1
00:00:00,600 --> 00:00:02,936
(bold music)

2
00:00:11,378 --> 00:00:12,579
- Take a look,

3
00:00:12,579 --> 00:00:15,048
this is an asteroid
observed during

4
00:00:15,048 --> 00:00:17,017
a close approach to Earth,

5
00:00:17,017 --> 00:00:19,486
taken just a few
weeks ago using radar.

6
00:00:19,486 --> 00:00:23,656
Asteroid 2014 JO25, came within
1.2 million miles of Earth.

7
00:00:26,593 --> 00:00:30,230
It was a kilometer,
or 2/3 of a mile wide,

8
00:00:30,230 --> 00:00:32,665
the largest to come
so close to our planet

9
00:00:32,665 --> 00:00:34,401
in the past 13 years.

10
00:00:35,835 --> 00:00:38,805
Hello, I'm Gay Yee Hill, at
NASA's Jet Propulsion Laboratory

11
00:00:38,805 --> 00:00:40,206
in Pasadena, California.

12
00:00:40,206 --> 00:00:42,542
NASA takes planetary defense,

13
00:00:42,542 --> 00:00:46,479
and the hunt for asteroids
and comets very seriously.

14
00:00:46,479 --> 00:00:50,150
NASA-funded projects
account for over 90%

15
00:00:50,150 --> 00:00:52,852
of worldwide efforts to find,

16
00:00:52,852 --> 00:00:56,423
track, and characterize
near Earth objects,

17
00:00:56,423 --> 00:00:58,792
that get too close for comfort.

18
00:00:58,792 --> 00:01:02,195
Tiny asteroids hit our
atmosphere all the time,

19
00:01:02,195 --> 00:01:04,230
producing meteors or fireballs.

20
00:01:04,230 --> 00:01:08,001
This chart shows the hundreds
of significant fireballs

21
00:01:08,001 --> 00:01:13,006
detected by US government
sensors from 1988 until now.

22
00:01:13,006 --> 00:01:17,177
It doesn't happen often, but
bigger asteroids hit Earth too,

23
00:01:17,177 --> 00:01:19,446
it happened a few years ago.

24
00:01:19,446 --> 00:01:23,283
A 20-meter asteroid
exploded in the atmosphere

25
00:01:24,651 --> 00:01:26,386
above Chelyabinsk, Russia.

26
00:01:26,386 --> 00:01:29,422
So, it's important
to be on the lookout.

27
00:01:29,422 --> 00:01:33,026
To start things off, let's give
you a simplified explanation

28
00:01:33,026 --> 00:01:35,595
of how we hunt for space rocks.

29
00:01:36,996 --> 00:01:40,033
- [Narrator] How do we
spot near Earth asteroids?

30
00:01:40,033 --> 00:01:44,104
To start, survey
telescopes scan the sky.

31
00:01:44,104 --> 00:01:46,439
When multiple pictures
of the same spot

32
00:01:46,439 --> 00:01:50,176
show a speck that's moving,
computers automatically check it

33
00:01:50,176 --> 00:01:53,613

against a database
of known objects.

34
00:01:53,613 --> 00:01:55,048
If there's no match,

35
00:01:55,048 --> 00:01:58,985
it gets added to a list
of objects to confirm.

36
00:01:58,985 --> 00:02:01,287
And if it looks like it'll
pass very close to us,

37
00:02:01,287 --> 00:02:03,923
we give it top priority.

38
00:02:03,923 --> 00:02:07,327
Then it's time to call
in reinforcements.

39
00:02:08,728 --> 00:02:11,297
More astronomers from
NASA, other institutions,

40
00:02:11,297 --> 00:02:13,433
and even the amateur community,

41
00:02:13,433 --> 00:02:15,802
submit additional observations.

42
00:02:15,802 --> 00:02:17,403
Each new data point

43
00:02:17,403 --> 00:02:18,872
helps refine the projected path,

44
00:02:18,872 --> 00:02:19,806
and this asteroid

45
00:02:19,806 --> 00:02:22,509
is gonna fly right on by.

46
00:02:22,509 --> 00:02:24,978
All the info will
be posted online,

47
00:02:24,978 --> 00:02:28,748
so it can continue to be
tracked and monitored.

48
00:02:28,748 --> 00:02:30,483
Nice work planetary
defense team.

49
00:02:30,483 --> 00:02:32,485
Keep watching the skies.

50
00:02:36,789 --> 00:02:41,628
- Now NASA is directed
by Congress to find
90% of asteroids

51
00:02:41,628 --> 00:02:45,632
460 feet, that's 140
meters, or greater in size.

52
00:02:47,433 --> 00:02:49,903
NASA's Planetary Defense
Coordination Office

53
00:02:49,903 --> 00:02:52,438
is responsible for
finding, tracking,

54
00:02:52,438 --> 00:02:54,974
and characterizing
potentially hazardous

55
00:02:54,974 --> 00:02:58,144
asteroids and comets
coming near Earth.

56
00:02:58,144 --> 00:03:01,581
Lindley Johnson is the agency's
Planetary Defense Officer,

57
00:03:01,581 --> 00:03:03,816
and Kelly Fast is
the Manager of the

58
00:03:03,816 --> 00:03:06,920
Near Earth Object
Observations Program.

59
00:03:06,920 --> 00:03:08,288
They join us now,

60
00:03:08,288 --> 00:03:10,757
live from NASA Headquarters
in Washington DC,

61
00:03:10,757 --> 00:03:14,594
where all NASA planetary
defense efforts are managed.

62
00:03:14,594 --> 00:03:16,329
Hi Lindley, hi Kelly,

63
00:03:17,497 --> 00:03:19,165
Let's start out
with a question--

64
00:03:19,165 --> 00:03:20,633
- Hi.
- Hi.

65
00:03:20,633 --> 00:03:22,969

- Let's start off with
a question for Lindley.

66
00:03:22,969 --> 00:03:26,339
What exactly is NASA
doing to protect Earth

67
00:03:26,339 --> 00:03:29,342
from dangerous
asteroids and comets?

68
00:03:31,511 --> 00:03:33,813
- Well Gay, that's the
whole purpose behind

69
00:03:33,813 --> 00:03:36,249
our Planetary Defense
Coordination Office,

70
00:03:36,249 --> 00:03:38,017
is to oversee the
efforts of NASA

71
00:03:38,017 --> 00:03:41,354
in our observatories
that are finding,

72
00:03:41,354 --> 00:03:44,257
tracking, and characterizing
near Earth objects.

73
00:03:44,257 --> 00:03:47,393
And to work with other
government agencies

74
00:03:47,393 --> 00:03:51,464
to develop a response if we
happen to find one that is

75
00:03:51,464 --> 00:03:55,235

on an impact trajectory
with the Earth.

76
00:03:55,235 --> 00:03:58,504
We work with the Federal
Emergency Management Agency

77
00:03:58,504 --> 00:04:02,609
and other government
agencies to develop the plans

78
00:04:02,609 --> 00:04:04,644
and the strategies
that would be used

79
00:04:04,644 --> 00:04:07,480
to respond to a
detected impactor.

80
00:04:09,582 --> 00:04:12,485
But the most important
part of our business

81
00:04:12,485 --> 00:04:15,555
is to find them, we
have to find them

82
00:04:15,555 --> 00:04:17,190
to be able to do
anything about them.

83
00:04:17,190 --> 00:04:20,059
So our main priority
is to find them

84
00:04:20,059 --> 00:04:21,628
as early as we can
and that's what

85
00:04:21,628 --> 00:04:24,230

the near Earth
Object Observations
Program is all about.

86
00:04:24,230 --> 00:04:26,466
- All right, so
question for Kelly.

87
00:04:26,466 --> 00:04:28,468
How are we finding them?

88
00:04:32,171 --> 00:04:35,375
- Well Gay, NASA funds
observatories to survey

89
00:04:35,375 --> 00:04:38,511
the skies each clear
night to try to find

90
00:04:38,511 --> 00:04:40,780
these near Earth objects,
to discover them.

91
00:04:40,780 --> 00:04:43,616
And then we also fund
a number of astronomers

92
00:04:43,616 --> 00:04:47,153
to follow up those
discoveries to try to get

93
00:04:47,153 --> 00:04:49,656
more observations of the
positions of those objects

94
00:04:49,656 --> 00:04:51,724
to better understand
how they're moving.

95
00:04:51,724 --> 00:04:54,360

Now all of those observations
from the people we fund

96
00:04:54,360 --> 00:04:56,362
and anybody observing
around the world

97
00:04:56,362 --> 00:05:00,166
go to the Minor Planets
Center where they catalog

98
00:05:00,166 --> 00:05:02,635
and keep all those observations,

99
00:05:02,635 --> 00:05:05,872
but also they do a
calculation of the orbit

100
00:05:05,872 --> 00:05:08,207
based on how those
objects are moving

101
00:05:08,207 --> 00:05:11,511
to try to figure out where
it's going to be in the future

102
00:05:11,511 --> 00:05:14,847
and if there is a near-term
impact risk to Earth

103
00:05:14,847 --> 00:05:17,216
they will let NASA
know about it.

104
00:05:17,216 --> 00:05:20,053
Now also, JPL's Center for
near Earth Object Studies,

105
00:05:20,053 --> 00:05:23,222
they also take those

positions, those observations

106
00:05:23,222 --> 00:05:25,525
and they do precision
orbit calculation,

107
00:05:25,525 --> 00:05:27,660
looking at where those
asteroids will be

108
00:05:27,660 --> 00:05:30,730
in the near term but
also into the future,

109
00:05:30,730 --> 00:05:32,432
decades into the future.

110
00:05:32,432 --> 00:05:35,601
Because if there was something
that posed an impact risk,

111
00:05:35,601 --> 00:05:38,338
you'd wanna know about
it well ahead of time

112
00:05:38,338 --> 00:05:40,239
so that you could plan
your response to it.

113
00:05:40,239 --> 00:05:43,976
- And Kelly, are we alone
in this whole process?

114
00:05:43,976 --> 00:05:46,979
Are other countries
involved at all?

115
00:05:48,381 --> 00:05:51,084
- Oh yeah, there are other
countries involved and in fact,

116
00:05:51,084 --> 00:05:54,320
there is an International
Asteroid Warning Network

117
00:05:54,320 --> 00:05:56,089
that is a UN-sanctioned group

118
00:05:56,089 --> 00:05:58,624
and NASA is a signatory
to that group.

119
00:05:58,624 --> 00:06:02,061
And it's a group
involving space agencies,

120
00:06:02,061 --> 00:06:05,198
national institutes,
and observatories

121
00:06:05,198 --> 00:06:08,768
that coordinate on the
search, the discovery,

122
00:06:08,768 --> 00:06:12,772
follow up, characterization,
and orbit determination

123
00:06:12,772 --> 00:06:16,943
for these objects so that
we have all the information

124
00:06:16,943 --> 00:06:21,180
that's possible out there
contributing to the task.

125
00:06:21,180 --> 00:06:24,117
And so yes there is significant
international participation.

126
00:06:24,117 --> 00:06:26,185
- Lindley, one more question.

127
00:06:26,185 --> 00:06:28,888
If there is a dangerous asteroid

128
00:06:28,888 --> 00:06:31,624
and it's on a collision
course with Earth,

129
00:06:31,624 --> 00:06:34,560
can we really do
anything about it?

130
00:06:36,829 --> 00:06:38,798
- Well, that would
depend on how big it is

131
00:06:38,798 --> 00:06:42,635
and how much time we have
before the predicted impact.

132
00:06:42,635 --> 00:06:45,805
We would assess the
size of the object

133
00:06:46,973 --> 00:06:49,375
and try to determine
what the mass is,

134
00:06:49,375 --> 00:06:51,944
and that would determine
what techniques

135
00:06:51,944 --> 00:06:54,747
might be able to be used on it.

136
00:06:54,747 --> 00:06:56,482
And we have, as

part of our program,

137
00:06:56,482 --> 00:06:59,285
developing those
kind of capabilities.

138
00:06:59,285 --> 00:07:01,788
But it all depends on
how much time we have.

139
00:07:01,788 --> 00:07:03,656
If we only have days or weeks,

140
00:07:03,656 --> 00:07:05,591
that's not enough time
to mount a space mission

141
00:07:05,591 --> 00:07:09,095
to deflect it in space, and
so we would just have to

142
00:07:09,095 --> 00:07:12,465
prepare with FEMA
to take the impact,

143
00:07:12,465 --> 00:07:14,333
if it was on US territory.

144
00:07:14,333 --> 00:07:17,570
So the key to our program
is to find em early.

145
00:07:17,570 --> 00:07:21,107
- Alright, so we have
just a few more minutes,

146
00:07:21,107 --> 00:07:22,341
and I'd like to take some time

147

00:07:22,341 --> 00:07:24,243
for a couple of social
media questions.

148
00:07:24,243 --> 00:07:26,479
I have one for Lindley first,

149
00:07:26,479 --> 00:07:29,515
David and others on
Twitter are asking,

150
00:07:29,515 --> 00:07:31,584
are there any near Earth objects

151
00:07:31,584 --> 00:07:33,920
that post a danger to Earth?

152
00:07:35,988 --> 00:07:38,424
- Well of the catalog
that we have now,

153
00:07:38,424 --> 00:07:40,860
over 16,000 near Earth objects,

154
00:07:40,860 --> 00:07:43,396
there's none that have any
significant probability

155
00:07:43,396 --> 00:07:44,897
of impacting the Earth.

