put out 50

145
00:06:04,019 --> 00:06:00,969
kilowatts of power we're talking about a

146
00:06:06,420 --> 00:06:04,029
SEP system that can push that is using

147
00:06:09,059 --> 00:06:06,430
basically as powered with 40 kilowatts

148
00:06:10,200 --> 00:06:09,069
of power Dawn's thrusters are basically

149
00:06:12,990 --> 00:06:10,210
powered at about two-and-a-half

150
00:06:14,550 --> 00:06:13,000
kilowatts so we're talking about a major

151
00:06:16,409 --> 00:06:14,560
upgrade in power

152
00:06:18,450 --> 00:06:16,419
but even more importantly we're talking

153
00:06:20,309 --> 00:06:18,460
about a major throughput of propellant

154
00:06:23,820 --> 00:06:20,319
we're talking about using as much as 10

155
00:06:27,360 --> 00:06:23,830
tons of xenon the Dawn spacecraft is

156
00:06:29,490 --> 00:06:27,370
carrying less than 500 kilograms so

157
00:06:32,969 --> 00:06:29,500
we're talking about a major ability to

158
00:06:34,559 --> 00:06:32,979
move large mass in the solar system like

159
00:06:37,260 --> 00:06:34,569
I said maybe as much as a thousand tons

160
00:06:40,350 --> 00:06:37,270
tons that wasn't kilograms and that

161
00:06:43,499 --> 00:06:40,360
wasn't grams that was tons operation in

162
00:06:45,600 --> 00:06:43,509
close proximity to a near-earth object

163
00:06:47,939 --> 00:06:45,610

in fact with our option B will actually

164
00:06:50,279 --> 00:06:47,949
land on the object and interact with it

165
00:06:52,230 --> 00:06:50,289
directly but either way we'll be using

166
00:06:54,240 --> 00:06:52,240
terrain relative navigation optical

167
00:06:57,389 --> 00:06:54,250
navigation to control our spacecraft

168
00:06:59,010 --> 00:06:57,399
around the asteroid in both cases we're

169
00:07:01,260 --> 00:06:59,020
going to we also have a capability to

170
00:07:02,290 --> 00:07:01,270
demonstrate some planetary defense

171
00:07:05,860 --> 00:07:02,300
techniques

172
00:07:08,710 --> 00:07:05,870
could divert a potentially hazardous

173
00:07:10,540 --> 00:07:08,720
asteroid if it was on it attracted to

174
00:07:12,550 --> 00:07:10,550
harm the earth these are not necessarily

175
00:07:13,839 --> 00:07:12,560
primary techniques but will describe all

176
00:07:15,490 --> 00:07:13,849
the Scrat them for you in a little bit a

177
00:07:19,450 --> 00:07:15,500
little bit more and then very

178
00:07:22,480 --> 00:07:19,460
importantly this is a target for the

179
00:07:24,460 --> 00:07:22,490
maybe as early as the second crewed

180
00:07:27,939 --> 00:07:24,470
mission of the Space Launch System and

181
00:07:32,140 --> 00:07:27,949
Orion so this is a chance for humans to

182
00:07:33,610 --> 00:07:32,150
go back to the moon in fact be literally

183
00:07:34,570 --> 00:07:33,620
farther in deep space than humans have

184
00:07:36,820 --> 00:07:34,580
ever gone before

185
00:07:39,399 --> 00:07:36,830
rendezvous dock in fact with our

186
00:07:41,890 --> 00:07:39,409
spacecraft and and perform an extra

187
00:07:44,439 --> 00:07:41,900
vehicular activity to sample our

188
00:07:49,689 --> 00:07:44,449

asteroid and this is also and this is in

189
00:07:51,070 --> 00:07:49,699
fact a building block for much more this

190
00:07:54,399 --> 00:07:51,080
charge is really important to me because

191
00:07:56,740 --> 00:07:54,409
it shows how NASA is changing its

192
00:07:59,350 --> 00:07:56,750
adopted the asteroid redirect mission as

193
00:08:02,409 --> 00:07:59,360
a central part of its strategy and the

194
00:08:04,119 --> 00:08:02,419
strategy starts today with where we are

195
00:08:06,100 --> 00:08:04,129
now earth we're what we call Earth

196
00:08:07,809 --> 00:08:06,110
ProLiant we're in low-earth orbit the

197
00:08:09,459 --> 00:08:07,819
capabilities that we've built using the

198
00:08:12,999 --> 00:08:09,469
shuttle and with Space Station but

199
00:08:14,200 --> 00:08:13,009
that's where we've been since 1981 well

200
00:08:16,689 --> 00:08:14,210
we're moving to is what we call the

201
00:08:18,730 --> 00:08:16,699
proving ground this is an the region in

202
00:08:21,760 --> 00:08:18,740
the cislunar space in which we can now

203
00:08:25,059 --> 00:08:21,770
prove out new capabilities we can

204
00:08:27,189 --> 00:08:25,069
develop put into operation develop new

205
00:08:28,570 --> 00:08:27,199
hardware test out that hardware develop

206
00:08:30,969 --> 00:08:28,580
new capabilities test out those

207
00:08:34,420 --> 00:08:30,979
capabilities to get experience in

208
00:08:35,440 --> 00:08:34,430
working beyond low-earth orbit and I'll

209
00:08:37,240 --> 00:08:35,450
describe a little bit more about the

210
00:08:40,089 --> 00:08:37,250
nature of the crewed mission but here

211
00:08:41,589 --> 00:08:40,099
but with this basically arm is one of is

212
00:08:44,290 --> 00:08:41,599
really literally the first building

213
00:08:47,650 --> 00:08:44,300

block in this proving ground upon which

214
00:08:49,060 --> 00:08:47,660
we can then extend ultimately from that

215
00:08:51,220 --> 00:08:49,070
built from this proving ground we can

216
00:08:53,110 --> 00:08:51,230
move on to Mars in fact we've shown that

217
00:08:55,480 --> 00:08:53,120
the district retrograde orbit which is

218
00:08:57,160 --> 00:08:55,490
about 70,000 kilometers above the

219
00:08:59,530 --> 00:08:57,170
surface of the Moon is a very good

220
00:09:01,449 --> 00:08:59,540
staging area for building up systems

221
00:09:05,410 --> 00:09:01,459
that we can then send to Mars

222
00:09:07,030 --> 00:09:05,420
so again arm you see here in the in

223
00:09:09,550 --> 00:09:07,040
orbit around the moon you can see

224
00:09:11,949 --> 00:09:09,560
elements of arm going to Mars in fact

225
00:09:14,530 --> 00:09:11,959
our concepts for extending the arm

226
00:09:15,360 --> 00:09:14,540
spacecraft from a 50 kilowatt system to

227
00:09:17,940 --> 00:09:15,370
150

228
00:09:20,960 --> 00:09:17,950
kilowatt system enables us to move large

229
00:09:23,640 --> 00:09:20,970
payloads 40-ton ish class payloads to

230
00:09:26,070 --> 00:09:23,650
the Mars system to either put them in

231
00:09:28,740 --> 00:09:26,080
orbit ready for humans or maybe put them

232
00:09:31,650 --> 00:09:28,750
on Phobos or Deimos for surface missions

233
00:09:36,120 --> 00:09:31,660
there so arm is an integral part of the

234
00:09:38,490 --> 00:09:36,130
future of human exploration so arm

235
00:09:40,890 --> 00:09:38,500
itself is made up of three major

236
00:09:42,660 --> 00:09:40,900
elements and and it's actually funded

237
00:09:44,160 --> 00:09:42,670
and supported by I should say it's

238
00:09:46,590 --> 00:09:44,170

supported by three major elements at

239
00:09:47,790 --> 00:09:46,600
NASA headquarters major partner is the

240
00:09:49,500 --> 00:09:47,800
human exploration and operations

241
00:09:52,170 --> 00:09:49,510
directorate led by bill Gerstenmaier

242
00:09:55,320 --> 00:09:52,180
this space technology mission director

243
00:09:57,030 --> 00:09:55,330
led by mike is Eric and in supported by

244
00:10:00,240 --> 00:09:57,040
the science Mission Directorate under

245
00:10:03,090 --> 00:10:00,250
John Grunsfeld the science program is

246
00:10:06,240 --> 00:10:03,100
helping us find our targets through

247
00:10:09,000 --> 00:10:06,250
ground-based telescopes and space-based

248
00:10:12,269 --> 00:10:09,010
telescopes we are looking for candidate

249
00:10:14,370 --> 00:10:12,279
targets for for vote for option a these

250
00:10:16,290 --> 00:10:14,380
are the single asteroids the 10-meter

251
00:10:17,579 --> 00:10:16,300
class asteroids which by the way are

252
00:10:19,920 --> 00:10:17,589
very hard to find these are real

253
00:10:21,840 --> 00:10:19,930
challenges for the observers but but

254
00:10:23,280 --> 00:10:21,850
they're up to it and they've we found at

255
00:10:24,890 --> 00:10:23,290
least three target we found three

256
00:10:27,600 --> 00:10:24,900
targets right now that we've adequately

257
00:10:30,000 --> 00:10:27,610
characterized to say that yes these are

258
00:10:31,590 --> 00:10:30,010
targets we could go to and bring back

259
00:10:35,370 --> 00:10:31,600
and I'll tell you a little bit more

260
00:10:37,650 --> 00:10:35,380
about that as well in in addition once

261
00:10:40,440 --> 00:10:37,660
we find a target we use other assets

262
00:10:42,750 --> 00:10:40,450
like our radar here the the JPL operates

263
00:10:45,870 --> 00:10:42,760

to characterize to understand the spin

264
00:10:48,120 --> 00:10:45,880
rate the size improve our understanding

265
00:10:49,769 --> 00:10:48,130
of the orbit and that whole program is

266
00:10:52,140 --> 00:10:49,779
basically run under the near-earth

267
00:10:54,769 --> 00:10:52,150
observation program which Don Yeomans

268
00:10:57,660 --> 00:10:54,779
runs for Lindley Johnson at headquarters

269
00:10:59,160 --> 00:10:57,670
so this is an integral part of the

270
00:11:01,710 --> 00:10:59,170
program and helps us identify our

271
00:11:03,360 --> 00:11:01,720
targets by the way that we have targets

272
00:11:05,400 --> 00:11:03,370
for our option B as well which of these

273
00:11:07,920 --> 00:11:05,410
larger asteroids which are much easier

274
00:11:09,660 --> 00:11:07,930
to identify obviously we found them but

275
00:11:10,769 --> 00:11:09,670
we need to characterize them as well we

276
00:11:12,960 --> 00:11:10,779
need to understand whether there's

277
00:11:15,750 --> 00:11:12,970
boulders on the surface of those bodies

278
00:11:17,030 --> 00:11:15,760
so the redirect mission there's two

279
00:11:19,260 --> 00:11:17,040
options we're looking at right now

280
00:11:21,720 --> 00:11:19,270
option a again capture the whole

281
00:11:24,120 --> 00:11:21,730
asteroid option B to land on the surface

282
00:11:26,160 --> 00:11:24,130
and bring back a boulder and we're going

283
00:11:27,600 --> 00:11:26,170
to make a decision that NASA is going to

284
00:11:28,860 --> 00:11:27,610
make a decision on which of these

285
00:11:30,690 --> 00:11:28,870
options to pursue

286
00:11:32,820 --> 00:11:30,700
toward the middle around the middle of

287
00:11:34,800 --> 00:11:32,830
December and part of what my team is

288
00:11:37,170 --> 00:11:34,810

doing this cross-agency team is doing is

289
00:11:40,080 --> 00:11:37,180
is developing the technical details

290
00:11:42,330 --> 00:11:40,090
working all the working out the issues

291
00:11:44,580 --> 00:11:42,340
understanding the risks developing our

292
00:11:47,640 --> 00:11:44,590
cost story to bring that to NASA in

293
00:11:49,020 --> 00:11:47,650
December and then then there is the

294
00:11:50,940 --> 00:11:49,030
exploration phase this is where the

295
00:11:52,860 --> 00:11:50,950
humans where the crew mission gets

296
00:11:55,200 --> 00:11:52,870
involved and actually interacts with the

297
00:11:59,310 --> 00:11:55,210
asteroid and brings back material from

298
00:12:01,980 --> 00:11:59,320
the asteroid itself so how do we conduct

299
00:12:05,010 --> 00:12:01,990
this mission we start with a launch from

300
00:12:07,320 --> 00:12:05,020
the earth obviously our current baseline

301
00:12:09,420 --> 00:12:07,330
is that we do we do a direct injection

302
00:12:12,540 --> 00:12:09,430
we direct we launch directly to the

303
00:12:13,980 --> 00:12:12,550
target or we we launch to a gravity

304
00:12:16,770 --> 00:12:13,990
assist by the moon depends on which

305
00:12:19,470 --> 00:12:16,780
target we're looking at and our what I

306
00:12:23,460 --> 00:12:19,480
call the nav imagines Nathan strange and

307
00:12:24,900 --> 00:12:23,470
