Episode 9:
Developing Technology

April 2019

@NASAKennedy
#NASARocketRanch

New episodes every month!

1
00:00:00,700 --> 00:00:04,920
You might credit some modern technology to
NASA, but have you ever wondered how that

2
00:00:04,920 --> 00:00:08,900
technology got from use in space exploration
to you.

3
00:00:08,900 --> 00:00:12,879
And do you think you could you go an entire
day without using NASA technology?

4
00:00:12,879 --> 00:00:15,410
Next, on the Rocket Ranch.

5
00:00:15,410 --> 00:00:22,120
These are spacecraft that can keep on going
forever and ever in space, and they will open

6
00:00:22,120 --> 00:00:28,120
up the resources of the solar system to humanity
so we don’t have just one planet any more.

7
00:00:28,120 --> 00:00:35,780
EGS Program Chief Engineer, verify no constraints
to launch.

8
00:00:35,780 --> 00:00:38,810
EGS Chief Engineer team has no constraints.

9
00:00:38,810 --> 00:00:39,810
I copy that.

10
00:00:39,810 --> 00:00:40,810
You are clear to launch.

11
00:00:40,810 --> 00:00:43,360
Five, four, three, two, one, and lift-off.

12
00:00:43,360 --> 00:00:46,300
All clear.

13
00:00:46,300 --> 00:00:58,080
Now passing through max q, maximum dynamic
pressure.

14
00:00:58,080 --> 00:01:02,500
Welcome to space.

15
00:01:02,500 --> 00:01:07,789
NASA has a reputation for creating history
changing technology, and much of that technology

16
00:01:07,789 --> 00:01:10,649
is available to you right now.

17
00:01:10,649 --> 00:01:14,829
One of our secrets to success is that we aren’t
developing all of this by ourselves.

18
00:01:14,829 --> 00:01:19,109
We’re leveraging industry and students to
make innovative leaps.

19
00:01:19,109 --> 00:01:23,740
This is done primarily through our small business
innovative research and small business technology

20
00:01:23,740 --> 00:01:26,649
transfer research programs.

21
00:01:26,649 --> 00:01:30,819
But before we get going, we want to make sure
you know we’d love to hear your questions.

22
00:01:30,819 --> 00:01:34,630
We’ll tackle one each show and you might
even inspire a whole episode.

23
00:01:34,630 --> 00:01:39,479
Tweet us using hashtag rocketranch.

24
00:01:39,479 --> 00:01:43,659
Today we’re going to talk with Dr Phil Metzger,
who works for the University of Central Florida

25
00:01:43,659 --> 00:01:48,049
in partnership with NASA, about his World
Is Not Enough robotic spacecraft.

26
00:01:48,049 --> 00:01:53,439
But first, we caught up with Mike Vinje, the
Small Business Technology Manager with NASA’s

27
00:01:53,439 --> 00:01:58,499
Kennedy Space Center who helped us understand
how the foundation of our collaborative programs

28
00:01:58,499 --> 00:01:59,499
work.

29
00:01:59,499 --> 00:02:00,499
All right.

30
00:02:00,499 --> 00:02:02,789
I am in the booth now with Mike Vinje.

31
00:02:02,789 --> 00:02:04,789
Mike, thanks for being here today.

32
00:02:04,789 --> 00:02:05,789
Happy to be here.

33
00:02:05,789 --> 00:02:12,100
Joshua Santora: So, I want to start with this
-- this very broad question of, could I go

34
00:02:12,100 --> 00:02:16,410
a day without using NASA technology in America?

35
00:02:16,410 --> 00:02:18,310
I don't -- I don't think you could.

36
00:02:18,310 --> 00:02:20,849
I really don't.

37
00:02:20,849 --> 00:02:25,220
If you really make a strong effort to be kind
of backpacking out in the woods, I think,

38
00:02:25,220 --> 00:02:26,760
yeah, you could maybe get there.

39
00:02:26,760 --> 00:02:29,730
But even then you'd probably be surprised
at the stuff that's inside your backpack,

40
00:02:29,730 --> 00:02:33,849
or even the liner inside your jacket has probably
got a lot to do with some of the materials

41
00:02:33,849 --> 00:02:34,849
work that we've done.

42
00:02:34,849 --> 00:02:38,540
A lot of people are familiar with the emergency
blankets that you'll see people using -- the

43
00:02:38,540 --> 00:02:43,370
Red Cross, for example, or ambulances will
have the aluminum-foil Mylar blankets.

44
00:02:43,370 --> 00:02:48,150
If you think back to the Apollo program, that's
actually the material that we put around the

45
00:02:48,150 --> 00:02:53,430
outside of the legs of the lunar lander to
make sure that the temperature variations

46
00:02:53,430 --> 00:02:55,760
weren't something that would cause problems
with the structure underneath.

47
00:02:55,760 --> 00:03:01,379
So we were literally developing this material
to wrap it around the outside parts of our

48
00:03:01,379 --> 00:03:06,159
spacecraft, and that's the very same material
you see folded up in the little Mylar blanket

49
00:03:06,159 --> 00:03:07,799
that people use for Red Cross.

50
00:03:07,799 --> 00:03:14,620
How did it go from a lunar lander or some
other NASA application to the department store

51
00:03:14,620 --> 00:03:18,200
or to your local convenience store?

52
00:03:18,200 --> 00:03:24,319
I think, a lot of times, what is unique about
NASA technology development is, you're bringing

53
00:03:24,319 --> 00:03:29,510
together a diverse group of people who are
looking at a problem in a fresh way.

54
00:03:29,510 --> 00:03:33,430
And it's that group of people, who come a
lot of times from different industries -- As

55
00:03:33,430 --> 00:03:39,989

an example, the SBIR Program -- Small Business
Innovation Research Program -- we put out

56
00:03:39,989 --> 00:03:46,230
a solicitation that has about 90 to 100 different
research problems that NASA has, and that's

57
00:03:46,230 --> 00:03:51,120
open for everybody across the country to answer
if they're a small company.

58
00:03:51,120 --> 00:03:55,910
Now, what we get is a very interesting variety
of responses from small businesses that are

59
00:03:55,910 --> 00:03:59,130
in industries that we might not have thought
of originally to even talk to.

60
00:03:59,130 --> 00:04:03,389
But yet, the problems we describe in that
type of solicitation ends up being similar

61
00:04:03,389 --> 00:04:07,000
to something that they've seen in their situation,
and they know how to adapt it.

62
00:04:07,000 --> 00:04:11,349
And many times, there's that sort of incremental
progress that can really make a big difference

63
00:04:11,349 --> 00:04:12,849
for technology development.

64
00:04:12,849 --> 00:04:15,720
For those who have been following the progress
that we've had on the International Space

65
00:04:15,720 --> 00:04:20,890
Station, a few years ago, we had a really

remarkable moment where, for the first time,

66
00:04:20,890 --> 00:04:25,560
humans grew their own crop in space, and were
able to eat that crop.