156
00:07:44,897 --> 00:07:46,966
Yes, there are objects that
will come near the Earth,

157
00:07:46,966 --> 00:07:49,869
but our already determined
folks out there,

158

00:07:49,869 --> 00:07:51,871
JPL as a matter of fact,

159
00:07:53,206 --> 00:07:56,008
have shown that the
probability of any of those

160
00:07:56,008 --> 00:07:57,176
is really low.

161
00:07:58,311 --> 00:08:01,147
So there is no immediate
threat to the Earth

162
00:08:01,147 --> 00:08:04,083
being impacted by the
objects that we know about.

163
00:08:04,083 --> 00:08:06,152
But we have a lot
more of em to find.

164
00:08:06,152 --> 00:08:08,888
- Alright, here's another
one, this one's for Kelly.

165
00:08:08,888 --> 00:08:11,090
Lisa on Twitter wants to know,

166
00:08:11,090 --> 00:08:14,026
if there was an asteroid
headed for Earth,

167
00:08:14,026 --> 00:08:17,029
would we be told or
would NASA keep it quiet?

168
00:08:17,029 --> 00:08:20,132
And Kahleed asks,
would you Tweet it?

169
00:08:22,268 --> 00:08:26,339
- Oh absolutely the
public would be told,

170
00:08:26,339 --> 00:08:28,841
in fact it wouldn't be
possible to keep it quiet

171
00:08:28,841 --> 00:08:31,477
because we coordinate
with astronomers

172
00:08:31,477 --> 00:08:33,412
all over the world,
over the internet,

173
00:08:33,412 --> 00:08:36,682
and so the information
would be out there.

174
00:08:36,682 --> 00:08:38,651
And also all of the
observations, as we've said,

175
00:08:38,651 --> 00:08:39,952
go to the Minor Planet Center,

176
00:08:39,952 --> 00:08:41,554
and it's on their website,

177
00:08:41,554 --> 00:08:45,157
and then the predictions
that are determined out at

178
00:08:45,157 --> 00:08:47,260
the Center for near Earth
Objects Studies at JPL,

179

00:08:47,260 --> 00:08:48,461
it's on their website.

180
00:08:48,461 --> 00:08:49,896
So the information is out there,

181
00:08:49,896 --> 00:08:52,632
and we have a communication
plan here too at NASA

182
00:08:52,632 --> 00:08:55,735
to communicate
within our government

183
00:08:55,735 --> 00:08:57,436
and with other governments so,

184
00:08:57,436 --> 00:08:59,572
absolutely this would
go out to the public

185
00:08:59,572 --> 00:09:01,774
and eventually it would
end up on Twitter, too.

186
00:09:01,774 --> 00:09:04,944
- Alright, so Lindley,
Kelly thank you so much,

187
00:09:04,944 --> 00:09:08,080
we will be checking with you
again later on in the show.

188
00:09:08,080 --> 00:09:10,116
And you can find out more about

189
00:09:10,116 --> 00:09:12,518
NASA's Planetary Defense
Coordination Office

190
00:09:12,518 --> 00:09:16,589
by going to
nasa.gov/planetarydefense.

191
00:09:17,924 --> 00:09:21,093
(upbeat techno music)

192
00:09:36,709 --> 00:09:40,980
As you hear earlier, NASA has
to be on a constant lookout

193
00:09:40,980 --> 00:09:43,449
for potentially
hazardous space rocks.

194
00:09:43,449 --> 00:09:45,985
The goal is to discover
them early enough

195
00:09:45,985 --> 00:09:48,254
to be able to do
something about them.

196
00:09:48,254 --> 00:09:50,456
On average, NASA
sponsored projects

197
00:09:50,456 --> 00:09:53,759
spot about five near
Earth objects a night,

198
00:09:53,759 --> 00:09:56,662
and fine tune the
orbits of many more.

199
00:09:56,662 --> 00:09:59,198
NASA has adapted the
NEOWISE Space Telescope

200

00:09:59,198 --> 00:10:00,666
to survey the skies,

201
00:10:00,666 --> 00:10:04,704
but the real workhorses are
unique ground telescopes

202
00:10:04,704 --> 00:10:08,107
at the Catalina Sky Survey
on Mount Lemmon, Arizona,

203
00:10:08,107 --> 00:10:10,443
and the Panoramic
Survey Telescope

204
00:10:10,443 --> 00:10:14,113
And Rapid Response System,
it's called Pan-STARRS,

205
00:10:14,113 --> 00:10:16,515
located on Haleakala, Hawaii.

206
00:10:21,587 --> 00:10:24,924
(dramatic guitar music)

207
00:10:37,069 --> 00:10:39,772
- Catalina Sky Survey and
other survey programs,

208
00:10:39,772 --> 00:10:41,507
are really sort of
the start of the whole

209
00:10:41,507 --> 00:10:44,510
planetary protection ecosystem.

210
00:10:44,510 --> 00:10:47,046
It starts with discovery,
it goes onto followup,

211
00:10:47,046 --> 00:10:50,650
and characterization,
impact risk analysis,

212
00:10:50,650 --> 00:10:53,886
mitigation studies,
but you can't

213
00:10:53,886 --> 00:10:55,921
follow up, and you
can't characterize,

214
00:10:55,921 --> 00:10:58,991
and you can't calculate
the impact risk

215
00:10:58,991 --> 00:11:00,660
of something you don't discover.

216
00:11:00,660 --> 00:11:02,795
In order to find and
near Earth asteroid,

217
00:11:02,795 --> 00:11:05,131
we take four images
of a patch of sky,

218
00:11:05,131 --> 00:11:07,033
separated by about five minutes.

219
00:11:07,033 --> 00:11:08,367
- And we take those four images,

220
00:11:08,367 --> 00:11:09,935
and we blink them really fast,

221
00:11:09,935 --> 00:11:12,038
and it creates this
little animation

222
00:11:12,038 --> 00:11:14,740
so we can see that the
stars in the background

223
00:11:14,740 --> 00:11:16,442
are static, as they should be.

224
00:11:16,442 --> 00:11:19,045
And if there's anything
that's moving, it'll pop out.

225
00:11:19,045 --> 00:11:21,280
- And our software
compares those images,

226
00:11:21,280 --> 00:11:23,349
and identifies things
that are not moving,

227
00:11:23,349 --> 00:11:24,784
which are stars,
and removes those.

228
00:11:24,784 --> 00:11:28,187
Identifies things are
transient from frame to frame,

229
00:11:28,187 --> 00:11:30,923
and tries to link those up.

230
00:11:30,923 --> 00:11:33,826
(thoughtful music)

231
00:11:35,227 --> 00:11:37,830
- We've probably seen
about a million asteroids

232
00:11:37,830 --> 00:11:41,367

in the last seven years that
Pan-STARRS has been operating.

233
00:11:41,367 --> 00:11:44,403
It's like picking a
needle out of a haystack.

234
00:11:44,403 --> 00:11:46,539
We're looking for
distinctive motion,

235
00:11:46,539 --> 00:11:49,542
and when we see distinctive
motion in asteroids,

236
00:11:49,542 --> 00:11:52,144
we report them to the
Minor Planet Center.

237
00:11:52,144 --> 00:11:54,980
The Minor Planet
Center is the sort of

238
00:11:54,980 --> 00:11:58,684
world clearing house for
near Earth asteroids.

239
00:11:58,684 --> 00:12:03,389
- The Center for NEO Studies
takes these observations

240
00:12:03,389 --> 00:12:05,825
from the Minor Planet
Center and computes

241
00:12:05,825 --> 00:12:10,096
the high-precision orbits that
we use to make predictions.

242
00:12:10,096 --> 00:12:12,431

CNEOS is also kind of
an early warning system

243
00:12:12,431 --> 00:12:14,867
for newly discovered asteroids.

244
00:12:14,867 --> 00:12:18,404
We take the early data, and
we compute whether or not

245
00:12:18,404 --> 00:12:20,406
that asteroid could
hit the Earth.

246
00:12:20,406 --> 00:12:23,008
If there's a chance, we'll
send out an early warning,

247
00:12:23,008 --> 00:12:24,977
an alert, for
followup observations

248
00:12:24,977 --> 00:12:28,047
so that we can get more data
and then we would know perhaps

249
00:12:28,047 --> 00:12:31,050
whether it can hit
the Earth or not.

250
00:12:34,353 --> 00:12:35,921
- Asteroid impacts
are a fact of life.

251
00:12:35,921 --> 00:12:37,857
The Earth has been
impacted by asteroids

252
00:12:37,857 --> 00:12:39,759
continually through its history.

253
00:12:39,759 --> 00:12:44,029
- We saw in 2013 in
Russia, a fairly small,

254
00:12:44,029 --> 00:12:46,132
by the standards of
what we're finding,

255
00:12:46,132 --> 00:12:48,100
asteroid did hit the Earth.

256
00:12:48,100 --> 00:12:50,336
I feel a little bit like
a guardian of the planet,

257
00:12:50,336 --> 00:12:52,772
I'm doing my bit to
try and protect people.

258
00:12:52,772 --> 00:12:55,241
It is a long term process.

259
00:12:55,241 --> 00:12:57,243
It's going to take
many, many years to find

260
00:12:57,243 --> 00:12:59,278
all of the dangerous asteroids.

261
00:12:59,278 --> 00:13:01,714
- The goal is to find
near Earth asteroids

262
00:13:01,714 --> 00:13:03,382
before they find us.

263
00:13:12,191 --> 00:13:17,029
- Well tracking asteroids

takes a worldwide effort.

264
00:13:17,029 --> 00:13:19,665
Here's a map of
NASA-sponsored projects,

265
00:13:19,665 --> 00:13:21,567
but there's more
to it than this.

266
00:13:21,567 --> 00:13:24,770
Add in all the
observers, amateurs,

267
00:13:24,770 --> 00:13:27,640
and professionals all
over the world and now

268
00:13:27,640 --> 00:13:30,042
there are hundreds
of additional eyes

269
00:13:30,042 --> 00:13:33,078
looking for asteroids
all around the planet.

270
00:13:33,078 --> 00:13:36,215
These observers report
their asteroid sightings

271
00:13:36,215 --> 00:13:38,951
to the Minor Planet Center
in Cambridge, Massachusetts.

272
00:13:38,951 --> 00:13:42,288
That is a key player
in planetary defense.

273
00:13:42,288 --> 00:13:44,824
The Minor Planet Center

shares the information

274
00:13:44,824 --> 00:13:47,059
with astronomers worldwide about

275
00:13:47,059 --> 00:13:49,628
potentially hazardous objects.

276
00:13:49,628 --> 00:13:53,966
This allows for
multiple observations
of the same asteroid.

277
00:13:53,966 --> 00:13:57,136
Matt Holman is the director
of the Minor Planet Center,

278
00:13:57,136 --> 00:14:00,072
and he joins us
live now, hi Matt.

279
00:14:00,072 --> 00:14:01,073
- Hi Gay.

280
00:14:01,073 --> 00:14:02,741
- Alright so you
told me earlier,

281
00:14:02,741 --> 00:14:05,744
this is all about
following all the dots.

282
00:14:05,744 --> 00:14:09,148
So tell me exactly,
what is the MPC?

283
00:14:09,148 --> 00:14:11,684
- The MPC, or the
Minor Planet Center,

284
00:14:11,684 --> 00:14:15,154
is the world's clearinghouse
for asteroid observations.

285
00:14:15,154 --> 00:14:18,257
We get observations of
asteroids from hundreds,

286
00:14:18,257 --> 00:14:20,793
even thousands of
different observatories,

287
00:14:20,793 --> 00:14:22,494
and we collect all
those data together,

288
00:14:22,494 --> 00:14:25,197
distribute it to
everyone who needs it,

289
00:14:25,197 --> 00:14:26,599
or anyone who's interested.

290
00:14:26,599 --> 00:14:29,301
But we're also busying
ourselves trying to determine

291
00:14:29,301 --> 00:14:31,971
which of those asteroid
observations correspond

292
00:14:31,971 --> 00:14:35,608
to something that urgently
needs followup observations.

293
00:14:35,608 --> 00:14:37,042
- Well tell me why you even need

294
00:14:37,042 --> 00:14:40,145

a clearinghouse for
all of these objects?

295
00:14:40,145 --> 00:14:42,147
Why is it necessary?

296
00:14:42,147 --> 00:14:43,682
- Well there's so
many people involved,

297
00:14:43,682 --> 00:14:46,785
it really would not be
efficient to have them

298
00:14:46,785 --> 00:14:49,321
try to distribute their
data to each other.

299
00:14:49,321 --> 00:14:52,157
It's much more efficient if
they just sent it all to us,

300
00:14:52,157 --> 00:14:56,095
then we can bring it together
and we're trying to see if

301
00:14:56,095 --> 00:14:59,698
people have incidentally
observed the same object,

302
00:14:59,698 --> 00:15:01,600
and you can then
collate those data

303
00:15:01,600 --> 00:15:03,969
and very quickly
feed it back to them,

304
00:15:03,969 --> 00:15:05,371
to say okay, these are

the things that need

305
00:15:05,371 --> 00:15:07,506
even more observations.

306
00:15:07,506 --> 00:15:09,942
- Alright, so it's
a central contact

307
00:15:09,942 --> 00:15:11,510
so you work more efficiently.