his his mission designers have are just

308
00:12:27,420 --> 00:12:24,910
amazing at how they can develop these

309
00:12:29,670 --> 00:12:27,430
these concepts and run the analysis to

310
00:12:32,970 --> 00:12:29,680
show how we actually make these work so

311
00:12:34,920 --> 00:12:32,980
we launch we fly by the moon or not and

312
00:12:37,110 --> 00:12:34,930
we rendezvous with the asteroid that

313
00:12:39,300 --> 00:12:37,120

that process takes on the order of a

314
00:12:41,340 --> 00:12:39,310
year and we're using our solar electric

315
00:12:43,650 --> 00:12:41,350
propulsion system pretty much running it

316
00:12:46,200 --> 00:12:43,660
100% of the time to rendezvous with the

317
00:12:48,780 --> 00:12:46,210
asteroid as quickly as we can once there

318
00:12:50,370 --> 00:12:48,790
we will first of all rendezvous with it

319
00:12:52,350 --> 00:12:50,380
we have to find it we have to find it

320
00:12:54,870 --> 00:12:52,360
with our optical cameras then we

321
00:12:56,790 --> 00:12:54,880
approach we characterize if it's a small

322
00:12:58,830 --> 00:12:56,800
asteroid will characterize it you know

323
00:13:00,690 --> 00:12:58,840
over a matter of a few you know a few

324
00:13:02,010 --> 00:13:00,700
weeks maybe if it's a large asteroid

325
00:13:03,300 --> 00:13:02,020
it's going to take a little bit more

326
00:13:05,070 --> 00:13:03,310
time because we really have to map the

327
00:13:07,340 --> 00:13:05,080
whole surface and find the targets that

328
00:13:10,350 --> 00:13:07,350
we're looking for find those 2 to 4

329
00:13:12,210 --> 00:13:10,360
meter class asteroids or boulders on the

330
00:13:14,670 --> 00:13:12,220
surface and then we'll go through the

331
00:13:16,500 --> 00:13:14,680
process of actually capturing the

332
00:13:17,700 --> 00:13:16,510
asteroid and all part of the asteroid

333
00:13:20,070 --> 00:13:17,710
and I'll describe that for in detail

334
00:13:22,830 --> 00:13:20,080
once we've done that then we begin our

335
00:13:25,320 --> 00:13:22,840
journey back to earth and in fact with

336
00:13:27,630 --> 00:13:25,330
the small asteroids we're coming with

337
00:13:29,280 --> 00:13:27,640
them the asteroid we're looking for ones

338
00:13:33,150 --> 00:13:29,290

that naturally will come back to the

339
00:13:34,860 --> 00:13:33,160
earth system in 2023 2024 2025 and that

340
00:13:37,860 --> 00:13:34,870
to those time periods so we're just

341
00:13:39,360 --> 00:13:37,870
actually grabbed hold of the asteroid

342
00:13:42,000 --> 00:13:39,370
holding on to the asteroid and and

343
00:13:44,880 --> 00:13:42,010
diverting it just enough that it'll get

344
00:13:46,890 --> 00:13:44,890
- it will fly past the moon and pick up

345
00:13:49,560 --> 00:13:46,900
a gravity assist input and slingshot it

346
00:13:51,840 --> 00:13:49,570
into the orbit around the moon that

347
00:13:54,090 --> 00:13:51,850
process from the asteroid back to the

348
00:13:56,100 --> 00:13:54,100
earth-moon system takes about two years

349
00:13:58,830 --> 00:13:56,110
depending again on the on the mission

350
00:14:00,420 --> 00:13:58,840
the more time we have the more mass we

351
00:14:02,460 --> 00:14:00,430
can bring back and the bigger the

352
00:14:03,990 --> 00:14:02,470
asteroid we can bring back and then once

353
00:14:07,380 --> 00:14:04,000
in the district retrograde orbit the

354
00:14:10,440 --> 00:14:07,390
70,000 kilometer orbit will wait for the

355
00:14:13,770 --> 00:14:10,450
crew to to arrive and I'll describe all

356
00:14:17,070 --> 00:14:13,780
that in a little more detail so here's

357
00:14:20,190 --> 00:14:17,080
the option a here's the whole asteroid

358
00:14:23,760 --> 00:14:20,200
capture concept the key to this concept

359
00:14:26,550 --> 00:14:23,770
is a capture bag now why would you use a

360
00:14:28,800 --> 00:14:26,560
bag to capture an asteroid well the

361
00:14:31,110 --> 00:14:28,810
answer is that we know so little about

362
00:14:33,240 --> 00:14:31,120
the nature of these bodies we don't even

363
00:14:34,860 --> 00:14:33,250

know how they're held together we know

364
00:14:36,540 --> 00:14:34,870
there's gravity there there may be other

365
00:14:39,630 --> 00:14:36,550
forces there but they could be very

366
00:14:42,780 --> 00:14:39,640
loose rubble piles such that when we

367
00:14:45,540 --> 00:14:42,790
touch them they might fall apart so the

368
00:14:47,760 --> 00:14:45,550
logical solution is we need some way to

369
00:14:50,310 --> 00:14:47,770
encapsulate and that's what the bag is

370
00:14:52,800 --> 00:14:50,320
about that bag is about 15 meters in

371
00:14:55,940 --> 00:14:52,810
diameter and about 10 meters tall it

372
00:14:58,590 --> 00:14:55,950
would use the better part of this room

373
00:15:01,800 --> 00:14:58,600
the technology behind it is pretty basic

374
00:15:04,940 --> 00:15:01,810
it's actually we're using a captain

375
00:15:07,830 --> 00:15:04,950
material for the bag and we're in it

376
00:15:09,690 --> 00:15:07,840
deploying it using inflatable tubes and

377
00:15:12,870 --> 00:15:09,700
you'll see that in an intern animation

378
00:15:15,810 --> 00:15:12,880
in a second the whole system we

379
00:15:17,700 --> 00:15:15,820
basically stand off from the asteroid we

380
00:15:21,120 --> 00:15:17,710
after we've characterized it we'd open

381
00:15:22,920 --> 00:15:21,130
our bag and we fly very slowly on the

382
00:15:25,740 --> 00:15:22,930
order of about five centimeters a second

383
00:15:29,070 --> 00:15:25,750
in to the point where we we basically

384
00:15:36,310 --> 00:15:29,080
dock with the asteroid so let's see if

385
00:15:46,580 --> 00:15:41,810
it's a very short video oh there it is

386
00:15:47,930 --> 00:15:46,590
oh we lost it alright let's see what the

387
00:15:50,210 --> 00:15:47,940
guys can go back we had a little problem

388
00:16:02,360 --> 00:15:50,220

with the video before which is not

389
00:16:05,360 --> 00:16:02,370
uncommon alright if we can't get it

390
00:16:11,200 --> 00:16:05,370
we'll just we'll go on hopefully we can

391
00:16:19,400 --> 00:16:13,990
that's not it

392
00:16:20,890 --> 00:16:19,410
that was the third video alright alright

393
00:16:25,550 --> 00:16:20,900
guys why don't we

394
00:16:27,500 --> 00:16:25,560
let's go on give me back control of the

395
00:16:28,610 --> 00:16:27,510
screen ah here we go let's see we'll

396
00:16:30,770 --> 00:16:28,620
play there we go

397
00:16:34,070 --> 00:16:30,780
now you see the pedals opening up just

398
00:16:36,680 --> 00:16:34,080
like a flower you see this this this is

399
00:16:38,510 --> 00:16:36,690
a transparent captain material which we

400
00:16:41,390 --> 00:16:38,520
may or may not use exactly that material

401
00:16:44,240 --> 00:16:41,400
but that's the type of low low density

402
00:16:47,780 --> 00:16:44,250
low mass strong material and now you see

403
00:16:50,390 --> 00:16:47,790
us basically flying up to the asteroid

404
00:16:52,940 --> 00:16:50,400
this is again much faster than will

405
00:17:00,590 --> 00:16:52,950
actually happen let's not run that video

406
00:17:06,590 --> 00:17:00,600
just yet so and let's see here keeping

407
00:17:08,120 --> 00:17:06,600
back control please we can go capture

408
00:17:12,440 --> 00:17:08,130
asteroids but we still have trouble with

409
00:17:17,210 --> 00:17:12,450
this stuff alright can we go back there

410
00:17:19,520 --> 00:17:17,220
we go there we go so here is the the

411
00:17:21,530 --> 00:17:19,530
video finished bus basically after we

412
00:17:23,900 --> 00:17:21,540
had as we were approaching the asteroid

413
00:17:26,390 --> 00:17:23,910

what we're actually I like to think of

414
00:17:28,400 --> 00:17:26,400
this as docking because this is a very

415
00:17:30,500 --> 00:17:28,410
massive thing and you know it's it maybe

416
00:17:32,630 --> 00:17:30,510
it's a thousand tons our spacecraft at

417
00:17:34,040 --> 00:17:32,640
this point maybe still 10 tons I mean

418
00:17:38,690 --> 00:17:34,050
it's it's heavier than the Cassini

419
00:17:41,120 --> 00:17:38,700
spacecraft so we basically have to dock

420
00:17:42,710 --> 00:17:41,130
with it and we have to deal with its

421
00:17:45,680 --> 00:17:42,720
relative motion relative of the

422
00:17:47,570 --> 00:17:45,690
spacecraft and once we've done that then

423
00:17:48,060 --> 00:17:47,580
we basically are now at a point where we

424
00:17:51,870 --> 00:17:48,070
can close

425
00:17:53,310 --> 00:17:51,880
the bag around the asteroid and so the

426
00:17:55,740 --> 00:17:53,320
beautiful thing about this inflatable

427
00:17:57,990 --> 00:17:55,750
system is we can control how far it's

428
00:18:00,030 --> 00:17:58,000
deployed we can control how it behaves

429
00:18:02,430 --> 00:18:00,040
as we want to close it down and so we

430
00:18:05,070 --> 00:18:02,440
basically now are capturing the asteroid

431
00:18:07,680 --> 00:18:05,080
enveloping it in our in our captain bag

432
00:18:09,210 --> 00:18:07,690
and finally we're finished we've cloak

433
00:18:10,920 --> 00:18:09,220
captured that we can actually close our

434
00:18:14,040 --> 00:18:10,930
petals around it a little bit in order

435
00:18:16,320 --> 00:18:14,050
to control it and have it in a good

436
00:18:18,150 --> 00:18:16,330
position for us to return to Earth now

437
00:18:19,830 --> 00:18:18,160
I'm just going to I want you to think

438
00:18:21,690 --> 00:18:19,840

about the fact now that when the crew

439
00:18:24,330 --> 00:18:21,700
gets here the crew is actually going to

440
00:18:26,310 --> 00:18:24,340
go between those petals and get access

441
00:18:28,860 --> 00:18:26,320
to the asteroid and you'll see a little

442
00:18:31,410 --> 00:18:28,870
bit of that in a future animation so

443
00:18:33,240 --> 00:18:31,420
this is our configuration as we fly back

444
00:18:34,440 --> 00:18:33,250
to the earth-moon system and this is

445
00:18:38,250 --> 00:18:34,450
what it'll look like as the crew

446
00:18:40,890 --> 00:18:38,260
approaches it we have a testbed up on

447
00:18:43,500 --> 00:18:40,900
the hill here at JPL we've built a 1/5

448
00:18:47,010 --> 00:18:43,510
scale so we're talking about a 3 meter

449
00:18:50,100 --> 00:18:47,020
diameter by over 2 meters tall system in

450
00:18:52,110 --> 00:18:50,110
which we can have all the basic elements

451
00:18:53,340 --> 00:18:52,120
many of them are flight like the Kapton

452
00:18:56,880 --> 00:18:53,350
bag is the real thing

453
00:18:59,580 --> 00:18:56,890
and we can demonstrate and work with

454
00:19:00,900 --> 00:18:59,590
these soft goods which is think you know

455
00:19:02,490 --> 00:19:00,910
when those of us that have worked on

456
00:19:04,800 --> 00:19:02,500
airbags and parachutes and whatnot

457
00:19:07,980 --> 00:19:04,810
realize this is something you have to do

458
00:19:10,710 --> 00:19:07,990
by by by hand and so we built this to

459
00:19:12,660 --> 00:19:10,720
work with to understand and what the

460
00:19:15,450 --> 00:19:12,670
capability we've also built into the

461
00:19:18,540 --> 00:19:15,460
system is the ability to dynamic - -

462
00:19:20,370 --> 00:19:18,550
during the capture process measure the

463
00:19:23,370 --> 00:19:20,380

forces associated with the relative

464
00:19:25,710 --> 00:19:23,380
motion of the the asteroid body with our

465
00:19:28,530 --> 00:19:25,720
spacecraft we want to understand what

466
00:19:31,320 --> 00:19:28,540
happens as a rotating asteroid inside

467
00:19:33,180 --> 00:19:31,330
the bag makes contact as we close on it

468
00:19:35,130 --> 00:19:33,190
so this is a capability that measures

