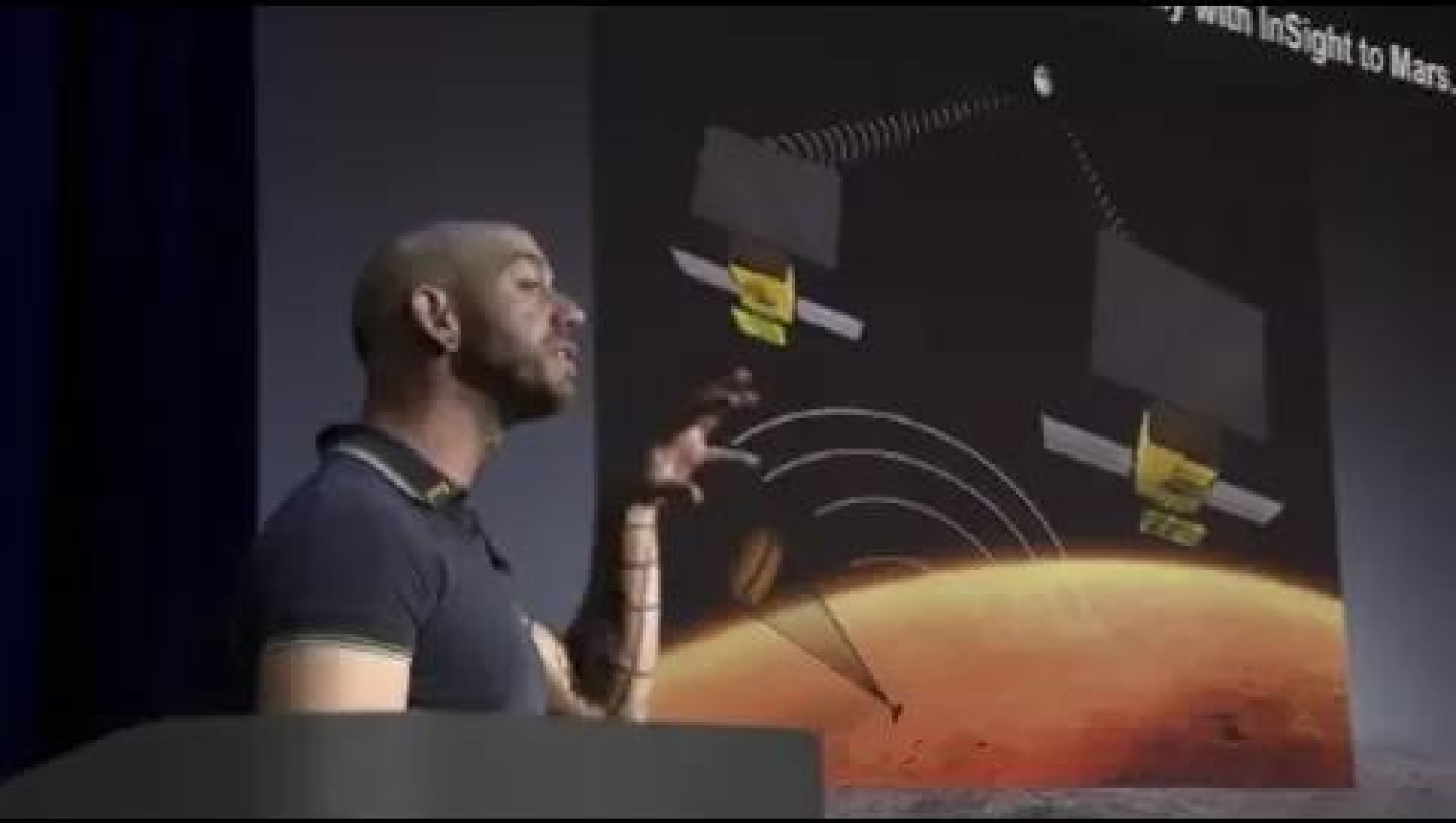
with InSight to Mars,

1
00:00:01,134 --> 00:00:02,869
>> Presenter: NASA's Jet
Propulsion Laboratory presents

2
00:00:03,836 --> 00:00:05,104
the Von Karman Lecture.

3
00:00:05,137 --> 00:00:08,007
A series of talks by
scientists and engineers

4
00:00:08,040 --> 00:00:11,778
who are exploring our
planet, our solar system,

5
00:00:11,811 --> 00:00:13,813
and all that lies beyond.

6
00:00:13,846 --> 00:00:16,016
[calm music]

7
00:00:25,091 --> 00:00:26,926
>> Good evening,
ladies and gentlemen.

8
00:00:26,959 --> 00:00:27,994
How's everyone tonight?

9
00:00:29,028 --> 00:00:30,797
[cheers and applaud]

10
00:00:30,830 --> 00:00:31,931
Thank you very much.

11
00:00:31,964 --> 00:00:33,933
As always, thank you
very much for coming out

12

00:00:33,966 --> 00:00:35,835
to join us tonight.

13
00:00:35,868 --> 00:00:37,103
The InSight Mission to Mars

14
00:00:37,136 --> 00:00:39,138
scheduled to launch in May 2018

15
00:00:39,171 --> 00:00:40,973
will be the first NASA mission

16
00:00:41,006 --> 00:00:43,643
to observe the deep
interior of Mars

17
00:00:43,676 --> 00:00:44,944
and help us learn
about the history

18
00:00:44,977 --> 00:00:47,013
and evolution of the planet.

19
00:00:47,046 --> 00:00:50,716
The instruments InSight will
bring are conceptually simple,

20
00:00:50,749 --> 00:00:53,820
yet also sensitive,
delicate, and complex.

21
00:00:53,853 --> 00:00:55,988
The spacecraft itself
uses proven hardware

22
00:00:56,021 --> 00:00:57,957
from previous Mars
service missions,

23

00:00:57,990 --> 00:01:00,793
but also features new activities

24
00:01:00,826 --> 00:01:04,730
crucial to the success
of InSight Science.

25
00:01:04,763 --> 00:01:06,732
Our guest this evening
will help us dig deep

26
00:01:06,765 --> 00:01:09,669
into the workings of
the next Mars adventure.

27
00:01:09,702 --> 00:01:12,772
Tonight's guest exults in
a lifelong love of space,

28
00:01:12,805 --> 00:01:14,807
rocks, science, and engineering.

29
00:01:14,840 --> 00:01:17,110
And is found in his role
as a planetary geologist

30
00:01:17,143 --> 00:01:19,846
an instrument engineer at JPL

31
00:01:19,879 --> 00:01:22,115
a perfect marriage
of these interests.

32
00:01:22,148 --> 00:01:24,817
He received a bachelor's
degrees from MIT

33
00:01:24,850 --> 00:01:26,886
in both Materials
Science and Engineering

34
00:01:26,919 --> 00:01:29,956
and Earth Atmospheric
and Planetary Sciences.

35
00:01:29,989 --> 00:01:32,658
He then earned his
doctorates at Caltech's

36
00:01:32,691 --> 00:01:34,861
Geological and Planetary
Sciences Department

37
00:01:34,894 --> 00:01:37,130
where he focused on
investigations of the growth,

38
00:01:37,163 --> 00:01:41,000
evolution, and loss of
subsurface ice on Mars.

39
00:01:41,033 --> 00:01:43,803
He has participated in a
number of field campaigns

40
00:01:43,836 --> 00:01:45,805
to study life in
extreme environments

41
00:01:45,838 --> 00:01:48,007
and to test prototype
Mars instruments

42
00:01:48,040 --> 00:01:50,076
from the ice caps of Greenland

43
00:01:50,109 --> 00:01:52,044
to the heights of
Earth's stratosphere.

44
00:01:52,077 --> 00:01:54,847
Places surprisingly
similar to Mars.

45
00:01:54,880 --> 00:01:56,749
When he came to JPL in 2008,

46
00:01:56,782 --> 00:01:58,985
he served on the instrument
team for the MECA instrument

47
00:01:59,018 --> 00:02:00,820
on the Phoenix Mars lander.

48
00:02:00,853 --> 00:02:03,756
And since 2010, he has been
a part of the science team

49
00:02:03,789 --> 00:02:05,725
for the InSight mission
where he is also

50
00:02:05,758 --> 00:02:07,126
the JPL instrument
systems engineer

51
00:02:07,159 --> 00:02:10,663
for the lander's German
built heat flow instrument.

52
00:02:10,696 --> 00:02:11,964
Ladies and gentlemen,
please help me welcome

53
00:02:11,997 --> 00:02:14,767
tonight's guest,
Dr. Troy Hudson.

54
00:02:14,800 --> 00:02:17,871

[audience applauding]

55
00:02:24,109 --> 00:02:27,680
>> Hello and thank
you for coming with me

56
00:02:27,713 --> 00:02:28,915
on this journey this evening.

57
00:02:30,916 --> 00:02:35,888
Over the past two decades, 11
missions have visited Mars,

58
00:02:35,921 --> 00:02:40,660
but our newest mission InSight
will look at the Red Planet

59
00:02:40,693 --> 00:02:41,961
in a totally new way.

60
00:02:43,862 --> 00:02:48,000
From orbiters to
landers to rovers,

61
00:02:48,033 --> 00:02:52,705
we've explored our neighbor's
atmosphere and surface

62
00:02:52,738 --> 00:02:56,109
with ever-increasing levels
of detail and sophistication.

63
00:02:57,843 --> 00:03:01,047
But, and to be a bit cliche,
these missions have only

64
00:03:01,080 --> 00:03:02,949
just scratched the surface.

65

00:03:04,116 --> 00:03:07,720
There are many deep
questions we have about Mars.

66
00:03:07,753 --> 00:03:10,923
As a planet, how did it form?

67
00:03:10,956 --> 00:03:13,759
How is it changed over time?

68
00:03:13,792 --> 00:03:15,662
And what is it like today?

69
00:03:17,863 --> 00:03:21,000
Mars is one of a
family of planets.

70
00:03:21,033 --> 00:03:23,069
Rocky planets.

71
00:03:23,102 --> 00:03:26,906
They're quite distinct from
a gas giant like Jupiter

72
00:03:28,040 --> 00:03:31,944
and different still from
the trillions of comets

73
00:03:31,977 --> 00:03:34,781
and asteroids that still
inhabit our solar system.

74
00:03:35,981 --> 00:03:39,952
They're a family, but they're
a very diverse family.

75
00:03:39,985 --> 00:03:43,756
And one of the big
questions we have is why?

76
00:03:43,789 --> 00:03:47,660
Did they in fact form
from the same stuff?

77
00:03:47,693 --> 00:03:50,062
And once they formed,
how have they changed?

78
00:03:50,095 --> 00:03:52,031
What brought them
to where they are?

79
00:03:52,064 --> 00:03:57,036
Are there laws that govern the
formation of a rocky planet?

80
00:03:58,704 --> 00:04:00,806
Maybe there are tendencies
that they follow,

81
00:04:00,839 --> 00:04:02,808
but can deviate from.

82
00:04:02,841 --> 00:04:07,680
And maybe coincidence
played a role in giving us

83
00:04:07,713 --> 00:04:10,750
Mercury, Venus, Earth,
Mars, and the moon.

84
00:04:12,885 --> 00:04:16,055
Go back in time four and
a half billion years ago

85
00:04:16,088 --> 00:04:19,726
when the solar system
was forming and
planets were growing.

86
00:04:20,893 --> 00:04:24,664
As gravity brought
together matter into clumps

87
00:04:24,697 --> 00:04:27,700
that grew over time, these
clumps began to heat up.

88
00:04:28,901 --> 00:04:31,871
And when they got hot
enough, they began to melt.

89
00:04:31,904 --> 00:04:34,774
Heavy things like iron
fell to the center,

90
00:04:34,807 --> 00:04:39,779
whereas lighter minerals and
elements rose to the surface.

91
00:04:40,879 --> 00:04:43,816
This process, this
differentiation

92
00:04:43,849 --> 00:04:47,653
is thought to be common
to all such bodies.

93
00:04:47,686 --> 00:04:50,823
A birthright of
terrestrial planets.

94
00:04:51,924 --> 00:04:55,094
And this process gave
rise to familiar layers,

95
00:04:55,127 --> 00:04:58,831
core, mantle, and crust.

96

00:04:58,864 --> 00:05:02,868
And indeed, all of these
objects share these features,

97
00:05:02,901 --> 00:05:04,871
but in very different ways.

98
00:05:05,971 --> 00:05:08,908
So with InSight we
will be going to Mars

99
00:05:08,941 --> 00:05:13,780
to look beneath the surface
and see what it's like inside.

100
00:05:14,913 --> 00:05:17,783
Consider though for
a moment that crust.

101
00:05:17,816 --> 00:05:18,918
The Earth's crust.

102
00:05:20,052 --> 00:05:23,823
Everything you've ever
seen with your own eyes,

103
00:05:23,856 --> 00:05:27,727
every person,
every living thing,

104
00:05:27,760 --> 00:05:30,963
every mountain,
canyon, and ocean

105
00:05:30,996 --> 00:05:35,801
all exist on the crust of the
earth, and that layer is thin.

106
00:05:36,969 --> 00:05:39,105
SEIS for size Earth's

crust is thinner

107
00:05:39,138 --> 00:05:40,873
than the skin of an apple.

108
00:05:42,040 --> 00:05:46,812
So much of a planet is unseen.

109
00:05:46,845 --> 00:05:49,782
And so with InSight,
we will look with tools

110
00:05:49,815 --> 00:05:51,784
other than our eyes

111
00:05:51,817 --> 00:05:55,922
to find out what is
Mars like as a planet.

112
00:05:57,823 --> 00:06:01,093
We know the Earth and
the moon pretty well.

113
00:06:01,126 --> 00:06:06,098
100 years of seismology and
geology have taught us a lot

114
00:06:06,131 --> 00:06:08,801
about what Earth
looks like inside.

115
00:06:08,834 --> 00:06:10,903
We know it's a very warm place.

116
00:06:10,936 --> 00:06:14,874
There is a liquid outer
core churning and moving,

117
00:06:14,907 --> 00:06:18,711

and this moving magnetic
fluid, iron fluid

118
00:06:18,744 --> 00:06:20,680
creates Earth's magnetic field.

119
00:06:21,814 --> 00:06:22,948
Earth is a very active place.

120
00:06:22,981 --> 00:06:24,717
We have volcanoes.

121
00:06:24,750 --> 00:06:28,788
We have the bane of Southern
California of earthquakes.

122
00:06:28,821 --> 00:06:30,756
We have plate tectonics.

123
00:06:30,789 --> 00:06:34,059
A process which has
recycled and evolved

124
00:06:34,092 --> 00:06:36,996
Earth's mantle and crust
since it was formed.

125
00:06:38,797 --> 00:06:41,667
The moon we know about
because of Apollo.

126
00:06:41,700 --> 00:06:44,937
The Apollo astronauts went
there, brought back rocks,

127
00:06:44,970 --> 00:06:47,706
and they left
seismometers on the moon.

128

00:06:47,739 --> 00:06:50,643
These tools continued to operate

129
00:06:50,676 --> 00:06:51,944
long after the
astronauts had gone

130
00:06:51,977 --> 00:06:56,082
bringing back over a decade
worth of data of moonquakes.

131
00:06:57,149 --> 00:06:58,784
We've learned that the moon,

132
00:06:58,817 --> 00:07:02,688
despite its early violent
and active history,

133
00:07:02,721 --> 00:07:05,858
origins is now rather cold.

134
00:07:05,891 --> 00:07:09,094
Solid throughout, there is
no intrinsic magnetic field,

135
00:07:09,127 --> 00:07:11,697
most of its activity
was in the past.

136
00:07:12,965 --> 00:07:17,002
Because of its size,
it didn't experience

137
00:07:17,035 --> 00:07:19,038
all of the processes
that Earth did.

138
00:07:19,071 --> 00:07:20,739
It didn't get as hot.

139
00:07:20,772 --> 00:07:22,141
There weren't as high pressures.

140
00:07:22,174 --> 00:07:24,877
And so a lot of the
early formation processes

141
00:07:24,910 --> 00:07:27,914
that happened on earth
didn't happen for the moon.

142
00:07:29,882 --> 00:07:34,019
Mars, scientifically,
is an ideal in-between.

143
00:07:34,052 --> 00:07:38,657
A Goldilocks planet
because it's big enough

144
00:07:38,690 --> 00:07:42,995
to have experienced those
pressures and temperatures

145
00:07:43,028 --> 00:07:45,731
in a very active history
similar to Earth's.

146
00:07:46,698 --> 00:07:47,933
But it's small.

147
00:07:47,966 --> 00:07:51,871
Small enough that it lost
a lot of that early heat.

148
00:07:51,904 --> 00:07:54,940
Whatever dynamo it had to
create a magnetic field

149
00:07:54,973 --> 00:07:57,109

early in its life is now gone.

150
00:07:57,142 --> 00:07:58,711
It's stopped.

151
00:07:58,744 --> 00:08:02,648
Mars has frozen
into an early state.

152
00:08:02,681 --> 00:08:05,718
Possibly a state like
Earth when it was young

153
00:08:05,751 --> 00:08:08,153
before Earth erased
that evidence

154
00:08:08,186 --> 00:08:11,123
with tectonics and convection.

155
00:08:11,156 --> 00:08:14,727
So by studying Mars,
we get a glimpse

156
00:08:14,760 --> 00:08:16,829
into what Earth may
have once been like.

157
00:08:18,797 --> 00:08:22,067
This chart shows you our
current state of knowledge

158
00:08:22,100 --> 00:08:25,938
for major layers of the
earth, and the moon, and Mars.

159
00:08:25,971 --> 00:08:28,908
But the key point here is
to look at the numbers.

160
00:08:28,941 --> 00:08:31,911
The numbers for Earth and
the moon are just numbers.