308
00:15:11,510 --> 00:15:14,647
Can you go ahead and just
walk me through the process?

309
00:15:14,647 --> 00:15:16,181
How does it all work?

310
00:15:16,181 --> 00:15:18,517
- Well on any given night,

311
00:15:18,517 --> 00:15:20,319
the Minor Planet Center receives

312
00:15:20,319 --> 00:15:24,757
something like 100,000
individual observations
of asteroids.

313
00:15:24,757 --> 00:15:28,928
And we ask ourselves immediately
this question constantly,

314
00:15:28,928 --> 00:15:32,865
which of these observations
correspond to an object

315
00:15:32,865 --> 00:15:34,633

that we've seen before?

316
00:15:34,633 --> 00:15:36,468
And which of them
correspond to something

317
00:15:36,468 --> 00:15:37,670
that's a new discovery,

318
00:15:37,670 --> 00:15:41,307
potentially a hazardous
near Earth object?

319
00:15:41,307 --> 00:15:43,542
And believe it or
not, 90% of the time,

320
00:15:43,542 --> 00:15:46,145
we know what those objects are,

321
00:15:46,145 --> 00:15:47,746
we've seen them
before and we have

322
00:15:47,746 --> 00:15:49,748
very precisely
determined orbits.

323
00:15:49,748 --> 00:15:51,984
We can take those 90%
and set them aside,

324
00:15:51,984 --> 00:15:55,020
and focus our attention
on the remaining 10%

325
00:15:55,020 --> 00:15:57,222
to try to determine if those are

326

00:15:57,222 --> 00:15:59,858
potentially hazardous
near Earth objects,

327
00:15:59,858 --> 00:16:02,828
or a garden variety
main belt asteroids.

328
00:16:02,828 --> 00:16:04,229
- So how do you
tell the difference

329
00:16:04,229 --> 00:16:08,334
between the main belt asteroids,
which are far, far away,

330
00:16:08,334 --> 00:16:11,570
and the ones that are
actually kind of close?

331
00:16:11,570 --> 00:16:14,306
- Well as Richard Wainscoat
kind of suggested,

332
00:16:14,306 --> 00:16:17,576
we use the pattern
of motion on the sky.

333
00:16:17,576 --> 00:16:19,111
Let me give you an analogy,

334
00:16:19,111 --> 00:16:21,613
so imagine you're in a car and
you're driving along the road

335
00:16:21,613 --> 00:16:23,082
and you look out the window,

336
00:16:23,082 --> 00:16:25,317
and you look at the fence posts.

337
00:16:25,317 --> 00:16:26,885
Those fence posts will
appear to be moving

338
00:16:26,885 --> 00:16:28,153
very, very quickly.

339
00:16:28,153 --> 00:16:30,255
If you look at the trees
behind the fence posts,

340
00:16:30,255 --> 00:16:32,858
they'll appear to be
moving less quickly,

341
00:16:32,858 --> 00:16:34,660
and if you look at the
mountains way in the background,

342
00:16:34,660 --> 00:16:36,762
they won't appear
to be moving at all.

343
00:16:36,762 --> 00:16:38,664
In fact, none of those
things are moving,

344
00:16:38,664 --> 00:16:40,065
it's the car that's moving,

345
00:16:40,065 --> 00:16:43,702
and the apparent rate of
motion is a proxy for distance,

346
00:16:43,702 --> 00:16:45,471
the things that are close to you

347
00:16:45,471 --> 00:16:46,939

appear to be moving
more quickly,

348
00:16:46,939 --> 00:16:48,974
and that's really what's
going on with asteroids too.

349
00:16:48,974 --> 00:16:50,642
It's something we call paralax,

350
00:16:50,642 --> 00:16:53,746
so the set of dots that
are really moving quickly

351
00:16:53,746 --> 00:16:56,415
along the sky, those are
very likely to be things

352
00:16:56,415 --> 00:16:57,883
that are pretty
close to the Earth,

353
00:16:57,883 --> 00:16:59,385
and that's what
we concentrate on.

354
00:16:59,385 --> 00:17:01,987
- So if you find
something that needs

355
00:17:01,987 --> 00:17:04,656
a little bit more
double checking,

356
00:17:04,656 --> 00:17:07,192
how do you tell your observers?

357
00:17:07,192 --> 00:17:10,562
- Well we have something called
the NEO Confirmation Page.

358
00:17:10,562 --> 00:17:12,998
It's a website that
the Minor Planet Center

359
00:17:12,998 --> 00:17:15,834
is constantly updating,
and so that's where

360
00:17:15,834 --> 00:17:19,738
we maintain a prioritized
list of objects

361
00:17:19,738 --> 00:17:21,807
that need additional
observations.

362
00:17:21,807 --> 00:17:24,043
- Well we learned a lot Matt,

363
00:17:24,043 --> 00:17:26,011
thank you so much
for joining us.

364
00:17:26,011 --> 00:17:27,246
- My pleasure.

365
00:17:27,246 --> 00:17:29,081
- And if you would
like to learn more,

366
00:17:29,081 --> 00:17:31,316
you can check out the
Minor Planet Center,

367
00:17:31,316 --> 00:17:35,387
the website that is, it
is minorplanetcenter.net.

368

00:17:39,525 --> 00:17:42,694
(upbeat techno music)

369
00:17:59,845 --> 00:18:02,648
October 6th, 2008, was a day

370
00:18:02,648 --> 00:18:06,819
when NASA's asteroid hunting
team was put to the test.

371
00:18:06,819 --> 00:18:10,122
The Catalina Sky Survey
team spotted an asteroid

372
00:18:10,122 --> 00:18:13,892
that eventually would
hit Earth, just 19 hours

373
00:18:13,892 --> 00:18:17,129
before it was predicted
to enter the atmosphere.

374
00:18:17,129 --> 00:18:19,832
The Near Earth Objects
team and astronomers

375
00:18:19,832 --> 00:18:22,801
all over the world
sprang into action.

376
00:18:22,801 --> 00:18:25,270
Their observations
allowed us to figure out

377
00:18:25,270 --> 00:18:28,774
exactly where and when
the object would hit.

378
00:18:28,774 --> 00:18:33,112
At only a few meters

across, it posed no danger,

379
00:18:33,112 --> 00:18:35,013
it was small and
posed no threat.

380
00:18:35,013 --> 00:18:38,750
On October 7th, 2008,
with officials alerted,

381
00:18:38,750 --> 00:18:42,554
Asteroid TC3 plunged
through our atmosphere

382
00:18:42,554 --> 00:18:46,725
and exploded 23 miles above
the remote desert in the Sudan.

383
00:18:47,960 --> 00:18:51,563
Hundreds of meteorites
were later recovered.

384
00:18:51,563 --> 00:18:55,200
Now this was the first time
an asteroid was spotted

385
00:18:55,200 --> 00:18:57,636
and its location
calculated prior to

386
00:18:57,636 --> 00:18:59,571
hitting Earth's atmosphere.

387
00:18:59,571 --> 00:19:00,839
The system worked.

388
00:19:00,839 --> 00:19:03,142
NASA's Center for near
Earth Object Studies,

389
00:19:03,142 --> 00:19:06,812
here at the Jet Propulsion
Laboratory, played a big role.

390
00:19:06,812 --> 00:19:09,815
The center computes
high precision objects

391
00:19:09,815 --> 00:19:14,353
of near Earth objects and
predicts the future path,

392
00:19:14,353 --> 00:19:15,687
and assesses whether or not

393
00:19:15,687 --> 00:19:17,789
they'll actually
impact the Earth.

394
00:19:17,789 --> 00:19:20,359
Paul Chodas is the
manager of CNEOS.

395
00:19:20,359 --> 00:19:22,694
What was that day like for TC3?

396
00:19:22,694 --> 00:19:24,463
- That was an exciting
day, believe me.

397
00:19:24,463 --> 00:19:26,398
And it was all compressed
into a single day,

398
00:19:26,398 --> 00:19:28,967
because it was discovered,
we had to run the numbers,

399
00:19:28,967 --> 00:19:30,402

we had to realize it was
going to hit the Earth,

400
00:19:30,402 --> 00:19:32,204
and then we had to
figure out where

401
00:19:32,204 --> 00:19:33,572
it was going to hit the Earth,

402
00:19:33,572 --> 00:19:36,008
notify people, and
encourage more observations,

403
00:19:36,008 --> 00:19:37,576
all compressed into one day!

404
00:19:37,576 --> 00:19:39,912
Fortunately, we
knew it was small.

405
00:19:39,912 --> 00:19:41,246
That was the first
question to ask,

406
00:19:41,246 --> 00:19:42,581
and we could see
that it was small.

407
00:19:42,581 --> 00:19:46,985
- But it must have been
just gathering together

408
00:19:46,985 --> 00:19:51,056
and picking up the
phone call and hearing,

409
00:19:51,056 --> 00:19:54,893
I mean you guys just
jumped on it, everybody.

410
00:19:54,893 --> 00:19:57,729
- Yeah all the teams did,
the Minor Planet Center,

411
00:19:57,729 --> 00:20:00,232
our team, and Lindley Johnson
of course was involved

412
00:20:00,232 --> 00:20:03,502
in communicating this
to the higher ups

413
00:20:04,903 --> 00:20:06,972
at NASA and in our government.

414
00:20:06,972 --> 00:20:08,840
So it was a busy
day for everyone.

415
00:20:08,840 --> 00:20:10,876
- Why do you say that
this was a real test,

416
00:20:10,876 --> 00:20:13,212
and you guys passed?

417
00:20:13,212 --> 00:20:15,280
- Well our calculations early on

418
00:20:15,280 --> 00:20:17,449
indicated it would hit in
the Nubian Desert in Sudan,

419
00:20:17,449 --> 00:20:21,320
and so we identified
the location early,

420
00:20:21,320 --> 00:20:23,689

and as we got more
and more observations,

421
00:20:23,689 --> 00:20:27,192
we identified even the
ground track so well

422
00:20:27,192 --> 00:20:30,195
that two months later
when some astronomers

423
00:20:30,195 --> 00:20:32,030
went out to look for the
meteorites, we told them

424
00:20:32,030 --> 00:20:33,298
exactly where to find them.
- Wow!

425
00:20:33,298 --> 00:20:34,833
- There they were,
right on the path.

426
00:20:34,833 --> 00:20:38,270
- Okay so it is the job
of CNEOS, over the center,

427
00:20:38,270 --> 00:20:40,372
to figure out the orbit.

428
00:20:40,372 --> 00:20:43,775
And I think we should also
explain to some people,

429
00:20:43,775 --> 00:20:46,278
some people don't realize that

430
00:20:47,946 --> 00:20:52,284
near Earth objects are orbiting
the sun just like Earth is,

431
00:20:52,284 --> 00:20:54,720
and what you're figuring out is

432
00:20:54,720 --> 00:20:57,155
the orbit of this body
and whether or not

433
00:20:57,155 --> 00:20:59,758
it'll one day intersect
with Earth's orbit.

434
00:20:59,758 --> 00:21:01,793
- That's right,
near Earth objects

435
00:21:01,793 --> 00:21:03,295
orbit the sun, just
like the planets,

436
00:21:03,295 --> 00:21:05,797
and they're on ellipses,
and sometimes some of those

437
00:21:05,797 --> 00:21:08,133
ellipses come very close
to the Earth's orbit.

438
00:21:08,133 --> 00:21:11,069
If there's an intersection
of the orbits,

439
00:21:11,069 --> 00:21:13,605
then the next question
is, well will the Earth

440
00:21:13,605 --> 00:21:15,707
ever be there when the
asteroid gets there?

441
00:21:15,707 --> 00:21:17,743
And that's kind of a very
precision calculation

442
00:21:17,743 --> 00:21:20,212
that we have to run,
and we want to do that

443
00:21:20,212 --> 00:21:22,514
many decades into the future.

444
00:21:22,514 --> 00:21:25,117
Apophis was an early
example of that.

445
00:21:25,117 --> 00:21:26,184
Back in 2004,

446
00:21:27,986 --> 00:21:29,588
the orbit of Apophis

447
00:21:29,588 --> 00:21:31,890
looked like there was
a chance that Apophis,

448
00:21:31,890 --> 00:21:32,891
which is a large asteroid.

449
00:21:32,891 --> 00:21:33,892
- [Gay] I remember that!

450
00:21:33,892 --> 00:21:34,893
- You remember that?

451
00:21:34,893 --> 00:21:37,929
- It was 1,000 feet across.

452
00:21:37,929 --> 00:21:39,965

It looked like in 2029
that there was a chance

453
00:21:39,965 --> 00:21:43,869
that it could hit the Earth
at that intersection point.

454
00:21:43,869 --> 00:21:46,505
And we were worried
the impact probability

455
00:21:46,505 --> 00:21:48,307
kept getting a little
higher and a little higher

456
00:21:48,307 --> 00:21:50,509
as we took more and
more observations.

457
00:21:50,509 --> 00:21:53,111
- So let's take
Apophis as an example.

458
00:21:53,111 --> 00:21:56,315
Very early on, I remember
hearing the reports,

459
00:21:56,315 --> 00:22:00,085
oh it looks like there's
4% chance that it could it.

460
00:22:00,085 --> 00:22:04,156
And then, as the time went
by, then oh maybe not,

461
00:22:04,156 --> 00:22:08,794
and then finally there was a
report saying absolutely not.

462
00:22:08,794 --> 00:22:11,029

Was NASA wrong at the start?