469
00:19:37,650 --> 00:19:35,140
the forces and we can do closed loop

470
00:19:39,690 --> 00:19:37,660
simulation of that whole system so it's

471
00:19:41,550 --> 00:19:39,700
a beautiful way to understand exactly

472
00:19:44,280 --> 00:19:41,560
how the system is going to perform and

473
00:19:46,200 --> 00:19:44,290
we when we go to flight as we start to

474
00:19:49,080 --> 00:19:46,210
build up for flight this is a system we

475
00:19:51,210 --> 00:19:49,090
can test fully here on earth in 1g that

476
00:19:53,070 --> 00:19:51,220
system deploys in 1 gravity will make a

477
00:19:56,940 --> 00:19:53,080
system that can do that will be able to

478
00:19:58,740 --> 00:19:56,950
fully evaluate test and evaluate

479
00:20:00,970 --> 00:19:58,750
performance of the whole system right

480
00:20:08,590 --> 00:20:00,980
here on earth right here hopefully it

481
00:20:13,180 --> 00:20:08,600
pl so that's option a so here's option B

482
00:20:15,190 --> 00:20:13,190
pick up a boulder this this is a much

483
00:20:17,380 --> 00:20:15,200
more challenging job actually this is

484
00:20:19,930 --> 00:20:17,390
technically a very challenging job

485
00:20:21,909 --> 00:20:19,940
because we're needing we're landing

486
00:20:23,950 --> 00:20:21,919
we're taking a whole 10-ton spacecraft

487
00:20:26,919 --> 00:20:23,960
and landing it on a rotating asteroid

488
00:20:30,250 --> 00:20:26,929

that we know very little about will know

489
00:20:31,870 --> 00:20:30,260
where the boulders are but will not know

490
00:20:34,570 --> 00:20:31,880
a lot more about the nature of the

491
00:20:35,830 --> 00:20:34,580
asteroid its surface for example then we

492
00:20:38,440 --> 00:20:35,840
won't know a lot until we actually touch

493
00:20:40,600 --> 00:20:38,450
it so our strategy is to use three

494
00:20:43,780 --> 00:20:40,610
landing legs that are about five meters

495
00:20:46,330 --> 00:20:43,790
long and a pair of row of seven degree

496
00:20:48,760 --> 00:20:46,340
of freedom robotic arms with special end

497
00:20:50,140 --> 00:20:48,770
effector to grab the asteroid those arms

498
00:20:52,270 --> 00:20:50,150
are about two meters well they're at

499
00:20:55,960 --> 00:20:52,280
least 2 meters or more long very much

500
00:20:59,049 --> 00:20:55,970
like our MSL arms and those legs are

501
00:21:01,750 --> 00:20:59,059
specially designed to to control the

502
00:21:03,100 --> 00:21:01,760
landing and also to push up but the part

503
00:21:04,840 --> 00:21:03,110
of what makes this challenging is we've

504
00:21:06,460 --> 00:21:04,850
got these big solar arrays and I'll show

505
00:21:09,039 --> 00:21:06,470
you how big they are in a minute they're

506
00:21:12,070 --> 00:21:09,049
part of the spacecraft so this is a very

507
00:21:13,270 --> 00:21:12,080
very interesting challenging problem but

508
00:21:15,070 --> 00:21:13,280
one of the nice things about working

509
00:21:17,169 --> 00:21:15,080
with asteroids versus like the surface

510
00:21:19,270 --> 00:21:17,179
of Mars gravity is very low we're

511
00:21:21,549 --> 00:21:19,280
talking about micro G of gravity so

512
00:21:24,039 --> 00:21:21,559
instead of the seven minutes of Terror

513
00:21:26,140 --> 00:21:24,049

this'll be Bab the seven hours of terror

514
00:21:28,180 --> 00:21:26,150
you know so it's we've got a lot more

515
00:21:30,430 --> 00:21:28,190
time because things will happen slowly

516
00:21:42,830 --> 00:21:30,440
so let's see if we can run the video

517
00:21:54,890 --> 00:21:49,610
be patient okay good we're gonna back

518
00:22:12,950 --> 00:21:54,900
out to Windows here and I don't even see

519
00:22:15,440 --> 00:22:12,960
it up there the yes it would probably be

520
00:22:19,040 --> 00:22:15,450
VxWorks which is what we're running on

521
00:22:20,240 --> 00:22:19,050
750 today so they the avionics you'll

522
00:22:23,120 --> 00:22:20,250
still talk about the spacecraft in a

523
00:22:25,340 --> 00:22:23,130
second but the avionics and the software

524
00:22:28,460 --> 00:22:25,350
would be derived heavily from from JPL

525
00:22:31,910 --> 00:22:28,470
heritage if with our current

526
00:22:40,460 --> 00:22:31,920
implementation so let's see what John's

527
00:22:46,550 --> 00:22:40,470
up to if I say I'm ready to give up I'm

528
00:22:51,890 --> 00:22:46,560
sure it'll work all right why do we go

529
00:22:53,060 --> 00:22:51,900
there we go see okay so you didn't quite

530
00:22:56,600 --> 00:22:53,070
see it from the beginning I hope we

531
00:22:58,580 --> 00:22:56,610
could play and replay it but keep just

532
00:22:58,850 --> 00:22:58,590
go through it well we can replay that'll

533
00:23:04,730 --> 00:22:58,860
be great

534
00:23:06,380 --> 00:23:04,740
I know that's asking a lot okay there

535
00:23:08,750 --> 00:23:06,390
now you see it landing and again this is

536
00:23:10,910 --> 00:23:08,760
very much faster than would actually

537
00:23:13,160 --> 00:23:10,920
happen the legs absorb the the energy

538
00:23:15,230 --> 00:23:13,170

you see the two robotic arms coming down

539
00:23:17,660 --> 00:23:15,240
with with micro spine grippers they're

540
00:23:21,800 --> 00:23:17,670
grabbing the asteroid or the boulder and

541
00:23:24,260 --> 00:23:21,810
then the legs push us off and then we we

542
00:23:26,450 --> 00:23:24,270
Nestle they the boulder into the surface

543
00:23:29,180 --> 00:23:26,460
of the the spacecraft and then we close

544
00:23:33,740 --> 00:23:29,190
the robotic the landing legs around it

545
00:23:36,970 --> 00:23:33,750
and hold it for for the crude phase so

546
00:23:39,290 --> 00:23:36,980
but you can see these solar arrays that

547
00:23:42,830 --> 00:23:39,300
span that wingspan will those solar

548
00:23:46,310 --> 00:23:42,840
arrays is 35 meters this is a big this

549
00:23:48,730 --> 00:23:46,320
is a very big spacecraft okay now can we

550
00:23:58,960 --> 00:23:53,180
thank you John all right let's see we

551
00:24:05,030 --> 00:24:01,070
we'll make this work better tomorrow

552
00:24:05,570 --> 00:24:05,040
night so they're probably trying okay

553
00:24:08,870 --> 00:24:05,580
here we go

554
00:24:11,360 --> 00:24:08,880
so as in the case of option a we've got

555
00:24:13,280 --> 00:24:11,370
some great testbed work going on out of

556
00:24:16,010 --> 00:24:13,290
Goddard and Langley these are a couple

557
00:24:17,630 --> 00:24:16,020
of pictures of the testing the test

558
00:24:19,550 --> 00:24:17,640
setup for those landing legs that's

559
00:24:22,130 --> 00:24:19,560
going on at Langley Research Center I've

560
00:24:24,920 --> 00:24:22,140
got a big air bearing floor you've got

561
00:24:28,010 --> 00:24:24,930
these large I think on the order of 5

562
00:24:30,170 --> 00:24:28,020
meter long arms and starting tomorrow

563
00:24:32,780 --> 00:24:30,180

we're actually demonstrating the

564
00:24:35,570 --> 00:24:32,790
capability of these arms to operate in a

565
00:24:36,830 --> 00:24:35,580
coordinated fashion to Lant and simulate

566
00:24:39,320 --> 00:24:36,840
the landing will be eventually

567
00:24:42,890 --> 00:24:39,330
simulating the actual capture of the of

568
00:24:45,770 --> 00:24:42,900
the asteroid so this is again a great

569
00:24:47,600 --> 00:24:45,780
multi center effort that's another thing

570
00:24:49,160 --> 00:24:47,610
that makes it unique we're we're multi

571
00:24:50,780 --> 00:24:49,170
were funded by multiple directorates

572
00:24:52,640 --> 00:24:50,790
it's actually the work of multiple

573
00:24:56,660 --> 00:24:52,650
centers to to accomplish a mission like

574
00:24:59,720 --> 00:24:56,670
this let me talk a little bit about

575
00:25:01,070 --> 00:24:59,730
solar electric propulsion I know there's

576
00:25:03,110 --> 00:25:01,080
a number of people in the audience here

577
00:25:05,570 --> 00:25:03,120
who have some more than working

578
00:25:08,090 --> 00:25:05,580
familiarity with that but but this is

579
00:25:10,490 --> 00:25:08,100
enabling for the asteroid redirect

580
00:25:13,430 --> 00:25:10,500
mission and it's and it's now recognized

581
00:25:14,720 --> 00:25:13,440
as enabling for these other missions

582
00:25:17,030 --> 00:25:14,730
that we want to do in the human

583
00:25:18,980 --> 00:25:17,040
exploration program as I said we're

584
00:25:21,290 --> 00:25:18,990
talking about a 50 kilowatt system here

585
00:25:24,740 --> 00:25:21,300
that takes 40 kilowatts of that power

586
00:25:28,280 --> 00:25:24,750
and turns it in and and uses that to

587
00:25:30,230 --> 00:25:28,290
propel to accelerate xenon atoms the

588
00:25:33,080 --> 00:25:30,240

unites our propellant to about 30

589
00:25:35,660 --> 00:25:33,090
kilometers a second this is an extremely

590
00:25:37,040 --> 00:25:35,670
efficient system but it's but the force

591
00:25:39,500 --> 00:25:37,050
we're talking about is only about one

592
00:25:42,020 --> 00:25:39,510
and a half Newtons it's a very low force

593
00:25:44,510 --> 00:25:42,030
but it's a very efficient system so it

594
00:25:47,720 --> 00:25:44,520
takes a long time look like I said a

595
00:25:49,460 --> 00:25:47,730
couple of years to to apply enough delta

596
00:25:51,680 --> 00:25:49,470
v to move that asteroid and the amount

597
00:25:53,810 --> 00:25:51,690
of delta v is only about 150 to 200

598
00:25:55,730 --> 00:25:53,820
meters per second and that's how much

599
00:25:58,010 --> 00:25:55,740
change we can we're able to do over two

600
00:26:00,710 --> 00:25:58,020
years but that's just enough to get

601
00:26:02,720 --> 00:26:00,720
these asteroids to get the asteroid to

602
00:26:04,190 --> 00:26:02,730
fly by the mode and get into orbit so

603
00:26:06,650 --> 00:26:04,200
there you see one of the engines that as

604
00:26:08,720 --> 00:26:06,660
they exist up in the test lab here at

605
00:26:10,940 --> 00:26:08,730
JPL and also testing

606
00:26:12,320 --> 00:26:10,950
and one of the key things is that solar

607
00:26:15,050 --> 00:26:12,330
array that solar array

608
00:26:17,360 --> 00:26:15,060
you know big solar arrays exist but they

609
00:26:20,840 --> 00:26:17,370
don't exist at this this high efficiency

610
00:26:23,360 --> 00:26:20,850
these are 30% efficient cells on a

611
00:26:25,820 --> 00:26:23,370
blanket it's not a rigid solar array so

612
00:26:27,530 --> 00:26:25,830
the the specific power of these arrays

613
00:26:29,750 --> 00:26:27,540

is quite a bit higher than anything is

614
00:26:33,950 --> 00:26:29,760
flying today by at least on the order of

615
00:26:37,550 --> 00:26:33,960
about 50% and it's scalable it's

616
00:26:40,940 --> 00:26:37,560
scaleable up from this 50 200 to 150

617
00:26:42,800 --> 00:26:40,950
maybe even to 200 and beyond so that's a

618
00:26:44,390 --> 00:26:42,810
big part of what we're doing is is this

619
00:26:47,530 --> 00:26:44,400
extensible is what we're doing

620
00:26:49,580 --> 00:26:47,540
extensible to these future applications

621
00:26:51,650 --> 00:26:49,590
here's what the spacecraft

622
00:26:53,480 --> 00:26:51,660
configurations look like the option a on

623
00:26:55,250 --> 00:26:53,490
the left and option B on the right you

624
00:26:57,020 --> 00:26:55,260
can see these are big machines they

625
00:27:01,190 --> 00:26:57,030
they're bigger quite a bit bigger than

626
00:27:03,260 --> 00:27:01,200
Cassini the and of course big part is

627
00:27:07,100 --> 00:27:03,270
we're carrying 10 tonnes of propellant

628
00:27:09,320 --> 00:27:07,110
and very long tanks this tens ton system

629
00:27:11,540 --> 00:27:09,330
is got to be scalable itself we wanted

630
00:27:12,920 --> 00:27:11,550