161
00:08:31,944 --> 00:08:34,113
The ones from Mars
have question marks.

162
00:08:34,146 --> 00:08:38,117
Our state of knowledge
of Mars is informed by

163
00:08:38,150 --> 00:08:40,786
some information
from satellites,

164
00:08:40,819 --> 00:08:45,057
some application of
physics and geology

165
00:08:45,090 --> 00:08:47,693
and our understanding of
how those play together,

166
00:08:47,726 --> 00:08:50,763
but there are still
big uncertainties.

167
00:08:50,796 --> 00:08:53,666
So we wanna look into Mars.

168
00:08:53,699 --> 00:08:55,968
In the language of
the InSight Mission,

169
00:08:56,001 --> 00:08:57,970
we call these vital signs.

170
00:08:58,003 --> 00:08:59,638

We want to look
at Mars' structure

171
00:08:59,671 --> 00:09:02,074
and we will do that
with Marsquakes.

172
00:09:02,107 --> 00:09:04,009
Much like a doctor
can use ultrasound

173
00:09:04,042 --> 00:09:07,012
to look inside your body,
we will look inside Mars

174
00:09:07,045 --> 00:09:09,916
with these planetary-scale
vibrations.

175
00:09:11,683 --> 00:09:13,652
We also want to take
Mars' temperature.

176
00:09:13,685 --> 00:09:17,656
Find out what is still
in the planet that churns

177
00:09:17,689 --> 00:09:19,959
and creates geologic activity,

178
00:09:19,992 --> 00:09:21,827
and what was it
like in the past?

179
00:09:22,828 --> 00:09:23,996
And Mars has reflexes.

180
00:09:24,029 --> 00:09:27,666
It spins in space, but
it wobbles as it does so

181
00:09:27,699 --> 00:09:31,003
and this wobble can tell
us about the interior.

182
00:09:33,939 --> 00:09:37,710
I've hinted at the goals
of this InSight Mission,

183
00:09:37,743 --> 00:09:38,844
but here they are in concrete.

184
00:09:38,877 --> 00:09:39,845
Some of the things
we want to know.

185
00:09:39,878 --> 00:09:41,113
We want to know the core.

186
00:09:41,146 --> 00:09:42,915
How big is it?

187
00:09:42,948 --> 00:09:45,117
What is it made of and
what state is it in?

188
00:09:45,150 --> 00:09:49,121
Is it solid, liquid, or
somewhere in between?

189
00:09:50,889 --> 00:09:54,961
What is the structure of
the crust and the mantle?

190
00:09:55,894 --> 00:09:57,129
And how warm is the interior?

191
00:09:57,162 --> 00:10:01,934
How much energy is there in

that planetary heat engine

192
00:10:01,967 --> 00:10:03,069
that drives geology?

193
00:10:04,736 --> 00:10:05,971
These are great questions,

194
00:10:06,004 --> 00:10:08,874
but they're not easy
questions to answer.

195
00:10:08,907 --> 00:10:11,710
Even if you had a ruler long
enough and you were on Mars,

196
00:10:11,743 --> 00:10:13,112
you couldn't measure the
thickness of the mantle.

197
00:10:13,145 --> 00:10:15,648
It's not accessible.

198
00:10:15,681 --> 00:10:18,083
And so we have to look
to answer these questions

199
00:10:18,116 --> 00:10:19,852
in indirect ways.

200
00:10:21,753 --> 00:10:23,889
We do this with seismology.

201
00:10:23,922 --> 00:10:27,993
How powerful are seismic
events on the planet?

202
00:10:28,026 --> 00:10:29,762
How often do they happen

203
00:10:29,795 --> 00:10:31,764
and where on the
planet do they happen?

204
00:10:32,864 --> 00:10:35,801
And how does Mars'
surface and body react

205
00:10:35,834 --> 00:10:39,071
to external influences,
like a meteorite impact

206
00:10:39,104 --> 00:10:41,140
or the movement of
its moon, Phobos?

207
00:10:42,741 --> 00:10:45,878
Again, how does it spin
and wobble in space?

208
00:10:45,911 --> 00:10:48,113
And how does its
temperature in the ground

209
00:10:48,146 --> 00:10:50,016
change with depth?

210
00:10:51,783 --> 00:10:54,920
These are our measurements
to help us answer our goals.

211
00:10:56,154 --> 00:10:57,890
And there's not a
one-to-one correspondence.

212
00:10:57,923 --> 00:11:01,660
Some of the questions and some
of the goals work together.

213
00:11:01,693 --> 00:11:04,063
We can take multiple
types of measurements

214
00:11:04,096 --> 00:11:06,065
to answer a single question

215
00:11:06,098 --> 00:11:09,835
giving more robustness
to that investigation

216
00:11:09,868 --> 00:11:11,971
and deepening our understanding.

217
00:11:13,872 --> 00:11:15,808
So to make these measurements,

218
00:11:15,841 --> 00:11:19,144
InSight has three
primary instruments

219
00:11:19,177 --> 00:11:22,815
and I'll be talking in
particular about those.

220
00:11:24,116 --> 00:11:28,087
SEIS, RISE, and HP3.

221
00:11:28,120 --> 00:11:30,055
But before I get into them,

222
00:11:30,088 --> 00:11:32,691
I want you to have
a look at the lander

223
00:11:32,724 --> 00:11:34,760
as it will look when
it's on the surface

224
00:11:35,994 --> 00:11:37,830
and see that it's not just
these three instruments.

225
00:11:37,863 --> 00:11:40,099
There's a whole
lot of other things

226
00:11:40,132 --> 00:11:42,768
that make up InSight's payload.

227
00:11:42,801 --> 00:11:46,105
We have a robotic arm,
we have two cameras

228
00:11:46,138 --> 00:11:49,008
and we have a suite of
environmental sensors.

229
00:11:50,709 --> 00:11:54,046
These devices help the primary
instruments do their job

230
00:11:54,079 --> 00:11:57,750
and provide context
for the data they take.

231
00:12:02,154 --> 00:12:05,691
First, we're gonna look
a little bit at SEIS

232
00:12:05,724 --> 00:12:07,860
And SEIS is an
instrument that anyone

233
00:12:07,893 --> 00:12:11,096
who lives with earthquakes
knows about, it's a seismometer.

234

00:12:11,129 --> 00:12:14,833
There you see it deployed
from the surface of the lander

235
00:12:14,866 --> 00:12:16,035
to the surface of Mars.

236
00:12:17,135 --> 00:12:19,905
And SEIS is not just
one seismometer.

237
00:12:19,938 --> 00:12:21,840
It's actually six.

238
00:12:21,873 --> 00:12:23,776
There's three of a type called

239
00:12:23,809 --> 00:12:26,979
very broad baseline
seismometers or VBBs,

240
00:12:28,079 --> 00:12:31,817
there's the short-period
seismometers or SP.

241
00:12:31,850 --> 00:12:36,688
And these are all packaged
together into a dense sphere

242
00:12:36,721 --> 00:12:38,891
about the size of a volleyball.

243
00:12:38,924 --> 00:12:40,959
You can see there on the
left some of the engineers

244
00:12:40,992 --> 00:12:43,695
at CNES, the French Space Agency

245

00:12:43,728 --> 00:12:46,031
which is an international
partner with InSight

246
00:12:46,064 --> 00:12:48,967
who led a consortium of
international partners

247
00:12:49,000 --> 00:12:50,869
to produce this instrument.

248
00:12:50,902 --> 00:12:53,739
This incredibly
sensitive instrument.

249
00:12:55,006 --> 00:12:58,844
SEIS is as sensitive as the
best seismometers on earth.

250
00:12:58,877 --> 00:13:02,881
So sensitive that it can measure
displacements in the ground

251
00:13:02,914 --> 00:13:04,784
smaller than a hydrogen atom.

252
00:13:06,918 --> 00:13:10,756
It's also robust it can
survive the rigors of launch,

253
00:13:10,789 --> 00:13:12,858
interplanetary space flight,

254
00:13:12,891 --> 00:13:15,861
and the temperature fluctuations
on the surface of Mars.

255
00:13:17,062 --> 00:13:19,665
It can survive these things,
but it's so sensitive

256
00:13:19,698 --> 00:13:22,768
that we still have to
protect it from noise,

257
00:13:22,801 --> 00:13:27,005
from signals that would
swamp out the weaker quakes,

258
00:13:27,038 --> 00:13:29,975
and shakes, and motions
of Mars' surface.

259
00:13:32,077 --> 00:13:34,813
Some other components of
SEIS like the electronics box

260
00:13:34,846 --> 00:13:36,682
and the tether
help it do its job

261
00:13:36,715 --> 00:13:38,884
connect that seismometer
back to the lander.

262
00:13:38,917 --> 00:13:40,953
But I really want you
to draw your attention

263
00:13:40,986 --> 00:13:43,121
to that figure at the top
where the seismometer,

264
00:13:43,154 --> 00:13:46,758
that golden volleyball
is inside this

265
00:13:46,791 --> 00:13:49,027
copper hexagon of insulation.

266
00:13:49,060 --> 00:13:51,797
That protects the
seismometer from some of the

267
00:13:51,830 --> 00:13:54,033
thermal changes it
would see on Mars.

268
00:13:55,700 --> 00:13:57,703
That's what you'll see
picked up off the lander

269
00:13:57,736 --> 00:14:00,973
and placed on the ground
first after we arrive.

270
00:14:01,006 --> 00:14:02,908
But it's not enough.

271
00:14:02,941 --> 00:14:05,911
We need more protection
both from the sun

272
00:14:05,944 --> 00:14:07,112
and also from wind.

273
00:14:08,847 --> 00:14:11,016
Mars' atmosphere is quite
thin, but it's still enough

274
00:14:11,049 --> 00:14:13,085
to shake and jitter
that seismometer

275
00:14:13,118 --> 00:14:15,921
to a point where we
couldn't get good data.

276
00:14:15,954 --> 00:14:18,724

So we have something called
the wind in thermal shield.

277
00:14:18,757 --> 00:14:21,093
That white dome on
the upper right.

278
00:14:21,126 --> 00:14:24,796
This is picked up by the
arm and placed on top

279
00:14:24,829 --> 00:14:26,031
of the seismometer.

280
00:14:26,064 --> 00:14:30,102
And that golden skirt you
see around the bottom,

281
00:14:30,135 --> 00:14:32,137
that's actually chainmail

282
00:14:32,170 --> 00:14:35,674
just like you would find on
the medieval suit of armor.

283
00:14:35,707 --> 00:14:37,643
We have that so
that it can conform

284
00:14:37,676 --> 00:14:39,111
to the irregular
ground surface of Mars

285
00:14:39,144 --> 00:14:41,980
and essentially
prevent drafts from

286
00:14:42,013 --> 00:14:44,016
getting underneath
and disturbing SEIS.

287
00:14:47,085 --> 00:14:48,720
Once we've got rid
of all those noise,

288
00:14:48,753 --> 00:14:49,721
what are we looking for?

289
00:14:49,754 --> 00:14:52,024
We're looking for Marsquakes.

290
00:14:52,057 --> 00:14:54,760
How do we know there
are Marsquakes?

291
00:14:54,793 --> 00:14:55,994
We've seen faults.

292
00:14:56,027 --> 00:14:58,931
Just like the San Andreas,
we see places on Mars

293
00:14:58,964 --> 00:15:01,834
where the ground has
moved relative to itself.

294
00:15:03,068 --> 00:15:05,771
We've mapped these that the
figure on the lower left

295
00:15:05,804 --> 00:15:06,972
has some red and green lines

296
00:15:07,005 --> 00:15:10,676
showing where there
are faults on Mars.

297
00:15:10,709 --> 00:15:14,746
And by combining

these observations
with our knowledge of

298
00:15:14,779 --> 00:15:16,982
geophysics and how
it operates on earth,

299
00:15:17,015 --> 00:15:21,119
we predict what
kind of seismicity.

300
00:15:21,152 --> 00:15:24,723
What frequency of event
we might see on Mars.

301
00:15:25,790 --> 00:15:27,125
In that chart,
there's a red line.

302
00:15:27,158 --> 00:15:29,661
That's quiet places on Earth.

303
00:15:29,694 --> 00:15:31,897
Not Ring of Fire like we have
here in Southern California,

304
00:15:31,930 --> 00:15:32,965
but quiet places.

305
00:15:34,733 --> 00:15:38,103
The magenta line, the pink
line there, that's the moon.

306
00:15:38,136 --> 00:15:41,840
Mars, Goldilocks again,
is somewhere in between.

307
00:15:42,974 --> 00:15:44,876
At the top, you
see some numbers,

308
00:15:44,909 --> 00:15:47,713
the familiar Richter
magnitude scale

309
00:15:47,746 --> 00:15:50,749
and what this plot
says is we predict

310
00:15:50,782 --> 00:15:54,753
somewhere between 10 and
100 Richter five earthquake,

311
00:15:54,786 --> 00:15:57,690
Marsquakes, excuse
me, every year.

312
00:15:58,891 --> 00:16:02,728
For a magnitude six, it would
be somewhere like one to 10.

313
00:16:03,728 --> 00:16:05,697
That's this prediction.

314
00:16:05,730 --> 00:16:07,799
Mars could surprise us.

315
00:16:07,832 --> 00:16:09,868
It could be much more active,

316
00:16:09,901 --> 00:16:11,903
or it could be much less active.

317
00:16:11,936 --> 00:16:15,107
Either way, it's an
interesting scientific result.

318
00:16:15,140 --> 00:16:17,843
But we have other things

that we will be looking at

319
00:16:17,876 --> 00:16:20,012
with SEIS which
are more definite

320
00:16:20,045 --> 00:16:21,914
and still tell us
about the planet.

321
00:16:24,049 --> 00:16:26,818
One of these is
the tide of Phobos.

322
00:16:26,851 --> 00:16:30,989
Phobos is the larger of Mars'
two moons, but it's small.

323
00:16:31,022 --> 00:16:34,993
It's a lumpy potato,
27 kilometers in its
biggest dimension.

324
00:16:35,026 --> 00:16:37,996
That's the distance from
Pasadena to Santa Monica.

325
00:16:38,029 --> 00:16:42,067
It's tiny, but it's
so much closer to Mars

326
00:16:42,100 --> 00:16:46,038
than the moon is to Earth,
that as it passes overhead,

327
00:16:46,071 --> 00:16:51,010
its gravity causes the ground
on Mars to RISE and fall.

328
00:16:52,077 --> 00:16:53,812

This is not something
you'd ever feel,

329
00:16:53,845 --> 00:16:57,115
not something you'd
ever see, but SEIS can.

330
00:16:57,148 --> 00:17:00,652
And by looking at this
regular motion of the ground

331
00:17:00,685 --> 00:17:02,054
as Phobos passes overhead

332
00:17:02,087 --> 00:17:03,922
and we do happen to
land on the equator,

333
00:17:03,955 --> 00:17:08,927
so it passes right overhead,
we learn about Mars' interior.

334
00:17:10,929 --> 00:17:12,964
There's another
source of excitation

335
00:17:12,997 --> 00:17:15,133
which again is Mars' atmosphere.

336
00:17:15,166 --> 00:17:17,936
It's thin, but it has regions
of high and low pressure.

337
00:17:17,969 --> 00:17:19,671
And as these pass
over the surface,

338
00:17:19,704 --> 00:17:22,141
they also cause it
to flex up and down.

339
00:17:24,142 --> 00:17:29,114
This excites modes like a
ringing bell and makes Mars hum,

340
00:17:30,782 --> 00:17:34,820
a seismic hum which
Earth also experiences.

341
00:17:36,020 --> 00:17:39,691
But here is an instance
where studying another planet

342
00:17:39,724 --> 00:17:41,860
teaches us about Earth.

343
00:17:41,893 --> 00:17:44,863
Mars has a seismic hum
because of its atmosphere,

344
00:17:44,896 --> 00:17:46,031
so does Earth.

345
00:17:46,064 --> 00:17:48,767
But Earth also has oceans.

346
00:17:48,800 --> 00:17:50,735
And the waves crashing
into the shores,

347
00:17:50,768 --> 00:17:54,706
and the swells from sea
storms, and the tides,

348
00:17:54,739 --> 00:17:57,008
these create an oceanic hum.

349
00:17:57,041 --> 00:17:58,910
But on Earth, they

are mixed up together.

350
00:17:58,943 --> 00:18:01,947
It's hard to separate
the two effects.

351
00:18:01,980 --> 00:18:04,116
So by studying Mars, we
can see what's the effect

352
00:18:04,149 --> 00:18:06,918
of an oceanless planet.

353
00:18:06,951 --> 00:18:10,889
And then we can learn more
about how Earth's hum works.

354
00:18:14,159 --> 00:18:15,894
Another source, the last source

355
00:18:15,927 --> 00:18:19,731
and probably the most dramatic
is the impact of meteorites.

356
00:18:22,000 --> 00:18:24,669
We have orbiting
spacecraft at Mars

357
00:18:24,702 --> 00:18:25,937
that are taking
pictures of the surface.

358
00:18:25,970 --> 00:18:30,075
And every now and then we'll
see, oh, look, a new dark spot.

359
00:18:30,108 --> 00:18:31,877
That wasn't there in
the previous images.

360
00:18:31,910 --> 00:18:32,811
It's new.

361
00:18:34,078 --> 00:18:38,850
And the impact of meteorites
on Mars is happening today.

362
00:18:38,883 --> 00:18:41,019
Actually, somewhat more
frequently than on Earth.

363
00:18:41,052 --> 00:18:43,722
The thinner atmosphere
lets a lot of those come in

364
00:18:43,755 --> 00:18:45,691
and make it all the
way to the surface.

365
00:18:47,025 --> 00:18:49,661
A meteorite impact has
a particular character.