463
00:22:11,029 --> 00:22:13,832
- No, because we add data.

464
00:22:13,832 --> 00:22:15,067
We get more and
more information.

465
00:22:15,067 --> 00:22:18,337
We make our projections,
it's kind of like

466
00:22:18,337 --> 00:22:20,005
shining a flashlight actually.

467
00:22:20,005 --> 00:22:22,974
- [Gay] And we have an image
that we can probably put up.

468
00:22:22,974 --> 00:22:24,476
- [Paul] Yeah, yeah,
so we would say,

469
00:22:24,476 --> 00:22:26,645
here's what it
looks like in 2029.

470
00:22:26,645 --> 00:22:27,846
We think the asteroid could pass

471
00:22:27,846 --> 00:22:29,081
somewhere within the ellipse,

472
00:22:29,081 --> 00:22:30,582
and look the Earth is
within the ellipse.

473
00:22:30,582 --> 00:22:31,783

We get a probability
- Okay.

474
00:22:31,783 --> 00:22:34,453
- Maybe it was 2% there,
and then a day later

475
00:22:34,453 --> 00:22:36,688
we get a little more
data, and the next step,

476
00:22:36,688 --> 00:22:38,957
there's another ellipse and
look, it's even more likely

477
00:22:38,957 --> 00:22:43,528
to hit the Earth as you
get more data, 4% now.

478
00:22:43,528 --> 00:22:45,597
But then we found some
more observations,

479
00:22:45,597 --> 00:22:48,600
actually in the
archives of Apophis,

480
00:22:49,768 --> 00:22:51,236
and we ran the
calculation again,

481
00:22:51,236 --> 00:22:54,206
and we get an even
more precise prediction

482
00:22:54,206 --> 00:22:57,743
and now look, the Earth is
no long inside the ellipse,

483
00:22:57,743 --> 00:22:59,244

so it can't hit.

484
00:22:59,244 --> 00:23:02,381
- So it's a matter of getting
more and more information.

485
00:23:02,381 --> 00:23:06,918
How do you get that information
to dial in the orbit,

486
00:23:06,918 --> 00:23:08,620
and get a more exact idea?

487
00:23:08,620 --> 00:23:11,656
- What I like to say is,
we take all the numbers

488
00:23:11,656 --> 00:23:13,291
and we plot the path, you know.

489
00:23:13,291 --> 00:23:16,661
And so we're trying
to see in the future

490
00:23:16,661 --> 00:23:18,663
how close it can
come, basically.

491
00:23:18,663 --> 00:23:20,065
We're plotting the path.

492
00:23:20,065 --> 00:23:21,833
We're running the numbers
in high precision.

493
00:23:21,833 --> 00:23:23,535
- Alright so when you're
running the numbers

494

00:23:23,535 --> 00:23:27,672
on all these sightings that
are coming in every single day,

495
00:23:27,672 --> 00:23:31,843
how do you figure out and how
do you give an early warning

496
00:23:32,778 --> 00:23:34,479
to folks and flag them that,

497
00:23:34,479 --> 00:23:36,848
oh this is something
to keep an eye on,

498
00:23:36,848 --> 00:23:40,652
oh that's not gonna be a
problem for at least 100 years.

499
00:23:40,652 --> 00:23:42,120
I mean how do you do that?

500
00:23:42,120 --> 00:23:45,090
- Well we calculate
a probability,

501
00:23:45,090 --> 00:23:47,025
and we have two
systems to do this.

502
00:23:47,025 --> 00:23:49,127
One is what we call
a sentry system,

503
00:23:49,127 --> 00:23:52,264
which runs a very long
term, 100 year calculation,

504
00:23:52,264 --> 00:23:53,832
running the numbers

and seeing how close

505
00:23:53,832 --> 00:23:55,100
the asteroids could get.

506
00:23:55,100 --> 00:23:59,037
We have a short term
system for the NEOCP,

507
00:23:59,037 --> 00:24:01,106
the Near Earth Object
Confirmation Page

508
00:24:01,106 --> 00:24:02,541
that Matt just mentioned.

509
00:24:02,541 --> 00:24:03,975
These are for brand
newly discovered objects,

510
00:24:03,975 --> 00:24:06,445
that just got discovered
and very little data,

511
00:24:06,445 --> 00:24:07,913
but we'd like to know.

512
00:24:07,913 --> 00:24:09,548
Objects are usually discovered

513
00:24:09,548 --> 00:24:10,582
when they're close to the Earth.

514
00:24:10,582 --> 00:24:12,117
Could it hit the Earth?

515
00:24:12,117 --> 00:24:14,786
You know even before we've
even confirmed the object.

516
00:24:14,786 --> 00:24:18,256
So that's a short term
impact hazard calculation,

517
00:24:18,256 --> 00:24:19,758
that's the SCOUT system.

518
00:24:19,758 --> 00:24:22,694
So we run the numbers both in
short term and in long term.

519
00:24:22,694 --> 00:24:25,163
- Alright and you keep
track of all the sightings

520
00:24:25,163 --> 00:24:27,566
and we can actually
put up the number

521
00:24:27,566 --> 00:24:29,501
that you have sighted so far.

522
00:24:29,501 --> 00:24:30,802
- Well this is NASA,

523
00:24:30,802 --> 00:24:33,305
and in fact the entire catalog

524
00:24:34,673 --> 00:24:36,942
is now at 16,245 asteroids.

525
00:24:38,243 --> 00:24:40,645
That's the blue graph there.

526
00:24:40,645 --> 00:24:44,249
In 2017, which will be
on the right axis there,

527
00:24:44,249 --> 00:24:45,784
you can see we're past 16,000.

528
00:24:45,784 --> 00:24:48,987
We're seeing them at about
1800 per year right now.

529
00:24:48,987 --> 00:24:50,355
- Wow.

530
00:24:50,355 --> 00:24:52,257
- Now some people are concerned,
they say look how fast

531
00:24:52,257 --> 00:24:54,793
we're discovering them,
why are all of a sudden

532
00:24:54,793 --> 00:24:55,961
asteroids hitting the Earth?

533
00:24:55,961 --> 00:24:57,395
That wasn't happening
before, was it?

534
00:24:57,395 --> 00:25:00,232
It was, it was, we're just
getting better at finding them.

535
00:25:00,232 --> 00:25:03,435
So we want to keep that
discovery rate increasing.

536
00:25:03,435 --> 00:25:07,606
- Alright, well I have a
social media question for you.

537
00:25:08,974 --> 00:25:12,277
Bob wants to know, how

exactly do you know the size

538
00:25:12,277 --> 00:25:14,846
of passing asteroids?

539
00:25:14,846 --> 00:25:18,183
- They're only a point of
light in these telescopes.

540
00:25:18,183 --> 00:25:19,451
- [Gay] Absolutely.

541
00:25:19,451 --> 00:25:20,719
- So all we know is
how bright they are.

542
00:25:20,719 --> 00:25:24,122
So we have to assume a
certain reflectivity,

543
00:25:24,122 --> 00:25:25,624
we're seeing them
by reflected light.

544
00:25:25,624 --> 00:25:30,061
So we assume they're kind
of as reflective as 14%

545
00:25:30,061 --> 00:25:31,863
of the sunshine is
being reflected.

546
00:25:31,863 --> 00:25:35,800
So we calculate a rough size,
just based on brightness.

547
00:25:35,800 --> 00:25:38,169
- Alright, well thank
you so much Paul.

548
00:25:38,169 --> 00:25:42,407
And we have a website for you
if you want more information

549
00:25:42,407 --> 00:25:45,310
on CNEOS, go to
cneos.jpl.nasa.gov.

550
00:25:50,615 --> 00:25:53,785
(upbeat techno music)

551
00:26:09,501 --> 00:26:12,137
NASA relies on
trusted astronomers

552
00:26:12,137 --> 00:26:15,073
to do followup
observations to confirm

553
00:26:15,073 --> 00:26:18,043
if a near Earth object
is really there,

554
00:26:18,043 --> 00:26:20,445
and to help us refine the orbit.

555
00:26:20,445 --> 00:26:23,148
One followup observer
is Robert Holmes.

556
00:26:23,148 --> 00:26:25,417
Bob started as a
volunteer observer,

557
00:26:25,417 --> 00:26:28,820
but he's so good,
NASA now pays him

558
00:26:28,820 --> 00:26:31,189

to hunt asteroids full time.

559
00:26:31,189 --> 00:26:34,292
He's one of the world's
most prolific observers.

560
00:26:34,292 --> 00:26:35,727
How does he do it?

561
00:26:35,727 --> 00:26:40,031
We went to his home in Illinois
farm country to find out.

562
00:26:40,031 --> 00:26:43,034
(easy guitar music)

563
00:26:54,846 --> 00:26:56,548
- We do followup observations,

564
00:26:56,548 --> 00:26:59,050
with NASA's near Earth
Observations program.

565
00:26:59,050 --> 00:27:02,587
All night long, I'm
running big telescopes.

566
00:27:03,755 --> 00:27:07,559
One's a 24 inch, a 30
inch, and a 32 inch.

567
00:27:07,559 --> 00:27:10,228
And then the 50 inch is
my biggest telescope.

568
00:27:10,228 --> 00:27:13,765
Having four
telescopes allows me,

569

00:27:13,765 --> 00:27:15,934
really to do four
times as much work

570
00:27:15,934 --> 00:27:19,904
as the typical observatory
that just has one telescope.

571
00:27:19,904 --> 00:27:22,073
So it is a huge advantage.

572
00:27:24,676 --> 00:27:27,245
I work on a nightly basis

573
00:27:27,245 --> 00:27:30,649
and I use these telescopes
to look at asteroids.

574
00:27:30,649 --> 00:27:34,753
We do followup observations
for the discoveries

575
00:27:34,753 --> 00:27:37,022
that are made by the
large sky surveys.

576
00:27:37,022 --> 00:27:41,026
By looking at these asteroids
and measuring these asteroids,

577
00:27:41,026 --> 00:27:43,428
we can determine what
their possibilities

578
00:27:43,428 --> 00:27:46,798
of actually hitting the Earth
in the future are going to be.

579
00:27:46,798 --> 00:27:49,401
NASA provides coordinates

of specific objects

580
00:27:49,401 --> 00:27:51,770
that they need observations on.

581
00:27:51,770 --> 00:27:54,239
I'm going to punch in
the coordinates here.

582
00:27:54,239 --> 00:27:59,110
And I'm doing this remotely
from inside a control room.

583
00:27:59,110 --> 00:28:01,513
Not at the telescope.

584
00:28:01,513 --> 00:28:03,348
And so we look these objects up,

585
00:28:03,348 --> 00:28:06,217
and then use those
coordinates to look at

586
00:28:06,217 --> 00:28:09,187
a tiny piece of the sky that
this object happens to be in.

587
00:28:09,187 --> 00:28:11,489
And then we follow those objects

588
00:28:11,489 --> 00:28:15,760
and define and refine
orbits for those objects,

589
00:28:15,760 --> 00:28:18,596
and we do see uncertainty
of where it's going to go

590
00:28:18,596 --> 00:28:20,465

in the near future.

591
00:28:20,465 --> 00:28:23,234
I started off as a
volunteer in 2006.

592
00:28:23,234 --> 00:28:26,504
It's just blossomed into
a full time opportutnity

593
00:28:26,504 --> 00:28:29,574
to work for NASA under
their grant program,

594
00:28:29,574 --> 00:28:33,211
where I'm now doing this
every single clear night.

595
00:28:33,211 --> 00:28:36,715
You know we're start
the observing run for

596
00:28:37,682 --> 00:28:38,516
2017 KK3.

597
00:28:40,752 --> 00:28:43,354
You don't build a
telescope that's this big

598
00:28:43,354 --> 00:28:46,257
without being passionate
about what you do.

599
00:28:46,257 --> 00:28:48,993
I'm really driven to
be a part of a program

600
00:28:48,993 --> 00:28:52,897
that's important and has
importance to the future.

601
00:28:52,897 --> 00:28:55,834
And we're not talking about
next year or the year after,

602
00:28:55,834 --> 00:28:57,736
we're talking about
asteroids that could

603
00:28:57,736 --> 00:28:59,938
potentially hit the
Earth 100 years from now.

604
00:28:59,938 --> 00:29:01,306
And the work we do today

605
00:29:01,306 --> 00:29:04,709
may make a difference
100 years from now.

606
00:29:10,148 --> 00:29:13,151
- Like Bob Holmes, the
Magdalena Ridge Observatory

607
00:29:13,151 --> 00:29:14,886
does followup observations.

608
00:29:14,886 --> 00:29:18,623
It's located 10,600
feet in the mountains

609
00:29:18,623 --> 00:29:20,091
near Socorro, New Mexico.

610
00:29:20,091 --> 00:29:23,261
Magdalena also
characterizes asteroids.

611
00:29:23,261 --> 00:29:25,663

How fast the
asteroid is spinning,

612
00:29:25,663 --> 00:29:27,065
what kind of shape it has,

613
00:29:27,065 --> 00:29:30,301
and what's it made
out of, how big is it?

614
00:29:30,301 --> 00:29:33,238
The observatory has
a fast telescope

615
00:29:33,238 --> 00:29:37,876
capable of tracking rockets,
asteroids, even space junk.

616
00:29:37,876 --> 00:29:40,545
Eilene Ryan is the
Director of the telescope,

617
00:29:40,545 --> 00:29:43,281
and she joins us now
via Skype, hi Eilene!