67
00:04:25,560 --> 00:04:30,660
On August 10, astronauts on the International
Space Station sampled their first space-grown

68
00:04:30,660 --> 00:04:34,100
salad and pronounced it, “good”.

69
00:04:34,100 --> 00:04:38,810
They were treated to freshly-harvested red
romaine lettuce grown in the VEGGIE plant

70
00:04:38,810 --> 00:04:43,890
growth chamber – a special structure designed
to make gardens flourish in weightlessness.

71
00:04:43,890 --> 00:04:45,300
Which is awesome.

72
00:04:45,300 --> 00:04:46,300
Yeah.

73
00:04:46,300 --> 00:04:47,480
That had never happened before.

74
00:04:47,480 --> 00:04:52,970
And one of the reasons that was possible several
years ago was because the SBIR Program helped

75
00:04:52,970 --> 00:04:57,460
fund the research for the development of something
called the Veggie, which was the growth chamber

76
00:04:57,460 --> 00:04:59,400

that the actual growth took place inside of.

77
00:04:59,400 --> 00:05:03,480
And that's something that took multiple years
and a lot of work with different folks.

78
00:05:03,480 --> 00:05:07,420
But it was something that, actually, we relied
on the innovation coming out of small businesses

79
00:05:07,420 --> 00:05:09,370
in order to accomplish.

80
00:05:09,370 --> 00:05:13,940
The systems that you would normally use to
water a crop don't work as you would expect.

81
00:05:13,940 --> 00:05:16,630
Because, if you think about it, when you're
watering a crop, that's something that normally

82
00:05:16,630 --> 00:05:20,570
happens with Earth gravity, and you can rely
on the gravity to drag the water down to the

83
00:05:20,570 --> 00:05:23,310
roots, who need the moisture.

84
00:05:23,310 --> 00:05:27,900
In a weightless environment there is no up
and down so roots grow in all directions.

85
00:05:27,900 --> 00:05:33,180
Water and substrate, the materials used to
anchor these plants and allow for root growth

86
00:05:33,180 --> 00:05:35,450
tend to float away.

87

00:05:35,450 --> 00:05:40,330
With VEGGIE, these problems are solved by
using plant pillows, bags of substrate with

88
00:05:40,330 --> 00:05:43,580
space dirt and controlled-released fertilizer.

89
00:05:43,580 --> 00:05:48,110
Wicks are implanted in the bags to draw water
into the substrate and provide a place to

90
00:05:48,110 --> 00:05:53,390
glue the seeds, which are orientated so roots
will grow down into the substrate and shoots

91
00:05:53,390 --> 00:05:55,930
that emerge will push out of the bag.

92
00:05:55,930 --> 00:06:00,780
And although we did have some prototype systems,
we found out quickly that we were, unfortunately,

93
00:06:00,780 --> 00:06:05,160
having to task -- ask the astronauts to help
by manually watering some of the roots and

94
00:06:05,160 --> 00:06:06,160
stuff.

95
00:06:06,160 --> 00:06:10,510
And that ended up creating a need that we
realized to have some sort of watering system

96
00:06:10,510 --> 00:06:12,530
that didn't rely on gravity.

97
00:06:12,530 --> 00:06:15,520
Hi, Scott Kelly onboard the International
Space Station.

98
00:06:15,520 --> 00:06:23,720
I wanna go and check on my flowers I am growing
here in the Columbus module.

99
00:06:23,720 --> 00:06:26,770
Kind of nice to have some flowers up here.

100
00:06:26,770 --> 00:06:32,690
You don’t see much that is alive and growing
besides the six of us here.

101
00:06:32,690 --> 00:06:41,210
So, there was an example of the type of technology
call that went out, and so people across other

102
00:06:41,210 --> 00:06:45,710
agricultural industries, who had never thought
that they were gonna have a need to talk or

103
00:06:45,710 --> 00:06:51,820
an opportunity to talk to NASA suddenly found
themselves to be right in the area of discussion.

104
00:06:51,820 --> 00:06:56,220
One interesting area in the past few years
has been the fields of autonomy, as an example.

105
00:06:56,220 --> 00:06:57,220
Sure.

106
00:06:57,220 --> 00:07:03,130
We have found, on the NASA side of autonomy,
we have an interest in making sure that we

107
00:07:03,130 --> 00:07:08,900
have reliable systems that are rugged and
can work unattended on other planets for some

108
00:07:08,900 --> 00:07:10,080

period of time.

109
00:07:10,080 --> 00:07:14,970
And that's the type of autonomy that we would
have, is some sort of smart system that would

110
00:07:14,970 --> 00:07:18,250
be able to detect when there's maintenance
problems, or even perform its own maintenance

111
00:07:18,250 --> 00:07:22,750
and that sort of thing, and make it to where
it's ready for human occupation at a later

112
00:07:22,750 --> 00:07:24,570
date or that sort of task.

113
00:07:24,570 --> 00:07:26,800
So, you mentioned autonomy being a good example.

114
00:07:26,800 --> 00:07:31,050
So, essentially, we know that, as we return
to the moon, we're looking to do that with

115
00:07:31,050 --> 00:07:35,460
commercial companies, and so we're gonna try
and do a little up-front kick-starting of

116
00:07:35,460 --> 00:07:41,090
autonomy in commercial world, hoping that
they will evolve further than the initial

117
00:07:41,090 --> 00:07:46,870
product so that we can glean from them and
use them to help us get there effectively

118
00:07:46,870 --> 00:07:47,900
and efficiently.

119

00:07:47,900 --> 00:07:51,840
It's even more terrestrial than that, although
the lunar example was good.

120
00:07:51,840 --> 00:07:52,840
Yeah, just an example.

121
00:07:52,840 --> 00:07:58,430
But let's take, for example, when we're talking
about autonomy as it has to deal with a processing

122
00:07:58,430 --> 00:07:59,870
of materials.

123
00:07:59,870 --> 00:08:04,990
The same type of autonomy that would be advantageous
to NASA in terms of a robot driving a scoop

124
00:08:04,990 --> 00:08:10,460
of lunar dirt by itself, that same type of
autonomy is also of use for a mining company

125
00:08:10,460 --> 00:08:15,310
that has an autonomous dump truck down in
a tunnel 200 feet below the ground.

126
00:08:15,310 --> 00:08:21,110
I did want to ask -- so, we heard about this
project that we're gonna find more out about,

127
00:08:21,110 --> 00:08:23,520
WINE -- World Is Not Enough.

128
00:08:23,520 --> 00:08:30,810
So can you kind of talk me through, what's
been the process for the WINE project as they've

129
00:08:30,810 --> 00:08:34,840
kind of worked through the SBIR process?

130
00:08:34,840 --> 00:08:35,840
Sure.

131
00:08:35,840 --> 00:08:44,040
This particular company, they were able to
essentially produce a robotic rover -- a robotic

132
00:08:44,040 --> 00:08:51,270
free-flyer that can utilize the resources
on the planetary bodies that it lands upon

133
00:08:51,270 --> 00:08:53,340
in order to get to the next location.

134
00:08:53,340 --> 00:08:56,760
That's about the best way to describe it.