366
00:18:49,694 --> 00:18:53,832
It's a bit different from
intrinsic internal Marsquake.

367
00:18:56,901 --> 00:19:01,806
SEIS has those six
seismometers that can detect

368
00:19:01,839 --> 00:19:04,910
not only the direction
from which a seismic signal

369
00:19:04,943 --> 00:19:08,146
is coming, but the
approximate distance.

370

00:19:08,179 --> 00:19:10,882
With that information, we can
send the orbiting spacecraft

371
00:19:10,915 --> 00:19:12,150
to go look in that area.

372
00:19:12,183 --> 00:19:14,719
Look for the new dark spot.

373
00:19:14,752 --> 00:19:19,724
Once we find that, we have
a location and exact time.

374
00:19:19,757 --> 00:19:21,893
From the SEIS of the
crater, we know the energy

375
00:19:21,926 --> 00:19:25,697
and a perfect correspondence
between observation

376
00:19:25,730 --> 00:19:28,133
and our ground truth
from the seismometer.

377
00:19:29,901 --> 00:19:32,971
This is exactly the sort of
information that we would use

378
00:19:33,004 --> 00:19:37,976
to make and change our models
of what Mars is like inside.

379
00:19:39,978 --> 00:19:42,647
Here's an animation
looking inside Mars

380
00:19:42,680 --> 00:19:44,649
for a meteorite impact,

381
00:19:44,682 --> 00:19:47,018
but it could be for
any seismic source.

382
00:19:47,051 --> 00:19:51,122
The event happens and waves
spread out through the planet.

383
00:19:51,155 --> 00:19:55,961
Pressure waves, compression,
shear waves, shearing.

384
00:19:55,994 --> 00:19:58,663
They interact with the surface,

385
00:19:58,696 --> 00:20:00,098
they reflect across boundaries

386
00:20:00,131 --> 00:20:03,068
like ripples in a pond
or light in a prism.

387
00:20:04,702 --> 00:20:06,838
And we can study the
character of these waves

388
00:20:06,871 --> 00:20:11,676
where they arrive at
the seismometer and
change our models.

389
00:20:11,709 --> 00:20:16,682
That's the goal here is to
use physics, use geology,

390
00:20:17,949 --> 00:20:22,053
and make our model of Mars
exactly match our data.

391
00:20:22,086 --> 00:20:25,657
That's the real goal because
the models can change.

392
00:20:25,690 --> 00:20:27,092
The data, that's real.

393
00:20:27,125 --> 00:20:27,993
That's physical.

394
00:20:28,026 --> 00:20:29,761
That is the world.

395
00:20:33,031 --> 00:20:34,866
So that's our seismometer.

396
00:20:36,000 --> 00:20:37,969
The next instrument that
was mentioned is RISE.

397
00:20:38,002 --> 00:20:39,904
And RISE is the thing that
will be looking at Mars

398
00:20:39,937 --> 00:20:41,139
as wobble.

399
00:20:41,172 --> 00:20:44,709
As it spins in space, it
doesn't spin perfectly evenly.

400
00:20:44,742 --> 00:20:47,012
It does wiggle
and wobble around.

401
00:20:47,045 --> 00:20:50,115
And it turns out this
wobble carries information

402
00:20:50,148 --> 00:20:52,751
about the interior of Mars.

403
00:20:52,784 --> 00:20:54,052
Its core in particular.

404
00:20:55,920 --> 00:20:59,691
RISE is part of InSight's
telecommunications system.

405
00:20:59,724 --> 00:21:02,694
It has two antennas
that send a tone.

406
00:21:02,727 --> 00:21:04,896
A single frequency
back to Earth.

407
00:21:04,929 --> 00:21:06,097
And by listening to this tone

408
00:21:06,130 --> 00:21:08,099
in the small changes that happen

409
00:21:08,132 --> 00:21:12,971
as Mars rotates, we can very
precisely measure the distance

410
00:21:13,004 --> 00:21:16,141
between the receiving
station on Earth

411
00:21:16,174 --> 00:21:18,643
and the InSight transmitter.

412
00:21:18,676 --> 00:21:21,746
Not just they're
extremely precisely

413
00:21:21,779 --> 00:21:23,715
within 10 centimeters

414
00:21:23,748 --> 00:21:25,917
for something that's
millions of kilometers away,

415
00:21:25,950 --> 00:21:28,753
that's incredible accuracy.

416
00:21:28,786 --> 00:21:31,956
Not only will RISE allow us
to make this movement once,

417
00:21:31,989 --> 00:21:33,158
we will make it continuously.

418
00:21:33,191 --> 00:21:35,727
For the entire
time we're on Mars,

419
00:21:35,760 --> 00:21:37,095
we'll be making
RISE measurements

420
00:21:37,128 --> 00:21:39,798
and extending that baseline.

421
00:21:39,831 --> 00:21:43,669
Improving our knowledge
of Mars' deep structure.

422
00:21:47,038 --> 00:21:51,777
The last instrument
I'll speak of is HP3.

423
00:21:52,977 --> 00:21:54,913
The heat flow and physical
properties package

424
00:21:54,946 --> 00:21:57,849
is the instrument I
spent most of my time

425
00:21:57,882 --> 00:21:59,584
working on with InSight.

426
00:21:59,617 --> 00:22:01,953
And so I'll delve a
little bit more deeply

427
00:22:01,986 --> 00:22:04,789
into the science and
technical aspects

428
00:22:04,822 --> 00:22:08,760
of this literally
groundbreaking instrument.

429
00:22:09,861 --> 00:22:11,796
You see the support
structure of HP3

430
00:22:11,829 --> 00:22:13,064
deployed on the surface,

431
00:22:13,097 --> 00:22:15,767
and what you see there is
the heat flow probe of HP3

432
00:22:15,800 --> 00:22:19,705
has already started its journey
penetrating into the ground.

433
00:22:21,005 --> 00:22:23,908
Looking a bit closer
at that structure,

434

00:22:23,941 --> 00:22:25,110
there's a grapple
hook at the top

435
00:22:25,143 --> 00:22:27,679
which we'll use
for the deployment,

436
00:22:27,712 --> 00:22:29,013
and the engineering
tether at left

437
00:22:29,046 --> 00:22:32,084
which connects it
back to the lander.

438
00:22:33,718 --> 00:22:36,054
Within that structure,
we have a few sensors,

439
00:22:36,087 --> 00:22:39,958
and then there's a tether
which connects to the mole

440
00:22:39,991 --> 00:22:43,862
That mole has a
mechanism for hammering.

441
00:22:43,895 --> 00:22:45,697
It has tilt sensors.

442
00:22:45,730 --> 00:22:47,098
And it has some
instruments for measuring

443
00:22:47,131 --> 00:22:48,700
thermal conductivity.

444
00:22:50,001 --> 00:22:51,669
But why?

445
00:22:51,702 --> 00:22:52,103
Why dig?

446
00:22:52,136 --> 00:22:53,872
Why a more?

447
00:22:53,905 --> 00:22:57,842
Why did we need something that
goes even deeper into Mars

448
00:22:57,875 --> 00:22:59,778
than we have with the
other instruments?

449
00:23:01,813 --> 00:23:04,949
The purpose of HP3 is
to measure heat flow,

450
00:23:04,982 --> 00:23:07,986
and heat flow tells us
about both the thermal

451
00:23:08,019 --> 00:23:10,822
and chemical history
of the planet.

452
00:23:12,089 --> 00:23:13,992
Remember when the planet formed,

453
00:23:14,025 --> 00:23:15,960
it brought in matter
under gravity.

454
00:23:15,993 --> 00:23:18,797
And that matter included
radioactive elements.

455
00:23:20,064 --> 00:23:23,768

These unstable atoms as
they decay release energy

456
00:23:23,801 --> 00:23:27,005
and this energy becomes
trapped in the planet.

457
00:23:27,038 --> 00:23:30,742
It's one of the major sources
of the primordial heat.

458
00:23:32,777 --> 00:23:35,079
We understand the physics
of radioactivity quite well,

459
00:23:35,112 --> 00:23:38,049
and so we can look
at how Mars is today

460
00:23:38,082 --> 00:23:41,052
and figure out the inventory

461
00:23:41,085 --> 00:23:43,721
of radioactive
elements in the past.

462
00:23:43,754 --> 00:23:45,790
Are they what we expect
for where Mars formed

463
00:23:45,823 --> 00:23:47,759
relative to the
earth and the sun,

464
00:23:47,792 --> 00:23:48,893
or is there something different?

465
00:23:48,926 --> 00:23:51,897
Some reason why we need
to refine those models.

466
00:23:53,898 --> 00:23:56,701
We want to understand
the thermal history

467
00:23:56,734 --> 00:23:58,837
and how those radioactive
elements have changed

468
00:23:58,870 --> 00:24:02,774
Mars' heat engine, and
what's it like right now.

469
00:24:02,807 --> 00:24:05,076
How much energy
is there to drive

470
00:24:05,109 --> 00:24:07,112
present day geologic activity.

471
00:24:09,714 --> 00:24:11,883
To measure this heat
flow, we need two numbers.

472
00:24:11,916 --> 00:24:13,985
We need thermal conductivity

473
00:24:14,018 --> 00:24:16,120
which is a property
of the ground

474
00:24:16,153 --> 00:24:18,122
and we need to measure
the thermal gradient.

475
00:24:18,155 --> 00:24:21,126
That's how the temperature
changes as you go deeper.

476

00:24:22,793 --> 00:24:23,995
This is why we need the mole.

477
00:24:24,028 --> 00:24:26,898
We need to get down into
the ground to avoid things

478
00:24:26,931 --> 00:24:28,833
like surface disturbances.

479
00:24:28,866 --> 00:24:32,003
Just like SEIS, we
don't want to see

480
00:24:32,036 --> 00:24:33,838
the temperature
differences at the surface.

481
00:24:33,871 --> 00:24:35,674
We need to get below that.

482
00:24:36,941 --> 00:24:40,144
And so the mole will take us
deeper than we've ever gone

483
00:24:40,177 --> 00:24:43,715
human or robotic
on any other body.

484
00:24:43,748 --> 00:24:45,717
The Apollo astronauts
in their space suits

485
00:24:45,750 --> 00:24:47,685
with big hand tools got down

486
00:24:47,718 --> 00:24:50,688
to a little less than
two and a half meters.

487
00:24:50,721 --> 00:24:52,690
We're targeting five.

488
00:24:52,723 --> 00:24:53,791
That's 16 feet.

489
00:24:53,824 --> 00:24:55,126
That's taller than
this building.

490
00:24:56,694 --> 00:24:58,129
And once we're there,
we want to measure

491
00:24:58,162 --> 00:25:00,899
those temperature differences
for that thermal gradient

492
00:25:00,932 --> 00:25:03,801
to within 100th of a degree.

493
00:25:03,834 --> 00:25:06,905
So there are some really
key engineering challenges

494
00:25:06,938 --> 00:25:08,073
that we needed to solve,

495
00:25:09,774 --> 00:25:14,012
and the star of HP3's
engineering feat is the mole.

496
00:25:16,781 --> 00:25:18,049
The mole, it's a small device.

497
00:25:18,082 --> 00:25:20,084
It's about the
diameter of a quarter.

498
00:25:20,117 --> 00:25:22,720
It's about as long
as my forearm.

499
00:25:22,753 --> 00:25:23,955
And it doesn't weigh that much.

500
00:25:23,988 --> 00:25:25,957
Maybe about a
kilogram and a half.

501
00:25:27,158 --> 00:25:30,695
Main components are a
hammer and some springs,

502
00:25:30,728 --> 00:25:34,832
a motor that winds up that
hammer against the springs.

503
00:25:34,865 --> 00:25:37,035
And then what you see in
this movie at the left

504
00:25:37,068 --> 00:25:39,804
is that instant
of hammer release.

505
00:25:39,837 --> 00:25:43,808
When the cam is wound
up, the hammer strikes

506
00:25:43,841 --> 00:25:45,877
and drives them all
into the ground.

507
00:25:45,910 --> 00:25:49,047
There's a few secondary
strikes and settling,

508

00:25:49,080 --> 00:25:51,950
but this instant of hammering

509
00:25:51,983 --> 00:25:53,851
is what makes the
mole move forward.

510
00:25:53,884 --> 00:25:55,019
This is slowed down.

511
00:25:55,052 --> 00:25:57,722
It takes about a
10th of a second.

512
00:25:57,755 --> 00:26:00,825
And each hammer stroke
as that cam goes around

513
00:26:00,858 --> 00:26:04,696
is about every three
to four seconds.

514
00:26:04,729 --> 00:26:06,031
So imagine you're on Mars.

515
00:26:12,803 --> 00:26:15,073
It's a very stately pace,

516
00:26:15,106 --> 00:26:20,044
but millimeter by millimeter,
we penetrate Mars' surface

517
00:26:20,077 --> 00:26:21,680
to do our science.

518
00:26:23,714 --> 00:26:26,951
Some statistics and other
information about the mole,

519

00:26:26,984 --> 00:26:28,987
we've got are three
seconds per hammer stroke,

520
00:26:29,020 --> 00:26:31,823
and then we don't
penetrate all at once.

521
00:26:31,856 --> 00:26:35,059
We have cycles where we
penetrate and then we pause.

522
00:26:35,092 --> 00:26:37,662
The penetration process
creates a lot of heat

523
00:26:37,695 --> 00:26:39,731
and we let that heat dissipate.

524
00:26:39,764 --> 00:26:42,033
And then we heat
the mole itself.

525
00:26:42,066 --> 00:26:45,136
Built into the structure
of the mole are heaters.

526
00:26:45,169 --> 00:26:46,904
And by heating the mole up

527
00:26:46,937 --> 00:26:50,842
and letting that heat
diffuse away into the ground,

528
00:26:50,875 --> 00:26:53,077
we learn the thermal
conductivity.

529
00:26:53,110 --> 00:26:55,913
We determine the thermal

property of the soil

530
00:26:55,946 --> 00:26:57,983
which is key to that
heat flow measurement.

531
00:26:59,884 --> 00:27:03,688
It takes about 24 hours to
make that thermal measurement

532
00:27:03,721 --> 00:27:05,690
and then we hammer again.

533
00:27:05,723 --> 00:27:07,025
10 times we hope to do this.

534
00:27:07,058 --> 00:27:11,763
Stairstepping our way down
to five meters on Mars.

535
00:27:15,900 --> 00:27:16,768
The mole

536
00:27:19,737 --> 00:27:21,773
might encounter a rock.

537
00:27:21,806 --> 00:27:22,974
We are going to a place on Mars

538
00:27:23,007 --> 00:27:27,078
which is relatively rock-free,
but it's still possible.

539
00:27:27,111 --> 00:27:30,782
We've seen in some laboratory
experiments that the mole

540
00:27:30,815 --> 00:27:33,918
can push small rocks out

of its way underground.

541
00:27:33,951 --> 00:27:36,688
Larger rocks, the mole
gets deflected a little bit

542
00:27:36,721 --> 00:27:38,656
and the rock gets
deflected a little bit.

543
00:27:38,689 --> 00:27:41,693
Still larger rocks, the
mole itself can deflect.

544
00:27:42,793 --> 00:27:45,763
We use the tilt sensor
in the back of the mole

545
00:27:45,796 --> 00:27:48,066
combined with a
measurement of the tether

546
00:27:48,099 --> 00:27:51,903
that gets pulled out
to reconstruct its
path in the ground.

547
00:27:53,037 --> 00:27:55,139
We do this because we
need to precisely know

548
00:27:55,172 --> 00:27:58,042
where those conductivity
measurements are made

549
00:27:58,075 --> 00:28:00,611
and where the
temperature sensors

550
00:28:00,644 --> 00:28:02,981

that the mole pulls
behind it end up.

551
00:28:06,751 --> 00:28:07,885
This is a timelapse video.

552
00:28:07,918 --> 00:28:09,087
And in the very quick moment,

553
00:28:09,120 --> 00:28:10,822
you'll see them
all at the bottom,

554
00:28:10,855 --> 00:28:13,124
it's at the top of a slow
column and it's gonna disappear.

555
00:28:13,157 --> 00:28:14,025
There it is.

556
00:28:15,025 --> 00:28:16,127
It started to dig.

557
00:28:16,160 --> 00:28:19,697
This is a column five
meters tall in Germany

558
00:28:19,730 --> 00:28:22,033
where we are testing the
operation of the mole.

559
00:28:22,066 --> 00:28:23,968
That plot at the right
with the green line,

560
00:28:24,001 --> 00:28:27,905
that's the progress from
this test where continuously,

561

00:28:27,938 --> 00:28:31,976
we reached five meters
in five and a half hours.

562
00:28:32,009 --> 00:28:35,713
And this is in one of the
more difficult materials

563
00:28:35,746 --> 00:28:37,749
that we use to
simulate Mars' surface.

564
00:28:37,782 --> 00:28:39,718
So the mole is quite
a capable thing.

565
00:28:41,185 --> 00:28:44,656
As it goes down, you might
see these little white specks

566
00:28:45,890 --> 00:28:48,960
going down on the tether,
those are temperature sensors.

567
00:28:48,993 --> 00:28:51,829
14 of them embedded
in the tether.

568
00:28:51,862 --> 00:28:55,667
The tether itself is a
scientific instrument.

569
00:29:01,105 --> 00:29:05,777
So the mole brings us
down into the ground

570
00:29:05,810 --> 00:29:08,780
measuring that key thermal
property of conductivity.

571

00:29:10,014 --> 00:29:13,017
Once it's down, once we've
reached our final depth,

572
00:29:13,050 --> 00:29:15,953
which we hope to be five meters,
but we can do our science

573
00:29:15,986 --> 00:29:18,022
if we only make it a
little bit shallower.