618
00:29:43,281 --> 00:29:44,582
- Hello Gay.

619
00:29:44,582 --> 00:29:48,453
- So explain to me
this fast telescope.

620
00:29:48,453 --> 00:29:49,687
What do you mean by that?

621
00:29:49,687 --> 00:29:52,257
I mean can it whip
in a direction

622
00:29:52,257 --> 00:29:54,159
and track something
really quickly?

623
00:29:54,159 --> 00:29:56,795
Is it the F stop, what
are talking about?

624
00:29:56,795 --> 00:30:00,098
- Well actually we're talking
about the telescope motion.

625
00:30:00,098 --> 00:30:02,200
It can move 10 times faster

626
00:30:02,200 --> 00:30:04,469
than a normal
astronomical telescope,

627
00:30:04,469 --> 00:30:08,473
and that's pretty fast,
so we are at an advantage

628
00:30:08,473 --> 00:30:10,809
when we're looking at
asteroids that come

629
00:30:10,809 --> 00:30:12,877
very close to the Earth
because they can also

630
00:30:12,877 --> 00:30:15,246
move very rapidly
through the sky.

631
00:30:15,246 --> 00:30:17,615
So if we want to
demonstrate this,

632

00:30:17,615 --> 00:30:20,185
we can watch a
movie that we took

633
00:30:20,185 --> 00:30:22,921
of an asteroid that came
very close to the Earth

634
00:30:22,921 --> 00:30:26,090
in November 2015,
Asteroid 2015 VY105.

635
00:30:27,859 --> 00:30:30,962
So the bright central
dot in the movie is

636
00:30:30,962 --> 00:30:34,332
what our 2.4 meter telescope
is locked on and tracking.

637
00:30:34,332 --> 00:30:37,802
And as you can see, the
streaks that are going by,

638
00:30:37,802 --> 00:30:40,438
they're background
stars that the asteroid

639
00:30:40,438 --> 00:30:43,675
is rapidly speeding
by, so pretty fast.

640
00:30:45,710 --> 00:30:49,080
It's pretty amazing that
we can look at this,

641
00:30:49,080 --> 00:30:52,283
and analyze
close-approaching asteroids,

642

00:30:52,283 --> 00:30:54,018
but what's most interesting
about the movie,

643
00:30:54,018 --> 00:30:56,287
if you look at the final
frame of the movie,

644
00:30:56,287 --> 00:30:59,157
we have captured Asteroid VY105

645
00:30:59,157 --> 00:31:01,526
coming so close to the
Earth, that it actually

646
00:31:01,526 --> 00:31:04,562
passed through our
geosynchronous satellite zone.

647
00:31:04,562 --> 00:31:08,399
So if you watch the movie
for the final frame,

648
00:31:09,801 --> 00:31:13,504
you can see an odd angled streak
at the bottom of the frame.

649
00:31:13,504 --> 00:31:16,074
And that's not a
star streaking by,

650
00:31:16,074 --> 00:31:18,743
it's actually one of NASA's
communication satellites.

651
00:31:18,743 --> 00:31:22,013
So the asteroid passed very
close by this satellite

652
00:31:22,013 --> 00:31:25,416

as well as several others,
but luckily it didn't hit.

653
00:31:25,416 --> 00:31:27,518
- That was very close.

654
00:31:27,518 --> 00:31:31,890
But as you mentioned, you know
we're look at it same as you

655
00:31:31,890 --> 00:31:33,958
they're just little
points of light.

656
00:31:33,958 --> 00:31:38,029
How are you able to get any
characteristic information

657
00:31:38,029 --> 00:31:39,864
on something so small?

658
00:31:41,032 --> 00:31:42,734
- Well it's actually
pretty fun and amazing

659
00:31:42,734 --> 00:31:46,037
to realize how much we can
learn from a point of light.

660
00:31:46,037 --> 00:31:49,908
One of the things that we study,
and we specialize in at MRO

661
00:31:49,908 --> 00:31:53,344
is looking asteroid
rotation rate.

662
00:31:53,344 --> 00:31:55,446
So asteroids spin on their
axis as they're moving

663
00:31:55,446 --> 00:31:57,215
in their orbit around the sun.

664
00:31:57,215 --> 00:31:59,017
And so here I have
model asteroid,

665
00:31:59,017 --> 00:32:01,052
and you may have noticed
it's not very round.

666
00:32:01,052 --> 00:32:04,789
Most asteroids are potato
shaped or irregularly shaped,

667
00:32:04,789 --> 00:32:08,259
but if we use this
model to examine

668
00:32:08,259 --> 00:32:10,428
how could we find
from a point of light,

669
00:32:10,428 --> 00:32:12,330
or light variation, a spin rate?

670
00:32:12,330 --> 00:32:15,533
Well, asteroids shine
by reflected sunlight,

671
00:32:15,533 --> 00:32:19,170
so here as they rotate,
and this model asteroid,

672
00:32:19,170 --> 00:32:21,940
and you can see the
surface area is changing.

673

00:32:21,940 --> 00:32:24,242
So we might have a
little bit of light

674
00:32:24,242 --> 00:32:26,411
reflected back to the
instruments on our telescope

675
00:32:26,411 --> 00:32:28,379
when the asteroid
is in this position.

676
00:32:28,379 --> 00:32:31,015
And then we get a lot of
light, a little bit of light,

677
00:32:31,015 --> 00:32:33,151
a lot of light,
and a little bit.

678
00:32:33,151 --> 00:32:35,286
Let's look at this next
movie and we can see this

679
00:32:35,286 --> 00:32:37,855
schematically represented by

680
00:32:37,855 --> 00:32:39,891
an egg shaped asteroid rotating.

681
00:32:39,891 --> 00:32:42,327
You can see as the
asteroid rotates,

682
00:32:42,327 --> 00:32:46,731
the light is changing and we
get two peaks and two dips,

683
00:32:46,731 --> 00:32:49,067
which represent

a rotation cycle.

684
00:32:49,067 --> 00:32:51,736
This is usually referred
to as a light curve,

685
00:32:51,736 --> 00:32:52,971
this changing brightness.

686
00:32:52,971 --> 00:32:54,839
And when we go through
this whole cycle,

687
00:32:54,839 --> 00:32:56,474
we get one rotation rate.

688
00:32:56,474 --> 00:33:00,778
So we can have asteroids
spinning as short a time

689
00:33:00,778 --> 00:33:04,115
as tens of seconds
to many, many hours,

690
00:33:04,115 --> 00:33:07,118
but we can look at this
and analyze the asteroid

691
00:33:07,118 --> 00:33:10,588
to understand
potentially its strength,

692
00:33:10,588 --> 00:33:13,324
whether it's a rubble
pile or an intact object.

693
00:33:13,324 --> 00:33:15,760
And we look at the
peaks and dips to see

694
00:33:15,760 --> 00:33:19,864
if we can also infer the
actual shape of the asteroid.

695
00:33:19,864 --> 00:33:21,499
- I remember once when
we were first talking,

696
00:33:21,499 --> 00:33:25,670
that you see these flybys
as a mission coming to you.

697
00:33:28,306 --> 00:33:31,976
That you know we work so
hard to send space craft

698
00:33:31,976 --> 00:33:36,848
far, far away to explore comets,
and asteroids, and planets,

699
00:33:36,848 --> 00:33:40,785
but here is this wonderful
moment where they come to you

700
00:33:40,785 --> 00:33:43,321
and you're saying
that you're hitting it

701
00:33:43,321 --> 00:33:44,722
with everything you've got.

702
00:33:44,722 --> 00:33:46,190
And so you have
- That's right!

703
00:33:46,190 --> 00:33:49,527
- Many instruments, what else
do you find as this thing

704

00:33:49,527 --> 00:33:51,429
is just swinging by you,

705
00:33:51,429 --> 00:33:54,932
what more information
can you gather?

706
00:33:54,932 --> 00:33:57,969
- Well, we can also do,
in addition to spin rates,

707
00:33:57,969 --> 00:34:00,004
we want to get
everything, as you said,

708
00:34:00,004 --> 00:34:01,439
while we have it in our sights.

709
00:34:01,439 --> 00:34:04,308
So we can look at an asteroid

710
00:34:04,308 --> 00:34:06,511
and also determine
its composition.

711
00:34:06,511 --> 00:34:08,913
One advantage we
have at MRO is that

712
00:34:08,913 --> 00:34:11,315
we can mount multiple
instruments at the same time

713
00:34:11,315 --> 00:34:13,584
on our telescope, so
we can easily switch

714
00:34:13,584 --> 00:34:15,586
from a light-changing
instrument,

715
00:34:15,586 --> 00:34:18,289
to something called
a spectrometer,

716
00:34:18,289 --> 00:34:20,925
which will separate the light
into different wavelengths

717
00:34:20,925 --> 00:34:24,328
and we can then analyze
and get a fingerprint

718
00:34:24,328 --> 00:34:27,265
of the particular
composition of an asteroid.

719
00:34:27,265 --> 00:34:30,968
So asteroids can be metal, rock,
or combinations of the two,

720
00:34:30,968 --> 00:34:33,971
and as Paul Chodas mentioned
earlier in the broadcast,

721
00:34:33,971 --> 00:34:37,742
when we know overall
reflectivity based
on the composition,

722
00:34:37,742 --> 00:34:41,879
we can get an estimate of
size, which is very important.

723
00:34:41,879 --> 00:34:45,817
And specifically, different
types of asteroids,

724
00:34:45,817 --> 00:34:49,087
different compositions, would

require different approaches

725
00:34:49,087 --> 00:34:52,290
for deflection if we ever
found a hazardous one

726
00:34:52,290 --> 00:34:54,492
that we needed to
so something about

727
00:34:54,492 --> 00:34:56,027
while it was still in space.

728
00:34:56,027 --> 00:34:58,930
So a very vital information
characterization

729
00:34:58,930 --> 00:35:01,265
and an important practical
role it can play.

730
00:35:01,265 --> 00:35:04,068
- So getting as much
information as you can,

731
00:35:04,068 --> 00:35:05,436
so you know what
you're dealing with?

732
00:35:05,436 --> 00:35:06,671
- [Eilene] Absolutely.

733
00:35:06,671 --> 00:35:08,739
- Alright well I
understand you told me

734
00:35:08,739 --> 00:35:12,376
that there is a little
side story that you have

735
00:35:12,376 --> 00:35:17,281
a mirror that you use, it's
got a little bit of a legacy,

736
00:35:17,281 --> 00:35:20,118
a little bit of heritage there.

737
00:35:20,118 --> 00:35:21,619
- Actually it's pretty exciting.

738
00:35:21,619 --> 00:35:24,856
Our telescope mirror is
actually one of two spares

739
00:35:24,856 --> 00:35:27,492
leftover from the Hubble
Space Telescope program.

740
00:35:27,492 --> 00:35:30,328
So we have the
only working spare

741
00:35:30,328 --> 00:35:32,430
incorporated into our telescope,

742
00:35:32,430 --> 00:35:35,166
the other spare went to
the Smithsonian Museum

743
00:35:35,166 --> 00:35:37,935
in Washington DC after it
wasn't needed for Hubble.

744
00:35:37,935 --> 00:35:40,705
So we feel very honored
to have such a mirror,

745
00:35:40,705 --> 00:35:43,674
and it performs

absolutely beautifully,

746
00:35:43,674 --> 00:35:46,110
and so New Mexico
Tech University,

747
00:35:46,110 --> 00:35:48,012
which runs Magdalena
Ridge Observatory

748
00:35:48,012 --> 00:35:49,647
actually got it for free.

749
00:35:49,647 --> 00:35:51,516
- Wow, great story.

750
00:35:51,516 --> 00:35:54,385
I have a social media
question for you, Eilene.

751
00:35:54,385 --> 00:35:58,222
Here it is, many out there
on social media want to know

752
00:35:58,222 --> 00:36:02,093
when there are close approaches
by passing asteroids.

753
00:36:02,093 --> 00:36:05,196
Can you see them
with your naked eye?

754
00:36:06,531 --> 00:36:09,300
- Sometimes you can, it
depends on how bright they are.

755
00:36:09,300 --> 00:36:10,768
Most of the time that we needed

756

00:36:10,768 --> 00:36:13,938
even just a small
backyard telescope.

757
00:36:13,938 --> 00:36:16,374
Naturally if you went
outside and you looked

758
00:36:16,374 --> 00:36:18,442
in the night sky
you might see things

759
00:36:18,442 --> 00:36:21,379
of a visual magnitude
of five or six,

760
00:36:21,379 --> 00:36:23,848
even asteroids that come
very close to the Earth,

761
00:36:23,848 --> 00:36:25,616
we might even have them being

762
00:36:25,616 --> 00:36:28,753
as bright as 10 or 12
on our brightness scale.

763
00:36:28,753 --> 00:36:30,621
So you can see them through,

764
00:36:30,621 --> 00:36:32,089
sometimes your
backyard telescope,

765
00:36:32,089 --> 00:36:34,058
sometimes they're
very faint still

766
00:36:34,058 --> 00:36:36,827
and we need big telescopes

like our 2.4 meter telescope

767
00:36:36,827 --> 00:36:38,829
to actually study.

768
00:36:38,829 --> 00:36:41,365
- Alright Eilene, always
a pleasure to talk to you.