135
00:08:56,760 --> 00:08:57,890
Sounds cool, right?

136
00:08:57,890 --> 00:09:00,410
Now here’s Dr. Phil Metzger to talk more
about it.

137
00:09:00,410 --> 00:09:01,410
All right.

138
00:09:01,410 --> 00:09:03,810
I am here in the booth with Dr. Phil Metzger.

139
00:09:03,810 --> 00:09:05,700
Dr. Metzger, thanks for being here.

140
00:09:05,700 --> 00:09:06,700
Hello, Josh.

141
00:09:06,700 --> 00:09:07,700
I'm glad to be here.

142
00:09:07,700 --> 00:09:08,700
Thanks.

143
00:09:08,700 --> 00:09:15,120
Hey, so, we are talking today about getting
technology from NASA into the hands of the

144
00:09:15,120 --> 00:09:16,120
general public.

145
00:09:16,120 --> 00:09:18,800
And we do that, obviously, through different
means.

146
00:09:18,800 --> 00:09:24,630
But I've been told you're working on a project
called WINE, which is an acronym -- the World

147
00:09:24,630 --> 00:09:25,630
Is Not Enough.

148
00:09:25,630 --> 00:09:29,029
So I feel like we need to [Sings] Ba-da, ba-dum
Ba-dum-um

149
00:09:29,029 --> 00:09:30,029
[Laughs]

150
00:09:30,029 --> 00:09:31,029
So, what is WINE?

151
00:09:31,029 --> 00:09:33,090
Where did we get the name World Is Not Enough?

152
00:09:33,090 --> 00:09:37,060
Because obviously, like, that's a pretty powerful
name.

153
00:09:37,060 --> 00:09:43,140
We're at a critical point in our development
as a species here on planet earth.

154
00:09:43,140 --> 00:09:47,720
I think we've got a civilization that has
outgrown the planet.

155
00:09:47,720 --> 00:09:54,050
And we see a lot of symptoms of that with
the way that our civilization's affecting

156
00:09:54,050 --> 00:09:57,780
the climate, the way that we're depleting
resources.

157
00:09:57,780 --> 00:10:02,720
And so in order for our civilization to keep
moving forward, doing ever bigger and greater

158
00:10:02,720 --> 00:10:08,720
things, we need to stop relying on one planet
for all of civilization's resources.

159
00:10:08,720 --> 00:10:14,250
I think it's time that we start putting the
machinery of civilization off the planet and

160
00:10:14,250 --> 00:10:19,560
allow biology to have more living space here
on this world.

161
00:10:19,560 --> 00:10:20,560
And we can do that.

162
00:10:20,560 --> 00:10:26,130
We know there are ways to start moving the
machinery on industry off the world, and yet

163

00:10:26,130 --> 00:10:31,490
support civilization here on the Earth, as
well as doing greater things in space.

164
00:10:31,490 --> 00:10:34,860
So, you talk about, we've depleted the Earth's
resources.

165
00:10:34,860 --> 00:10:40,950
Now, are we talking, like, we're in a doomsday
scenario here, or do we have time?

166
00:10:40,950 --> 00:10:45,480
I do not believe we've actually depleted the
resources on the Earth.

167
00:10:45,480 --> 00:10:53,080
What I'm talking about is, we've used up the
most easily accessible resources.

168
00:10:53,080 --> 00:11:01,730
It takes ever more energy to access and process
the lower-grade resources that are not depleted.

169
00:11:01,730 --> 00:11:06,740
And because of that, our industrial footprint
becomes ever greater.

170
00:11:06,740 --> 00:11:12,420
We need to process more energy, process more
raw materials in order to produce the same

171
00:11:12,420 --> 00:11:13,420
outcome.

172
00:11:13,420 --> 00:11:19,690
And we also still need to make sure the whole
world has a good economy, and access to healthcare

173
00:11:19,690 --> 00:11:24,940

and education, and so we're not done industrializing
yet all over the world.

174
00:11:24,940 --> 00:11:30,100
What I'm talking about is reducing the industrial
footprint on the Earth by putting the machinery

175
00:11:30,100 --> 00:11:31,410
off the planet.

176
00:11:31,410 --> 00:11:32,480
Okay.

177
00:11:32,480 --> 00:11:35,820
The total resources have never left this world.

178
00:11:35,820 --> 00:11:37,070
They're still all here.

179
00:11:37,070 --> 00:11:42,990
And it's just a matter of energy to process
everything, and the efficiency of that processing

180
00:11:42,990 --> 00:11:47,580
is getting less as we've used up a lot of
the higher-grade ore bodies.

181
00:11:47,580 --> 00:11:53,700
So, you're proposing this idea of going somewhere
like the moon or Mars and bringing resources

182
00:11:53,700 --> 00:11:54,880
back here?

183
00:11:54,880 --> 00:11:58,589
Well, it's a decades-long program, I think.

184
00:11:58,589 --> 00:12:05,850
But the real goal would be to eventually have

power systems that are off the planet beaming

185
00:12:05,850 --> 00:12:11,590
clean energy down to the surface so we can
move the entire energy sector off the planet,

186
00:12:11,590 --> 00:12:15,520
and the entire industrial supply chain that
supports the energy sector.

187
00:12:15,520 --> 00:12:19,270
We can also move the majority of computing
off the planet.

188
00:12:19,270 --> 00:12:25,160
Right now, the energy needs of computing is
growing exponentially, and at the current

189
00:12:25,160 --> 00:12:29,560
rate, according to the Semiconductor Research
Corporation and the Semiconductor Industry

190
00:12:29,560 --> 00:12:36,020
Association, the computing here on planet
Earth is gonna require the world's entire

191
00:12:36,020 --> 00:12:39,060
energy supply by the mid-2040s.

192
00:12:39,060 --> 00:12:42,840
[Laughs] Wait, wait, wait.

193
00:12:42,840 --> 00:12:50,380
So, we're gonna need all the energy of Earth
to run computer servers by the 2040s?

194
00:12:50,380 --> 00:12:51,380
Well --

195

00:12:51,380 --> 00:12:52,380
An estimated figure.

196
00:12:52,380 --> 00:12:53,420
It won't actually happen.

197
00:12:53,420 --> 00:12:58,630
What will happen is, eventually there's gonna
be increased cost for the energy to supply

198
00:12:58,630 --> 00:13:01,750
what computing requires or desires.

199
00:13:01,750 --> 00:13:02,750
I see.

200
00:13:02,750 --> 00:13:06,940
And so it's gonna result in a reduction in
the amount of computing we can do, and that's

201
00:13:06,940 --> 00:13:09,710
gonna limit the benefits of computing.

202
00:13:09,710 --> 00:13:14,710
We won't be able to do as much supercomputing
to solve for new drugs, you know, figuring

203
00:13:14,710 --> 00:13:16,080
out how proteins fold.

204
00:13:16,080 --> 00:13:22,390
There's gonna be limitations to what we can
do digitally unless we can move the computing

205
00:13:22,390 --> 00:13:24,710
off the planet.