574
00:29:19,857 --> 00:29:21,092
The mole has done its
job at that point.

575
00:29:21,125 --> 00:29:22,827
It's done.

576
00:29:22,860 --> 00:29:25,763
The remainder of the
time on Mars, we monitor.

577
00:29:25,796 --> 00:29:28,800
We monitor temperatures
with that science tether.

578
00:29:31,702 --> 00:29:32,904
One thing you might
see is in the tether,

579
00:29:32,937 --> 00:29:35,673
you have those little markings
on the left and the right,

580
00:29:35,706 --> 00:29:38,042
those little dots, that's code.

581
00:29:38,075 --> 00:29:41,646
That's what that tether

length monitor uses to measure

582
00:29:41,679 --> 00:29:42,947
the amount of tether
that's been pulled

583
00:29:42,980 --> 00:29:44,715
by the mole into the ground

584
00:29:44,748 --> 00:29:47,685
so we can reconstruct
the path of the mole,

585
00:29:47,718 --> 00:29:52,089
but also so we can reconstruct
exactly within a centimeter

586
00:29:52,122 --> 00:29:54,725
where those temperature
sensors end up with depth,

587
00:29:54,758 --> 00:29:55,827
and that's important

588
00:29:56,927 --> 00:29:58,996
because we need to
determine that number,

589
00:29:59,029 --> 00:30:00,131
that thermal gradient.

590
00:30:00,164 --> 00:30:02,733
At the bottom of that
graph there, that line,

591
00:30:02,766 --> 00:30:04,135
that's what we're after.

592
00:30:04,168 --> 00:30:07,738

Closer to the surface,
one or two meters down,

593
00:30:07,771 --> 00:30:09,941
there's still a
lot of fluctuation.

594
00:30:09,974 --> 00:30:14,946
Annual, seasonal changes
propagate into the ground

595
00:30:15,913 --> 00:30:17,682
and they are noise for us.

596
00:30:18,749 --> 00:30:20,952
And so with the mole, we dig.

597
00:30:23,787 --> 00:30:26,924
But first, after InSight
has arrived on Mars,

598
00:30:26,957 --> 00:30:29,093
after we've gone through
the seven minutes of terror

599
00:30:29,126 --> 00:30:30,862
and landed on the surface

600
00:30:30,895 --> 00:30:33,731
and the lander is
healthy and doing fine,

601
00:30:33,764 --> 00:30:35,800
the instruments still aren't
where they need to be.

602
00:30:35,833 --> 00:30:37,101
They have one last journey.

603

00:30:38,736 --> 00:30:40,738
Seismometer can't do
its job on the lander.

604
00:30:40,771 --> 00:30:41,973
It's too noisy of
an environment,

605
00:30:42,006 --> 00:30:44,943
especially with those big solar
panels flapping in the wind.

606
00:30:46,710 --> 00:30:50,114
And HP3 capable as the mole
is you do not want to dig

607
00:30:50,147 --> 00:30:52,750
through the body
of the spacecraft.

608
00:30:53,984 --> 00:30:56,020
So we have the robotic arm.

609
00:30:56,053 --> 00:30:59,891
And what you'll see in this
next video is a bit sped up.

610
00:31:01,058 --> 00:31:04,829
How the arm will deploy
first the seismometer,

611
00:31:04,862 --> 00:31:08,900
then the wind and thermal
shield, and finally HP3.

612
00:31:08,933 --> 00:31:10,134
Now this is sped up.

613
00:31:10,167 --> 00:31:12,870
So the process of picking

up one of these items

614
00:31:12,903 --> 00:31:16,140
and putting it back on the
ground takes about 10 minutes.

615
00:31:17,708 --> 00:31:19,043
But this video or this animation

616
00:31:19,076 --> 00:31:20,878
has also been severely edited.

617
00:31:20,911 --> 00:31:24,916
There's a whole lot of back and
forth between Mars and Earth

618
00:31:24,949 --> 00:31:28,753
making sure we grappled
the object correctly,

619
00:31:28,786 --> 00:31:30,121
making sure we
placed it correctly,

620
00:31:30,154 --> 00:31:33,991
and all of the other checkouts
and cross-checks we do

621
00:31:34,024 --> 00:31:36,994
to make sure we get it
right the first time.

622
00:31:37,027 --> 00:31:40,097
Here, the arm is picking up
the wind in thermal shield

623
00:31:40,130 --> 00:31:43,701
and that skirt and its
legs just drop right down,

624
00:31:43,734 --> 00:31:46,838
and it comes over and
gets placed on top
of the seismometer.

625
00:31:48,072 --> 00:31:50,808
The arm doesn't
have a huge reach.

626
00:31:50,841 --> 00:31:53,077
There's a small workspace
in front of the lander there

627
00:31:53,110 --> 00:31:54,812
that it can go to.

628
00:31:54,845 --> 00:31:56,914
And we have preferred places
where we'd like to put

629
00:31:56,947 --> 00:32:01,719
these instruments, but
there could be a rock.

630
00:32:01,752 --> 00:32:02,954
There could be several rocks.

631
00:32:02,987 --> 00:32:06,757
We have to take
pictures of the area

632
00:32:06,790 --> 00:32:09,060
and then decide exactly where
we want to put the instrument.

633
00:32:09,093 --> 00:32:10,728
It seems like it's simple.

634
00:32:10,761 --> 00:32:14,098

This whole process seems
like a simple thing,

635
00:32:14,131 --> 00:32:15,866
but it's complicated

636
00:32:15,899 --> 00:32:17,668
and this is the first
time we've done it.

637
00:32:17,701 --> 00:32:21,939
We've never deployed an
instrument from a spacecraft

638
00:32:21,972 --> 00:32:23,874
onto the surface of
another body before.

639
00:32:23,907 --> 00:32:26,143
We've had instruments
on the end of the arm,

640
00:32:26,176 --> 00:32:28,746
but we've never done
something like this.

641
00:32:28,779 --> 00:32:31,749
Here, you see HP3 getting
placed on the ground

642
00:32:31,782 --> 00:32:35,987
and the whole process from
landing to this point here

643
00:32:36,020 --> 00:32:38,756
where HP3 is on the ground
and the mole can start digging

644
00:32:38,789 --> 00:32:43,695
will take about 45

days in the best cases.

645
00:32:45,863 --> 00:32:48,899
And so Insight is
a mission to Mars.

646
00:32:48,932 --> 00:32:50,067
We will be studying Mars.

647
00:32:50,100 --> 00:32:53,070
We will be learning
about its interior.

648
00:32:53,103 --> 00:32:56,107
But by extension
and by comparison,

649
00:32:56,140 --> 00:33:00,011
we are learning about
the other rocky planets

650
00:33:00,044 --> 00:33:02,680
in our solar system,

651
00:33:02,713 --> 00:33:05,082
the laws that govern
their formation,

652
00:33:05,115 --> 00:33:07,718
the tendencies they follow,

653
00:33:07,751 --> 00:33:11,722
and possibly, what
coincidental chance events

654
00:33:11,755 --> 00:33:14,025
led to them being the
way they are today.

655

00:33:15,692 --> 00:33:18,763
And we have discovered
around other stars,

656
00:33:18,796 --> 00:33:22,033
other rocky planets, other
members of that family

657
00:33:23,133 --> 00:33:26,737
and we will through this
mission gain InSight

658
00:33:26,770 --> 00:33:30,007
into that formation
process which could happen

659
00:33:30,040 --> 00:33:31,909
all over the universe.

660
00:33:35,145 --> 00:33:36,981
I'll spend a few moments
now talking a bit

661
00:33:37,014 --> 00:33:39,016
about where Insight
is at the present

662
00:33:39,049 --> 00:33:41,886
and what you can expect to
see in the coming months.

663
00:33:44,121 --> 00:33:45,923
The spacecraft has been built.

664
00:33:45,956 --> 00:33:47,825
It has been packaged
up and it has been sent

665
00:33:47,858 --> 00:33:50,995
to Vandenberg Air Force

Base here in California.

666
00:33:51,028 --> 00:33:53,030
This will be the
first time a mission,

667
00:33:53,063 --> 00:33:56,034
an interplanetary mission
has launched from Vandenberg.

668
00:33:57,768 --> 00:33:59,904
Our scheduled launch
period is in May and June

669
00:33:59,937 --> 00:34:02,106
and our first target
launch date is May 5th.

670
00:34:03,974 --> 00:34:07,078
Once we launch, we'll cruise
to Mars for about six months

671
00:34:07,111 --> 00:34:10,915
landing on November 26th, 2018.

672
00:34:10,948 --> 00:34:13,084
This is that seven
minutes of terror

673
00:34:13,117 --> 00:34:17,021
where we come through
the atmosphere first
on a heat shield,

674
00:34:17,054 --> 00:34:18,789
then a parachute,

675
00:34:18,822 --> 00:34:22,827
then a brief moment of
free-fall and retro rockets.

676
00:34:22,860 --> 00:34:25,129
that bring us gently
down to the surface.

677
00:34:25,162 --> 00:34:28,833
Very much like the Phoenix,
Mars lander arrived

678
00:34:28,866 --> 00:34:31,769
in the polar regions
of Mars in 2008.

679
00:34:31,802 --> 00:34:34,772
InSights might look
familiar because it is based

680
00:34:34,805 --> 00:34:36,674
on the Phoenix spacecraft.

681
00:34:37,908 --> 00:34:40,811
Once we've arrived,
we'll do our checkout

682
00:34:40,844 --> 00:34:42,813
and that whole
deployment process

683
00:34:42,846 --> 00:34:44,048
will calibrate the instruments,

684
00:34:44,081 --> 00:34:46,050
HP3 each will penetrate,

685
00:34:46,083 --> 00:34:49,887
and then the whole system
goes into its listening mode.

686
00:34:49,920 --> 00:34:53,757

We listen to Mars
for its quakes,

687
00:34:53,790 --> 00:34:55,092
we listen to its temperature,

688
00:34:55,125 --> 00:34:56,694
we observe its wobble.

689
00:34:59,663 --> 00:35:02,867
The primary mission for
InSight is one Mars year.

690
00:35:02,900 --> 00:35:04,669
That's two Earth years.

691
00:35:05,903 --> 00:35:10,108
And if our history with
engineering such spacecraft

692
00:35:11,008 --> 00:35:12,043
has any indication,

693
00:35:13,710 --> 00:35:15,045
for instance the Opportunity
rover was designed

694
00:35:15,078 --> 00:35:16,881
to operate 90 days on Mars

695
00:35:16,914 --> 00:35:21,819
and it just celebrated its
5,000th day operating on Mars.

696
00:35:21,852 --> 00:35:24,021
InSight could be going
for a decade or more.

697
00:35:26,790 --> 00:35:30,027

We'll be landing at a place
on Mars called Elysium.

698
00:35:30,060 --> 00:35:31,762
Elysium Planitia.

699
00:35:31,795 --> 00:35:33,864
It's quite close to where
Curiosity is right now

700
00:35:33,897 --> 00:35:35,066
exploring Gale Crater.

701
00:35:36,800 --> 00:35:41,005
We chose this location because
it's safe for the lander

702
00:35:42,706 --> 00:35:43,807
and it can let the
instruments do their jobs.

703
00:35:43,840 --> 00:35:45,042
When we get those
first pictures back,

704
00:35:45,075 --> 00:35:46,777
they're probably gonna be
the most boring pictures

705
00:35:46,810 --> 00:35:48,846
you've ever seen from
the surface of Mars

706
00:35:48,879 --> 00:35:50,748
because it's smooth
and flat and boring

707
00:35:50,781 --> 00:35:52,049
and that's exactly what we want.

708
00:35:53,050 --> 00:35:55,052
SEIS is studying the planet.

709
00:35:55,085 --> 00:35:57,855
It could do its
job from anywhere.

710
00:35:57,888 --> 00:36:00,591
HP3 also studying the planet,

711
00:36:00,624 --> 00:36:02,693
but it wants broken up regolith.

712
00:36:02,726 --> 00:36:04,995
Broken up ground to dig into.

713
00:36:05,028 --> 00:36:06,897
We can't dig through rock.

714
00:36:06,930 --> 00:36:08,832
And so with those constraints

715
00:36:08,865 --> 00:36:11,735
and the various engineering
constraints of the lander,

716
00:36:11,768 --> 00:36:15,005
we've chosen this location
that will be our home

717
00:36:15,038 --> 00:36:17,742
for a long time once
InSight arrives.

718
00:36:19,109 --> 00:36:22,813
InSight will not be alone
on its journey to Mars.

719

00:36:22,846 --> 00:36:27,051
It will be followed by
two CubeSats called MarCO.

720
00:36:27,084 --> 00:36:28,886
CubeSats, they're small.

721
00:36:28,919 --> 00:36:30,721
Literally this big.

722
00:36:30,754 --> 00:36:34,058
And this is the first time
one of these microsatellites

723
00:36:34,091 --> 00:36:36,127
has gone on an
interplanetary mission.

724
00:36:37,761 --> 00:36:39,063
MarCO will act as mirrors.

725
00:36:39,096 --> 00:36:40,798
Radio mirrors.

726
00:36:40,831 --> 00:36:45,135
Receivers and transmitters
relays for the InSight lander

727
00:36:45,168 --> 00:36:48,873
as it comes through
the atmosphere to
land on the surface.

728
00:36:50,007 --> 00:36:51,842
We have orbiters
around Mars right now

729
00:36:51,875 --> 00:36:54,745
that can relay signals, but
they can't do it simultaneously.

730
00:36:54,778 --> 00:36:56,113
They can't listen to the lander

731
00:36:56,146 --> 00:36:58,683
and send the information
back to the Earth.

732
00:36:59,716 --> 00:37:00,884
InSight will be on autopilot

733
00:37:00,917 --> 00:37:03,754
as it goes through the
atmosphere to land,

734
00:37:03,787 --> 00:37:05,689
but MarCo will be able to relay

735
00:37:05,722 --> 00:37:08,659
all the information it
gives us in real time.

736
00:37:08,692 --> 00:37:09,927
Well, as close to
real-time as you can get

737
00:37:09,960 --> 00:37:11,796
when your many
light minutes away.

738
00:37:14,131 --> 00:37:16,700
And now some of the
things we've been doing

739
00:37:16,733 --> 00:37:18,836
to engage the public

740
00:37:18,869 --> 00:37:21,672
and everyone who is

part of this mission,

741
00:37:21,705 --> 00:37:26,677
that there's a microchip on
InSight 2.4 million names on it.

742
00:37:27,878 --> 00:37:29,713
Many of you in this room
maybe going to Mars this way,

743
00:37:29,746 --> 00:37:31,649
many of you watching
may also be going

744
00:37:31,682 --> 00:37:34,118
and we thank you for that, and
we hope you enjoy the ride.

745
00:37:35,886 --> 00:37:37,921
Here in California, we'll
be doing a road show.

746
00:37:37,954 --> 00:37:40,691
We'll be taking some exhibits

747
00:37:40,724 --> 00:37:44,061
and some scientists and
engineers to various locations

748
00:37:44,094 --> 00:37:46,897
in the months leading
up to the launch.

749
00:37:46,930 --> 00:37:48,999
So if you're in these areas,

750
00:37:49,032 --> 00:37:52,736
up in Shasta, San
Francisco, Sacramento

751
00:37:52,769 --> 00:37:55,072
and the towns along the
coast near Vandenberg,

752
00:37:55,105 --> 00:37:56,974
there'll be a number of
events that you can go to

753
00:37:57,007 --> 00:38:00,878
and get some more
hands-on feel for InSight

754
00:38:00,911 --> 00:38:03,948
and the exciting engineering
and science of this mission.

755
00:38:06,083 --> 00:38:08,986
And finally, please follow
us on our Journey to Mars.

756
00:38:09,019 --> 00:38:11,088
You can watch the launch online.

757
00:38:11,121 --> 00:38:12,890
I think there's now
a Google Earth widget

758
00:38:12,923 --> 00:38:15,793
where you can see the flight
path of the launch vehicle.

759
00:38:15,826 --> 00:38:18,062
You'll see if you can see
it from where you live.

760
00:38:18,095 --> 00:38:20,998
And there's an app, an
app called Be a Martian.

761

00:38:22,933 --> 00:38:26,837
This will be returning
data from InSight.

762
00:38:26,870 --> 00:38:29,073
The first data, once the
instruments all calibrate,

763
00:38:29,106 --> 00:38:32,676
will come back in March of 2019.

764
00:38:32,709 --> 00:38:34,144
You get a notification
on your phone.

765
00:38:34,177 --> 00:38:35,879
There's been a Marsquake.

766
00:38:35,912 --> 00:38:37,981
Here are the current conditions
at the InSight lander

767
00:38:38,014 --> 00:38:39,116
and more.

768
00:38:39,149 --> 00:38:42,886
So you can look on
the NASA website,

769
00:38:42,919 --> 00:38:44,688
you can find us on Facebook

770
00:38:44,721 --> 00:38:48,859
and you can follow
us on Twitter, and
continue to be a part

771
00:38:48,892 --> 00:38:50,961
as you have been
with me this evening

772
00:38:50,994 --> 00:38:55,132
on our next journey
to the planet Mars.

773
00:38:56,099 --> 00:38:57,134
Thank you.

774
00:38:57,167 --> 00:39:00,671
[audience applauding]

775
00:39:09,880 --> 00:39:13,817
I would be thrilled to
take your questions.

776
00:39:13,850 --> 00:39:15,152
If you would, there
is a microphone

777
00:39:15,185 --> 00:39:17,688
in the center of the aisle, if
you'd like to come up to that

778
00:39:17,721 --> 00:39:19,890
so that those on the broadcast

779
00:39:19,923 --> 00:39:21,726
can hear your question as well.

780
00:39:26,096 --> 00:39:27,030
>> Yeah, I have two questions.