769
00:36:41,365 --> 00:36:44,368
Thank you so much for
helping us out today.

770
00:36:44,368 --> 00:36:46,204
- [Eilene] Thanks Gay.

771
00:36:47,104 --> 00:36:50,274
(upbeat techno music)

772
00:37:04,222 --> 00:37:07,291
- At the start of the show,
we showed a radar movie

773
00:37:07,291 --> 00:37:09,060
of Asteroid 2014 JO25

774
00:37:11,262 --> 00:37:13,931
made using the 70 meter antenna

775
00:37:13,931 --> 00:37:16,334
at Goldstone Station
in the Mohave Desert.

776
00:37:16,334 --> 00:37:19,470
The antenna is part of
NASA's Deep Space Network,

777
00:37:19,470 --> 00:37:21,138
which communicates

with our space craft

778
00:37:21,138 --> 00:37:24,842
across the solar system,
from this room in fact.

779
00:37:24,842 --> 00:37:27,845
But that communications
disc is actually

780
00:37:27,845 --> 00:37:30,648
a terrific scientific
instrument as well.

781
00:37:30,648 --> 00:37:32,984
Using it for radar
gives us a chance

782
00:37:32,984 --> 00:37:36,020
to see asteroids
in great detail.

783
00:37:36,020 --> 00:37:38,956
Let me introduce you
now to radar scientist,

784
00:37:38,956 --> 00:37:42,126
Marina Brozovic, here at NASA's
Jet Propulsion Laboratory.

785
00:37:42,126 --> 00:37:42,960
Hi Marina!

786
00:37:42,960 --> 00:37:44,395
- Hi.

787
00:37:44,395 --> 00:37:48,199
- Okay, explain to us how radar
works, in the first place.

788
00:37:48,199 --> 00:37:50,534
- Well our planetary
radars are very much

789
00:37:50,534 --> 00:37:53,738
like the airport radars that
track airplanes in the sky.

790
00:37:53,738 --> 00:37:57,642
But airport radars, they track
airplanes that are within

791
00:37:57,642 --> 00:38:02,013
60 mile radius, and
our planetary radars
reach much further.

792
00:38:02,013 --> 00:38:03,447
So we are tracking
near Earth objects

793
00:38:03,447 --> 00:38:04,949
that are hundreds of thousands,

794
00:38:04,949 --> 00:38:07,718
sometimes more than millions
of miles away from Earth.

795
00:38:07,718 --> 00:38:09,186
And for this you need

796
00:38:09,186 --> 00:38:11,455
really powerful transmitters
and very large antennas,

797
00:38:11,455 --> 00:38:13,958
such as, there is
a 300 meter dish,

798

00:38:13,958 --> 00:38:16,794
Arecibo, in Puerto Rico,
and then we also have

799
00:38:16,794 --> 00:38:20,564
our 70 meter, the SS-14
antenna at Goldstone.

800
00:38:20,564 --> 00:38:22,967
And so let me show you, there
is a like a brief animation

801
00:38:22,967 --> 00:38:24,568
of how radar really works.

802
00:38:24,568 --> 00:38:27,905
So it transmits radio waves,
and these radio waves,

803
00:38:27,905 --> 00:38:29,307
they bounce off the asteroid.

804
00:38:29,307 --> 00:38:31,575
And the echo that
comes back carries

805
00:38:31,575 --> 00:38:33,978
a lot of information
about that asteroid.

806
00:38:33,978 --> 00:38:36,981
So for example, when we
observed Asteroid Apophis

807
00:38:36,981 --> 00:38:41,319
during 2013 flyby,
there is a video showing

808
00:38:41,319 --> 00:38:45,356
how we zapped the asteroid

as it was going by.

809
00:38:45,356 --> 00:38:47,525
We zapped it with radar,
and we basically wanted

810
00:38:47,525 --> 00:38:49,760
to very precisely
measure where it is

811
00:38:49,760 --> 00:38:51,295
and how fast its moving.

812
00:38:51,295 --> 00:38:52,663
And we use these measurements

813
00:38:52,663 --> 00:38:55,099
in order to improve our
orbital calculations,

814
00:38:55,099 --> 00:38:57,635
because better data
means better orbits.

815
00:38:57,635 --> 00:39:01,005
- So what does radar
then bring to the table?

816
00:39:01,005 --> 00:39:04,108
- Well radar is a little
bit like a Swiss Army knife,

817
00:39:04,108 --> 00:39:08,479
because it reveals so much
about asteroid at once.

818
00:39:08,479 --> 00:39:10,414
You know in optical telescopes,

819

00:39:10,414 --> 00:39:12,616
asteroids are these
specks of lights,

820
00:39:12,616 --> 00:39:16,220
but in radar images, they
become worlds of their own.

821
00:39:16,220 --> 00:39:19,223
And you can see all
these details in them,

822
00:39:19,223 --> 00:39:21,659
so in the radar images
you directly see

823
00:39:21,659 --> 00:39:23,527
how asteroid looks like.

824
00:39:23,527 --> 00:39:26,430
If it has a satellite,
how large it is.

825
00:39:26,430 --> 00:39:28,499
How it's rotating,
and we can even see

826
00:39:28,499 --> 00:39:29,967
surface features on it.

827
00:39:29,967 --> 00:39:33,804
So we see ridges, and
facets, and concavities,

828
00:39:35,906 --> 00:39:39,543
and boulders, and basically
all the nooks and crannies.

829
00:39:39,543 --> 00:39:41,479
And we have such example,

830
00:39:41,479 --> 00:39:43,414
there is a video
you already showed,

831
00:39:43,414 --> 00:39:45,649
this asteroid we observed
a couple of months ago,

832
00:39:45,649 --> 00:39:48,386
2014 JO25, so it
turned out to be

833
00:39:49,587 --> 00:39:52,957
this 2/3 of a mile
long space peanut.

834
00:39:52,957 --> 00:39:56,193
And we were just watching it
rotate in front of our eyes

835
00:39:56,193 --> 00:39:58,996
during four eyes of
radar observations,

836
00:39:58,996 --> 00:40:00,898
and it's fasincating
that you could see

837
00:40:00,898 --> 00:40:04,034
how this front lobe is
casting radar shadow

838
00:40:04,034 --> 00:40:05,669
and the back lobe,
and you can see

839
00:40:05,669 --> 00:40:07,037
all the concavities and ridges,

840
00:40:07,037 --> 00:40:08,806
and if you look very carefully,

841
00:40:08,806 --> 00:40:10,741
there are these
radar bright specks

842
00:40:10,741 --> 00:40:12,376
that are rotating with asteroid,

843
00:40:12,376 --> 00:40:15,613
and we believe that these are
meter-sized surface boulders,

844
00:40:15,613 --> 00:40:17,948
and all this is visible
while the asteroid

845
00:40:17,948 --> 00:40:21,919
was 1.8 million miles
away from Earth.

846
00:40:21,919 --> 00:40:23,921
- Well it's interesting,
sometimes you can even see

847
00:40:23,921 --> 00:40:28,726
if there's more than one
asteroid, and they're together!

848
00:40:28,726 --> 00:40:32,263
- Yes, these are binary
asteroids, and now we know,

849
00:40:32,263 --> 00:40:35,599
thanks to radar, and
optical telescopes,

850
00:40:35,599 --> 00:40:39,170

we know that one in
six asteroids in near
Earth population,

851
00:40:39,170 --> 00:40:42,973
asteroids that are larger
than about 140 meters in size,

852
00:40:42,973 --> 00:40:44,875
they have a companion.

853
00:40:44,875 --> 00:40:47,111
We even found two
triple systems.

854
00:40:47,111 --> 00:40:48,646
So there are actually
- Wow.

855
00:40:48,646 --> 00:40:52,049
- Two asteroids that we know
of, that have two satellites.

856
00:40:52,049 --> 00:40:54,585
- Alright, so all of
this focus has been

857
00:40:54,585 --> 00:40:58,022
on getting an understanding
of an asteroid

858
00:40:58,022 --> 00:41:01,492
that may be coming to
us, headed this way.

859
00:41:01,492 --> 00:41:03,894
But could we use this
information to help us

860
00:41:03,894 --> 00:41:06,230

if we want to go
exploring asteroids?

861
00:41:06,230 --> 00:41:08,499
- Absolutely, so
radar observations,

862
00:41:08,499 --> 00:41:10,234
they have been used in the past

863
00:41:10,234 --> 00:41:11,802
to support space craft missions.

864
00:41:11,802 --> 00:41:14,472
And in fact, Mission OSIRIS-REx,

865
00:41:15,906 --> 00:41:19,410
that it's on its
way to rendezvous
Asteroid Bennu in 2018,

866
00:41:19,410 --> 00:41:21,645
has definitely benefited from

867
00:41:21,645 --> 00:41:24,815
the existing radar observations
because based on that

868
00:41:24,815 --> 00:41:28,519
we had a full reconstruction
of Bennu's shape,

869
00:41:28,519 --> 00:41:30,554
we had an estimate of its size,

870
00:41:30,554 --> 00:41:32,656
of its spin state,
and even mass.

871

00:41:32,656 --> 00:41:34,892
And you can imagine all this
information is really useful

872
00:41:34,892 --> 00:41:37,328
when you are planning proximity

873
00:41:37,328 --> 00:41:39,396
space craft operations
around asteroid.

874
00:41:39,396 --> 00:41:42,867
It just gives you kind of level
of safety for the mission,

875
00:41:42,867 --> 00:41:45,903
and it also allows
for you to better plan

876
00:41:45,903 --> 00:41:47,438
the scientific observations.

877
00:41:47,438 --> 00:41:50,140
- Okay, I have a
social media question.

878
00:41:50,140 --> 00:41:53,410
And this one is someone
who's trying to understand,

879
00:41:53,410 --> 00:41:56,747
why do asteroids
have these odd names,

880
00:41:56,747 --> 00:42:00,417
like 2014 JO25, why
don't you call it Madge?

881
00:42:03,487 --> 00:42:05,055
(laughing)

882
00:42:05,055 --> 00:42:06,490
Why do you have these names?

883
00:42:06,490 --> 00:42:09,693
- Yeah so there is actually
a good reason for it,

884
00:42:09,693 --> 00:42:12,930
so Minor Planet Center assigns
these temporary designations

885
00:42:12,930 --> 00:42:14,965
and they mean something to us.

886
00:42:14,965 --> 00:42:17,701
For example, 2014 JO25.

887
00:42:17,701 --> 00:42:20,738
2014 means it was
discovered in 2014.

888
00:42:20,738 --> 00:42:23,574
Letter J tells me
that it was discovered

889
00:42:23,574 --> 00:42:25,643
in first two weeks of May.

890
00:42:25,643 --> 00:42:28,612
And then O25, there's
a little formula.

891
00:42:28,612 --> 00:42:32,683
That tells me that it
was 639th minor planet

892
00:42:32,683 --> 00:42:35,486
that was discovered in

that two week period.

893
00:42:35,486 --> 00:42:37,621
So there is a method
to the madness.

894
00:42:37,621 --> 00:42:41,825
- Alright, so when people
see that, 2014 2025,

895
00:42:41,825 --> 00:42:43,127
they understand.

896
00:42:43,127 --> 00:42:45,195
- Yes, there is
actually meaning.

897
00:42:45,195 --> 00:42:46,297
- Thanks Marina.

898
00:42:46,297 --> 00:42:48,299
- Absolutely, thank you.

899
00:42:49,600 --> 00:42:52,770
(upbeat techno music)

900
00:43:07,818 --> 00:43:12,056
- We mentioned NASA's NEOWISE
space telescope earlier.

901
00:43:12,056 --> 00:43:14,858
NEOWISE is a space telescope,

902
00:43:14,858 --> 00:43:18,495
now it was originally
designed to image the sky

903
00:43:18,495 --> 00:43:22,132
in the infrared spectrum,

that is the spectrum

904
00:43:22,132 --> 00:43:23,634
that detects heat.

905
00:43:25,603 --> 00:43:29,106
Now originally this
was the WISE telescope,

906
00:43:29,106 --> 00:43:31,342
and it was sent to
survey the skies.

907
00:43:31,342 --> 00:43:35,746
Then it completed its job
and it was mothballed,

908
00:43:35,746 --> 00:43:39,550
and then it was realized
that maybe it was very good

909
00:43:39,550 --> 00:43:41,952
at detecting asteroids.

910
00:43:41,952 --> 00:43:44,488
So then it was taken
out of mothballs

911
00:43:44,488 --> 00:43:47,725
and became the NEOWISE Mission,

912
00:43:47,725 --> 00:43:51,629
in which it allowed us to
actually search for asteroids.

913
00:43:51,629 --> 00:43:55,332
It's focus now to
characterizing and finding

914

00:43:55,332 --> 00:43:57,034
near Earth asteroids.

915
00:43:57,034 --> 00:44:00,471
It turns out that infrared
is just a great tool

916
00:44:00,471 --> 00:44:03,540
for hunting space rocks,
especially the dark ones

917
00:44:03,540 --> 00:44:06,944
that are difficult for the
ground telescopes to spot.

918
00:44:06,944 --> 00:44:10,180
Amy Mainzer is the principal
investigator for NEOWISE,

919
00:44:10,180 --> 00:44:14,351
Amy can you explain to me why
this is such a great tool,

920
00:44:16,020 --> 00:44:18,455
why is infrared so great?

921
00:44:18,455 --> 00:44:19,657
- Thanks Gay.