206
00:13:24,710 --> 00:13:32,310
And there's a hope that we can improve the

efficiency of computing, but even if we do,

207
00:13:32,310 --> 00:13:36,050
even if we make the most optimally efficient
computer, that's only gonna delay the crunch

208
00:13:36,050 --> 00:13:37,220
another 10 years.

209
00:13:37,220 --> 00:13:38,220
Sure.

210
00:13:38,220 --> 00:13:44,399
So, by the mid-2050s at the latest, we're
gonna have to either dramatically increase

211
00:13:44,399 --> 00:13:48,480
the energy supply of planet Earth or start
to move computing off the planet.

212
00:13:48,480 --> 00:13:52,060
So I'm not looking at bringing physical resources
back from the Earth.

213
00:13:52,060 --> 00:13:57,750
I'm looking at ways that we can create infrastructure
off the planet in order to support life here

214
00:13:57,750 --> 00:14:00,910
on the planet using massless transport up
and down.

215
00:14:00,910 --> 00:14:04,610
So, kind of a part of this -- you mentioned
a robot that never dies.

216
00:14:04,610 --> 00:14:11,891
Because you're not proposing that this robot
is gonna solve all these world problems, but

217
00:14:11,891 --> 00:14:14,780
I'm curious to know, what does this robot
that never dies do?

218
00:14:14,780 --> 00:14:15,780
Okay.

219
00:14:15,780 --> 00:14:18,310
So, it's actually a prospecting robot.

220
00:14:18,310 --> 00:14:25,240
So this is a spacecraft that could go out
to any relatively low-gravity object outside

221
00:14:25,240 --> 00:14:32,089
planet Earth -- it could be asteroids, it
could be the moon, it could be Europa or Titan

222
00:14:32,089 --> 00:14:34,399
or even Pluto.

223
00:14:34,399 --> 00:14:40,180
Anywhere that's got low enough gravity and
has access to volatiles like water at the

224
00:14:40,180 --> 00:14:41,180
surface.

225
00:14:41,180 --> 00:14:45,980
So, the technical definition of a volatile
is a substance easily evaporated at normal

226
00:14:45,980 --> 00:14:46,980
temperatures.

227
00:14:46,980 --> 00:14:47,980
Mm-hmm.

228

00:14:47,980 --> 00:14:52,690
And so for our purposes, oftentimes it's thinking
about cryogenic materials -- things that we

229
00:14:52,690 --> 00:14:57,300
have to cool drastically in order to be a
liquid, but at room temperature, they are

230
00:14:57,300 --> 00:14:58,300
a gas.

231
00:14:58,300 --> 00:14:59,300
Right.

232
00:14:59,300 --> 00:15:05,120
And this robotic spacecraft mines the surface
to extract the volatiles, and it converts

233
00:15:05,120 --> 00:15:15,180
it into steam, and then it can hop in the
low-gravity environment using steam propulsion.

234
00:15:15,180 --> 00:15:20,210
So it never runs out of rocket fuel as long
as it's got an energy supply, which could

235
00:15:20,210 --> 00:15:24,520
be solar energy in the inner solar system,
or it would have to probably be a nuclear

236
00:15:24,520 --> 00:15:26,830
decay source in the outer solar system.

237
00:15:26,830 --> 00:15:32,399
As long as it has energy and access to volatiles,
it can just keep on exploring.

238
00:15:32,399 --> 00:15:33,399
Can it ever get stuck?

239
00:15:33,399 --> 00:15:37,870
Like, is there ever a chance where this thing,
like, hops into a hole or lands on a rock

240
00:15:37,870 --> 00:15:38,970
funny and tips over?

241
00:15:38,970 --> 00:15:41,070
Like, how do we know this isn't gonna happen?

242
00:15:41,070 --> 00:15:43,190
Well, it definitely can happen.

243
00:15:43,190 --> 00:15:49,899
And when we devised this project, our thinking
was that, "We will send swarms of these out

244
00:15:49,899 --> 00:15:50,899
into space.”

245
00:15:50,899 --> 00:15:58,300
They can be made very inexpensively using
student teams, using off-the-shelf CubeSat

246
00:15:58,300 --> 00:16:01,730
hardware, 3-D printing the custom components.

247
00:16:01,730 --> 00:16:08,600
So this was designed to be built in massive
quantities and sent out into space in swarms.

248
00:16:08,600 --> 00:16:09,600
The idea --

249
00:16:09,600 --> 00:16:10,600
That sounds really creepy.

250
00:16:10,600 --> 00:16:12,029

You know that, right?

251
00:16:12,029 --> 00:16:15,540
We will send swarms of these out into space.

252
00:16:15,540 --> 00:16:16,620
[Laughs]

253
00:16:16,620 --> 00:16:21,710
These giant, like, kilometer-long hopping
robots.

254
00:16:21,710 --> 00:16:23,300
Like, that sounds really creepy.

255
00:16:23,300 --> 00:16:26,040
Hopping through the solar system like roaches.

256
00:16:26,040 --> 00:16:30,649
[Laughter] Yeah, well, so, they would not
be intelligent.

257
00:16:30,649 --> 00:16:31,959
They could not take over.

258
00:16:31,959 --> 00:16:32,959
Okay.

259
00:16:32,959 --> 00:16:33,959
Good.

260
00:16:33,959 --> 00:16:34,959
Whew!

261
00:16:34,959 --> 00:16:35,959
Yeah.

262
00:16:35,959 --> 00:16:38,830

They would -- The idea is that, some of them
are gonna land on asteroids that have water,

263
00:16:38,830 --> 00:16:42,440
and they're gonna refuel, and then they're
gonna study that asteroid and send data back,

264
00:16:42,440 --> 00:16:44,200
and then they'll hop to another one.

265
00:16:44,200 --> 00:16:48,830
But other ones are gonna hop onto an asteroid
that doesn't have water, and they get stuck.

266
00:16:48,830 --> 00:16:49,830
Interesting.

267
00:16:49,830 --> 00:16:50,830
So that's the end of their mission.

268
00:16:50,830 --> 00:16:54,510
So, over time, they're gonna end up stuck
on asteroids.

269
00:16:54,510 --> 00:16:55,510
And that's fine.

270
00:16:55,510 --> 00:16:59,029
They'll still provide data about the dynamics
of that asteroid as they radio back their

271
00:16:59,029 --> 00:17:04,520
location, but eventually, over time, the swarm
will be thinned down.

272
00:17:04,520 --> 00:17:05,520
Okay.

273
00:17:05,520 --> 00:17:08,510

And when you say a swarm, kind of give me
a frame of reference.

274
00:17:08,510 --> 00:17:12,209
Are we talking, like, a dozen, 100, 1,000?

275
00:17:12,209 --> 00:17:13,269
What's the number look like?

276
00:17:13,269 --> 00:17:20,709
It could be thousands, because these are built
with off-the-shelf hardware that's designed

277
00:17:20,709 --> 00:17:21,709
for CubeSat.

278
00:17:21,709 --> 00:17:26,869
So they can be very inexpensive, and they
can be built by student teams as projects.