to scalable up to 16 tonnes that's the

631
00:27:15,040 --> 00:27:12,930
kind of propellant load we think we need

632
00:27:16,880 --> 00:27:15,050
to go to to move big cargo to Mars

633
00:27:18,800 --> 00:27:16,890
another thing I want to point out is the

634
00:27:20,510 --> 00:27:18,810
modularity because this is being

635
00:27:23,120 --> 00:27:20,520
developed across the agency we needed a

636
00:27:25,700 --> 00:27:23,130
design that was modular that we could

637
00:27:27,740 --> 00:27:25,710
imagine working on in different

638
00:27:31,490 --> 00:27:27,750

organizations with clean interfaces and

639
00:27:32,600 --> 00:27:31,500
so we've got the set module which is the

640
00:27:34,940 --> 00:27:32,610
responsibility of Glenn Research Center

641
00:27:37,190 --> 00:27:34,950
the mission module which is JPL's

642
00:27:39,140 --> 00:27:37,200
responsibility and the capture system so

643
00:27:41,000 --> 00:27:39,150
for option a that responsibilities JPL

644
00:27:44,240 --> 00:27:41,010
for option B that responsibility is

645
00:27:47,240 --> 00:27:44,250
Goddard and Langley so again you know

646
00:27:49,310 --> 00:27:47,250
these are these are massive machines but

647
00:27:51,980 --> 00:27:49,320
because of these clean interfaces we

648
00:27:57,920 --> 00:27:51,990
think we can develop them in a in a very

649
00:28:01,340 --> 00:27:57,930
efficient way so here are those big

650
00:28:04,970 --> 00:28:01,350
solar arrays I talked about the the mega

651
00:28:07,970 --> 00:28:04,980
flex from ATK 35 meter wingspan

652
00:28:11,390 --> 00:28:07,980
the Rosa from deployable space systems

653
00:28:13,370 --> 00:28:11,400
51 meters these are big solar arrays so

654
00:28:15,380 --> 00:28:13,380
part of the challenge for our guidance

655
00:28:17,600 --> 00:28:15,390
and control team is how do we control

656
00:28:19,850 --> 00:28:17,610
these big flexible systems when we're

657
00:28:21,020 --> 00:28:19,860
grabbing hold of an asteroid and when

658
00:28:22,670 --> 00:28:21,030
we're landing on the surface of an

659
00:28:24,530 --> 00:28:22,680
asteroid

660
00:28:26,660 --> 00:28:24,540
very interesting challenging problem

661
00:28:29,330 --> 00:28:26,670
luckily again because gravity's low

662
00:28:30,350 --> 00:28:29,340
things don't happen real fast and we

663
00:28:35,660 --> 00:28:30,360

think we've got a pretty good strategy

664
00:28:37,010 --> 00:28:35,670
for controlling these systems want to

665
00:28:38,570 --> 00:28:37,020
talk a little bit about planetary

666
00:28:41,000 --> 00:28:38,580
defense

667
00:28:43,190 --> 00:28:41,010
you probably recognize those images up

668
00:28:45,910 --> 00:28:43,200
above the one of course is is the

669
00:28:49,010 --> 00:28:45,920
dinosaur killer the 65 million year ago

670
00:28:52,070 --> 00:28:49,020
impact of a very large kilometer class

671
00:28:54,440 --> 00:28:52,080
asteroid which did which was a planet

672
00:28:55,850 --> 00:28:54,450
killer is the way we refer to it and

673
00:28:58,340 --> 00:28:55,860
they're over there on the right is an

674
00:29:01,960 --> 00:28:58,350
example of like the may be the asteroid

675
00:29:05,180 --> 00:29:01,970
that came in over Tunguska Tunguska in

676
00:29:07,760 --> 00:29:05,190
Siberia or the one the smaller one the

677
00:29:11,030 --> 00:29:07,770
17 meter went over Chelyabinsk so those

678
00:29:13,220 --> 00:29:11,040
are the hazards that asteroids represent

679
00:29:15,110 --> 00:29:13,230
and if there was a big one comin at us

680
00:29:16,970 --> 00:29:15,120
you know hundreds of meters or bigger

681
00:29:17,480 --> 00:29:16,980
we'd have to we'd need to do something

682
00:29:20,360 --> 00:29:17,490
about it

683
00:29:23,480 --> 00:29:20,370
well there's various techniques kinetic

684
00:29:25,850 --> 00:29:23,490
and nuclear but we have with the armed

685
00:29:29,030 --> 00:29:25,860
system the capability to do what we call

686
00:29:31,010 --> 00:29:29,040
these gradual but precise changes in

687
00:29:32,450 --> 00:29:31,020
velocity and there's a couple of

688
00:29:35,210 --> 00:29:32,460

techniques that arm can directly

689
00:29:37,370 --> 00:29:35,220
demonstrate so for option B we can

690
00:29:39,560 --> 00:29:37,380
demonstrate the gravity tractor or what

691
00:29:41,270 --> 00:29:39,570
we call enhanced gravity tractor and and

692
00:29:43,610 --> 00:29:41,280
the way a gravity tractor works is it's

693
00:29:46,430 --> 00:29:43,620
the gravity force between the big body

694
00:29:48,680 --> 00:29:46,440
and the little body that is represents

695
00:29:51,650 --> 00:29:48,690
like a string that holds the two bodies

696
00:29:53,930 --> 00:29:51,660
together and then we use our

697
00:29:56,320 --> 00:29:53,940
is this very light you know this very

698
00:29:59,300 --> 00:29:56,330
low force thruster to just pull

699
00:30:01,880 --> 00:29:59,310
basically the the asteroid and give it

700
00:30:04,130 --> 00:30:01,890
some small Delta V it's a very small

701
00:30:06,590 --> 00:30:04,140
change in velocity for for what we could

702
00:30:09,080 --> 00:30:06,600
do on a couple hundred meter object it's

703
00:30:10,730 --> 00:30:09,090
a it's a it's a hundred it's a few

704
00:30:13,430 --> 00:30:10,740
hundredths of a millimeter per second

705
00:30:15,320 --> 00:30:13,440
over about sixty days but that's enough

706
00:30:17,900 --> 00:30:15,330
that our deep space network can measure

707
00:30:19,340 --> 00:30:17,910
that grab that change in velocity and

708
00:30:21,290 --> 00:30:19,350
would give us some evidence that we'd

709
00:30:22,760 --> 00:30:21,300
actually accomplished that I don't feel

710
00:30:24,650 --> 00:30:22,770
we necessarily have to accomplish you

711
00:30:26,960 --> 00:30:24,660
actually demonstrate the measurement but

712
00:30:29,720 --> 00:30:26,970
we know how to do it the other approach

713
00:30:32,210 --> 00:30:29,730

which is a unique one is called ion beam

714
00:30:34,640 --> 00:30:32,220
deflection where we take our thrusters

715
00:30:36,560 --> 00:30:34,650
and we basically turn the spacecraft to

716
00:30:40,070 --> 00:30:36,570
back end toward the asteroid

717
00:30:42,110 --> 00:30:40,080
and we start firing our engines now the

718
00:30:44,450 --> 00:30:42,120
it's basically has the effect of

719
00:30:46,940 --> 00:30:44,460
billions and billions of xenon atoms

720
00:30:49,760 --> 00:30:46,950
running impacting the asteroid surface

721
00:30:52,580 --> 00:30:49,770
and providing the change in momentum to

722
00:30:54,410 --> 00:30:52,590
change its velocity so that is also a

723
00:30:56,330 --> 00:30:54,420
technique that we can demonstrate and on

724
00:30:58,220 --> 00:30:56,340
a small asteroid we can change its

725
00:30:59,900 --> 00:30:58,230
velocity like a millimeter per second

726
00:31:02,600 --> 00:30:59,910
which is very easily measured by the

727
00:31:04,460 --> 00:31:02,610
Deep Space Network in just an hour so

728
00:31:07,100 --> 00:31:04,470
we've got techniques that we can show

729
00:31:09,620 --> 00:31:07,110
and demonstrate and and have confident

730
00:31:11,480 --> 00:31:09,630
we understand the basic principles but

731
00:31:13,810 --> 00:31:11,490
if we were faced with a real target

732
00:31:15,650 --> 00:31:13,820
again there's probably these would be

733
00:31:17,680 --> 00:31:15,660
augmentations to probably what would

734
00:31:19,850 --> 00:31:17,690
need to be a much more serious

735
00:31:22,460 --> 00:31:19,860
capability associated with the kinetic

736
00:31:24,350 --> 00:31:22,470
device okay

737
00:31:26,000 --> 00:31:24,360
so I'm running I'm coming to the end

738
00:31:28,880 --> 00:31:26,010

here on my talk I'm going to talk a

739
00:31:31,340 --> 00:31:28,890
little bit about the crude mission here

740
00:31:34,700 --> 00:31:31,350
you see the crew launching on the Space

741
00:31:37,010 --> 00:31:34,710
Launch System on Orion and hopefully

742
00:31:40,730 --> 00:31:37,020
you'll be tuning in to the test launch

743
00:31:44,570 --> 00:31:40,740
of the Orion on a delta 4 or an Atlas I

744
00:31:46,610 --> 00:31:44,580
guess on December 4th first flight of an

745
00:31:49,190 --> 00:31:46,620
the new human carrying capsule there's

746
00:31:50,660 --> 00:31:49,200
no there would be no crew aboard - a few

747
00:31:53,690 --> 00:31:50,670
orbits around the earth and then and

748
00:31:56,330 --> 00:31:53,700
re-enter then you see the Orion and it's

749
00:32:00,310 --> 00:31:56,340
a service module on its way from Earth

750
00:32:03,530 --> 00:32:00,320
toward the moon rendezvous in with the

751
00:32:07,360 --> 00:32:03,540
the arm robotic spacecraft and then the

752
00:32:10,760 --> 00:32:07,370
crew egressing from the Orion and

753
00:32:13,520 --> 00:32:10,770
sampling the the asteroid the crewed

754
00:32:15,140 --> 00:32:13,530
mission involves actually two EVs we

755
00:32:17,360 --> 00:32:15,150
believe we've got the capability for -

756
00:32:22,100 --> 00:32:17,370
Evi for our EBA s that can accomplish

757
00:32:24,290 --> 00:32:22,110
this and then the Orion leaves earth or

758
00:32:26,330 --> 00:32:24,300
lunar orbit comes back to earth

759
00:32:28,640 --> 00:32:26,340
re-enters the Earth's atmosphere and

760
00:32:31,940 --> 00:32:28,650
parachutes safely to the to the water as

761
00:32:38,410 --> 00:32:31,950
as was done on Apollo so we have one

762
00:32:40,790 --> 00:32:38,420
more video to do let's see how we do now

763
00:32:42,850 --> 00:32:40,800

I'm going to narrate this I've got a

764
00:32:46,820 --> 00:32:42,860
great soundtrack that goes with it

765
00:32:49,590 --> 00:32:46,830
called born to be wild and fortunate I

766
00:32:52,900 --> 00:32:49,600
don't have the rights to use it

767
00:32:55,540 --> 00:32:52,910
but it really goes well with you can hum

768
00:33:03,490 --> 00:32:55,550
along we can all have along it it really

769
00:33:05,460 --> 00:33:03,500
goes well with this video so yes I guess

770
00:33:09,070 --> 00:33:05,470
while they're doing that I will show you

771
00:33:11,470 --> 00:33:09,080
this is the bag material this is about

772
00:33:13,780 --> 00:33:11,480
all we think we need this is captain

773
00:33:16,900 --> 00:33:13,790
plastic which is something we use to

774
00:33:20,920 --> 00:33:16,910
make all of our thermal blankets here's

775
00:33:22,360 --> 00:33:20,930
it reinforced okay here is okay so

776
00:33:24,550 --> 00:33:22,370
that's the target that's the arm

777
00:33:30,370 --> 00:33:24,560
spacecraft in orbit at the distant

778
00:33:33,970 --> 00:33:30,380
retrograde orbit and now here you see

779
00:33:38,920 --> 00:33:33,980
Orion launching so here's the words get

780
00:33:42,040 --> 00:33:38,930
out on the highway looking for adventure

781
00:33:43,890 --> 00:33:42,050
you know yeah here we go so here's the

782
00:33:46,210 --> 00:33:43,900
crew it's a two-man crew that's that's

783
00:33:49,180 --> 00:33:46,220
the capability right now that we have

784
00:33:51,970 --> 00:33:49,190
with with the first generation of space

785
00:33:56,700 --> 00:33:51,980
launch system to inject to come to the

786
00:34:00,310 --> 00:33:56,710
moon here we're leaving Earth orbit and

787
00:34:02,650 --> 00:34:00,320
there and the human spacecraft will do a

788
00:34:04,630 --> 00:34:02,660

close flyby of the moon and do again a

789
00:34:06,850 --> 00:34:04,640
gravity assist which is something we've

790
00:34:09,220 --> 00:34:06,860
never done with human with crewed

791
00:34:11,050 --> 00:34:09,230
spacecraft before again an expertise

792
00:34:14,230 --> 00:34:11,060
that JPL is developed and is the world's