781
00:39:27,063 --> 00:39:28,899
I hope they're brief.

782
00:39:28,932 --> 00:39:31,668
The first is, does
the grapple have a job

783
00:39:31,701 --> 00:39:33,937
after it's deployed
the two instruments?

784
00:39:33,970 --> 00:39:35,906
>> The grapple itself, no.

785
00:39:35,939 --> 00:39:38,108
We don't have
anything for it to do,

786
00:39:38,141 --> 00:39:41,745
but the robotic arm itself
has a scoop on the end of it

787
00:39:41,778 --> 00:39:44,748
and we may do some
geologic investigations

788
00:39:44,781 --> 00:39:46,750
of the surface soil with the arm

789
00:39:46,783 --> 00:39:49,019
after it's deployed
the instruments.

790
00:39:49,052 --> 00:39:51,088
>> I assume when
the mole is digging

791
00:39:51,121 --> 00:39:52,990
that the seismometer
can hear it.

792
00:39:53,023 --> 00:39:55,692
Does it make enough
signal to hear reflections

793
00:39:55,725 --> 00:39:57,728

from the internal parts of Mars?

794
00:39:57,761 --> 00:39:59,663
>> Oh, that's a
fantastic question

795
00:39:59,696 --> 00:40:02,933
and it's particularly relevant
'cause just this Monday,

796
00:40:02,966 --> 00:40:05,736
we went out to the
field to do some

797
00:40:05,769 --> 00:40:08,105
preliminary geophysical
surveying of a site

798
00:40:08,138 --> 00:40:12,109
that we will use to test mole
seismometer interactions.

799
00:40:12,142 --> 00:40:13,877
They are not designed for this.

800
00:40:13,910 --> 00:40:16,713
The signals that we get
from the seismometers

801
00:40:16,746 --> 00:40:18,782
are quite long period

802
00:40:18,815 --> 00:40:23,053
and the impact of
the mole is too fast

803
00:40:23,086 --> 00:40:26,757
for this seismometer
to see in full detail.

804
00:40:26,790 --> 00:40:28,692
So we have developed
some techniques

805
00:40:28,725 --> 00:40:31,962
where we can take advantage
of this known seismic source.

806
00:40:31,995 --> 00:40:35,065
By taking various spectra
every time the mole hammers

807
00:40:35,098 --> 00:40:37,935
and stacking them up,
we can get a picture

808
00:40:37,968 --> 00:40:40,737
of what the near
subsurface is like.

809
00:40:40,770 --> 00:40:42,806
We can't learn about
the deep interior,

810
00:40:42,839 --> 00:40:46,743
but we might learn how deep
is that soil we're digging in

811
00:40:46,776 --> 00:40:48,078
and where is that
first reflector,

812
00:40:48,111 --> 00:40:49,780
that first piece of bedrock,

813
00:40:49,813 --> 00:40:51,114
and that's a nice
piece of information

814

00:40:51,147 --> 00:40:53,016
for the seismometer to have.

815
00:40:53,049 --> 00:40:56,920
So we're working to really
understand that process

816
00:40:56,953 --> 00:40:59,923
so when we get to Mars,
yes, we can use HP3

817
00:40:59,956 --> 00:41:01,692
as a known source for SEIS.

818
00:41:03,159 --> 00:41:04,061
>> Hello.

819
00:41:04,094 --> 00:41:05,029
Thanks for the talk.

820
00:41:06,062 --> 00:41:08,832
Have you an estimate of

821
00:41:08,865 --> 00:41:11,702
what is the chance of there
being like a big rock underneath

822
00:41:11,735 --> 00:41:12,903
that you can't drill through?

823
00:41:12,936 --> 00:41:14,839
>> We have with,

824
00:41:15,939 --> 00:41:17,841
so we've looked at the surface

825
00:41:17,874 --> 00:41:20,911
and using information
from other geologic sites

826
00:41:20,944 --> 00:41:22,980
on Mars that we've
visited with landers,

827
00:41:23,013 --> 00:41:25,916
and also looking at
evidence from craters

828
00:41:25,949 --> 00:41:27,017
in the nearby region,

829
00:41:27,050 --> 00:41:29,786
we can estimate the
distance to the bedrock

830
00:41:29,819 --> 00:41:31,822
and also the rock abundance.

831
00:41:31,855 --> 00:41:35,058
And we think for very
conservative assumptions,

832
00:41:35,091 --> 00:41:39,062
the chance of us encountering
a 10-centimeter rock

833
00:41:39,095 --> 00:41:44,068
is on the order of 73%
in the five-meter depth.

834
00:41:46,036 --> 00:41:47,938
Now, we encounter a
10-centimeter rock,

835
00:41:47,971 --> 00:41:50,707
that doesn't say
that'll stop the mole

836

00:41:50,740 --> 00:41:52,142
because depending on
the shape of the rock

837
00:41:52,175 --> 00:41:55,145
and how it's oriented, we
may pass by it entirely.

838
00:41:57,013 --> 00:41:59,016
And if you take less
conservative assumptions,

839
00:41:59,049 --> 00:42:01,986
our chances of success
go up to the high 90s.

840
00:42:05,822 --> 00:42:06,723
>> Hi.

841
00:42:06,756 --> 00:42:07,290
Great talk.

842
00:42:07,323 --> 00:42:08,992
I have three questions.

843
00:42:09,025 --> 00:42:10,160
One is how long,

844
00:42:12,696 --> 00:42:15,866
how long does the mole
have to stop pinging

845
00:42:15,899 --> 00:42:18,001
before it settles down

846
00:42:18,034 --> 00:42:20,070
and you can take
temperature measurements?

847

00:42:21,705 --> 00:42:23,807
>> So in the digging process,

848
00:42:23,840 --> 00:42:25,976
you mean the temp
measurements of the tether?

849
00:42:26,009 --> 00:42:26,910
>> Yes.

850
00:42:26,943 --> 00:42:28,145
>> Yeah.

851
00:42:28,178 --> 00:42:31,749
So the process of digging itself
injects heat into the soil.

852
00:42:32,882 --> 00:42:35,085
And we do need this
heat to dissipate,

853
00:42:35,118 --> 00:42:38,689
and it will depend in
part on how conductive

854
00:42:38,722 --> 00:42:41,658
Mars' surface soil is.

855
00:42:41,691 --> 00:42:44,995
If it's at the high range of
the conductivities we expect,

856
00:42:45,028 --> 00:42:46,663
by the time the mole
gets to the bottom,

857
00:42:46,696 --> 00:42:48,065
we'll be able to take good data.

858

00:42:48,098 --> 00:42:49,866
If it's at the lower
end of the range,

859
00:42:49,899 --> 00:42:52,970
we may need to wait
a few 10s of sols,

860
00:42:53,003 --> 00:42:54,838
but not longer than that.

861
00:42:54,871 --> 00:42:56,106
>> Okay.

862
00:42:56,139 --> 00:42:59,810
Second thing is,
what consequences,

863
00:43:00,977 --> 00:43:05,816
the possible communication
problems with MRO,

864
00:43:05,849 --> 00:43:09,019
the Mars Relay Orbiter,
going to have on you?

865
00:43:09,052 --> 00:43:13,824
I mean, you have two things
communicating directly to Earth,

866
00:43:14,824 --> 00:43:16,960
but it's just tonal stuff.

867
00:43:16,993 --> 00:43:21,798
For the data that
you're returning,

868
00:43:21,831 --> 00:43:25,969
you need to shoot it
up to MRO, I presume?

869
00:43:26,002 --> 00:43:27,771
>> Yeah, we need
a pretty big pipe

870
00:43:27,804 --> 00:43:30,941
to send that data back 'cause
there's quite a lot of it.

871
00:43:30,974 --> 00:43:34,077
And MRO is only one of the
orbiting assets that we can use.

872
00:43:34,110 --> 00:43:36,647
We can use Mars Odyssey as well,

873
00:43:36,680 --> 00:43:37,981
which is still in operation.

874
00:43:38,014 --> 00:43:39,850
It's getting a little
long in the tooth,

875
00:43:39,883 --> 00:43:41,084
but it's still there.

876
00:43:41,117 --> 00:43:43,720
And then there is a MAVEN.

877
00:43:43,753 --> 00:43:45,656
The MAVEN spacecraft that
observes the atmosphere,

878
00:43:45,689 --> 00:43:47,758
and that can also
act as a relay.

879
00:43:47,791 --> 00:43:49,026
>> You can use all three?

880
00:43:49,059 --> 00:43:49,926
>> Troy: Mm-hmm.

881
00:43:49,959 --> 00:43:50,894
>> All right.

882
00:43:50,927 --> 00:43:52,663
And the third thing is, just,

883
00:43:55,932 --> 00:43:58,702
I have a sense, okay,
let us take this

884
00:43:58,735 --> 00:44:00,604
and put it in my backyard

885
00:44:00,637 --> 00:44:05,676
and have the thing go down
five meters into my backyard.

886
00:44:06,042 --> 00:44:08,111
And suddenly, from this,

887
00:44:08,144 --> 00:44:10,647
well, not suddenly,
but over the course of

888
00:44:10,680 --> 00:44:14,751
let's say two Earth
years, I can ascertain

889
00:44:14,784 --> 00:44:17,021
the structure of
Earth albeit we have,

890
00:44:18,788 --> 00:44:21,958
plates floating around and
it's a lot bigger and so on,

891
00:44:21,991 --> 00:44:26,030
but it just seems to me this
is extrapolating enormously

892
00:44:27,831 --> 00:44:31,068
from a very small instrument.

893
00:44:31,101 --> 00:44:35,972
A very small suite
of instruments in a
single place in Mars.

894
00:44:36,005 --> 00:44:37,040
>> Yeah.

895
00:44:37,073 --> 00:44:40,677
Well, one is infinitely
larger than zero.

896
00:44:40,710 --> 00:44:42,813
[laughter]

897
00:44:44,881 --> 00:44:47,051
[applauding]

898
00:44:51,855 --> 00:44:53,824
The seismometer is the
thing that's looking at

899
00:44:53,857 --> 00:44:56,860
the overall structure
of the planet.

900
00:44:56,893 --> 00:44:58,995
The mole as an
instrument is looking at

901
00:44:59,028 --> 00:45:01,898

the local heat flow properties

902
00:45:01,931 --> 00:45:06,970
and this needs to be matched
then to models of Mars

903
00:45:07,003 --> 00:45:09,840
that say what the heat
flow might be like

904
00:45:09,873 --> 00:45:13,009
at different locations
depending on crustal thickness

905
00:45:13,042 --> 00:45:15,746
which is something that
SEIS can tell us about.

906
00:45:15,779 --> 00:45:18,081
Maybe the presence of
mantle convection with SEIS

907
00:45:18,114 --> 00:45:19,649
can also tell us about.

908
00:45:19,682 --> 00:45:22,886
So these measurements
work in concert.

909
00:45:22,919 --> 00:45:25,722
On Earth, Earth is a
very complicated place.

910
00:45:25,755 --> 00:45:29,059
And to get good geothermal
measurements, for instance,

911
00:45:29,092 --> 00:45:32,129
you have to go below
the water table.

912
00:45:32,162 --> 00:45:35,699
You have to get below any
kind of fluid circulation

913
00:45:35,732 --> 00:45:36,933
because Earth has lots of water

914
00:45:36,966 --> 00:45:39,035
and that really messes up
those kinds of measurements.

915
00:45:39,068 --> 00:45:44,041
So there are aspects about Mars
that make it easier for us,

916
00:45:45,809 --> 00:45:48,712
but the key point is this
has never been done before.

917
00:45:48,745 --> 00:45:52,883
We've never made these kinds
of measurements of heat flow

918
00:45:52,916 --> 00:45:54,684
anywhere on Mars.

919
00:45:54,717 --> 00:45:55,986
We've never had any seismometer.

920
00:45:56,019 --> 00:45:57,053
And there's quite
a lot you can do

921
00:45:57,086 --> 00:45:58,889
with only one seismometer.

922
00:45:58,922 --> 00:46:00,891
You can pinpoint the

epicenter of something

923
00:46:00,924 --> 00:46:03,126
with a seismometer
as sensitive as this

924
00:46:03,159 --> 00:46:05,762
that has those
multiple SEIS numbers,

925
00:46:05,795 --> 00:46:07,130
you can determine the direction

926
00:46:07,163 --> 00:46:09,032
and the character of the signal.

927
00:46:10,133 --> 00:46:11,868
There's a bit of a
bootstrapping process

928
00:46:11,901 --> 00:46:14,738
where you refine
your models of Mars,

929
00:46:14,771 --> 00:46:18,074
but the old days of
needing three seismometers

930
00:46:18,107 --> 00:46:20,110
to pinpoint the
epicenter of a quake,

931
00:46:20,143 --> 00:46:21,812
you don't need that anymore.

932
00:46:22,946 --> 00:46:24,014
>> Thank you.
>> You bet.

933

00:46:25,915 --> 00:46:29,853
>> Thank you for taking us
on this exciting journey.

934
00:46:29,886 --> 00:46:34,124
Lady Rocket's CEO and founder
of California Space Center

935
00:46:34,157 --> 00:46:36,693
and co-founder with
Grant Blaisdell

936
00:46:36,726 --> 00:46:39,896
of Copernic
blockchain technology.

937
00:46:39,929 --> 00:46:41,865
With Copernic token,

938
00:46:43,132 --> 00:46:47,704
which mission is to
seek space projects.

939
00:46:47,737 --> 00:46:51,675
Hopefully, like yours to
provide incremental funding,

940
00:46:51,708 --> 00:46:54,778
should funding originally
budgeted for the project

941
00:46:54,811 --> 00:46:55,879
is not sufficient.

942
00:46:57,146 --> 00:47:00,016
This is using the
power of cryptocurrency

943
00:47:00,049 --> 00:47:01,751
is to put it behind the industry

944
00:47:01,784 --> 00:47:05,755
that needs to get funded
better by us Americans.

945
00:47:05,788 --> 00:47:07,023
May I ask you a question?

946
00:47:07,056 --> 00:47:10,093
If you would be willing to
share some of your dreams

947
00:47:10,126 --> 00:47:13,763
that are aligned with

948
00:47:13,796 --> 00:47:16,900
what else would you
like to accomplish

949
00:47:16,933 --> 00:47:20,770
during or after the Mars mission

950
00:47:20,803 --> 00:47:23,874
if budget was available?

951
00:47:23,907 --> 00:47:25,843
And let's see if we
can make it happen.

952
00:47:27,076 --> 00:47:28,945
>> What I would like
to see personally

953
00:47:28,978 --> 00:47:30,780
or what we would like
to do with this mission?

954
00:47:30,813 --> 00:47:33,116
>> How about both

because you deserve

955
00:47:33,149 --> 00:47:36,119
personal dream fulfillment
of doing what you do,

956
00:47:36,152 --> 00:47:37,854
so give us both.

957
00:47:37,887 --> 00:47:40,757
But Copernic's mission
is to seek those projects

958
00:47:40,790 --> 00:47:42,893
which carry incredible value,

959
00:47:42,926 --> 00:47:45,795
but do not make it into
the traditional budget

960
00:47:45,828 --> 00:47:48,098
and see if we could bring
incremental funding.

961
00:47:48,131 --> 00:47:51,868
So looking at that on
potential commercialization

962
00:47:51,901 --> 00:47:53,870
of what you will
be generating there

963
00:47:53,903 --> 00:47:56,740
so we could create an
enterprise around it.

964
00:47:57,974 --> 00:47:59,075
>> Well, there's a number
of aspects of this.

965
00:47:59,108 --> 00:48:00,911
I mean, InSight was a mission

966
00:48:00,944 --> 00:48:03,079
that was competed within NASA.

967
00:48:03,112 --> 00:48:05,982
It was proposed along
with many other missions

968
00:48:06,015 --> 00:48:09,953
to be awarded the funds
of the Discovery program.

969
00:48:09,986 --> 00:48:13,990
And InSight was one out
of many missions submitted

970
00:48:14,023 --> 00:48:17,027
and three finalists that
ultimately got that funding.

971
00:48:17,060 --> 00:48:19,829
And so there are other
missions that NASA decided

972
00:48:19,862 --> 00:48:22,899
these are good enough
that we want to look

973
00:48:22,932 --> 00:48:25,836
more closely at them, but they
can only choose one winner.

974
00:48:27,070 --> 00:48:29,706
And these are all great
science and great engineering.

975
00:48:29,739 --> 00:48:34,010

And, I mean, my personal
favorites are things like

976
00:48:34,043 --> 00:48:35,979
I study planets,
I study geology,

977
00:48:36,012 --> 00:48:37,714
I want to know about Mars

978
00:48:37,747 --> 00:48:39,716
and I want to know about
asteroids and comets.

979
00:48:39,749 --> 00:48:44,054
And the idea of going to
visit an asteroid or a comet

980
00:48:44,087 --> 00:48:46,890
and to bring part of it home

981
00:48:46,923 --> 00:48:48,858
both from the
scientific perspective,

982
00:48:48,891 --> 00:48:50,994
but also potentially to use it.

983
00:48:51,027 --> 00:48:53,897
Can we make something
out of this resource?

984
00:48:57,000 --> 00:48:58,068
I'm an explorer.

985
00:48:58,101 --> 00:48:59,869
I love going to places
we haven't been yet,

986

00:48:59,902 --> 00:49:03,106
and that's one of the things
that excites me about InSight.

987
00:49:03,139 --> 00:49:04,908
>> Thank you.

988
00:49:04,941 --> 00:49:06,676
And just thank you for
mentioning Vandenberg
Air Force Base

989
00:49:06,709 --> 00:49:07,911
in your presentation.

990
00:49:07,944 --> 00:49:10,013
They are incredible team.

991
00:49:10,046 --> 00:49:11,781
Not as visited as Florida.