279
00:17:26,869 --> 00:17:32,139
They could be built even by community groups,
people who want to participate in space.

280
00:17:32,139 --> 00:17:39,639
You could have a Boy Scout group build a satellite
as one of their projects, and then it could

281
00:17:39,639 --> 00:17:45,749
go into space and participate as part of the
swarm of spacecraft exploring the asteroid

282
00:17:45,749 --> 00:17:46,789
belt.

283
00:17:46,789 --> 00:17:54,539
Right now, we're sending on average one spacecraft
to a small solar system body every two years.

284

00:17:54,539 --> 00:18:00,059
There are approximately 10 billion small solar
system bodies.

285
00:18:00,059 --> 00:18:06,769
At the rate we're going, we will never explore
them all until the end of the universe.

286
00:18:06,769 --> 00:18:11,779
But this would be a way to change that game,
to send out large numbers of spacecraft and

287
00:18:11,779 --> 00:18:17,539
visit many, many, many of these small objects
throughout this gigantic asteroid belt, and

288
00:18:17,539 --> 00:18:19,759
then out into the Kuiper Belt.

289
00:18:19,759 --> 00:18:26,570
So, it'll give us a chance to really take
survey of this home that we live in.

290
00:18:26,570 --> 00:18:32,110
So, how big of a robot are we talking about
here?

291
00:18:32,110 --> 00:18:34,070
It's the size of a microwave oven.

292
00:18:34,070 --> 00:18:35,070
Okay.

293
00:18:35,070 --> 00:18:38,779
In terms of CubeSats, it would be 27U.

294
00:18:38,779 --> 00:18:42,049
That's 27 units, so it's 3x3x3 CubeSats.

295

00:18:42,049 --> 00:18:49,290
So, for those not familiar, the CubeSat is
a very growing trend of spacefaring satellites,

296
00:18:49,290 --> 00:18:51,950
and they measure, what, 10 centimeters cubed?

297
00:18:51,950 --> 00:18:52,950
That's right.

298
00:18:52,950 --> 00:18:53,950
10 centimeters on a side.

299
00:18:53,950 --> 00:18:54,950
Okay.

300
00:18:54,950 --> 00:18:59,700
And so the WINE was just -- and, by the way,
the CubeSats are modular, so they're made

301
00:18:59,700 --> 00:19:04,820
to be hooked together, and so you can have
-- quite often, you'll see CubeSats that are

302
00:19:04,820 --> 00:19:07,279
3U, and so those would be 10x10x30.

303
00:19:07,279 --> 00:19:09,499
It's just three cubes hooked together.

304
00:19:09,499 --> 00:19:13,759
You often see them as 1x2x3, so that's a 6U.

305
00:19:13,759 --> 00:19:14,759
Okay.

306
00:19:14,759 --> 00:19:16,440
So what we're talking about is 27U.

307
00:19:16,440 --> 00:19:22,230
It's just 27 CubeSat-sized boxes hooked together,
three of them on a side.

308
00:19:22,230 --> 00:19:27,889
So, we've got robots exploring around our
solar system, and this would be on the much

309
00:19:27,889 --> 00:19:28,889
smaller side.

310
00:19:28,889 --> 00:19:30,269
Is that a fair assessment?

311
00:19:30,269 --> 00:19:31,269
Yeah.

312
00:19:31,269 --> 00:19:34,090
This is definitely a small spacecraft.

313
00:19:34,090 --> 00:19:40,789
And part of the idea of the WINE project was
to make use of the growing availability of

314
00:19:40,789 --> 00:19:42,820
CubeSat components.

315
00:19:42,820 --> 00:19:49,220
So we can use CubeSat reaction wheels, CubeSat
communication systems, CubeSat power systems

316
00:19:49,220 --> 00:19:51,460
and computers.

317
00:19:51,460 --> 00:19:54,989
However, we are not a CubeSat.

318
00:19:54,989 --> 00:20:02,149

So we are using CubeSat components, and we're
using CubeSat dimensions, but we don't actually

319
00:20:02,149 --> 00:20:08,190
have 27 modular units hooked together, because
the propellent tanks don't fit in just one

320
00:20:08,190 --> 00:20:09,190
unit.

321
00:20:09,190 --> 00:20:10,190
Sure.

322
00:20:10,190 --> 00:20:12,009
It's got legs attached to the side.

323
00:20:12,009 --> 00:20:14,470
It's got a nozzle sticking out the bottom.

324
00:20:14,470 --> 00:20:18,659
So it's not really fitting -- entirely fitting
the CubeSat philosophy.

325
00:20:18,659 --> 00:20:23,130
But it is leveraging CubeSat philosophy to
a degree.

326
00:20:23,130 --> 00:20:29,010
So, give me kind of a feeling -- We talked
about kind of the energy that it has to do

327
00:20:29,010 --> 00:20:30,010
propulsion.

328
00:20:30,010 --> 00:20:31,179
We've talked about its size.

329
00:20:31,179 --> 00:20:36,169
So, if we put this thing on Earth and you've

got it working at full power, how far can

330
00:20:36,169 --> 00:20:37,289
this thing hop?

331
00:20:37,289 --> 00:20:42,359
Well, here on Earth's gravity and in Earth's
atmosphere, it's not gonna perform very well.

332
00:20:42,359 --> 00:20:47,509
For one thing, the steam propulsion ha a great
advantage in space, because as you're blowing

333
00:20:47,509 --> 00:20:54,739
steam out the rocket nozzle, there's a huge
pressure difference from inside the upstream

334
00:20:54,739 --> 00:20:58,629
in the nozzle to outside the nozzle.

335
00:20:58,629 --> 00:21:04,629
And that pressure different is enough that
it causes the steam to go supersonic as it

336
00:21:04,629 --> 00:21:06,190
flows down the nozzle.

337
00:21:06,190 --> 00:21:11,359
But if you try to operate that inside of a
dense atmosphere, like on the Earth, you may

338
00:21:11,359 --> 00:21:14,940
not be below the critical pressure on the
outside.

339
00:21:14,940 --> 00:21:15,940
Okay.

340
00:21:15,940 --> 00:21:17,499

And so you may not get supersonic flow.

341
00:21:17,499 --> 00:21:24,889
So it's gonna dramatically reduce the ability
of the propulsion system to create thrust.

342
00:21:24,889 --> 00:21:26,760
The second problem is the high gravity.

343
00:21:26,760 --> 00:21:27,760
Sure.

344
00:21:27,760 --> 00:21:31,319
So, here on the Earth, I'm not sure you're
gonna get a very good hop at all.

345
00:21:31,319 --> 00:21:32,319
[Chuckles]

346
00:21:32,319 --> 00:21:37,419
In a thin atmosphere, like on Mars, it would
definitely work, and you could hop hundreds

347
00:21:37,419 --> 00:21:38,639
of meters.

348
00:21:38,639 --> 00:21:39,850
A single hop?

349
00:21:39,850 --> 00:21:40,850
Yeah.

350
00:21:40,850 --> 00:21:41,850
Hundreds of meters?