793
00:34:16,000 --> 00:34:14,240
world's best in so now the crew is

794
00:34:19,540 --> 00:34:16,010
arriving in the distant retrograde orbit

795
00:34:22,090 --> 00:34:19,550
and they are rendezvous in with our

796
00:34:23,369 --> 00:34:22,100
spacecraft which is sitting there

797
00:34:25,960 --> 00:34:23,379
waiting for it

798
00:34:28,119 --> 00:34:25,970
the crew will use a set of

799
00:34:30,940 --> 00:34:28,129
instrumentation to dock we have a

800
00:34:32,710 --> 00:34:30,950
docking ring on the spacecraft same

801
00:34:34,240 --> 00:34:32,720
instruments that the Orion will use to

802
00:34:36,730 --> 00:34:34,250
dock with us with the same instruments

803
00:34:38,649 --> 00:34:36,740
that we used to identify to dock with

804
00:34:44,560 --> 00:34:38,659
our asteroid and and to control the

805
00:34:46,600 --> 00:34:44,570
landing for option B again this is a

806
00:34:49,450 --> 00:34:46,610
first I mean this is a robotic

807
00:34:52,830 --> 00:34:49,460
spacecraft built by people who build

808
00:34:56,340 --> 00:34:52,840
robotic spacecraft working directly with

809
00:34:58,990 --> 00:34:56,350
human human spacecraft first-of-a-kind

810
00:35:00,430 --> 00:34:59,000
first and won't be the last this is

811
00:35:02,230 --> 00:35:00,440
really part of the way we're gonna do

812
00:35:04,390 --> 00:35:02,240
business so if we're going to go out

813
00:35:07,900 --> 00:35:04,400

and explore the solar system and beyond

814
00:35:10,390 --> 00:35:07,910
so you see the crew now with handholds

815
00:35:12,370 --> 00:35:10,400
that are on our spacecraft we've

816
00:35:14,920 --> 00:35:12,380
actually demonstrated in the neutral

817
00:35:16,599 --> 00:35:14,930
buoyancy lab at JSC the operations

818
00:35:18,490 --> 00:35:16,609
you're seeing here crew have actually

819
00:35:20,380 --> 00:35:18,500
with with the spacesuits they would

820
00:35:21,550 --> 00:35:20,390
likely fly and what currently is the

821
00:35:23,680 --> 00:35:21,560
current ones that we're thinking of

822
00:35:25,870 --> 00:35:23,690
flying we've demonstrated the egress

823
00:35:28,420 --> 00:35:25,880
from Orion the movement along the

824
00:35:30,790 --> 00:35:28,430
spacecraft actually opening up the bag

825
00:35:32,890 --> 00:35:30,800
and taking samples we've proven all that

826
00:35:34,780 --> 00:35:32,900
out because we wanted to understand with

827
00:35:36,310 --> 00:35:34,790
this spacesuit which isn't that

828
00:35:38,560 --> 00:35:36,320
necessary that our favourite choice for

829
00:35:41,320 --> 00:35:38,570
a spacesuit but one that is that meets

830
00:35:44,020 --> 00:35:41,330
other constraints that we can actually

831
00:35:46,990 --> 00:35:44,030
acts you know use that spacecraft that

832
00:35:50,230 --> 00:35:47,000
spacesuit to get to the the asteroid and

833
00:35:52,270 --> 00:35:50,240
gets the material so again we've proven

834
00:35:54,730 --> 00:35:52,280
the kind of the initial end-to-end

835
00:36:04,329 --> 00:35:54,740
concept of how that would be done so

836
00:36:06,130 --> 00:36:04,339
samples and return I didn't point out

837
00:36:08,079 --> 00:36:06,140
that this is this mission is a

838
00:36:10,300 --> 00:36:08,089

technology demonstration mission this is

839
00:36:12,220 --> 00:36:10,310
not a science mission there will be

840
00:36:14,050 --> 00:36:12,230
great science that will come from it

841
00:36:15,940 --> 00:36:14,060
just like you know Paulo Apollo was not

842
00:36:19,150 --> 00:36:15,950
a technology or is not a was not a

843
00:36:21,280 --> 00:36:19,160
science mission but the understanding of

844
00:36:23,440 --> 00:36:21,290
the asteroid of the whole asteroid or an

845
00:36:26,020 --> 00:36:23,450
understanding of the part of that

846
00:36:29,530 --> 00:36:26,030
asteroid will be wonderful opportunity

847
00:36:33,870 --> 00:36:29,540
for science and here you see Orion

848
00:36:36,250 --> 00:36:33,880
landing and when in fact Orion the test

849
00:36:42,190 --> 00:36:36,260
unit lands it will be right off the

850
00:36:46,920 --> 00:36:42,200
coast here of California okay we got all

851
00:36:50,290 --> 00:36:46,930
three videos done all right almost

852
00:36:52,690 --> 00:36:50,300
almost done here so what I want to do

853
00:36:55,270 --> 00:36:52,700
the my next okay so I want to talk just

854
00:36:58,060 --> 00:36:55,280
real briefly about how we're going to go

855
00:37:00,370 --> 00:36:58,070
implement this project we've been in a

856
00:37:02,859 --> 00:37:00,380
couple of years in this conceptual phase

857
00:37:03,940 --> 00:37:02,869
we're gonna make a decision about which

858
00:37:04,930 --> 00:37:03,950
mission we're going to go do and then

859
00:37:07,210 --> 00:37:04,940
we're going to go through a mission

860
00:37:11,020 --> 00:37:07,220
concept review in February where we

861
00:37:15,010 --> 00:37:11,030
basically hope to get permission to

862
00:37:16,059 --> 00:37:15,020
start the V project we'd have about 16

863
00:37:17,489 --> 00:37:16,069

months of formulation

864
00:37:20,079 --> 00:37:17,499
then we'd go into a three-year

865
00:37:22,209 --> 00:37:20,089
development those of us here the work on

866
00:37:23,910 --> 00:37:22,219
projects that you know understand three

867
00:37:26,259 --> 00:37:23,920
years is kind of aggressive these days

868
00:37:28,870 --> 00:37:26,269
but part of what this mission is about

869
00:37:32,019 --> 00:37:28,880
is helping change the way we do business

870
00:37:34,839 --> 00:37:32,029
in NASA in the human program and in the

871
00:37:37,839 --> 00:37:34,849
in the robotic program so we're being

872
00:37:39,939 --> 00:37:37,849
we're approaching this in a very in an

873
00:37:41,949 --> 00:37:39,949
innovative way what we call lean

874
00:37:44,199 --> 00:37:41,959
implementation we're gonna be very

875
00:37:45,609 --> 00:37:44,209
creative about how we do this job we've

876
00:37:48,549 --> 00:37:45,619
got good support at the highest levels

877
00:37:49,630 --> 00:37:48,559
of the agency to to kind of path find

878
00:37:51,549 --> 00:37:49,640
this way of doing business

879
00:37:55,630 --> 00:37:51,559
this current schedule has us launching

880
00:37:57,789 --> 00:37:55,640
as early as June of 2019 the we haven't

881
00:37:59,380 --> 00:37:57,799
got official approval from the Office of

882
00:38:01,449 --> 00:37:59,390
Management and Budget or the Congress

883
00:38:05,049 --> 00:38:01,459
yet we're hoping to see evidence of that

884
00:38:06,400 --> 00:38:05,059
as we as we go through the year but so

885
00:38:08,380 --> 00:38:06,410
the likelihood that we'll hold that the

886
00:38:10,749 --> 00:38:08,390
schedule is not very high but

887
00:38:13,299 --> 00:38:10,759
nevertheless the the approach we're

888
00:38:15,459 --> 00:38:13,309

taking this innovative approach and what

889
00:38:17,799 --> 00:38:15,469
we do and how we do it is is really

890
00:38:21,640 --> 00:38:17,809
central to the importance of this

891
00:38:25,289 --> 00:38:21,650
mission I'm gonna finish with this very

892
00:38:28,089 --> 00:38:25,299
brief again a return to the fundamental

893
00:38:31,449 --> 00:38:28,099
applications of the armed mission

894
00:38:34,509 --> 00:38:31,459
missions the robotic and the crewed

895
00:38:36,459 --> 00:38:34,519
mission to both future human exploration

896
00:38:39,969 --> 00:38:36,469
machine but also future science missions

897
00:38:42,989 --> 00:38:39,979
and you know the ability to move large

898
00:38:46,509 --> 00:38:42,999
payload around the solar system the the

899
00:38:48,849 --> 00:38:46,519
ability to use innovative sensors and

900
00:38:51,729 --> 00:38:48,859
sensor technologies to do efficient

901
00:38:54,370 --> 00:38:51,739
proximity operations to land and

902
00:38:57,189 --> 00:38:54,380
interact on the surface of natural

903
00:39:00,089 --> 00:38:57,199
bodies Logie bodies the design of

904
00:39:02,680 --> 00:39:00,099
missions for low thrust and and maybe

905
00:39:04,900 --> 00:39:02,690
combination of low thrust and chemical

906
00:39:06,430 --> 00:39:04,910
high thrust which was that which was

907
00:39:08,979 --> 00:39:06,440
really underlying principle behind that

908
00:39:11,259 --> 00:39:08,989
first picture I showed you then long

909
00:39:14,130 --> 00:39:11,269
duration and high power solar electric

910
00:39:17,019 --> 00:39:14,140
propulsion and finally you know further

911
00:39:20,769 --> 00:39:17,029
engagement of extra vehicular activity

912
00:39:22,239 --> 00:39:20,779
in in challenging environments so with

913
00:39:25,490 --> 00:39:22,249

that I'm gonna leave you with this

914
00:39:27,530 --> 00:39:25,500
beautiful collage of arm the moon

915
00:39:38,099 --> 00:39:27,540
and earth and open it up to any

916
00:39:43,540 --> 00:39:41,220
yes sir a quick question for the

917
00:39:47,020 --> 00:39:43,550
longer-range goals are there any plans

918
00:39:50,859 --> 00:39:47,030
for resources traction fuel feedstock

919
00:39:52,359 --> 00:39:50,869
extraction from from bodies for the Mars

920
00:39:55,599 --> 00:39:52,369
leg of things yeah well they're

921
00:39:57,280 --> 00:39:55,609
absolutely one of the applicants is a

922
00:39:59,170 --> 00:39:57,290
number of potential applications for

923
00:40:00,970 --> 00:39:59,180
this and we are talking to two

924
00:40:03,310 --> 00:40:00,980
organizations like deep space industries

925
00:40:05,349 --> 00:40:03,320
and Planetary Resources about how they

926
00:40:07,359 --> 00:40:05,359
would take advantage of what we're doing

927
00:40:09,580 --> 00:40:07,369
so they could take advantage of the

928
00:40:12,460 --> 00:40:09,590
materials that we actually bring back

929
00:40:13,930 --> 00:40:12,470
you know in maybe even you know in the

930
00:40:16,690 --> 00:40:13,940
time of our mission or in some

931
00:40:18,940 --> 00:40:16,700
subsequent mission so you know if we can

932
00:40:21,220 --> 00:40:18,950
bring back some carbonaceous chondrite

933
00:40:23,349 --> 00:40:21,230
with with hydrated minerals might be a

934
00:40:25,060 --> 00:40:23,359
great source for water but we know these

935
00:40:27,460 --> 00:40:25,070
will be great great sources for oxygen

936
00:40:30,010 --> 00:40:27,470
so there's there's a lot going on there

937
00:40:33,310 --> 00:40:30,020
and I think so we're going to include

938
00:40:38,050 --> 00:40:33,320

that in our planning and the second half

939
00:40:40,570 --> 00:40:38,060
is for the Rosetta team how much how

940
00:40:42,070 --> 00:40:40,580
much coordination is there on with it

941
00:40:44,230 --> 00:40:42,080
what they are in the process of learning

942
00:40:46,750 --> 00:40:44,240
we're not coordinating with Rosetta

943
00:40:49,570 --> 00:40:46,760
we're looking at at what osiris-rex is

944
00:40:51,010 --> 00:40:49,580
doing and trying to make sure we

945
00:40:53,940 --> 00:40:51,020
understand what's going on there but

946
00:40:56,980 --> 00:40:53,950
both in the case of both Rosetta and

947
00:40:59,440 --> 00:40:56,990
Syrus Rex there's not as much there's a

948
00:41:01,180 --> 00:40:59,450
lot of ground in the loop for our

949
00:41:03,099 --> 00:41:01,190
mission we're gonna go much more on the

950
00:41:04,690 --> 00:41:03,109
autonomous side so we're gonna learn

951
00:41:05,950 --> 00:41:04,700
from both those missions about the

952
00:41:07,750 --> 00:41:05,960
nature of the bodies that they're

953
00:41:09,849 --> 00:41:07,760
visiting and as a matter of fact venue

954
00:41:11,890 --> 00:41:09,859
which is Osiris is Rex target is a

955
00:41:13,900 --> 00:41:11,900
potential target for us we could go