992
00:49:11,814 --> 00:49:14,084
I just came back from
Vandenberg SpaceX rocket launch

993
00:49:14,117 --> 00:49:17,888
and looking forward
to seeing you in May.

994
00:49:18,955 --> 00:49:20,991
Thank you.
>> We'll be there.

995
00:49:23,092 --> 00:49:24,661
>> Thanks.

996
00:49:24,694 --> 00:49:26,029
I also saw that rocket
launch this morning.

997
00:49:27,163 --> 00:49:29,065
All right, so the
three questions.

998
00:49:29,098 --> 00:49:32,802
First, does the mole have
a method of being retracted

999
00:49:32,835 --> 00:49:35,138
in case it run into
too many rocks?

1000
00:49:35,171 --> 00:49:36,740
>> It does not.

1001
00:49:36,773 --> 00:49:40,010
The mole only goes one
way and that's forward.

1002
00:49:40,043 --> 00:49:41,945
And hopefully, that's also down.

1003
00:49:41,978 --> 00:49:44,114
[laughter]

1004
00:49:44,147 --> 00:49:46,149
>> Man: And I hope so too.

1005
00:49:46,182 --> 00:49:48,051
>> There were some early
designs about a way

1006
00:49:48,084 --> 00:49:50,020
that we will be able to
reverse the mole to come back,

1007
00:49:50,053 --> 00:49:51,755
but that's not part
of this design.

1008
00:49:51,788 --> 00:49:53,156
It only goes down.

1009
00:49:53,189 --> 00:49:54,057
>> All right, thanks.

1010
00:49:54,090 --> 00:49:55,759
Second question.

1011
00:49:55,792 --> 00:49:58,661
Why was Vandenberg
chosen over KSC?

1012
00:49:58,694 --> 00:49:59,963
And I hope you guys launch
in the evening again

1013
00:49:59,996 --> 00:50:01,865
to freak out LA again.

1014
00:50:01,898 --> 00:50:06,703
>> It turns out that
our initial launch time

1015
00:50:06,736 --> 00:50:08,972
is around three or
four in the morning,

1016
00:50:09,005 --> 00:50:10,974
so get up early and you
might be able to see

1017
00:50:11,007 --> 00:50:12,876
something pretty amazing.

1018
00:50:14,844 --> 00:50:19,115
Vandenberg was chosen, I
think, primarily because

1019
00:50:19,148 --> 00:50:24,121
the schedule of launches
at KSC in Florida

1020
00:50:25,721 --> 00:50:29,126
was such that it wasn't
possible to fit it in

1021
00:50:30,793 --> 00:50:32,729
in the time period where
we wanted to launch

1022
00:50:32,762 --> 00:50:34,898
so that we can land
at the correct time.

1023
00:50:34,931 --> 00:50:37,133
It's also possible because
InSight is going on

1024
00:50:37,166 --> 00:50:40,870
a very powerful rocket that
has enough lift capacity

1025
00:50:40,903 --> 00:50:42,739
to take us from this site

1026
00:50:42,772 --> 00:50:45,041
which is a little less favorable
than the one in Florida

1027
00:50:45,074 --> 00:50:46,109
all the way to Mars.

1028
00:50:47,677 --> 00:50:48,845
>> Again, last question.

1029
00:50:48,878 --> 00:50:50,880

Would you guys consider
using a Falcon Heavy

1030
00:50:50,913 --> 00:50:52,715
for future Mars missions?

1031
00:50:52,748 --> 00:50:55,151
>> We did, in fact,
consider using the Falcon

1032
00:50:55,184 --> 00:50:57,720
as one of the potential
launch vehicles for InSight.

1033
00:50:57,753 --> 00:51:00,023
That was an option
that was expressed

1034
00:51:00,056 --> 00:51:01,858
in one of the
original proposals.

1035
00:51:02,959 --> 00:51:04,127
We ultimately didn't
settle on that.

1036
00:51:04,160 --> 00:51:06,996
It wasn't developed
enough for us to use,

1037
00:51:07,029 --> 00:51:10,967
but it's a possibility
for future missions.

1038
00:51:11,000 --> 00:51:12,069
>> All right, thank you.

1039
00:51:16,706 --> 00:51:17,807
>> Hello.

1040
00:51:17,840 --> 00:51:19,909
Thank you very much for
the enlightening talk

1041
00:51:19,942 --> 00:51:22,812
and for giving me a chance
to ask you a question.

1042
00:51:22,845 --> 00:51:27,750
I hope this is not too
tangential to the main theme.

1043
00:51:27,783 --> 00:51:32,756
But ever since I was very
young, I've been following

1044
00:51:33,856 --> 00:51:36,860
with great interest
all of these projects

1045
00:51:36,893 --> 00:51:39,863
to send probes into
space especially to Mars.

1046
00:51:39,896 --> 00:51:41,097
And now it's getting
to the point where,

1047
00:51:41,130 --> 00:51:44,868
well, we've seen quite
a few of these projects

1048
00:51:44,901 --> 00:51:46,035
and especially those landed.

1049
00:51:46,068 --> 00:51:50,006
What kind of bothers
me that up till now,

1050

00:51:50,039 --> 00:51:52,709
there's been very
little collaboration

1051
00:51:52,742 --> 00:51:54,811
between all of these
different projects.

1052
00:51:55,912 --> 00:51:58,982
Is there any plans for
this particular project

1053
00:51:59,015 --> 00:52:03,987
to collaborate with
any past projects

1054
00:52:04,020 --> 00:52:05,788
or any future ones?

1055
00:52:05,821 --> 00:52:08,124
What I'm thinking about
in particular is that

1056
00:52:08,157 --> 00:52:11,895
I've just returned
from living in

1057
00:52:11,928 --> 00:52:15,832
the United Arab
Emirates in Dubai.

1058
00:52:15,865 --> 00:52:19,035
I was teaching at a
technical university there

1059
00:52:19,068 --> 00:52:24,007
called the Khalifa University
of Science and Technology.

1060
00:52:24,040 --> 00:52:27,076

I don't know if you've
heard of them yet.

1061
00:52:27,109 --> 00:52:31,648
They are trying very hard
to be the Caltech or MIT

1062
00:52:31,681 --> 00:52:32,882
of the Middle East,

1063
00:52:32,915 --> 00:52:36,019
and they've also come up
with a very ambitious project

1064
00:52:36,052 --> 00:52:38,922
to put a probe on
Mars themselves.

1065
00:52:38,955 --> 00:52:41,925
For a little country like
that, I was astounded

1066
00:52:41,958 --> 00:52:44,794
when I first heard about that
that they had these plans.

1067
00:52:44,827 --> 00:52:48,965
I'd have to say that
I am embarrassed

1068
00:52:48,998 --> 00:52:51,901
that I don't
remember the details.

1069
00:52:51,934 --> 00:52:53,102
What is the timeframe?

1070
00:52:53,135 --> 00:52:56,673
I think it's within the
next three years or so.

1071
00:52:56,706 --> 00:52:58,841
So my question is,
are you aware of that?

1072
00:52:58,874 --> 00:53:02,745
Are you aware of that
that there is this plan

1073
00:53:02,778 --> 00:53:05,748
on the part of the
United Arab Emirates

1074
00:53:05,781 --> 00:53:07,016
to put a probe on Mars?

1075
00:53:07,049 --> 00:53:09,118
And again, is there any plans

1076
00:53:09,151 --> 00:53:12,855
to coordinate with them on this?

1077
00:53:12,888 --> 00:53:16,759
>> I personally have
not heard of that effort

1078
00:53:16,792 --> 00:53:18,995
and I do wish them the
best of luck with it.

1079
00:53:19,028 --> 00:53:22,098
Going to Mars, going into
space is a difficult endeavor.

1080
00:53:22,131 --> 00:53:24,968
And NASA, in this
project in particular,

1081
00:53:25,001 --> 00:53:27,937

but for all of them is
a collaborative place.

1082
00:53:27,970 --> 00:53:30,807
We collaborate the
engineers and the scientists

1083
00:53:30,840 --> 00:53:34,010
communicate across
missions, learning lessons,

1084
00:53:34,043 --> 00:53:37,680
and making sure that
mistakes aren't made again.

1085
00:53:37,713 --> 00:53:40,683
InSight uses the Phoenix lander

1086
00:53:40,716 --> 00:53:44,954
so so much of that
engineering knowledge

1087
00:53:44,987 --> 00:53:47,123
that was gained in the
production of that spacecraft

1088
00:53:47,156 --> 00:53:49,058
has gone into this mission.

1089
00:53:49,091 --> 00:53:52,662
And as I mentioned,
InSight instruments

1090
00:53:52,695 --> 00:53:55,832
are contributed by
our foreign partners.

1091
00:53:55,865 --> 00:53:58,868
The SEIS instrument was
built by a consortium

1092
00:53:58,901 --> 00:54:01,804
led by the French Space
Agency which includes

1093
00:54:01,837 --> 00:54:03,873
a number of different
European countries.

1094
00:54:03,906 --> 00:54:07,110
HP3, built by the
German Space Agency.

1095
00:54:07,143 --> 00:54:11,147
So collaboration is not
a foreign thing for NASA.

1096
00:54:12,181 --> 00:54:15,084
But how a collaboration
comes to be,

1097
00:54:15,117 --> 00:54:18,788
who needs to be involved
in making that a reality

1098
00:54:18,821 --> 00:54:22,892
and keeping it going
once it's birthed

1099
00:54:22,925 --> 00:54:24,927
and see it all the
way through to the end

1100
00:54:24,960 --> 00:54:27,830
when you arrive on Mars,
it's a complicated thing,

1101
00:54:27,863 --> 00:54:29,099
but it's something that we do.

1102
00:54:30,900 --> 00:54:31,835
>> Man: Thank you.

1103
00:54:33,035 --> 00:54:35,138
>> Hi, thank you for
the presentation.

1104
00:54:35,171 --> 00:54:36,773
If I understood you correctly,

1105
00:54:36,806 --> 00:54:39,042
and I very well may
have not done so,

1106
00:54:40,142 --> 00:54:42,945
the launch window
begins May 5th,

1107
00:54:42,978 --> 00:54:45,682
but I thought I
understood you to say that

1108
00:54:45,715 --> 00:54:48,017
it could launch later in
May or in June depending on

1109
00:54:49,151 --> 00:54:51,688
I assume, weather or
other complications.

1110
00:54:51,721 --> 00:54:52,789
>> Troy: Exactly.

1111
00:54:52,822 --> 00:54:54,757
>> But the landing
date is November 26th.

1112
00:54:54,790 --> 00:54:56,025
>> Mm-hmm.

1113
00:54:56,058 --> 00:54:58,628
>> It's a consequence of how
the orbital dynamics work out.

1114
00:54:58,661 --> 00:55:01,964
We can, in fact, choose a
very precise landing date

1115
00:55:01,997 --> 00:55:06,836
and still have a window of
possible launch opportunities.

1116
00:55:06,869 --> 00:55:08,104
>> So regardless of
when it launches,

1117
00:55:08,137 --> 00:55:09,806
it will land on November 26th?

1118
00:55:09,839 --> 00:55:11,941
>> As long as it
launches in that period

1119
00:55:11,974 --> 00:55:14,777
of a month and a half, yes,
November 26 is the date.

1120
00:55:14,810 --> 00:55:16,012
>> Okay, thank you.
>> Mm-hmm.

1121
00:55:19,715 --> 00:55:23,053
>> Viking landed

1122
00:55:24,787 --> 00:55:28,725
in June 1976.

1123
00:55:28,758 --> 00:55:33,163

Now, this would be 42
years later practically.

1124
00:55:34,897 --> 00:55:39,836
And I remember Al Hepps was
talking about the Viking.

1125
00:55:43,906 --> 00:55:47,643
It was the first time, and
I'm sure that few people here

1126
00:55:47,676 --> 00:55:48,945
have seen him like that.

1127
00:55:50,045 --> 00:55:52,148
I'd like to know
what the technology,

1128
00:55:54,116 --> 00:55:59,022
how much it evolved from
the Viking until InSight

1129
00:56:00,790 --> 00:56:02,091
and what do you expect?

1130
00:56:02,124 --> 00:56:04,761
And you have a 42 years

1131
00:56:04,794 --> 00:56:08,898
and we had different missions
in between as you know,

1132
00:56:10,032 --> 00:56:13,936
and what is the technology?

1133
00:56:13,969 --> 00:56:15,037
And I don't know.

1134
00:56:15,070 --> 00:56:17,707

I mean, I wish Al
Hepps was here today

1135
00:56:17,740 --> 00:56:22,712
to see the improvement.

1136
00:56:23,779 --> 00:56:24,881
The big improvement
on that thing.

1137
00:56:24,914 --> 00:56:27,950
And what you'll
expect in the future.

1138
00:56:27,983 --> 00:56:31,821
>> Oh, there's so much that
has changed in our ability

1139
00:56:31,854 --> 00:56:35,759
to do planetary or
any space mission.

1140
00:56:36,959 --> 00:56:40,096
For instance, the seismograms
that SEIS will record,

1141
00:56:40,129 --> 00:56:41,831
we wouldn't be able to see,

1142
00:56:41,864 --> 00:56:43,966
we can't even now send those
back in their entirety.

1143
00:56:43,999 --> 00:56:46,936
We have to compress that
data and send it back

1144
00:56:47,937 --> 00:56:48,938
a bit at a time.

1145
00:56:48,971 --> 00:56:52,041
And so the intelligence
in the lander,

1146
00:56:52,074 --> 00:56:54,911
in the SEIS electronics
and the lander itself

1147
00:56:54,944 --> 00:56:59,615
can look at those signals,
pick out interesting events,

1148
00:56:59,648 --> 00:57:00,783
compress them and
send them home.

1149
00:57:00,816 --> 00:57:04,087
And that computing power
is one major advance.

1150
00:57:05,921 --> 00:57:08,724
So Viking had a
seismometer, did you know?

1151
00:57:08,757 --> 00:57:09,992
There was a
seismometer on Viking.

1152
00:57:10,025 --> 00:57:12,028
One of them, because there
were two Viking landers,

1153
00:57:12,061 --> 00:57:13,796
one of them did not work.

1154
00:57:13,829 --> 00:57:16,833
Its launch lock mechanism,
I don't think, disengaged

1155

00:57:16,866 --> 00:57:18,801
and so it never saw anything.

1156
00:57:18,834 --> 00:57:22,905
The other one saw things,
but it was pretty much

1157
00:57:22,938 --> 00:57:25,675
just the lander
shaking in the wind.

1158
00:57:25,708 --> 00:57:28,077
It made it all the way to Mars
and never got off the deck

1159
00:57:28,110 --> 00:57:29,946
because they didn't
actually have a way

1160
00:57:29,979 --> 00:57:32,715
to deploy that seismometer
onto the ground.

1161
00:57:32,748 --> 00:57:36,886
And so the principal
investigator of
InSight, Bruce Banerdt,

1162
00:57:36,919 --> 00:57:39,956
has been advocating
for a seismo,

1163
00:57:39,989 --> 00:57:41,824
and many geophysicists
have been doing this,

1164
00:57:41,857 --> 00:57:43,993
advocating for a seismometer

1165
00:57:44,026 --> 00:57:46,729

and other geophysical
instruments to go to Mars

1166
00:57:46,762 --> 00:57:48,064
for a very long time.

1167
00:57:48,097 --> 00:57:51,968
And we now have an
instrument which is as good

1168
00:57:52,001 --> 00:57:54,136
as the best
seismometers on Earth.

1169
00:57:54,169 --> 00:57:55,738
And that's just two examples.

1170
00:57:55,771 --> 00:57:57,673
Computing power and
the seismometer.

1171
00:57:57,706 --> 00:57:59,842
So many other things
also have improved.

1172
00:57:59,875 --> 00:58:04,914
And for the future,
I would expect that

1173
00:58:06,048 --> 00:58:07,850
it's gonna be a long
time before anything

1174
00:58:07,883 --> 00:58:10,653
about exploration
is plug and play

1175
00:58:10,686 --> 00:58:12,021
and it may never be so.

1176
00:58:12,054 --> 00:58:13,789
We're never gonna get
to the point of having

1177
00:58:13,822 --> 00:58:15,958
a Star Trek tricorder and
just be able to do everything

1178
00:58:15,991 --> 00:58:17,693
with one little device.

1179
00:58:17,726 --> 00:58:22,699
We have to design things for
the specific environment,

1180
00:58:23,766 --> 00:58:24,967
the specific constraints
of the mission,

1181
00:58:25,000 --> 00:58:28,704
and in particular, the
specific science questions.

1182
00:58:28,737 --> 00:58:30,706
Because every time
we design a mission

1183
00:58:30,739 --> 00:58:31,807
and we send it somewhere

1184
00:58:31,840 --> 00:58:33,943
and we get the data to
answer those questions,

1185
00:58:33,976 --> 00:58:35,077
we get more questions.

1186
00:58:35,110 --> 00:58:36,813
That's what science is about.

1187
00:58:38,914 --> 00:58:43,887
>> The day Viking landed
was my first day at JPL.

1188
00:58:44,720 --> 00:58:44,888
Starting at JPL.

1189
00:58:45,955 --> 00:58:47,757
>> Very exciting.
>> Yes.

1190
00:58:47,790 --> 00:58:49,926
[applauding]

1191
00:58:49,959 --> 00:58:52,828
>> My first day at
JPL was about 20 days

1192
00:58:52,861 --> 00:58:57,834
before Phoenix landed, so
it's a great way to start.

1193
00:58:58,767 --> 00:58:59,101
>> Man: I'm older than you.