351
00:21:41,850 --> 00:21:42,850
Yeah.

352

00:21:42,850 --> 00:21:43,850
That's true.

353
00:21:43,850 --> 00:21:44,850
That's correct.

354
00:21:44,850 --> 00:21:45,850
That's awesome.

355
00:21:45,850 --> 00:21:46,850
[Laughs]

356
00:21:46,850 --> 00:21:50,840
Now, the metric I was using was to try to
make it hop at least one kilometer per hop,

357
00:21:50,840 --> 00:21:57,249
and also to be able to heat the fuel, the
steam, in 10 days or less.

358
00:21:57,249 --> 00:22:02,249
So, you mine the water, and then you spend
some time heating it.

359
00:22:02,249 --> 00:22:05,519
You're using solar power if you're in the
inner solar system.

360
00:22:05,519 --> 00:22:06,519
Okay.

361
00:22:06,519 --> 00:22:11,779
So, over a 10-day period of time, you're trickling
in this solar energy and just building up

362
00:22:11,779 --> 00:22:15,289
temperature and pressure inside your water
tank.

363

00:22:15,289 --> 00:22:22,889
And my objective was to make sure the spacecraft
could get to hopping temperature within 10

364
00:22:22,889 --> 00:22:23,889
days.

365
00:22:23,889 --> 00:22:24,889
Okay.

366
00:22:24,889 --> 00:22:29,049
So, you could have a spacecraft -- you could
allow it to take longer than 10 days if you

367
00:22:29,049 --> 00:22:31,870
wanted to, but you have to draw the line somewhere...

368
00:22:31,870 --> 00:22:32,870
Sure.

369
00:22:32,870 --> 00:22:34,119
...for it to be a practical system.

370
00:22:34,119 --> 00:22:35,340
Makes sense.

371
00:22:35,340 --> 00:22:42,399
So, if you could heat it up in 10 days with
a sufficiently small set of solar arrays as

372
00:22:42,399 --> 00:22:47,799
your power source, then it becomes a very
viable spacecraft, according to our reckoning.

373
00:22:47,799 --> 00:22:53,600
And, so, when we talk about that, obviously
you have to not only account for the lift-off,

374
00:22:53,600 --> 00:22:57,239

so to speak, the hopping portion, but the
touchdown portion.

375
00:22:57,239 --> 00:23:03,109
Do you save some of the steam to kind of slow
your descent, or are the legs built so that

376
00:23:03,109 --> 00:23:04,789
they can withstand that force?

377
00:23:04,789 --> 00:23:08,370
We were planning to do soft landings using
the steam propulsion.

378
00:23:08,370 --> 00:23:13,119
So, when I say it hops a kilometer or more,
that means you're using about half of the

379
00:23:13,119 --> 00:23:17,570
steam for lift-off, you're using a little
bit of the steam for attitude control, using

380
00:23:17,570 --> 00:23:18,969
the tiny thrusters.

381
00:23:18,969 --> 00:23:19,969
[Chuckles]

382
00:23:19,969 --> 00:23:24,070
And so you're controlling the spacecraft using
the same steam, and then it uses the other

383
00:23:24,070 --> 00:23:27,950
half of the steam to set down softly at its
landing site.

384
00:23:27,950 --> 00:23:28,950
Cool.

385

00:23:28,950 --> 00:23:29,950
That's amazing.

386
00:23:29,950 --> 00:23:32,140
And you mentioned harvesting water.

387
00:23:32,140 --> 00:23:35,489
And I'm assuming we're not talking about,
like, streams of water, here.

388
00:23:35,489 --> 00:23:37,269
We're talking about frozen water.

389
00:23:37,269 --> 00:23:38,269
Is that correct?

390
00:23:38,269 --> 00:23:39,269
Yeah.

391
00:23:39,269 --> 00:23:42,259
Well, it really depends where you are, what
kind of a body you're on.

392
00:23:42,259 --> 00:23:45,659
So if you're on Europa, the whole surface
is ice.

393
00:23:45,659 --> 00:23:46,659
Okay.

394
00:23:46,659 --> 00:23:49,049
And is probably mixed-composition ice.

395
00:23:49,049 --> 00:23:52,980
It can be water, carbon dioxide, it can have
all kinds of organics.

396
00:23:52,980 --> 00:23:55,029
And for this spacecraft, it really doesn't

matter.

397
00:23:55,029 --> 00:24:00,379
Whatever it gets, it can convert all of that
to high-pressure vapor, and then shoot it

398
00:24:00,379 --> 00:24:02,110
out the nozzle and get propulsion.

399
00:24:02,110 --> 00:24:05,200
So we don't really care too much what the
composition is.

400
00:24:05,200 --> 00:24:08,309
That's one of the nice things about this very
simple system.

401
00:24:08,309 --> 00:24:13,929
If you're on the moon, then it's gonna be
ice mixed with dirt, mixed with mineral grains.

402
00:24:13,929 --> 00:24:14,929
Sure.

403
00:24:14,929 --> 00:24:17,619
And so the system has two coring tubes.

404
00:24:17,619 --> 00:24:22,470
It drives them down into the soil, and then
it heats the coring tubes.

405
00:24:22,470 --> 00:24:28,889
So the vapor will travel through the soil,
up the coring tube, into a pipe, and into

406
00:24:28,889 --> 00:24:32,029
the tank where it gets frozen.

407
00:24:32,029 --> 00:24:35,710

Some of the vapor will leak out the bottom
of the coring tube -- that's okay.

408
00:24:35,710 --> 00:24:37,749
We don't have to collect all of it.

409
00:24:37,749 --> 00:24:40,899
But you extract the coring tubes.

410
00:24:40,899 --> 00:24:45,779
The spacecraft has legs, so it then walks
a few centimeters, and it repeats the process.

411
00:24:45,779 --> 00:24:52,600
And it keeps doing one set of coring-tube
extraction operations after another until

412
00:24:52,600 --> 00:24:55,470
the tank is full of water.

413
00:24:55,470 --> 00:25:01,320
Every time, it'll shove that tube down in
the icy regolith, it'll get some of the vapor

414
00:25:01,320 --> 00:25:03,909
out, and it will pull the tube back out again.

415
00:25:03,909 --> 00:25:08,490
So, you can actually get the ice out of the
dirt.

416
00:25:08,490 --> 00:25:15,059
On the other hand, a third example, if you're
on a carbonaceous asteroid, let's say you're

417
00:25:15,059 --> 00:25:16,059
--

418
00:25:16,059 --> 00:25:17,059

Carbonaceous.

419
00:25:17,059 --> 00:25:18,059
That's an awesome word.

420
00:25:18,059 --> 00:25:19,059
[Laughs]

421
00:25:19,059 --> 00:25:21,850
[Chuckles] So, carbonaceous, those are the
asteroids that have a lot of clay in them.

422
00:25:21,850 --> 00:25:22,850
Okay.

423
00:25:22,850 --> 00:25:28,090
So Ceres, the largest asteroid, is a carbonaceous
asteroid, for one example.