956
00:41:16,240 --> 00:41:13,910
there and bring back a boulder from from

957
00:41:18,400 --> 00:41:16,250
Venu so yeah there's a lot there's a lot

958
00:41:20,050 --> 00:41:18,410
of things to be learned from from all

959
00:41:22,120 --> 00:41:20,060
these missions and we're we're sharing

960
00:41:26,710 --> 00:41:22,130
information as we go thank you

961
00:41:30,940 --> 00:41:26,720
yes sir I have two questions about Plan

962
00:41:35,440 --> 00:41:30,950
B mm-hmm so the first one is it looked

963
00:41:37,300 --> 00:41:35,450

like I can see the difficulty of having

964
00:41:40,240 --> 00:41:37,310
a bag there so there's no bag and you're

965
00:41:44,020 --> 00:41:40,250
in your image for Plan B not at this

966
00:41:47,620 --> 00:41:44,030
point and I could and so the my concern

967
00:41:49,450 --> 00:41:47,630
is that the thing you think is a boulder

968
00:41:51,460 --> 00:41:49,460
is just kind of a blob that kind of

969
00:41:54,160 --> 00:41:51,470
dissolves when you

970
00:41:56,740 --> 00:41:54,170
when you start to handle it yep and so

971
00:41:58,660 --> 00:41:56,750
the the other part of my question is how

972
00:42:01,870 --> 00:41:58,670
you mentioned you had some way of

973
00:42:04,540 --> 00:42:01,880
characterizing these large asteroids is

974
00:42:07,839 --> 00:42:04,550
having boulders and so you say a little

975
00:42:09,400 --> 00:42:07,849
bit more about that well of the we've

976
00:42:11,710 --> 00:42:09,410
got basically three targets we're

977
00:42:13,960 --> 00:42:11,720
looking at for option B when is it Okawa

978
00:42:15,730 --> 00:42:13,970
which Hayabusa went to which we have

979
00:42:17,740 --> 00:42:15,740
very good imaging of so that's a

980
00:42:19,900 --> 00:42:17,750
well-characterized body and we believe

981
00:42:22,420 --> 00:42:19,910
there are there are a number of boulders

982
00:42:24,220 --> 00:42:22,430
on that surface that are probably that

983
00:42:26,109 --> 00:42:24,230
are accessible to us and can be

984
00:42:29,500 --> 00:42:26,119
extracted but the point you bring out

985
00:42:31,809 --> 00:42:29,510
about the nature of actually the boulder

986
00:42:34,180 --> 00:42:31,819
itself how well what's the integrity of

987
00:42:37,210 --> 00:42:34,190
the boulder how well is it is it

988
00:42:39,400 --> 00:42:37,220

attached to the surface how well is how

989
00:42:41,650 --> 00:42:39,410
much of a cohesive force is there those

990
00:42:43,450 --> 00:42:41,660
are all issues we're absolutely aware of

991
00:42:46,510 --> 00:42:43,460
we're thinking of but we won't know for

992
00:42:48,309 --> 00:42:46,520
sure until we get there so that's not

993
00:42:50,200 --> 00:42:48,319
uncommon for us you know we're going a

994
00:42:51,339 --> 00:42:50,210
little land on Mars somewhere we won't

995
00:42:52,930 --> 00:42:51,349
know what it's like until we actually

996
00:42:55,150 --> 00:42:52,940
get there so we need to design our

997
00:42:56,740 --> 00:42:55,160
systems to be tolerant of that and

998
00:42:58,300 --> 00:42:56,750
that's a big part of what worth what

999
00:42:59,680 --> 00:42:58,310
we're thinking about but that's one of

1000
00:43:02,470 --> 00:42:59,690
the things that adds of the complexity

1001
00:43:05,050 --> 00:43:02,480
of option B but at the same time on

1002
00:43:06,819 --> 00:43:05,060
option a we don't the targets we have

1003
00:43:09,670 --> 00:43:06,829
today we have a pretty good

1004
00:43:11,440 --> 00:43:09,680
understanding of of the size and we have

1005
00:43:12,970 --> 00:43:11,450
a range you know make four to seven

1006
00:43:15,099 --> 00:43:12,980
meters or something like but we don't

1007
00:43:17,290 --> 00:43:15,109
know the mass absolutely in absolute

1008
00:43:18,790 --> 00:43:17,300
terms very well only one of our targets

1009
00:43:21,010 --> 00:43:18,800
we have a pretty good upper bound on

1010
00:43:23,470 --> 00:43:21,020
mass so that's another inherent

1011
00:43:29,740 --> 00:43:23,480
uncertainty associated with with this

1012
00:43:31,540 --> 00:43:29,750
kind of exploration thank you well I see

1013
00:43:34,510 --> 00:43:31,550

this is rather fascinating to put a

1014
00:43:36,880 --> 00:43:34,520
asteroid around the moon and we spend a

1015
00:43:42,870 --> 00:43:36,890
lot of money on all these missions from

1016
00:43:45,030 --> 00:43:42,880
you know Mars and but I have this

1017
00:43:50,470 --> 00:43:45,040
question that's never been answered

1018
00:43:52,839 --> 00:43:50,480
adequately oh heck haven't we set up a

1019
00:43:56,410 --> 00:43:52,849
space station on the moon uh-huh

1020
00:43:59,230 --> 00:43:56,420
why okay that's going on there's some

1021
00:44:02,290 --> 00:43:59,240
kind of a mystery and you cannot give me

1022
00:44:04,810 --> 00:44:02,300
an adequate answer I know that okay well

1023
00:44:06,970 --> 00:44:04,820
I I was the chief engineer

1024
00:44:09,100 --> 00:44:06,980
the constellation program and part of

1025
00:44:10,270 --> 00:44:09,110
the what the constellation programs one

1026
00:44:13,450 --> 00:44:10,280
of the first things we were going to do

1027
00:44:17,350 --> 00:44:13,460
was establish habitats on the surface of

1028
00:44:19,420 --> 00:44:17,360
the Moon there will allow us to prove

1029
00:44:23,500 --> 00:44:19,430
out the systems that would need to work

1030
00:44:25,570 --> 00:44:23,510
for weeks to months to years in a hat

1031
00:44:27,760 --> 00:44:25,580
the hazardous environment of the surface

1032
00:44:29,350 --> 00:44:27,770
of Mars so that's where we were going

1033
00:44:30,820 --> 00:44:29,360
with that particular program and

1034
00:44:33,520 --> 00:44:30,830
fortunate that program got got got

1035
00:44:36,970 --> 00:44:33,530
cancelled so there's still a need to

1036
00:44:39,070 --> 00:44:36,980
prove out long duration long high

1037
00:44:41,620 --> 00:44:39,080
reliability systems habit you know

1038
00:44:44,230 --> 00:44:41,630

habitats with an environmental life

1039
00:44:46,870 --> 00:44:44,240
support system that can operate for

1040
00:44:48,730 --> 00:44:46,880
years and can easily repair to one

1041
00:44:50,500 --> 00:44:48,740
that's part of what we need to go prove

1042
00:44:52,480 --> 00:44:50,510
out now why we're not doing that today

1043
00:44:55,900 --> 00:44:52,490
you need to go talk to a friends in

1044
00:44:58,270 --> 00:44:55,910
Congress or in the White House okay

1045
00:45:00,850 --> 00:44:58,280
that's not that's not NASA was was

1046
00:45:04,420 --> 00:45:00,860
moving in that direction but we that was

1047
00:45:07,330 --> 00:45:04,430
we were directed elsewhere to talk to

1048
00:45:09,370 --> 00:45:07,340
the politicians and to talk to elsewhere

1049
00:45:13,150 --> 00:45:09,380
besides a scientist is a better name and

1050
00:45:16,000 --> 00:45:13,160
well thank you yes yes unfortunately

1051
00:45:19,480 --> 00:45:16,010
scientists don't control the money much

1052
00:45:20,920 --> 00:45:19,490
as we wish we did yes sir first what's

1053
00:45:23,170 --> 00:45:20,930
the relationship between the equipped

1054
00:45:25,810 --> 00:45:23,180
ecliptic and the orbit plane of the

1055
00:45:27,490 --> 00:45:25,820
distant retrograde orbit they're pretty

1056
00:45:29,620 --> 00:45:27,500
close to the same we're pretty much fine

1057
00:45:32,200 --> 00:45:29,630
in the play no slip we can we can fly

1058
00:45:34,720 --> 00:45:32,210
with a quite a range of declination with

1059
00:45:36,400 --> 00:45:34,730
that dr oh yeah that made it easier for

1060
00:45:37,930 --> 00:45:36,410
the astronaut astronauts to get there

1061
00:45:39,400 --> 00:45:37,940
got a change you're overplaying yeah

1062
00:45:41,020 --> 00:45:39,410
we've looked very carefully what it

1063
00:45:43,750 --> 00:45:41,030

takes for the astronauts to the crew to

1064
00:45:45,790 --> 00:45:43,760
get there how much of you our propellant

1065
00:45:47,320 --> 00:45:45,800
budget can you afford to dump the

1066
00:45:49,300 --> 00:45:47,330
angular momentum that's going to be

1067
00:45:52,030 --> 00:45:49,310
inherited in any rotating asteroid very

1068
00:45:53,890 --> 00:45:52,040
good it you'd be a little surprised at

1069
00:45:55,450 --> 00:45:53,900
this but what we've we've looked at that

1070
00:45:58,300 --> 00:45:55,460
very closely and you'd be surprised at

1071
00:45:59,920 --> 00:45:58,310
how little it takes when when the way

1072
00:46:01,780 --> 00:45:59,930
the asteroid we're talking about let's

1073
00:46:03,250 --> 00:46:01,790
imagine the worst case scenario right

1074
00:46:06,580 --> 00:46:03,260
now is we're assuming the asteroid is

1075
00:46:08,080 --> 00:46:06,590
rotating at about half an hour p.m. so

1076
00:46:11,260 --> 00:46:08,090
it's not very fast but this is a big

1077
00:46:12,730 --> 00:46:11,270
object so once we grab hold of it all of

1078
00:46:14,680 --> 00:46:12,740
our analysis shows what's gonna happen

1079
00:46:17,200 --> 00:46:14,690
is we're gonna go from spinning like

1080
00:46:18,309 --> 00:46:17,210
this to spinning like this we'll go into

1081
00:46:23,019 --> 00:46:18,319
a flat spin

1082
00:46:25,630 --> 00:46:23,029
thrusters my hydrazine thrusters with a

1083
00:46:28,180 --> 00:46:25,640
big moment arm in a matter of of hours

1084
00:46:30,459 --> 00:46:28,190
or a day or two I can Dees pin that

1085
00:46:32,469 --> 00:46:30,469
asteroid and that's exactly what I what

1086
00:46:34,390 --> 00:46:32,479
we need to do before we start our

1087
00:46:35,789 --> 00:46:34,400
maneuver back to the moon if you're

1088
00:46:38,499 --> 00:46:35,799

using hydrazine just hydrazine thrusters

1089
00:46:40,900 --> 00:46:38,509
22 newton hydrazine thrusters and the

1090
00:46:44,170 --> 00:46:40,910
third is more of a comment than a

1091
00:46:46,839 --> 00:46:44,180
question you can get a lot more electric

1092
00:46:49,239 --> 00:46:46,849
power per kilogram and per cubic meter

1093
00:46:50,829 --> 00:46:49,249
with the space new clogzilla power

1094
00:46:52,569 --> 00:46:50,839
systems that were developed in the 70s

1095
00:46:55,239 --> 00:46:52,579
and you can with solar panels and he

1096
00:46:59,140 --> 00:46:55,249
plans to do that for very heavy you know

1097
00:47:00,609 --> 00:46:59,150
you're talking about what you're talking

1098
00:47:02,799 --> 00:47:00,619
about 10 tons you're talking about a

1099
00:47:04,989 --> 00:47:02,809
hundred ton spacecraft you're gonna need

1100
00:47:07,359 --> 00:47:04,999
something that can't possibly be powered

1101
00:47:08,680 --> 00:47:07,369
by solar power well again I'm not sure

1102
00:47:09,189 --> 00:47:08,690
exactly what nuclear system you're

1103
00:47:10,509 --> 00:47:09,199
talking about

1104
00:47:12,249 --> 00:47:10,519
that's the snap reactor for this

1105
00:47:14,739 --> 00:47:12,259
although those are very low power you

1106
00:47:17,380 --> 00:47:14,749
can't those the RTGS the RTGS we flew

1107
00:47:19,029 --> 00:47:17,390
here on Cassini were you know 100 watt

1108
00:47:22,949 --> 00:47:19,039
class no the snap was a hundred

1109
00:47:25,569 --> 00:47:22,959
kilowatts this snap yeah systems system

1110
00:47:27,160 --> 00:47:25,579
exerted power it was it was a reactor

1111
00:47:29,259 --> 00:47:27,170
not on earth okay a reactor because I'm

1112
00:47:30,699 --> 00:47:29,269
thinking of the small the smaller ones

1113
00:47:33,579 --> 00:47:30,709

in the hundred K someday you know

1114
00:47:36,999 --> 00:47:33,589
reactors may play a big role in you know

1115
00:47:38,620 --> 00:47:37,009
thermal nuclear propulsion yeah but but

1116
00:47:39,939 --> 00:47:38,630