922
00:44:19,657 --> 00:44:21,325
Well one of the great
things about using

923
00:44:21,325 --> 00:44:23,594
different wavelengths of
light to study these objects,

924
00:44:23,594 --> 00:44:26,096
is that we learn something
different and unique

925
00:44:26,096 --> 00:44:28,032
from each new way
that we look at it.

926
00:44:28,032 --> 00:44:30,300
We just heard about how
radar provides a whole array

927
00:44:30,300 --> 00:44:32,136
of useful information
about asteroids.

928
00:44:32,136 --> 00:44:35,172
Infrared light is
different from both

929
00:44:35,172 --> 00:44:38,609
visible light and radar in
terms of what it returns to us.

930
00:44:38,609 --> 00:44:40,577
With visible light, we're
seeing light bouncing

931
00:44:40,577 --> 00:44:43,447
off the surface of asteroid
and coming into our telescopes,

932
00:44:43,447 --> 00:44:46,650
so we're very sensitive to
the properties of the surface.

933
00:44:46,650 --> 00:44:48,185
If the surface is really dark,

934
00:44:48,185 --> 00:44:50,754
it's harder to see with
visible wavelengths.

935
00:44:50,754 --> 00:44:52,156
Whereas--

936
00:44:52,156 --> 00:44:54,158
- [Gay] And so Amy, we actually
have an infrared camera

937
00:44:54,158 --> 00:44:57,995
in the room with you,
and so what is it doing?

938
00:44:57,995 --> 00:44:59,730
It's just detecting the heat?

939
00:44:59,730 --> 00:45:01,231
- Yeah, that's right.

940
00:45:01,231 --> 00:45:03,367
So what you're seeing is the
heat that's coming off of me,

941
00:45:03,367 --> 00:45:05,235
you can see that
my nose is cold,

942
00:45:05,235 --> 00:45:06,937
my fingers are a little cold,

943
00:45:06,937 --> 00:45:08,572
but this I the kind of imaging

944
00:45:08,572 --> 00:45:10,107
that we use with the asteroids.

945
00:45:10,107 --> 00:45:13,177
And we look for them using
their heat signatures.

946

00:45:13,177 --> 00:45:16,346
So this lets us see them
regardless of whether

947
00:45:16,346 --> 00:45:19,450
they're kind of light in
color on their surfaces,

948
00:45:19,450 --> 00:45:21,318
or darker in color
on their surfaces.

949
00:45:21,318 --> 00:45:22,586
- [Gay] And how is that helpful

950
00:45:22,586 --> 00:45:25,122
in terms of being able
to spot the asteroids?

951
00:45:25,122 --> 00:45:28,125
- Well there definitely
are asteroids out there

952
00:45:28,125 --> 00:45:29,493
in the population that we know

953
00:45:29,493 --> 00:45:31,729
that are made of
carbonaceous materials,

954
00:45:31,729 --> 00:45:34,431
as opposed to lighter
colored stony materials.

955
00:45:34,431 --> 00:45:36,633
These really dark
colored objects

956
00:45:36,633 --> 00:45:38,469
are harder to spot

with visible light,

957
00:45:38,469 --> 00:45:40,738
but if we look for them
with their heat signatures,

958
00:45:40,738 --> 00:45:45,576
using infrared telescopes,
like NEOWISE, they pop out.

959
00:45:45,576 --> 00:45:49,012
- Alright, so tell me
more about NEOWISE.

960
00:45:49,012 --> 00:45:51,648
I tried to relay
this story about,

961
00:45:51,648 --> 00:45:54,118
that it wasn't
originally sent out there

962
00:45:54,118 --> 00:45:55,586
to look for asteroids.

963
00:45:55,586 --> 00:45:57,254
- That's right, the
original mission

964
00:45:57,254 --> 00:46:00,224
is the Wide-field Infrared
Survey Explorer mission.

965
00:46:00,224 --> 00:46:02,693
And the principal investigators,
Dr Ned Wright of UCLA,

966
00:46:02,693 --> 00:46:05,329
and the mission was
originally designed

967
00:46:05,329 --> 00:46:07,831
to survey the whole
sky in infrared light,

968
00:46:07,831 --> 00:46:09,933
to search for very
bright galaxies

969
00:46:09,933 --> 00:46:12,870
and very cool stars, it
did that beautifully.

970
00:46:12,870 --> 00:46:14,972
It finished its prime
mission successfully.

971
00:46:14,972 --> 00:46:17,074
But in the process
we found that it was

972
00:46:17,074 --> 00:46:19,176
quite effective at
spotting asteroids,

973
00:46:19,176 --> 00:46:20,911
particularly these
very dark objects.

974
00:46:20,911 --> 00:46:25,115
So when the mission
was completed in 2011,

975
00:46:25,115 --> 00:46:27,284
we thought that was
the end of the story.

976
00:46:27,284 --> 00:46:30,087
But we were lucky, we were
able to bring it back to life.

977
00:46:30,087 --> 00:46:33,590
- Absolutely not, we have a
graphic that I can pull up,

978
00:46:33,590 --> 00:46:37,761
and it shows all the discoveries
that NEOWISE has made.

979
00:46:39,096 --> 00:46:41,899
How many discoveries
has NEOWISE made?

980
00:46:41,899 --> 00:46:43,967
- Yeah so the graphic shows you

981
00:46:43,967 --> 00:46:46,637
the asteroids that
we've detected

982
00:46:46,637 --> 00:46:50,073
since the restart of
the mission in 2013.

983
00:46:50,073 --> 00:46:52,342
So if we include
the prime mission

984
00:46:52,342 --> 00:46:53,844
as well as the restart years,

985
00:46:53,844 --> 00:46:56,947
we have a total of around
34,000 new discoveries.

986
00:46:56,947 --> 00:47:00,951
- 34,000, alright so
we obviously have shown

987

00:47:00,951 --> 00:47:05,489
that this technology works,
so what do we see ahead

988
00:47:05,489 --> 00:47:07,291
as future technology?

989
00:47:07,291 --> 00:47:09,860
Kind of maximizing on
what we've learned.

990
00:47:09,860 --> 00:47:11,328
- Right, well one of
the great things about

991
00:47:11,328 --> 00:47:14,398
having gotten to use this
spacecraft for a new purpose,

992
00:47:14,398 --> 00:47:16,733
which is to search for
asteroids and comets,

993
00:47:16,733 --> 00:47:18,335
is that we've learned
a great deal about

994
00:47:18,335 --> 00:47:21,305
how do to do this work using
a space based telescope,

995
00:47:21,305 --> 00:47:25,142
an infrared telescope, for
discovery in large numbers.

996
00:47:25,142 --> 00:47:27,077
Now the thing is,
NEOWISE was never

997
00:47:27,077 --> 00:47:28,645

originally designed
for this purpose,

998
00:47:28,645 --> 00:47:30,881
and all good things are
going to come to an end.

999
00:47:30,881 --> 00:47:32,616
Eventually the mission
is going to end.

1000
00:47:32,616 --> 00:47:34,852
It was not designed
to last this long.

1001
00:47:34,852 --> 00:47:37,588
And it really wasn't
designed from the get-go

1002
00:47:37,588 --> 00:47:39,022
for searching for asteroids.

1003
00:47:39,022 --> 00:47:41,592
However we've been
looking for new ways

1004
00:47:41,592 --> 00:47:43,794
to search for asteroids
using a space telescope

1005
00:47:43,794 --> 00:47:46,530
that is designed
for this purpose.

1006
00:47:46,530 --> 00:47:50,200
And we call that the Near Earth
Object Camera, or NEO-Cam.

1007
00:47:50,200 --> 00:47:53,637
- [Gay] Alright, and

there is a picture of it.

1008
00:47:53,637 --> 00:47:57,875
- Right so it's basically
designed to go out

1009
00:47:57,875 --> 00:48:00,143
and spend all of its
time searching for

1010
00:48:00,143 --> 00:48:02,312
asteroids and comets
that could potentially

1011
00:48:02,312 --> 00:48:03,747
get close to the Earth.

1012
00:48:03,747 --> 00:48:05,782
And the main
difference from NEOWISE

1013
00:48:05,782 --> 00:48:07,951
is that it's going to
have a longer lifetime,

1014
00:48:07,951 --> 00:48:10,554
it can search a much
wider area of the sky,

1015
00:48:10,554 --> 00:48:14,124
and it has modern,
next-generation detectors.

1016
00:48:14,124 --> 00:48:16,159
So basically these
are the camera chips

1017
00:48:16,159 --> 00:48:18,729
that are capable of
sensing the asteroids

1018
00:48:18,729 --> 00:48:20,364
at the wavelengths where
they're really bright,

1019
00:48:20,364 --> 00:48:21,632
which is infrared.

1020
00:48:21,632 --> 00:48:24,534
- Perfect, well I have
a social media question.

1021
00:48:24,534 --> 00:48:29,172
And we have gotten several
about how things are named,

1022
00:48:29,172 --> 00:48:31,742
and I understand that
you have been involved

1023
00:48:31,742 --> 00:48:34,411
in naming asteroids in the past,

1024
00:48:35,812 --> 00:48:38,548
after women who
were very strong.

1025
00:48:39,917 --> 00:48:42,486
- You know one of
the great privileges

1026
00:48:42,486 --> 00:48:45,689
of discovering the asteroids
is that we do get to name them.

1027
00:48:45,689 --> 00:48:49,526
The discoverer has, the IAU
allows us to propose names

1028

00:48:49,526 --> 00:48:52,195
and submit them and
if they approve them,

1029
00:48:52,195 --> 00:48:53,730
then that's the
name of the object.

1030
00:48:53,730 --> 00:48:55,832
There's some just really
fantastic people out there

1031
00:48:55,832 --> 00:48:58,936
who I think deserve
asteroid names.

1032
00:48:58,936 --> 00:49:00,203
- Give us some examples.

1033
00:49:00,203 --> 00:49:02,272
- Well, Malala was
one, and actually

1034
00:49:02,272 --> 00:49:06,443
one of my colleagues, Dr Carrie
Nugent, over at Cal Tech,

1035
00:49:06,443 --> 00:49:08,946
and I were talking about
her and were just like

1036
00:49:08,946 --> 00:49:10,080
man she is amazing!

1037
00:49:10,080 --> 00:49:12,182
She needs an
asteroid. (laughing)

1038
00:49:12,182 --> 00:49:15,018
- Well yes, that

is a great perk.

1039
00:49:15,018 --> 00:49:16,553
Thank you so much, Amy.

1040
00:49:16,553 --> 00:49:17,955
- Thank you, Gay.

1041
00:49:19,056 --> 00:49:22,259
(upbeat techno music)

1042
00:49:36,740 --> 00:49:39,876
Okay, so what if we
identify an object

1043
00:49:39,876 --> 00:49:42,646
that actually is headed our way?

1044
00:49:42,646 --> 00:49:44,815
NASA has to deal with that too.

1045
00:49:44,815 --> 00:49:48,285
Let's check in with NASA's
Planetary Defense Officer,

1046
00:49:48,285 --> 00:49:50,287
Lindley Johnson and Kelly Fast,

1047
00:49:50,287 --> 00:49:54,291
Manager of the Near Earth
Object Observation program.

1048
00:49:54,291 --> 00:49:57,327
So Lindley and Kelly, we have
plenty of time right now,

1049
00:49:57,327 --> 00:50:00,864
and let's look at this
step of the whole phase

1050
00:50:00,864 --> 00:50:02,199
that you have to deal with.

1051
00:50:02,199 --> 00:50:04,001
I mean first of all Kelly,

1052
00:50:04,001 --> 00:50:06,203
say an asteroid is
headed for Earth,

1053
00:50:06,203 --> 00:50:08,338
would we tell the
public about it?

1054
00:50:08,338 --> 00:50:12,175
People seem to really
be concerned about that.

1055
00:50:13,310 --> 00:50:14,945
- Yes Gay, we would
tell the public

1056
00:50:14,945 --> 00:50:18,048
because first of all
the data are public.

1057
00:50:18,048 --> 00:50:19,983
The observations go to
the Minor Planet Center,

1058
00:50:19,983 --> 00:50:22,552
the orbit determination shows
up on the websites there,

1059
00:50:22,552 --> 00:50:24,921
and on the Center for
Near Earth Object Studies.

1060

00:50:24,921 --> 00:50:26,690
So the information would
be out there to begin with,

1061
00:50:26,690 --> 00:50:28,558
but first of all we'd
want to a confirmation.

1062
00:50:28,558 --> 00:50:31,528
At NASA we'd want to
work with our partners

1063
00:50:31,528 --> 00:50:33,530
in the International
Asteroid Warning Network

1064
00:50:33,530 --> 00:50:37,267
to look at orbit
determination and to look at

1065
00:50:37,267 --> 00:50:41,505
the risk of impact and
the effects of the impact

1066
00:50:41,505 --> 00:50:43,673
and to make sure that
everybody is on the same page,

1067
00:50:43,673 --> 00:50:44,641
or getting consistent answers.

1068
00:50:44,641 --> 00:50:46,109
To have that verification

1069
00:50:46,109 --> 00:50:48,845
so that the most accurate
information is going out there.

1070
00:50:48,845 --> 00:50:52,449
And then also at NASA there

is a notification procedure

1071
00:50:52,449 --> 00:50:55,485
in place where there
would be a notification

1072
00:50:55,485 --> 00:50:58,422
that would go up through
the NASA administrator

1073
00:50:58,422 --> 00:51:02,292
to the White House and
on to other US agencies,

1074
00:51:03,660 --> 00:51:07,364
onto Congress, and also
ultimately to other countries.