424
00:25:28,090 --> 00:25:32,549
So, if you're on a carbonaceous asteroid,
there is no ice.

425
00:25:32,549 --> 00:25:38,710
Instead, the water is actually locked into
the mineral structure of the clay itself.

426
00:25:38,710 --> 00:25:41,279
In that case, you can still get the water
out.

427
00:25:41,279 --> 00:25:47,460
You drive the coring tube down into the soil,
you heat the soil so much that the hydroxyl

428
00:25:47,460 --> 00:25:52,919
that's in the clay starts to break loose,
and it comes out in the form of water.

429

00:25:52,919 --> 00:25:54,059
So you still can --

430
00:25:54,059 --> 00:25:55,059
Crazy.

431
00:25:55,059 --> 00:25:58,369
...get water, even on a bone-dry asteroid.

432
00:25:58,369 --> 00:25:59,859
Man.

433
00:25:59,859 --> 00:26:01,659
This is, like, blowing my mind, Phil.

434
00:26:01,659 --> 00:26:02,739
This is awesome.

435
00:26:02,739 --> 00:26:10,749
So, obviously if you're harvesting in frozen
deposits of water or water mixed into regolith,

436
00:26:10,749 --> 00:26:13,279
we're in fairly cold environments.

437
00:26:13,279 --> 00:26:17,729
Is this thing -- is this robot able to survive
in these really, like, harsh environments?

438
00:26:17,729 --> 00:26:18,940
Sure.

439
00:26:18,940 --> 00:26:22,889
That was part of the calculation -- how much
energy it needs to stay warm.

440
00:26:22,889 --> 00:26:25,720
And there's a lot of different ways to do
it.

441
00:26:25,720 --> 00:26:30,840
One way is, you simply try to stay in a benign
environment.

442
00:26:30,840 --> 00:26:35,869
So, there are places in the solar system where
it's not so cold, and you design it to handle

443
00:26:35,869 --> 00:26:38,609
the average temperature.

444
00:26:38,609 --> 00:26:43,039
But if you want to go into a really, really
cold place like Pluto, then you're gonna have

445
00:26:43,039 --> 00:26:45,799
to have some warmth on the spacecraft.

446
00:26:45,799 --> 00:26:54,960
And the way that we do that in the space program
is, we use RHUs -- radioisotopic heater units.

447
00:26:54,960 --> 00:27:01,249
Each RHU is the size of a dime, and you just
simply glue them onto your spacecraft at various

448
00:27:01,249 --> 00:27:02,249
locations.

449
00:27:02,249 --> 00:27:08,220
They contain a tiny amount of a radioactive
material, and over time, that material decays

450
00:27:08,220 --> 00:27:11,489
and creates warmth that goes into your spacecraft.

451
00:27:11,489 --> 00:27:17,190
[Chuckles] So you're using radioactive dimes

to heat a spacecraft to keep it from freezing.

452
00:27:17,190 --> 00:27:19,359
Yeah, that's actually standard practice.

453
00:27:21,940 --> 00:27:20,359
[Laughs]

454
00:27:21,940 --> 00:27:23,080
But, yeah.

455
00:27:23,080 --> 00:27:27,230
So, to go to these colder areas, you would
have to do something to keep them warm in

456
00:27:27,230 --> 00:27:29,690
order to keep the electronics functional.

457
00:27:29,690 --> 00:27:35,820
And we talked about the way this thing gets
around, and how it kind of gathers its propulsive

458
00:27:35,820 --> 00:27:36,820
materials.

459
00:27:36,820 --> 00:27:40,849
But I'm assuming that this robot is for more
than just hopping around.

460
00:27:40,849 --> 00:27:45,129
It's got to have some kind of a function that's
scientifically beneficial.

461
00:27:45,129 --> 00:27:46,129
That's right.

462
00:27:46,129 --> 00:27:47,129
It would carry a payload.

463
00:27:47,129 --> 00:27:52,799
And one of the nice things about it is that
the spacecraft is already mining the volatiles.

464
00:27:52,799 --> 00:27:57,720
So if you want to study the volatiles, you've
already got access to them.

465
00:27:57,720 --> 00:28:01,229
So you could put some instruments on your
spacecraft, and you could study the chemistry

466
00:28:01,229 --> 00:28:07,119
of the volatiles, you could study what temperatures
the volatiles are released from the soil,

467
00:28:07,119 --> 00:28:13,590
and that gives you information about the clay
minerals and the physical state of the ice

468
00:28:13,590 --> 00:28:15,860
in the soil.

469
00:28:15,860 --> 00:28:18,989
You also could carry a camera.

470
00:28:18,989 --> 00:28:22,710
Obviously you will have a camera, because
you need visual awareness as you're hopping

471
00:28:22,710 --> 00:28:24,090
and landing.

472
00:28:24,090 --> 00:28:25,130
Sure.

473
00:28:25,130 --> 00:28:30,619
So you'll get visual imagery of the body that
you're exploring, but there's also accommodation

474
00:28:30,619 --> 00:28:31,639
for other payloads.

475
00:28:31,639 --> 00:28:39,850
So you could take magnetometers, or you could
take spectrometers or anything else to study

476
00:28:39,850 --> 00:28:45,100
the mineralogy or the planetary environment
wherever you go.

477
00:28:45,100 --> 00:28:47,929
What are some of the major challenges that
lie ahead for you all?

478
00:28:47,929 --> 00:28:52,480
Obviously the goal here is that this will
be operational in exploring somewhere in our

479
00:28:52,480 --> 00:28:57,019
solar system, but what are the big speed bumps
to getting there?

480
00:28:57,019 --> 00:28:58,019
Yeah.

481
00:28:58,019 --> 00:28:59,970
It's a matter of doing the engineering.

482
00:28:59,970 --> 00:29:03,090
So, NASA has a way of grading technology.

483
00:29:03,090 --> 00:29:04,090
Okay.

484
00:29:04,090 --> 00:29:06,190
It's called the Technology Readiness Level
scale.

485
00:29:06,190 --> 00:29:07,690
Did I say that right?

486
00:29:07,690 --> 00:29:08,759
That sounds right, yeah.

487
00:29:08,759 --> 00:29:09,860
Technology Readiness Level.

488
00:29:09,860 --> 00:29:10,860
Yeah.

489
00:29:10,860 --> 00:29:11,860
[Chuckles]

490
00:29:11,860 --> 00:29:13,399
So, it goes from one through nine.

491
00:29:13,399 --> 00:29:15,879
One means you've discovered something in physics.

492
00:29:15,879 --> 00:29:16,879
Okay.

493
00:29:16,879 --> 00:29:20,440
Two means you've come up with a way to use
it in technology.

494
00:29:20,440 --> 00:29:24,070
And then it goes all the way up to nine, which
means you are now flying it in space.

495
00:29:24,070 --> 00:29:25,070
Okay.

496
00:29:25,070 --> 00:29:30,179
So, we are at TRL 4, or partial TRL 5.

497
00:29:30,179 --> 00:29:31,179
Okay.