we don't need that today we can we

1117
00:47:42,189 --> 00:47:39,949
believe we can get up just like we're

1118
00:47:45,069 --> 00:47:42,199
doing at Jupiter now we're flying Juno

1119
00:47:46,989 --> 00:47:45,079
to Jupiter with solar arrays Rosetta was

1120
00:47:50,019 --> 00:47:46,999
out to five au with solar arrays we can

1121
00:47:50,709 --> 00:47:50,029
do that but and we believe we could

1122
00:47:52,239 --> 00:47:50,719
group huh

1123
00:47:54,039 --> 00:47:52,249
nothing very much bigger than those now

1124
00:47:55,630 --> 00:47:54,049
yeah it's you know we're not going to go

1125
00:47:57,880 --> 00:47:55,640
to Saturn with solar arrays I I don't

1126
00:48:00,430 --> 00:47:57,890
think but but we can we believe we can

1127
00:48:02,529 --> 00:48:00,440
assemble multi hundred watt solar array

1128
00:48:04,769 --> 00:48:02,539
configurations that can fly between the

1129
00:48:11,140 --> 00:48:04,779
earth and the moon and Earth and Mars

1130
00:48:15,999 --> 00:48:11,150
yes ma'am hi are there any plans to add

1131
00:48:18,189 --> 00:48:16,009
any additional I am thrusters to the

1132
00:48:24,099 --> 00:48:18,199
roboticle spacecraft to increase

1133
00:48:26,650 --> 00:48:24,109
velocity we yes there is the we've we're

1134
00:48:29,829 --> 00:48:26,660
looking today it upping our power saved

1135
00:48:31,630 --> 00:48:29,839
from 50 kilowatts to 60 to 80 and as we

1136
00:48:33,250 --> 00:48:31,640
go up in power

1137
00:48:34,990 --> 00:48:33,260
the basic of each of our thrusters is

1138
00:48:37,360 --> 00:48:35,000

about a 12 and a half kilowatt thruster

1139
00:48:40,810 --> 00:48:37,370
so if we want more power if we want to

1140
00:48:43,450 --> 00:48:40,820
be able to move more mass faster then we

1141
00:48:45,130 --> 00:48:43,460
would add a thruster and so we just kind

1142
00:48:47,620 --> 00:48:45,140
of would grow in increments of like 12

1143
00:48:49,780 --> 00:48:47,630
kilowatts so if you think of like a

1144
00:48:52,210 --> 00:48:49,790
hundred and fifty kilowatt system it's

1145
00:48:55,240 --> 00:48:52,220
three times our system so what we would

1146
00:48:57,580 --> 00:48:55,250
nominally do is take our three thrusters

1147
00:48:59,980 --> 00:48:57,590
turn them into nine and probably put a

1148
00:49:01,930 --> 00:48:59,990
spare or two on them and that gives us

1149
00:49:03,970 --> 00:49:01,940
the higher power and the higher thrust

1150
00:49:05,470 --> 00:49:03,980
capability of our systems on the other

1151
00:49:07,810 --> 00:49:05,480
hand maybe you're thinking we can

1152
00:49:10,120 --> 00:49:07,820
certainly go to higher power individual

1153
00:49:12,100 --> 00:49:10,130
thrusters we can go from the 12 and a

1154
00:49:15,010 --> 00:49:12,110
half kilowatt to two multiple you know

1155
00:49:16,510 --> 00:49:15,020
multiples of that two but again that's

1156
00:49:18,130 --> 00:49:16,520
stuff that needs to be proven one of the

1157
00:49:22,120 --> 00:49:18,140
things we have to prove with our solar

1158
00:49:24,160 --> 00:49:22,130
electric thrusters is how do you how do

1159
00:49:26,920 --> 00:49:24,170
you prove that you can operate a

1160
00:49:29,440 --> 00:49:26,930
thruster at the power levels we have and

1161
00:49:30,970 --> 00:49:29,450
push that much propellant through it you

1162
00:49:34,630 --> 00:49:30,980
know the ion thrusters of dawn are

1163
00:49:37,440 --> 00:49:34,640

basically pushing you know 150 or so

1164
00:49:40,750 --> 00:49:37,450
kilograms per thruster will be pushing

1165
00:49:43,120 --> 00:49:40,760
three tons 3,000 kilograms per thruster

1166
00:49:44,830 --> 00:49:43,130
so that's part of the arch and part of

1167
00:49:46,540 --> 00:49:44,840
the challenge of our solar electric

1168
00:49:51,450 --> 00:49:46,550
propulsion experts here at JPL in it

1169
00:49:58,390 --> 00:49:55,300
two questions one with your landing and

1170
00:49:59,710 --> 00:49:58,400
Boulder pickup plan did I understand

1171
00:50:02,350 --> 00:49:59,720
correctly that you're planning to store

1172
00:50:04,780 --> 00:50:02,360
energy like kinetically in those in the

1173
00:50:06,460 --> 00:50:04,790
legs not really stores now you won't

1174
00:50:09,730 --> 00:50:06,470
store you'll use the you know you'll

1175
00:50:11,920 --> 00:50:09,740
you've got actuators in the legs for

1176
00:50:15,130 --> 00:50:11,930
actuators per leg that basically will

1177
00:50:17,860 --> 00:50:15,140
allow you to comply them to land gently

1178
00:50:19,870 --> 00:50:17,870
and conform to the surface and then when

1179
00:50:21,490 --> 00:50:19,880
you're ready to takeoff you just go from

1180
00:50:23,920 --> 00:50:21,500
that spring point and turn the actuators

1181
00:50:27,040 --> 00:50:23,930
on and straighten them out okay the

1182
00:50:29,740 --> 00:50:27,050
second question with your bag strategy I

1183
00:50:31,240 --> 00:50:29,750
suppose both of them really since you

1184
00:50:32,710 --> 00:50:31,250
don't know the composition of the

1185
00:50:34,450 --> 00:50:32,720
asteroid you're not going to know the

1186
00:50:36,280 --> 00:50:34,460
center of mass ahead of time or any of

1187
00:50:39,100 --> 00:50:36,290
that so exactly right so how do you

1188
00:50:41,560 --> 00:50:39,110

articulate that payload or the engines

1189
00:50:42,940 --> 00:50:41,570
or well that's one of that's absolutely

1190
00:50:44,130 --> 00:50:42,950
one of our challenges we don't know the

1191
00:50:44,940 --> 00:50:44,140
shape for example

1192
00:50:46,500 --> 00:50:44,950
it's one of the things we're gonna have

1193
00:50:48,330 --> 00:50:46,510
to figure out how to deal with when we

1194
00:50:50,040 --> 00:50:48,340
actually get there and we'll have we'll

1195
00:50:51,570 --> 00:50:50,050
develop a model will know where the spin

1196
00:50:53,640 --> 00:50:51,580
axis is the rotation is we'll know the

1197
00:50:55,320 --> 00:50:53,650
CG is there but depending on where it is

1198
00:50:57,420 --> 00:50:55,330
we'll need to be able to accommodate

1199
00:50:59,760 --> 00:50:57,430
that so one of the studies we've done

1200
00:51:01,680 --> 00:50:59,770
today and will continue to do is look at

1201
00:51:03,810 --> 00:51:01,690
different configuration different shapes

1202
00:51:05,940 --> 00:51:03,820
different mass properties run some money

1203
00:51:07,560 --> 00:51:05,950
Carlo analyses and look kind of

1204
00:51:10,560 --> 00:51:07,570
probabilistically do we have a system

1205
00:51:13,440 --> 00:51:10,570
that can deal with the 99% probable

1206
00:51:16,020 --> 00:51:13,450
scenario now with those pedals we have

1207
00:51:18,090 --> 00:51:16,030
the ability to move the body around once

1208
00:51:20,340 --> 00:51:18,100
it's inside once the asteroid is inside

1209
00:51:22,830 --> 00:51:20,350
and once it's in you know touched on the

1210
00:51:25,500 --> 00:51:22,840
Speight on the on the surface of the

1211
00:51:27,780 --> 00:51:25,510
spacecraft on the top of spacecraft so

1212
00:51:29,730 --> 00:51:27,790
well we'll have to do we're going to

1213
00:51:31,080 --> 00:51:29,740

have to do some clever thinking when we

1214
00:51:32,610 --> 00:51:31,090
actually get there decide what we're

1215
00:51:37,860 --> 00:51:32,620
gonna do and that's the same will be

1216
00:51:40,290 --> 00:51:37,870
true with option B thank you so the

1217
00:51:42,360 --> 00:51:40,300
constellation program was cancelled I

1218
00:51:44,340 --> 00:51:42,370
think that's because of budget how would

1219
00:51:47,790 --> 00:51:44,350
you say we would go about going to Mars

1220
00:51:52,370 --> 00:51:47,800
if NASA had an ideal budget as opposed

1221
00:51:54,720 --> 00:51:52,380
to what it is now well you know some

1222
00:51:56,280 --> 00:51:54,730
there's a number of people that have

1223
00:51:57,990 --> 00:51:56,290
been looking at human exploration

1224
00:52:00,870 --> 00:51:58,000
architectures for the movie there was a

1225
00:52:02,580 --> 00:52:00,880
there was a what we call the DRA 5 which

1226
00:52:05,040 --> 00:52:02,590
was basically a design reference

1227
00:52:06,930 --> 00:52:05,050
architecture for human exploration and

1228
00:52:09,030 --> 00:52:06,940
it involved a lot of chemical propulsion

1229
00:52:11,610 --> 00:52:09,040
a lot of rocket launches and things like

1230
00:52:12,990 --> 00:52:11,620
that so we're looking at architectures

1231
00:52:15,630 --> 00:52:13,000
today that involve a lot more of these

1232
00:52:18,630 --> 00:52:15,640
SEP systems which are much more reusable

1233
00:52:20,910 --> 00:52:18,640
we believe than the other systems so I

1234
00:52:23,820 --> 00:52:20,920
haven't heard any new numbers on what

1235
00:52:25,830 --> 00:52:23,830
such a program would cost but but what

1236
00:52:28,170 --> 00:52:25,840
we're talking about today is what we

1237
00:52:30,930 --> 00:52:28,180
call a sustainable exploration strategy

1238
00:52:32,610 --> 00:52:30,940

something that builds on it tries to

1239
00:52:35,970 --> 00:52:32,620
work within the budget we have today

1240
00:52:38,520 --> 00:52:35,980
that builds on the the robotic and the

1241
00:52:41,130 --> 00:52:38,530
human program capabilities sharing those

1242
00:52:43,110 --> 00:52:41,140
like arm is doing builds on the

1243
00:52:45,990 --> 00:52:43,120
technology developments builds on

1244
00:52:48,090 --> 00:52:46,000
commercial capabilities and is going to

1245
00:52:51,270 --> 00:52:48,100
involve international but you know

1246
00:52:54,120 --> 00:52:51,280
partnerships so all of that is a you

1247
00:52:56,840 --> 00:52:54,130
know a real challenge to come to put

1248
00:53:00,170 --> 00:52:56,850
together a program that they actually is

1249
00:53:01,670 --> 00:53:00,180
can be accomplished it's it's meats it

1250
00:53:03,950 --> 00:53:01,680
fits within the kind of constraints we

1251
00:53:07,010 --> 00:53:03,960
can imagine so it's a it's a great dream

1252
00:53:08,120 --> 00:53:07,020
a lot of us have I don't know what what

1253
00:53:10,430 --> 00:53:08,130
the real if somebody could write a check

1254
00:53:12,800 --> 00:53:10,440
today I don't know exactly what it would

1255
00:53:19,580 --> 00:53:12,810
cost but it's in the you know tens of

1256
00:53:22,130 --> 00:53:19,590
billions thank you hi hi you mentioned

1257
00:53:24,260 --> 00:53:22,140
during a the the landing phase of option

1258
00:53:25,880 --> 00:53:24,270
B that you had some ideas how to I guess

1259
00:53:28,700 --> 00:53:25,890
preserve the integrity of the solar

1260
00:53:29,780 --> 00:53:28,710
panels mm-hmm and I just wonder if you

1261
00:53:32,410 --> 00:53:29,790
want to explain what some of those ideas

1262
00:53:35,570 --> 00:53:32,420
are well a little more detail sure well

1263
00:53:37,190 --> 00:53:35,580

again the depending on where you're

1264
00:53:39,050 --> 00:53:37,200
landing you've got to have a if you

1265
00:53:41,120 --> 00:53:39,060
imagine that that 50 meter wingspan

1266
00:53:43,400 --> 00:53:41,130
you've got to have a you know clear

1267
00:53:45,500 --> 00:53:43,410
access for those you'll obviously rotate

1268
00:53:48,340 --> 00:53:45,510
those solar arrays away from the surface

1269
00:53:50,300 --> 00:53:48,350
the the solar arrays themselves are very

1270
00:53:52,160 --> 00:53:50,310
flexible you know they're gonna be 1/10

1271
00:53:54,020 --> 00:53:52,170
of a Hertz system so we've got to deal

1272
00:53:56,390 --> 00:53:54,030
with with with that we need a system

1273
00:53:58,700 --> 00:53:56,400
that's recognizing and is controlling

1274
00:54:00,710 --> 00:53:58,710
all of that activity while we land very