1075
00:51:09,399 --> 00:51:12,402
And so yes it wold become
very public very quickly

1076
00:51:12,402 --> 00:51:13,637
and so we would just
want to make sure

1077
00:51:13,637 --> 00:51:15,605
that it happens in the
right and accurate way.

1078
00:51:15,605 --> 00:51:18,341
- Alright so people
should be rest assured

1079
00:51:18,341 --> 00:51:22,179
that that information
would never be withheld.

1080
00:51:24,414 --> 00:51:25,649
- Right, that's correct.

1081
00:51:25,649 --> 00:51:28,185
It really wouldn't
because again,

1082
00:51:28,185 --> 00:51:29,719
the information is on websites,

1083
00:51:29,719 --> 00:51:31,655
and people with the
right telescopes,

1084
00:51:31,655 --> 00:51:35,358
I mean the skies are open
so they can look themselves.

1085
00:51:35,358 --> 00:51:37,694
- So the next question
goes to Lindley,

1086
00:51:37,694 --> 00:51:41,531
what happens next, if
you do see something

1087
00:51:41,531 --> 00:51:45,702
that appears to be, going
to able to impact the Earth?

1088
00:51:49,239 --> 00:51:51,641
- Well Gay, that all
depends on how big it is,

1089
00:51:51,641 --> 00:51:55,045
you already shown us
an example of 2008 TC3,

1090
00:51:55,045 --> 00:51:57,214
a very small object,
that we knew that

1091
00:51:57,214 --> 00:51:59,282
the Earth's atmosphere
would protect us from it,

1092
00:51:59,282 --> 00:52:00,784
so we weren't too
worried about it.

1093
00:52:00,784 --> 00:52:03,253
We just wanted to determine
where it was going to impact,

1094
00:52:03,253 --> 00:52:06,323
what time, so we could go out
and collect all the meteorites

1095
00:52:06,323 --> 00:52:09,359
as you saw because
that's a very valuable

1096
00:52:09,359 --> 00:52:13,864
resource for the scientist to
learn more about asteroids.

1097
00:52:13,864 --> 00:52:17,767
So it's kind of a free
sample return, so to speak.

1098
00:52:17,767 --> 00:52:19,369
But if it's a larger object,

1099
00:52:19,369 --> 00:52:21,671
say a few tens of
meters in size,

1100
00:52:21,671 --> 00:52:23,440
that's where we have to get

1101
00:52:23,440 --> 00:52:27,744

the other federal agencies
involved and their counterparts

1102
00:52:27,744 --> 00:52:31,148
around the world
to first of all,

1103
00:52:31,148 --> 00:52:35,619
determine where on the
Earth it's going to impact,

1104
00:52:35,619 --> 00:52:37,654
so that we can alert them.

1105
00:52:37,654 --> 00:52:41,224
One thing about predicting
asteroid impacts is

1106
00:52:41,224 --> 00:52:44,794
that we can determine
precisely the time

1107
00:52:44,794 --> 00:52:46,096
that they're going to impact,

1108
00:52:46,096 --> 00:52:48,498
and with observations
as it comes in,

1109
00:52:48,498 --> 00:52:52,369
we can determine a location
very accurately too.

1110
00:52:52,369 --> 00:52:54,237
And so this is kind
of a unique thing

1111
00:52:54,237 --> 00:52:58,208
for FEMA and the other
emergency response community,

1112
00:52:58,208 --> 00:53:01,878
is that we can tell them
the time and location

1113
00:53:01,878 --> 00:53:05,382
of a potential disaster
before its gonna happen

1114
00:53:05,382 --> 00:53:08,718
so that was very valuable
information for them

1115
00:53:08,718 --> 00:53:10,387
to prepare the area,

1116
00:53:11,488 --> 00:53:13,456
the community that
might be affected by it

1117
00:53:13,456 --> 00:53:16,493
so that populations
can be evacuated

1118
00:53:16,493 --> 00:53:18,495
and infrastructure locked down.

1119
00:53:18,495 --> 00:53:20,664
Now if it's bigger than that,

1120
00:53:20,664 --> 00:53:24,000
and this is actually
our main objective at

1121
00:53:24,000 --> 00:53:26,503
the Planetary Defense
Coordination Office

1122
00:53:26,503 --> 00:53:29,940

and all of the projects
that we work with,

1123
00:53:29,940 --> 00:53:31,675
all that you have seen today,

1124
00:53:31,675 --> 00:53:35,212
is to find an object
that is large enough

1125
00:53:35,212 --> 00:53:39,115
that it could affect
a major metropolitan

1126
00:53:39,115 --> 00:53:43,653
or a statewide area, find
it far enough out in time

1127
00:53:43,653 --> 00:53:47,357
that we have time to
initiate a space mission

1128
00:53:47,357 --> 00:53:50,927
to go out an deflect it off
of that impact trajectory.

1129
00:53:50,927 --> 00:53:55,098
So we are looking at various
techniques and technologies

1130
00:53:56,700 --> 00:53:59,469
like a kinetic impactor
or a gravity tractor,

1131
00:53:59,469 --> 00:54:02,305
that we could send out
several years in advance

1132
00:54:02,305 --> 00:54:05,675
to prevent the impact

in the first place.

1133
00:54:05,675 --> 00:54:08,511
- So let's take
that as an example,

1134
00:54:08,511 --> 00:54:12,182
Kelly if there was something
as big as a football stadium,

1135
00:54:12,182 --> 00:54:15,619
is that something that
can be dealt with?

1136
00:54:17,287 --> 00:54:18,688
- Well actually I'm
going to kick that one

1137
00:54:18,688 --> 00:54:21,791
to Lindley and let
him address that.

1138
00:54:21,791 --> 00:54:24,194
- If Lindley if it's as
big as a football stadium,

1139
00:54:24,194 --> 00:54:28,365
is that something that we
have even thought about?

1140
00:54:29,566 --> 00:54:33,036
- Oh yes, that is
the type of scenario

1141
00:54:33,036 --> 00:54:35,705
that we are mainly looking at,

1142
00:54:35,705 --> 00:54:39,209
because the most common
hazardous asteroid

1143
00:54:43,246 --> 00:54:45,215
that we might have to face with

1144
00:54:45,215 --> 00:54:47,317
that we'd want to
deflect in space

1145
00:54:47,317 --> 00:54:51,021
is the size of a few
hundred meters or so,

1146
00:54:51,021 --> 00:54:54,691
and if we find it
several years in advance

1147
00:54:54,691 --> 00:54:56,926
and are able to get
space missions out to it,

1148
00:54:56,926 --> 00:55:01,498
an object of that size, we
only have to change the speed

1149
00:55:01,498 --> 00:55:04,567
of the asteroid by a few
centimeters per second,

1150
00:55:04,567 --> 00:55:07,170
and if we do that
several years in advance,

1151
00:55:07,170 --> 00:55:11,341
it will not reach the same
point in space as the Earth

1152
00:55:12,776 --> 00:55:14,911
at the predicted impact time,
we will have slowed it down

1153
00:55:14,911 --> 00:55:17,013
and so the Earth
will have already

1154
00:55:17,013 --> 00:55:18,181
passed that point in space.

1155
00:55:18,181 --> 00:55:19,449
So that is a
principle that is used

1156
00:55:19,449 --> 00:55:23,586
in all of our various
mitigation techniques.

1157
00:55:23,586 --> 00:55:26,990
So the kinetic impactor,
we just hit it hard,

1158
00:55:26,990 --> 00:55:29,859
with a space craft
that knocks off

1159
00:55:29,859 --> 00:55:34,431
a few inches per second
speed in its velocity,

1160
00:55:34,431 --> 00:55:37,133
and causes it to be a
miss instead of a hit.

1161
00:55:37,133 --> 00:55:40,503
The gravity tractor
operates similarly,

1162
00:55:40,503 --> 00:55:43,106
in that the mutual attraction

1163
00:55:43,106 --> 00:55:46,509

between the space craft
and the asteroid over time,

1164
00:55:46,509 --> 00:55:49,846
slowly, using nature's
tug rope gravity,

1165
00:55:51,281 --> 00:55:53,950
slowly tugs that asteroid
off of the impact trajectory

1166
00:55:53,950 --> 00:55:56,419
and then prevents it
from impacting the Earth.

1167
00:55:56,419 --> 00:55:58,955
- So we have just
a few minutes left,

1168
00:55:58,955 --> 00:56:03,026
if we could talk about that
in our last three minutes.

1169
00:56:03,026 --> 00:56:06,796
The fact that asteroids
are a natural hazard,

1170
00:56:08,398 --> 00:56:12,202
and from what we're hearing
all throughout this program,

1171
00:56:12,202 --> 00:56:16,373
it's a natural hazard that
appears to be preventable.

1172
00:56:18,875 --> 00:56:20,877
- Well that's very true.

1173
00:56:22,345 --> 00:56:25,515
It's one of the few natural

hazards, natural disasters,

1174
00:56:25,515 --> 00:56:27,384
that we know how to prevent.

1175
00:56:27,384 --> 00:56:31,287
If we detect em far enough
out into the future,

1176
00:56:33,690 --> 00:56:37,160
and so that is the objective
of our program here at NASA,

1177
00:56:37,160 --> 00:56:38,962
is find em early, as we say.

1178
00:56:38,962 --> 00:56:41,598
- Alright, so one more
question for Kelly.

1179
00:56:41,598 --> 00:56:43,500
If there were some key messages

1180
00:56:43,500 --> 00:56:47,203
that you would want out
there to tell the public,

1181
00:56:47,203 --> 00:56:51,374
what would those key messages
be, regarding asteroids?

1182
00:56:53,510 --> 00:56:56,079
- Well like we've been
hearing over and over again

1183
00:56:56,079 --> 00:56:59,716
throughout the program, is
that you want to find them,

1184

00:56:59,716 --> 00:57:02,085
find them early,
find them first.

1185
00:57:02,085 --> 00:57:05,722
Then you can determine
what the response might be,

1186
00:57:05,722 --> 00:57:06,956
but if you don't
know they're there,

1187
00:57:06,956 --> 00:57:08,858
you're not going to know
what to do about them.

1188
00:57:08,858 --> 00:57:11,494
However, at the same time,
as I always tell people,

1189
00:57:11,494 --> 00:57:13,430
it's not something that
we're lying awake at night

1190
00:57:13,430 --> 00:57:15,732
worrying about, I mean
we're doing what we can

1191
00:57:15,732 --> 00:57:17,967
and there's more that
needs to be done,

1192
00:57:17,967 --> 00:57:20,003
but when you put it in context,

1193
00:57:20,003 --> 00:57:22,071
we're hard at work here at NASA

1194
00:57:22,071 --> 00:57:25,175
and our colleagues all through

the US and through the world,

1195
00:57:25,175 --> 00:57:26,876
they're working
hard on the problem

1196
00:57:26,876 --> 00:57:30,346
but again, people shouldn't
be worried and fearful

1197
00:57:30,346 --> 00:57:32,115
if we're working on it.

1198
00:57:32,115 --> 00:57:34,017
- And that's what I
seem to be hearing.

1199
00:57:34,017 --> 00:57:38,188
It's possible to take a
proactive stance in all of this,

1200
00:57:39,489 --> 00:57:42,459
that we do know that
asteroids are out there,

1201
00:57:42,459 --> 00:57:46,062
we do know that they
could pose a real hazard,

1202
00:57:46,062 --> 00:57:49,332
but what I'm hearing
here is this is sort of

1203
00:57:49,332 --> 00:57:52,669
a proactive approach that
if they're out there,

1204
00:57:52,669 --> 00:57:56,840
let's find them and then let's
see what we're dealing with.

1205
00:57:58,808 --> 00:57:59,709
- Yes, Gay.

1206
00:58:00,877 --> 00:58:03,513
Because we have a space program,

1207
00:58:03,513 --> 00:58:08,418
we have the technologies
to go out and be able to

1208
00:58:08,418 --> 00:58:11,488
move these small
bodies in space now.

1209
00:58:12,655 --> 00:58:16,259
This is something
that we can prevent.

1210
00:58:16,259 --> 00:58:18,261
We just need to have the

1211
00:58:21,064 --> 00:58:23,633
will to put the
programs together,

1212
00:58:23,633 --> 00:58:28,471
to first of all find them
well before the impacts,

1213
00:58:28,471 --> 00:58:31,641
and then have the
capabilities demonstrated

1214
00:58:31,641 --> 00:58:35,044
that would be able to
divert the objects.

1215
00:58:36,179 --> 00:58:37,514

- Thank you so much.

1216
00:58:37,514 --> 00:58:41,050
This was a very, very
informative program,

1217
00:58:41,050 --> 00:58:43,152
and thank you so much
for your information.

1218
00:58:43,152 --> 00:58:45,822
Here are the
websites once again,

1219
00:58:45,822 --> 00:58:47,724
the Planetary Defense website,

1220
00:58:47,724 --> 00:58:49,559
the Minor Planet Center website,

1221
00:58:49,559 --> 00:58:51,127
and CNEOS.

1222
00:58:51,127 --> 00:58:52,896
Thank you so much
for joining us,

1223
00:58:52,896 --> 00:58:54,030
I hope you learned something,