1194
00:58:59,134 --> 00:59:01,638
[laughter]

1195
00:59:02,905 --> 00:59:07,677
>> You mentioned that you
expect to see seismic response

1196
00:59:07,710 --> 00:59:11,013
from the passage
of Phobos overhead,

1197
00:59:11,046 --> 00:59:14,717
and that's really amazing

considering how small it is.

1198
00:59:14,750 --> 00:59:19,689
And so my question is, I've
never quite understood,

1199
00:59:19,722 --> 00:59:22,692
yes, you have Phobos
as this little rock

1200
00:59:22,725 --> 00:59:25,928
and it could have
been an asteroid,

1201
00:59:25,961 --> 00:59:28,898
but it's in a more or
less circular orbit

1202
00:59:28,931 --> 00:59:33,903
and what do we speculate
on how it got there?

1203
00:59:35,004 --> 00:59:37,907
And I've also heard
some rumors that

1204
00:59:37,940 --> 00:59:39,709
Phobos may not be around

1205
00:59:39,742 --> 00:59:41,844
too many million
years in the future.

1206
00:59:41,877 --> 00:59:43,646
And maybe you could say
something about that?

1207
00:59:43,679 --> 00:59:48,651
>> So when an object is
in an elliptical orbit

1208
00:59:49,118 --> 00:59:51,721
and when an object is spinning,

1209
00:59:51,754 --> 00:59:53,856
the gravity of the
planet it's orbiting

1210
00:59:53,889 --> 00:59:56,025
can pull and tug on that object.

1211
00:59:56,058 --> 00:59:59,128
So Phobos itself has
been spun and turned

1212
00:59:59,161 --> 01:00:01,797
in different ways
by Mars' gravity.

1213
01:00:01,830 --> 01:00:06,803
And this movement of the
object isn't just a rigid body.

1214
01:00:08,037 --> 01:00:10,740
Phobos is big and rock is
flexible on those scales

1215
01:00:10,773 --> 01:00:13,042
and that dissipates energy.

1216
01:00:13,075 --> 01:00:15,845
Energy gets dissipated as heat.

1217
01:00:15,878 --> 01:00:19,782
That energy actually
comes from Phobos' orbit.

1218
01:00:19,815 --> 01:00:22,018
An elliptical orbit has more

energy than a circular one.

1219
01:00:22,051 --> 01:00:25,021
So over time, as the
energy of the orbit

1220
01:00:25,054 --> 01:00:28,691
gets dissipated away
as title heating

1221
01:00:28,724 --> 01:00:32,094
both in Mars and in Phobos,
the orbit circularizes.

1222
01:00:32,127 --> 01:00:34,797
And it also decays with time.

1223
01:00:34,830 --> 01:00:36,866
And this is what
your second point.

1224
01:00:36,899 --> 01:00:39,702
Over time this captured asteroid

1225
01:00:39,735 --> 01:00:41,737
which is probably
the origin of Phobos

1226
01:00:41,770 --> 01:00:44,774
will approach Mars
closer and closer,

1227
01:00:44,807 --> 01:00:47,743
and when it gets close
enough, it'll pass the point.

1228
01:00:47,776 --> 01:00:50,046
A certain point where
the tidal forces

1229
01:00:50,079 --> 01:00:52,982
overcome the
strength of the rock

1230
01:00:53,015 --> 01:00:55,017
and Phobos will break up.

1231
01:00:55,050 --> 01:00:58,120
And probably, for a few
million years at least,

1232
01:00:58,153 --> 01:01:00,656
be a ring around Mars.

1233
01:01:00,689 --> 01:01:01,657
>> Man: Cool.

1234
01:01:01,690 --> 01:01:01,991
Thank you.
>> Mm-hmm.

1235
01:01:04,793 --> 01:01:06,962
>> Hi, thanks for the lecture.

1236
01:01:06,995 --> 01:01:08,097
I came with my dad.

1237
01:01:08,130 --> 01:01:09,031
He's in the front.

1238
01:01:09,064 --> 01:01:09,932
He's a big nerd.

1239
01:01:11,867 --> 01:01:14,770
This might be opening
up a huge can of worms,

1240
01:01:14,803 --> 01:01:17,673

but I was just kind of wondering
about the design process

1241
01:01:17,706 --> 01:01:20,910
for you guys and how
collaborated in prototypes

1242
01:01:20,943 --> 01:01:23,813
and if something didn't work
how you pivoted from there.

1243
01:01:24,913 --> 01:01:27,116
>> That's basically
what JPL does

1244
01:01:27,149 --> 01:01:29,785
is solve those
kinds of problems.

1245
01:01:29,818 --> 01:01:32,021
And for every kind of problem,

1246
01:01:32,054 --> 01:01:33,856
and I'm talking
big categories here

1247
01:01:33,889 --> 01:01:37,827
whether it's developing
a communication system

1248
01:01:37,860 --> 01:01:40,096
or like one problem,
the seismometer.

1249
01:01:40,129 --> 01:01:44,100
The key components
of the seismo is VBB

1250
01:01:44,133 --> 01:01:47,103
are inside an

evacuated container.

1251
01:01:47,136 --> 01:01:49,672
Even Mars' thin
atmosphere is too much

1252
01:01:49,705 --> 01:01:50,840
for these really
sensitive devices.

1253
01:01:50,873 --> 01:01:53,709
They have to be in a
vacuum to work properly.

1254
01:01:53,742 --> 01:01:56,779
We had trouble making
that vacuum stay there

1255
01:01:56,812 --> 01:01:59,915
'cause it has to be there when
we assemble the spacecraft,

1256
01:01:59,948 --> 01:02:01,917
make it all the way to
Mars and stay that way

1257
01:02:01,950 --> 01:02:03,986
for at least two Earth years.

1258
01:02:04,019 --> 01:02:05,721
We had problems, we had leaks,

1259
01:02:05,754 --> 01:02:07,957
we had things we
had to figure out,

1260
01:02:07,990 --> 01:02:10,793
and there was lots of ways
that we approach that problem.

1261
01:02:10,826 --> 01:02:12,795
We created prototypes
in the lab,

1262
01:02:12,828 --> 01:02:15,131
we built things, and
then we cut them in half

1263
01:02:15,164 --> 01:02:19,068
and destroyed them to
understand why they failed

1264
01:02:19,101 --> 01:02:20,803
or why they worked.

1265
01:02:20,836 --> 01:02:22,705
We tried different solutions.

1266
01:02:22,738 --> 01:02:25,674
We formed teams of
people both here at JPL

1267
01:02:25,707 --> 01:02:27,109
and with our
international partners.

1268
01:02:27,142 --> 01:02:29,678
People whose only
job, this Tiger teams,

1269
01:02:29,711 --> 01:02:31,747
their only job is to
focus on that problem

1270
01:02:31,780 --> 01:02:33,116
because it's a big problem.

1271
01:02:34,983 --> 01:02:36,719
And we designed it first.

1272
01:02:36,752 --> 01:02:38,888
We didn't expect it to leak,
but it turns out that it did.

1273
01:02:38,921 --> 01:02:41,757
So there's a lot of
times where things pop up

1274
01:02:41,790 --> 01:02:43,793
that you don't really expect.

1275
01:02:43,826 --> 01:02:48,798
And learning lessons from
previous things, having experts,

1276
01:02:49,898 --> 01:02:51,967
people with their own
internal knowledge

1277
01:02:52,000 --> 01:02:53,736
and then the knowledge
of the institution,

1278
01:02:53,769 --> 01:02:57,106
those are all the things
that make this possible.

1279
01:02:59,741 --> 01:03:02,945
And as best we can be possible
on time and within budget.

1280
01:03:02,978 --> 01:03:05,047
[laughter]

1281
01:03:05,080 --> 01:03:06,849
>> And I was just wondering
how long you worked

1282

01:03:06,882 --> 01:03:07,950
on this project for?

1283
01:03:07,983 --> 01:03:09,084
>> Troy: I'm sorry?

1284
01:03:09,117 --> 01:03:10,119
>> How long you worked
on that project for?

1285
01:03:10,152 --> 01:03:11,854
I was just wondering.

1286
01:03:11,887 --> 01:03:14,156
>> I've been part of InSight
since it was a proposal.

1287
01:03:14,189 --> 01:03:17,760
When it was the Discovery
proposal in 2010,

1288
01:03:17,793 --> 01:03:19,962
so about seven years I've
been working on this.

1289
01:03:19,995 --> 01:03:24,066
First as a science
implementation engineer

1290
01:03:24,099 --> 01:03:27,903
sort of working with the
whole payload section,

1291
01:03:27,936 --> 01:03:30,072
and then focusing
more down on HP3.

1292
01:03:30,105 --> 01:03:32,908
And I've been working with
the German Space Agency

1293
01:03:32,941 --> 01:03:36,912
and serving as a liaison
between them and JPL

1294
01:03:36,945 --> 01:03:38,981
and Lockheed Martin who
built the spacecraft

1295
01:03:39,014 --> 01:03:40,983
for about six years now.

1296
01:03:41,984 --> 01:03:43,019
>> Thank you.
>> Mm-hmm.

1297
01:03:44,853 --> 01:03:46,689
>> Hi, thank you
for the lecture.

1298
01:03:46,722 --> 01:03:49,792
How well would these
instruments work on an asteroid

1299
01:03:49,825 --> 01:03:52,028
or a smaller body
with less gravity?

1300
01:03:52,995 --> 01:03:53,863
>> Yeah.

1301
01:03:55,063 --> 01:03:59,735
SEIS might work a lot
better in some respects

1302
01:04:00,802 --> 01:04:01,904
on a smaller body.

1303
01:04:03,872 --> 01:04:05,841

Well, I wanna take that back.

1304
01:04:05,874 --> 01:04:07,710
I don't actually know if
it work better or worse,

1305
01:04:07,743 --> 01:04:09,011
but there would be
challenges to doing it

1306
01:04:09,044 --> 01:04:10,746
'cause you need,

1307
01:04:10,779 --> 01:04:13,015
the SEIS has to have a good
coupling to the ground.

1308
01:04:13,048 --> 01:04:16,719
On Mars, the gravity
is enough to do that

1309
01:04:16,752 --> 01:04:19,855
even on a sandy
or rocky surface.

1310
01:04:19,888 --> 01:04:23,893
On an asteroid, you've
got the barest movement

1311
01:04:23,926 --> 01:04:25,961
and you'll start floating away

1312
01:04:25,994 --> 01:04:27,129
or bouncing around the surface

1313
01:04:27,162 --> 01:04:30,866
like the Philae
lander on Rosetta did.

1314

01:04:30,899 --> 01:04:32,101
You need to be
anchored to the ground.

1315
01:04:32,134 --> 01:04:33,836
Once you've solved that problem,

1316
01:04:33,869 --> 01:04:35,771
you can probably get some
really interesting data

1317
01:04:35,804 --> 01:04:37,006
from a seismometer.

1318
01:04:37,039 --> 01:04:39,975
And the heat flow
probe definitely useful

1319
01:04:40,008 --> 01:04:41,911
on a comet or asteroid.

1320
01:04:43,712 --> 01:04:45,714
The Rosetta mission
also included a
penetrator of its own.

1321
01:04:45,747 --> 01:04:47,750
It was a different
design, different shape,

1322
01:04:47,783 --> 01:04:50,152
but it was designed to
measure thermal conductivity.

1323
01:04:50,185 --> 01:04:52,922
The mole could potentially
be used on the moon

1324
01:04:52,955 --> 01:04:56,125
and could potentially be

used on an asteroid or comet.

1325
01:04:56,158 --> 01:04:58,027
But again, you'll have to
solve that anchoring problem,

1326
01:04:58,060 --> 01:05:01,664
otherwise it's gonna knock
itself away from the surface.

1327
01:05:01,697 --> 01:05:05,834
>> How about standardizing
these instruments

1328
01:05:05,867 --> 01:05:07,970
so that they could
be less expensive

1329
01:05:08,003 --> 01:05:11,807
and used on other bodies
or on other missions?

1330
01:05:13,875 --> 01:05:16,145
>> Standardization
might be possible

1331
01:05:16,178 --> 01:05:20,015
if you had a standard
set of purpose.

1332
01:05:20,048 --> 01:05:21,750
Of goals.

1333
01:05:21,783 --> 01:05:23,919
If you're investigating
different scientific questions

1334
01:05:23,952 --> 01:05:27,122
on different kinds of objects,
you're probably going to need

1335
01:05:27,155 --> 01:05:28,824
to go back to the drawing board

1336
01:05:28,857 --> 01:05:31,060
at least for some of
the major components.

1337
01:05:31,093 --> 01:05:33,762
And certainly, the
exterior pieces

1338
01:05:33,795 --> 01:05:36,131
of how it actually
interacts with the surface.

1339
01:05:36,164 --> 01:05:38,834
The seismometer, it's,

1340
01:05:40,902 --> 01:05:42,905
there are probably aspects
of it that could be used

1341
01:05:42,938 --> 01:05:45,975
on anybody, but getting
the instrument there

1342
01:05:46,008 --> 01:05:47,810
and taking the data is
only part of the story.

1343
01:05:47,843 --> 01:05:49,912
Being able to interpret
it is another.

1344
01:05:49,945 --> 01:05:54,683
So I would say it's possible,

1345
01:05:54,716 --> 01:05:55,684

but I don't think it's likely.

1346
01:05:55,717 --> 01:05:56,819
At least not anytime soon.

1347
01:05:56,852 --> 01:06:01,724
We don't have any kind
of assembly line process

1348
01:06:02,724 --> 01:06:04,126
for this sort of
instrumentation.

1349
01:06:04,159 --> 01:06:07,696
>> Yeah, it just seems
like these are the tools

1350
01:06:07,729 --> 01:06:09,131
to look at the interior.

1351
01:06:09,164 --> 01:06:12,701
Like a camera for the interior.

1352
01:06:12,734 --> 01:06:16,872
So like being able to
come up with a camera

1353
01:06:16,905 --> 01:06:20,109
that might work
on asteroids, say,

1354
01:06:20,142 --> 01:06:23,679
so you develop a low
gravity set of instruments

1355
01:06:23,712 --> 01:06:26,982
that you could put on multiple
bodies or multiple asteroids,

1356

01:06:27,015 --> 01:06:29,718
and it'll all be
the same instrument.

1357
01:06:29,751 --> 01:06:34,089
>> Even cameras for an orbiter,
say, are not standard things.

1358
01:06:34,122 --> 01:06:37,926
Depending on what frequencies
of light they're looking at

1359
01:06:37,959 --> 01:06:40,996
and how long they have to
stare at a particular place

1360
01:06:41,029 --> 01:06:43,766
and how much light
they have to collect,

1361
01:06:43,799 --> 01:06:46,769
whether they're looking at
Mars or Titan or the Earth,

1362
01:06:46,802 --> 01:06:49,938
there's not a one-stop
shop for even something

1363
01:06:49,971 --> 01:06:51,673
like a camera.

1364
01:06:51,706 --> 01:06:54,777
So like this seismometer, if
you wanted to put it on Venus,

1365
01:06:54,810 --> 01:06:55,911
you couldn't do it.

1366
01:06:55,944 --> 01:06:57,880
It would not last long enough.

1367
01:06:57,913 --> 01:06:59,715
You'd have to build
it out of something

1368
01:06:59,748 --> 01:07:02,651
that won't melt in
700-degree temperatures.

1369
01:07:02,684 --> 01:07:04,787
So you would have
to build it out of,

1370
01:07:04,820 --> 01:07:06,889
you'll make circuits out of
diamond or something like that.

1371
01:07:06,922 --> 01:07:07,990
Maybe it's physically possible,

1372
01:07:08,023 --> 01:07:10,125
but it's certainly not
what this thing can do.

1373
01:07:10,158 --> 01:07:11,860
Could you send it to Mercury?

1374
01:07:11,893 --> 01:07:12,828
Yeah.

1375
01:07:12,861 --> 01:07:14,096
Could you send it to the Moon?

1376
01:07:14,129 --> 01:07:15,998
Yeah, but you'd have to get
it there in a different way.

1377
01:07:16,031 --> 01:07:17,066
>> Thank you.

>> Mm-hmm.

1378
01:07:21,736 --> 01:07:22,738
>> Good evening.

1379
01:07:22,771 --> 01:07:23,839
Two questions.

1380
01:07:23,872 --> 01:07:26,875
One, is InSight
capable of detecting

1381
01:07:26,908 --> 01:07:28,144
the presence of liquid water?

1382
01:07:29,978 --> 01:07:32,948
>> Hmm, I would say no.

1383
01:07:35,750 --> 01:07:37,920
Where it's landing
on the equator,

1384
01:07:37,953 --> 01:07:41,090
we don't expect there to be
any subsurface ice for certain.

1385
01:07:41,123 --> 01:07:42,825
At least nothing stable.

1386
01:07:42,858 --> 01:07:46,895
And the liquid water
or the places on Mars

1387
01:07:46,928 --> 01:07:48,864
where there might
be liquid water

1388
01:07:48,897 --> 01:07:51,967
like salty brines that

form slope streaks,

1389
01:07:52,000 --> 01:07:53,903
that's nowhere near
where we're going.

1390
01:07:55,170 --> 01:07:58,140
And I think the abundance
of water on Mars is too low

1391
01:07:58,173 --> 01:08:01,610
for it to show up in any
kind of seismic signal.

1392
01:08:01,643 --> 01:08:04,746
And it would certainly
be a big surprise if,

1393
01:08:04,779 --> 01:08:06,748
it would show up in
conductivity data

1394
01:08:06,781 --> 01:08:08,717
'cause if water
is in the ground,

1395
01:08:08,750 --> 01:08:10,119
the conductivity
goes up very quickly

1396
01:08:10,152 --> 01:08:12,921
'cause you've got a
lot of that liquid

1397
01:08:12,954 --> 01:08:14,690
making contact
between particles.