1275
00:54:03,680 --> 00:54:00,720
gently so we don't excite anything so

1276
00:54:05,570 --> 00:54:03,690
that's a control design problem that we

1277
00:54:09,020 --> 00:54:05,580
we know how to handle one of these we

1278
00:54:11,810 --> 00:54:09,030
don't yet understand and how we're

1279
00:54:15,350 --> 00:54:11,820
trying to characterize is the potential

1280
00:54:17,480 --> 00:54:15,360
for dust or for debris during any of our

1281
00:54:19,640 --> 00:54:17,490
interactions that is we pull the boulder

1282
00:54:21,680 --> 00:54:19,650
off we're gonna pull some material with

1283
00:54:24,170 --> 00:54:21,690
us well what what happens to that

1284
00:54:27,080 --> 00:54:24,180
material is that we at some risk of that

1285
00:54:29,330 --> 00:54:27,090
and that's one of the ideas you know we

1286
00:54:32,180 --> 00:54:29,340
have do have some concepts where we

1287
00:54:35,930 --> 00:54:32,190
could use a bag to encapsulate the

1288
00:54:38,120 --> 00:54:35,940

boulder for option B if we were going to

1289
00:54:40,130 --> 00:54:38,130
Phobos for example bringing back a

1290
00:54:41,360 --> 00:54:40,140
sample from there for planetary

1291
00:54:43,580 --> 00:54:41,370
protection purposes where you night

1292
00:54:45,170 --> 00:54:43,590
might need to encapsulate so those are

1293
00:54:51,100 --> 00:54:45,180
options that we may look at in the

1294
00:54:53,750 --> 00:54:51,110
future but trying to understand you know

1295
00:54:55,520 --> 00:54:53,760
we won't again we will not know until we

1296
00:54:58,340 --> 00:54:55,530
get there what we're really facing in

1297
00:55:00,260 --> 00:54:58,350
terms of finding a safe Boulder to pick

1298
00:55:01,850 --> 00:55:00,270
up in a safe place to do it except an

1299
00:55:06,110 --> 00:55:01,860
inner cowl we think we can do that in a

1300
00:55:08,060 --> 00:55:06,120
cow a day to the do your study so far I

1301
00:55:08,359 --> 00:55:08,070
tend to favor one design versus the

1302
00:55:11,390 --> 00:55:08,369
other

1303
00:55:13,880 --> 00:55:11,400
terms today well ray of the solar I my

1304
00:55:14,960 --> 00:55:13,890
job is to be completely objective about

1305
00:55:21,739 --> 00:55:14,970
that

1306
00:55:23,900 --> 00:55:21,749
pretty Pro one or the other so our job

1307
00:55:26,359 --> 00:55:23,910
is to bring forward to the decision

1308
00:55:27,380 --> 00:55:26,369
makers robert lightfoot our associate

1309
00:55:30,859 --> 00:55:27,390
administrator being the principal

1310
00:55:32,089 --> 00:55:30,869
decision-maker here a balance story you

1311
00:55:34,039 --> 00:55:32,099
know what are the costs what are the

1312
00:55:35,720 --> 00:55:34,049
risks what are the cost risks you know

1313
00:55:38,120 --> 00:55:35,730

what are the benefits of one versus

1314
00:55:39,890 --> 00:55:38,130
another from different communities so I

1315
00:55:43,309 --> 00:55:39,900
can't tell you what what they're gonna

1316
00:55:45,140 --> 00:55:43,319
make that decision based on and and and

1317
00:55:47,630 --> 00:55:45,150
I can tell you though that I would be

1318
00:55:50,720 --> 00:55:47,640
extremely happy and I think we as an

1319
00:55:52,489 --> 00:55:50,730
institution JPL would love to do either

1320
00:55:54,739 --> 00:55:52,499
one of these options I think they're

1321
00:55:57,920 --> 00:55:54,749
both the kind of challenging exciting

1322
00:56:00,759 --> 00:55:57,930
kind of mission that that this

1323
00:56:02,329 --> 00:56:00,769
institution is just designed to go do

1324
00:56:06,950 --> 00:56:02,339
thanks very much

1325
00:56:10,460 --> 00:56:06,960
oh I got questions from the from the

1326
00:56:13,009 --> 00:56:10,470
internet here oh when is a demonstration

1327
00:56:14,749 --> 00:56:13,019
mission to test arm scheduled to be

1328
00:56:17,299 --> 00:56:14,759
flown a demonstration mission well there

1329
00:56:19,880 --> 00:56:17,309
is no demonstration mission to test arm

1330
00:56:23,239 --> 00:56:19,890
arm is a demonstration mission it's a

1331
00:56:25,700 --> 00:56:23,249
technology demonstration mission so we

1332
00:56:28,309 --> 00:56:25,710
don't feel there's any that we need any

1333
00:56:30,769 --> 00:56:28,319
precursors per se to to prove out the

1334
00:56:33,559 --> 00:56:30,779
spacecraft it's great to have precursors

1335
00:56:35,089 --> 00:56:33,569
of the targets so for example you know

1336
00:56:37,489 --> 00:56:35,099
when osiris-rex is at Venu

1337
00:56:39,499 --> 00:56:37,499
it's going to tell us a lot about that

1338
00:56:41,779 --> 00:56:39,509

object and where that we've got boulders

1339
00:56:45,470 --> 00:56:41,789
that we can go to but we won't know that

1340
00:56:47,479 --> 00:56:45,480
until about 2018 okay how do you

1341
00:56:49,809 --> 00:56:47,489
calculate the flight path away from an

1342
00:56:54,079 --> 00:56:49,819
asteroid with a variable unknown mass in

1343
00:56:55,849 --> 00:56:54,089
option B well it turns out option B is

1344
00:56:58,759 --> 00:56:55,859
fundamentally different than option a

1345
00:57:01,339 --> 00:56:58,769
option a because it's so massive you

1346
00:57:04,009 --> 00:57:01,349
know hundreds of tons we're going we're

1347
00:57:05,720 --> 00:57:04,019
following we're going with it it is you

1348
00:57:08,720 --> 00:57:05,730
know we're we've docked to it and we're

1349
00:57:12,109 --> 00:57:08,730
just nudging it a little bit with option

1350
00:57:14,359 --> 00:57:12,119
B when we're talking about 10 tons maybe

1351
00:57:15,920 --> 00:57:14,369
20 tons you know that's not much more

1352
00:57:17,870 --> 00:57:15,930
than the propellant we're carrying on

1353
00:57:21,109 --> 00:57:17,880
board so we're actually able to fly that

1354
00:57:22,000 --> 00:57:21,119
mission to where we want so we can

1355
00:57:24,370 --> 00:57:22,010
control

1356
00:57:27,040 --> 00:57:24,380
the velocity we put a lot more you can

1357
00:57:28,660 --> 00:57:27,050
put a lot more Delta V into that the the

1358
00:57:31,090 --> 00:57:28,670
difference though between a and B is

1359
00:57:32,500 --> 00:57:31,100
another big difference is the asteroids

1360
00:57:34,210 --> 00:57:32,510
that are coming the small asteroids are

1361
00:57:37,660 --> 00:57:34,220
coming back towards in the sister space

1362
00:57:40,750 --> 00:57:37,670
their relative velocity to earth their V

1363
00:57:44,560 --> 00:57:40,760

infinity is small it's one and a half to

1364
00:57:47,020 --> 00:57:44,570
two kilometers a second the big

1365
00:57:49,120 --> 00:57:47,030
asteroids are moving much faster so

1366
00:57:51,310 --> 00:57:49,130
we've got to provide a lot more Delta V

1367
00:57:54,430 --> 00:57:51,320
to bring back the boulder from the big

1368
00:57:56,920 --> 00:57:54,440
asteroid so our nav emissions here know

1369
00:58:01,210 --> 00:57:56,930
exactly how to do these calculations and

1370
00:58:03,820 --> 00:58:01,220
so we basically can deal with the

1371
00:58:06,400 --> 00:58:03,830
variable mass but we can't but there's a

1372
00:58:09,880 --> 00:58:06,410
limit to what we can bring back in a

1373
00:58:11,500 --> 00:58:09,890
certain period of time so if we find out

1374
00:58:13,420 --> 00:58:11,510
we've picked up too big a massive

1375
00:58:14,950 --> 00:58:13,430
boulder we want to get a certain get

1376
00:58:16,750 --> 00:58:14,960
back at a certain time we may have to

1377
00:58:18,190 --> 00:58:16,760
put it down drop it and go pick up

1378
00:58:20,530 --> 00:58:18,200
something else that maybe is a little

1379
00:58:22,750 --> 00:58:20,540
less massive on the other hand we can

1380
00:58:25,900 --> 00:58:22,760
also just take a little bit more time

1381
00:58:28,360 --> 00:58:25,910
assuming we have enough propellant okay

1382
00:58:29,650 --> 00:58:28,370
I've got two more questions here as well

1383
00:58:32,500 --> 00:58:29,660
the samples be contaminated by the

1384
00:58:36,430 --> 00:58:32,510
capture process very good question

1385
00:58:38,950 --> 00:58:36,440
the reality is yes to some extent you

1386
00:58:40,600 --> 00:58:38,960
know in the bag you know we may the bag

1387
00:58:44,350 --> 00:58:40,610
itself may represent some level of

1388
00:58:46,330 --> 00:58:44,360

contamination again this isn't a science

1389
00:58:47,560 --> 00:58:46,340
mission per se we're gonna be very

1390
00:58:50,800 --> 00:58:47,570
sensitive to what the science community

1391
00:58:53,860 --> 00:58:50,810
would like to do but we'll find ways to

1392
00:58:55,840 --> 00:58:53,870
try to minimize that effect but there's

1393
00:58:58,270 --> 00:58:55,850
a big difference here because you've got

1394
00:59:00,490 --> 00:58:58,280
a whole body you can scrape off some of

1395
00:59:02,740 --> 00:59:00,500
the surface and get inside it but that's

1396
00:59:04,960 --> 00:59:02,750
what you're interested in so there is

1397
00:59:07,120 --> 00:59:04,970
the chance on option B that you can

1398
00:59:09,940 --> 00:59:07,130
contaminate with xenon or even hydrazine

1399
00:59:12,220 --> 00:59:09,950
with option a you know you're inside the

1400
00:59:15,330 --> 00:59:12,230
bag or maybe a little more a little less

1401
00:59:17,560 --> 00:59:15,340
likely to be contaminated so we'll see

1402
00:59:20,020 --> 00:59:17,570
and again it's going to depend on what

1403
00:59:23,290 --> 00:59:20,030
what the science community would like us

1404
00:59:25,240 --> 00:59:23,300
to try to do potential value are there

1405
00:59:27,370 --> 00:59:25,250
and having this asteroid available to

1406
00:59:28,510 --> 00:59:27,380
the potential value okay why are we

1407
00:59:31,720 --> 00:59:28,520
doing this mission okay

1408
00:59:32,950 --> 00:59:31,730
well as far as you know I already told

1409
00:59:34,720 --> 00:59:32,960
you all about the spacecraft self but

1410
00:59:36,730 --> 00:59:34,730
having an asteroid material avail

1411
00:59:38,200 --> 00:59:36,740
available to us I mentioned what have

1412
00:59:40,450 --> 00:59:38,210
you asked about you know the idea of

1413
00:59:42,220 --> 00:59:40,460

using that material for commercial

1414
00:59:44,620 --> 00:59:42,230
purposes you know there are companies

1415
00:59:46,839 --> 00:59:44,630
that would love to find a way to to turn

1416
00:59:50,250 --> 00:59:46,849
asteroid material into useful things

1417
00:59:53,109 --> 00:59:50,260
like propellant and so we are bringing

1418
00:59:55,660 --> 00:59:53,119
samples large quantities of material

1419
00:59:58,960 --> 00:59:55,670
back that they can look at how to

1420
01:00:00,370 --> 00:59:58,970
process in fact could even process parts

1421
01:00:03,849 --> 01:00:00,380
you know parts of the asteroid that we

1422
01:00:06,370 --> 01:00:03,859
bring we brought back if you think of

1423
01:00:08,620 --> 01:00:06,380
the planetary defense problem you know

1424
01:00:10,569 --> 01:00:08,630
knowing how an asteroid is held together

1425
01:00:14,069 --> 01:00:10,579
knowing what the inner structure of an

1426
01:00:15,970 --> 01:00:14,079
asteroid is would be of enormous value

1427
01:00:18,099 --> 01:00:15,980
again from a science point of view

1428
01:00:21,510 --> 01:00:18,109
there's a lot of a lot of opportunities

1429
01:00:24,250 --> 01:00:21,520
for science and again I think you know

1430
01:00:25,540 --> 01:00:24,260
because this is a technology

1431
01:00:28,980 --> 01:00:25,550
demonstration and it's about human

1432
01:00:33,040 --> 01:00:28,990
exploration it really is about how do we

1433
01:00:35,920 --> 01:00:33,050
develop and operate for the first time

1434
01:00:38,890 --> 01:00:35,930
in in deep space with humans so with