1398
01:08:14,723 --> 01:08:18,727
So if we saw a really

surprisingly high
number from HP3,

1399
01:08:18,760 --> 01:08:20,729
we'd have to come up with
some explanation for that.

1400
01:08:20,762 --> 01:08:22,731
And water could
be an explanation,

1401
01:08:22,764 --> 01:08:24,733
but I don't think it's likely.

1402
01:08:24,766 --> 01:08:27,970
>> Okay, and number two,
is how will the science

1403
01:08:28,003 --> 01:08:30,673
collected from InSight
affect future missions?

1404
01:08:31,706 --> 01:08:32,074
>> Wow.

1405
01:08:33,708 --> 01:08:36,044
As I mentioned before,
every question we answer

1406
01:08:36,077 --> 01:08:37,846
raises new questions.

1407
01:08:37,879 --> 01:08:42,117
And so there might be a
desire to go back to Mars

1408
01:08:42,150 --> 01:08:46,822
with a different or additional
suite of instruments

1409
01:08:46,855 --> 01:08:48,824
to help answer some question

1410
01:08:48,857 --> 01:08:51,693
that we don't even
have at the moment.

1411
01:08:51,726 --> 01:08:53,128
And possibly, these instruments

1412
01:08:53,161 --> 01:08:54,897
as the previous
gentleman alluded to,

1413
01:08:54,930 --> 01:08:57,099
they could be used
on other objects.

1414
01:08:57,132 --> 01:08:59,001
If these are
particularly successful,

1415
01:08:59,034 --> 01:09:02,804
maybe mission where the French
or German Space Agencies

1416
01:09:02,837 --> 01:09:05,107
partner with to
Mercury, for instance,

1417
01:09:05,140 --> 01:09:10,045
would want to bring some
redos of these instruments

1418
01:09:10,078 --> 01:09:12,948
and use them again to
answer similar questions,

1419
01:09:12,981 --> 01:09:15,751

but different because
the bodies are different.

1420
01:09:16,785 --> 01:09:18,020
>> Thank you very much.
>> Mm-hmm.

1421
01:09:19,788 --> 01:09:20,756
>> Hello.

1422
01:09:20,789 --> 01:09:22,691
Thank you for the lecture.

1423
01:09:22,724 --> 01:09:24,727
So for the seismometers,

1424
01:09:27,095 --> 01:09:31,000
my question is what if
you don't find Marsquakes?

1425
01:09:32,133 --> 01:09:34,836
What if it's just from
the meteorites itself,

1426
01:09:34,869 --> 01:09:36,838
not from the planet?

1427
01:09:36,871 --> 01:09:39,675
>> That itself, a zero result,

1428
01:09:39,708 --> 01:09:41,710
if your instrument
is working properly

1429
01:09:41,743 --> 01:09:43,845
and you don't see the
things you expect,

1430
01:09:43,878 --> 01:09:45,981

that's still information.

1431
01:09:46,014 --> 01:09:49,685
That's still something
that you need to explain.

1432
01:09:49,718 --> 01:09:52,654
And it's gonna take a
lot of deep thinking

1433
01:09:52,687 --> 01:09:56,892
to understand why
Mars is so quiet.

1434
01:09:56,925 --> 01:10:00,095
But this is one of the reasons
why it's good to have Phobos

1435
01:10:00,128 --> 01:10:03,098
and have that atmospheric
excitation in meteorite impacts

1436
01:10:03,131 --> 01:10:04,099
because we know those happen

1437
01:10:04,132 --> 01:10:06,135
and we know we'll see something.

1438
01:10:07,869 --> 01:10:12,808
But if Mars were that quiet,
that would be big news.

1439
01:10:13,842 --> 01:10:15,110
>> Okay, thank you.
>> Mm-hmm.

1440
01:10:19,881 --> 01:10:22,884
We have some
questions from folks

1441
01:10:22,917 --> 01:10:26,655
that are listening
to the simulcast.

1442
01:10:26,688 --> 01:10:30,025
Manu asks, how did you
select Elysium Planitia

1443
01:10:30,058 --> 01:10:31,060
as a landing site?

1444
01:10:33,061 --> 01:10:36,031
So as I mentioned,
SEIS as a seismometer

1445
01:10:36,064 --> 01:10:39,101
looking at Mars as a planet,
can do its job from anywhere.

1446
01:10:39,134 --> 01:10:42,738
And HP3 once broken up ground.

1447
01:10:42,771 --> 01:10:44,740
But there are other
constraints for the lander.

1448
01:10:44,773 --> 01:10:46,141
It is solar powered,
for instance.

1449
01:10:46,174 --> 01:10:49,811
It doesn't have a
radioactive power source

1450
01:10:49,844 --> 01:10:50,812
like Curiosity does.

1451
01:10:50,845 --> 01:10:52,781
So it has to have the sun,

1452
01:10:52,814 --> 01:10:55,717
and it's supposed to operate
for a full Mars year.

1453
01:10:55,750 --> 01:10:58,053
And we might get dust storms,

1454
01:10:58,086 --> 01:10:59,755
dust settling on
the solar panels.

1455
01:10:59,788 --> 01:11:01,723
Things that would make
them weaken over time.

1456
01:11:01,756 --> 01:11:05,127
So we needed to pick a location
where we were going to have

1457
01:11:05,160 --> 01:11:07,829
plenty of sunlight
all year round.

1458
01:11:07,862 --> 01:11:09,865
So we went somewhere
near the equator.

1459
01:11:11,099 --> 01:11:14,136
Also, since we're coming
down on that heat shield

1460
01:11:14,169 --> 01:11:19,141
and parachute system, we need
to be low enough in elevation

1461
01:11:20,775 --> 01:11:21,977
that the atmosphere
thin though it is,

1462
01:11:22,010 --> 01:11:24,112
it's still thick enough for
that parachute to do its job.

1463
01:11:24,145 --> 01:11:27,983
If we landed in the highland
regions, a parachute would be

1464
01:11:28,016 --> 01:11:30,819
not working properly by
the time we hit the ground.

1465
01:11:32,721 --> 01:11:34,156
There are a few other
places along the equator

1466
01:11:34,189 --> 01:11:37,059
that would meet that
elevation requirement,

1467
01:11:37,092 --> 01:11:39,995
but they're really windy and
we don't want that either.

1468
01:11:40,028 --> 01:11:42,864
We don't wanna land in areas
that are particularly dusty,

1469
01:11:42,897 --> 01:11:45,067
we don't wanna land in
areas that are really rocky.

1470
01:11:45,100 --> 01:11:47,736
And you add all of these
constraints together,

1471
01:11:47,769 --> 01:11:49,771
there actually aren't
that many places on Mars

1472
01:11:49,804 --> 01:11:51,039
that fit the bill.

1473
01:11:51,072 --> 01:11:54,743
So this is the reason why
Elysium Planitia was chosen,

1474
01:11:54,776 --> 01:11:58,714
and there's a whole process,
a whole set of geologists

1475
01:11:58,747 --> 01:12:00,749
working here at JPL
led by Matt Golombek

1476
01:12:00,782 --> 01:12:05,821
who have worked to verify that
the landing site we've chosen

1477
01:12:06,788 --> 01:12:07,690
is the best place for us.

1478
01:12:08,990 --> 01:12:13,061
And then Michael asks, what is
the tip of the mole made of?

1479
01:12:13,094 --> 01:12:14,896
It's made of titanium.

1480
01:12:14,929 --> 01:12:17,733
And the hammer on
the inside is heavy

1481
01:12:17,766 --> 01:12:18,867
and it's made of tungsten.

1482
01:12:22,003 --> 01:12:25,674
Sadine asks, after the data
are sent back to Earth,

1483
01:12:25,707 --> 01:12:28,910
how long before scientists
around the world can use them?

1484
01:12:28,943 --> 01:12:30,112
NASA has rules about this.

1485
01:12:30,145 --> 01:12:32,848
NASA is a publicly-funded
institution,

1486
01:12:32,881 --> 01:12:35,083
and all the data we
take from every mission

1487
01:12:35,116 --> 01:12:36,952
becomes publicly available.

1488
01:12:36,985 --> 01:12:40,021
All the raw information that
comes down from the satellites

1489
01:12:40,054 --> 01:12:42,891
is put out there
for everyone to use,

1490
01:12:42,924 --> 01:12:44,993
but after a short embargo.

1491
01:12:45,026 --> 01:12:47,729
There's a short period
of time where the data

1492
01:12:47,762 --> 01:12:49,965
are the province
of the scientists

1493
01:12:49,998 --> 01:12:51,933

that have worked
on this mission.

1494
01:12:51,966 --> 01:12:53,969
Because in the scientific world,

1495
01:12:54,002 --> 01:12:55,904
getting first
access to that data

1496
01:12:55,937 --> 01:12:57,873
and being able to
publish your results

1497
01:12:57,906 --> 01:13:01,042
is very important thing for
the people who have spent

1498
01:13:01,075 --> 01:13:03,779
so many years working
on this project.

1499
01:13:03,812 --> 01:13:05,814
So they have a period of time

1500
01:13:05,847 --> 01:13:08,083
where they have sole
access to the data,

1501
01:13:08,116 --> 01:13:10,018
but NASA has rules
that this data

1502
01:13:10,051 --> 01:13:12,888
must become publicly
available in a short period.

1503
01:13:12,921 --> 01:13:15,824
I think at most,
it's six months,

1504
01:13:15,857 --> 01:13:17,058
but you have to justify that.

1505
01:13:17,091 --> 01:13:19,728
For InSight, I think it
will be much less than that.

1506
01:13:21,095 --> 01:13:23,064
And finally, Los Angeles asks,

1507
01:13:23,097 --> 01:13:25,033
what instruments
were considered,

1508
01:13:25,066 --> 01:13:27,035
but didn't make
the final payload?

1509
01:13:30,171 --> 01:13:33,875
>> It turns out that InSight
has been the brainchild

1510
01:13:33,908 --> 01:13:36,711
of our principal investigator
for quite some time,

1511
01:13:36,744 --> 01:13:38,713
not necessarily
with the same name

1512
01:13:38,746 --> 01:13:42,050
and not necessarily with the
same complement of instruments.

1513
01:13:42,083 --> 01:13:47,055
As it has been proposed in
different guises in the past,

1514

01:13:48,756 --> 01:13:51,126
this mission has had a different
complement of instruments

1515
01:13:51,159 --> 01:13:52,727
as part of its payload.

1516
01:13:52,760 --> 01:13:54,763
Sometimes more elaborate.

1517
01:13:54,796 --> 01:13:56,965
There was a previous
version, I think in 2006,

1518
01:13:56,998 --> 01:13:58,099
that had two moles,

1519
01:13:58,132 --> 01:14:00,035
just in case one of
them ran into a rock.

1520
01:14:01,970 --> 01:14:05,674
But as this mission has evolved,

1521
01:14:05,707 --> 01:14:07,976
so we've made choices about

1522
01:14:08,009 --> 01:14:09,978
what makes it into the
mission and what doesn't.

1523
01:14:10,011 --> 01:14:11,680
So these instruments,

1524
01:14:11,713 --> 01:14:14,115
what you see here is pretty
much what was proposed

1525
01:14:14,148 --> 01:14:17,786

when the mission first
went to NASA in 2010.

1526
01:14:17,819 --> 01:14:19,120
There are a few
additional things.

1527
01:14:19,153 --> 01:14:21,857
We added, I think, a
very sensitive barometer

1528
01:14:21,890 --> 01:14:24,659
to look for that
atmospheric excitation

1529
01:14:24,692 --> 01:14:26,027
and we added a magnetometer

1530
01:14:26,060 --> 01:14:28,096
to determine the local
magnetic characters.

1531
01:14:28,129 --> 01:14:30,766
So these are small add pieces.

1532
01:14:32,100 --> 01:14:35,070
And you'll never do
just anything with this.

1533
01:14:35,103 --> 01:14:37,072
You never just add a magnet,

1534
01:14:37,105 --> 01:14:39,107
or you never just put
a piece of tape there.

1535
01:14:39,140 --> 01:14:41,009
It's always complicated.

1536

01:14:41,042 --> 01:14:45,847
So there wasn't really
a selection process

1537
01:14:45,880 --> 01:14:47,682
for the instruments.

1538
01:14:47,715 --> 01:14:49,918
Now other missions
like Curiosity

1539
01:14:49,951 --> 01:14:53,688
and the mission similar
to it, Mars 2020,

1540
01:14:53,721 --> 01:14:55,891
which we'll be launching
in 2020, we hope,

1541
01:14:57,125 --> 01:14:59,995
did have a competitive
process for the payloads.

1542
01:15:00,028 --> 01:15:01,863
NASA put out a call that said,

1543
01:15:01,896 --> 01:15:06,034
here are the broad scientific
goals we want to address.

1544
01:15:06,067 --> 01:15:07,736
Feel free to propose
an instrument

1545
01:15:07,769 --> 01:15:08,904
that addresses one
or more of them,

1546
01:15:08,937 --> 01:15:10,872
and then that is competed.

1547
01:15:10,905 --> 01:15:13,909
The mission itself was
not, but the payloads were.

1548
01:15:13,942 --> 01:15:15,978
InSight didn't quite
follow that paradigm.

1549
01:15:18,980 --> 01:15:21,116
If there aren't
any more questions?

1550
01:15:21,149 --> 01:15:22,751
Sir?

1551
01:15:22,784 --> 01:15:23,985
Please.

1552
01:15:24,018 --> 01:15:28,790
>> Have you thought about
making an army of bees

1553
01:15:29,924 --> 01:15:31,126
and sending that
collect more data

1554
01:15:31,159 --> 01:15:34,862
as a faster way of collecting
data and making that thing

1555
01:15:36,030 --> 01:15:38,934
sort of like a docking
charging device?

1556
01:15:40,101 --> 01:15:45,073
>> Well, flying on Mars
is a difficult prospect.

1557

01:15:46,708 --> 01:15:47,776
It's got a really
thin atmosphere.

1558
01:15:49,010 --> 01:15:52,781
Nonetheless, we are actually
working on a Mars helicopter.

1559
01:15:52,814 --> 01:15:54,983
It's like a double-rotor drone

1560
01:15:55,016 --> 01:15:58,720
that may be going
on the 2020 rover.

1561
01:15:58,753 --> 01:16:02,958
We don't have a way of
producing very small moats

1562
01:16:02,991 --> 01:16:08,030
sort of individually
addressed sensors

1563
01:16:09,163 --> 01:16:10,865
that can move around
the surface of Mars.

1564
01:16:10,898 --> 01:16:12,801
It would be great to get
more data, but again,

1565
01:16:12,834 --> 01:16:15,704
the seismometer, that's about
as small as we can make it.

1566
01:16:15,737 --> 01:16:18,940
We don't have a device
that's that sensitive

1567
01:16:18,973 --> 01:16:20,675

that can be made so small.

1568
01:16:21,909 --> 01:16:23,812
>> And one more thing.
>> Mm-hmm.

1569
01:16:23,845 --> 01:16:25,880
>> Have you thought about
sending water to Mars

1570
01:16:25,913 --> 01:16:29,784
and see how it reacts
in like salt water

1571
01:16:29,817 --> 01:16:31,987
or like it's like
how it reacts to a...

1572
01:16:33,755 --> 01:16:35,123
>> I know the answer to
this question really well

1573
01:16:35,156 --> 01:16:37,892
'cause I spent six years
of my life building Mars

1574
01:16:37,925 --> 01:16:40,062
in walk in freezers when
I was a grad student.

1575
01:16:41,829 --> 01:16:45,934
I studied the growth
and evolution of
subsurface ice on Mars

1576
01:16:45,967 --> 01:16:50,872
and the whole idea behind
that is how does water

1577
01:16:50,905 --> 01:16:54,676

in Mars' atmosphere and in
the subsurface move around.

1578
01:16:54,709 --> 01:16:58,146
At the present on Mars,
water could not exist

1579
01:16:58,179 --> 01:17:00,782
in a stable form as a liquid,

1580
01:17:00,815 --> 01:17:02,784
it would either
evaporate or freeze.

1581
01:17:02,817 --> 01:17:05,086
If you add salt to it,
you might get to the point

1582
01:17:05,119 --> 01:17:06,988
where you can have
a really salty brine

1583
01:17:07,021 --> 01:17:08,890
that could exist on Mars today

1584
01:17:08,923 --> 01:17:10,792
on a warm day near the equator.

1585
01:17:12,694 --> 01:17:13,928
But we can understand
the physics.

1586
01:17:13,961 --> 01:17:16,831
The physics of water, the
physics of a salt solution

1587
01:17:16,864 --> 01:17:20,969
in an environment like Mars,
we can simulate that in the lab

1588
01:17:21,002 --> 01:17:23,672
and we know what to
expect in those cases.

1589
01:17:23,705 --> 01:17:24,806
But it doesn't mean
Mars still doesn't have

1590
01:17:24,839 --> 01:17:25,940
surprises for us,

1591
01:17:25,973 --> 01:17:30,879
but it's a big place in
the geologic context.

1592
01:17:31,813 --> 01:17:32,214
Where did that water come from?

1593
01:17:32,247 --> 01:17:33,081
Why is it there?

1594
01:17:33,114 --> 01:17:34,783
That's the important question,

1595
01:17:34,816 --> 01:17:36,852
not what it does
when it's there.

1596
01:17:40,154 --> 01:17:43,058
[indistinct talking]

1597
01:17:43,091 --> 01:17:44,993
The total power produced
by the solar rays,

1598
01:17:45,026 --> 01:17:47,796
I'd have to look that
number up, I'm sorry.

1599
01:17:47,829 --> 01:17:50,832
[indistinct talking]

1600
01:17:50,865 --> 01:17:52,067
And with that, we're done.

1601
01:17:52,100 --> 01:17:53,702
Thank you very much.