498
00:29:31,179 --> 00:29:36,940
Because we've built a partial prototype, and
we have tested it in a terrestrial environment

499
00:29:36,940 --> 00:29:40,849
using a gravity offloader, but using realistic
regolith and vacuums.

500
00:29:40,849 --> 00:29:46,059
So it was partially the realistic environment
and a partial prototype.

501
00:29:46,059 --> 00:29:51,109
So, in order to get a full TRL 5, we would
need the full prototype with all the spacecraft

502
00:29:51,109 --> 00:29:52,379
systems, I think.

503
00:29:52,379 --> 00:29:53,509
Okay.

504
00:29:53,509 --> 00:29:58,849
And then in a full, relevant environment for
the testing -- so maybe some testing in space,

505
00:29:58,849 --> 00:30:01,129
actually -- to get TRL 6.

506
00:30:01,129 --> 00:30:05,970
And once you're at TRL 6, that's the point
where you can sell it to your customer.

507
00:30:05,970 --> 00:30:12,129
Then the customer's job is to build the actual

flight units to go seven, eight, and nine.

508
00:30:12,129 --> 00:30:15,009
And for you, as you kind of look towards the
future, obviously it sounds like a customer

509
00:30:15,009 --> 00:30:17,499
gets involved, so they kind of have some say
in this.

510
00:30:17,499 --> 00:30:22,749
But do you have to go further than the moon
to be able to test this, or is the moon an

511
00:30:22,749 --> 00:30:26,120
acceptable testing ground for you guys?

512
00:30:26,120 --> 00:30:30,489
Well, to get TRL 6, you don't actually have
to go to space.

513
00:30:30,489 --> 00:30:31,620
You can simulate it.

514
00:30:31,620 --> 00:30:35,899
But you have to put together the full set
of relevant space conditions.

515
00:30:35,899 --> 00:30:36,899
Okay.

516
00:30:36,899 --> 00:30:38,630
So, we have tested in vacuum.

517
00:30:38,630 --> 00:30:42,019
We used a gravity offloader.

518
00:30:42,019 --> 00:30:47,070
But we would probably want to test the mining

process itself, the coring, in a reduced-gravity

519
00:30:47,070 --> 00:30:51,889
flight, and we would probably also need to
have the right thermal environment on the

520
00:30:51,889 --> 00:30:52,889
spacecraft.

521
00:30:52,889 --> 00:30:57,320
So not just a vacuum chamber, but a thermal
vacuum chamber for some of these tests.

522
00:30:57,320 --> 00:31:01,539
Once we've done all that, we could probably
claim TRL 6.

523
00:31:01,539 --> 00:31:02,669
Cool.

524
00:31:02,669 --> 00:31:07,679
Any words of advice that you would give to
aspiring planetary-research scientists?

525
00:31:07,679 --> 00:31:14,080
Or possibly something that you might say to
inspire people to be planetary-research scientists?

526
00:31:14,080 --> 00:31:16,320
Well, I'm having the time of my life.

527
00:31:16,320 --> 00:31:17,619
This is exciting.

528
00:31:17,619 --> 00:31:19,029
It's fun.

529
00:31:19,029 --> 00:31:20,600
I do something different every day.

530
00:31:20,600 --> 00:31:24,419
I'm working on about five or six different
projects at all times.

531
00:31:24,419 --> 00:31:28,809
So there's a lot of variety, and you get to
make everything up as you go along.

532
00:31:28,809 --> 00:31:29,809
So if you like --

533
00:31:29,809 --> 00:31:30,809
[Laughs]

534
00:31:30,809 --> 00:31:34,029
There's no book that tells you what to do
next.

535
00:31:34,029 --> 00:31:36,799
What we're doing is, we're creating an off-world
economy.

536
00:31:36,799 --> 00:31:40,299
So, I call myself an applied planetary scientist.

537
00:31:40,299 --> 00:31:41,299
Okay.

538
00:31:41,299 --> 00:31:43,869
Or I'm doing economic planetary science.

539
00:31:43,869 --> 00:31:49,859
Because we're working on the technologies
to do economic activities off the Earth.

540
00:31:49,859 --> 00:31:55,259
This is not an established field, and so we're
making it all up as we go along.

541
00:31:55,259 --> 00:31:58,190
This is also what the Swamp Works does at
the Kennedy Space Center.

542
00:31:58,190 --> 00:32:02,830
The Swamp Works, in my opinion, is the premier
laboratory for space mining and space-resource

543
00:32:02,830 --> 00:32:05,200
utilization in the world.

544
00:32:05,200 --> 00:32:11,190
And some of the best technologists in the
world are here in NASA doing this work.

545
00:32:11,190 --> 00:32:15,600
When I was at NASA as part of the Swamp Works,
we were making it up as we go along.

546
00:32:15,600 --> 00:32:18,850
We're trying to figure out -- we're inventing
technologies.

547
00:32:18,850 --> 00:32:20,610
We're inventing processes.

548
00:32:20,610 --> 00:32:25,730
We're inventing strategies and entire space
architectures.

549
00:32:25,730 --> 00:32:30,469
And then we convince people to give us the
money to do it, and then we get to have fun,

550
00:32:30,469 --> 00:32:36,840
and we go work on volcanoes, we fly in reduced-gravity
airplanes, and pretty much anything you want

551

00:32:36,840 --> 00:32:37,840
to do.

552
00:32:37,840 --> 00:32:42,169
We're working with real rockets and with robots.

553
00:32:42,169 --> 00:32:47,299
You know, so, robots, rockets, and we're doing
things to help humanity, so it's kind of the

554
00:32:47,299 --> 00:32:48,409
best of everything.

555
00:32:48,409 --> 00:32:49,409
All right.

556
00:32:49,409 --> 00:32:50,409
I'm ready to go.

557
00:32:50,409 --> 00:32:51,409
Sign me up.

558
00:32:51,409 --> 00:32:52,409
I'm in.

559
00:32:52,409 --> 00:32:53,409
All right.

560
00:32:53,409 --> 00:32:54,409
[Chuckles] So, there you go.

561
00:32:54,409 --> 00:33:00,129
So, as we look towards colonizing the moon
or Mars or other heavenly bodies, Phil Metzger

562
00:33:00,129 --> 00:33:04,849
is a brilliant man who has lots of data to
share, and obviously lots of energy to do

563
00:33:04,849 --> 00:33:05,849
so.

564
00:33:05,849 --> 00:33:07,100
So thank you for being with me today.

565
00:33:07,100 --> 00:33:10,139
Thank you, Josh.

566
00:33:10,139 --> 00:33:13,090
As promised, we wanted to answer a question
from a listener.

567
00:33:13,090 --> 00:33:17,950
Cassashine asks, “What is the most exciting
thing to look forward to regarding SpaceX

568
00:33:17,950 --> 00:33:22,190
and private companies also being about to
travel to outer space?”

569
00:33:22,190 --> 00:33:26,749
So you may or may not know, but part of NASA’s
mission is to expand commercial space.

570
00:33:26,749 --> 00:33:31,779
So for any company that gets into that game
of taking humans into space that’s a huge

571
00:33:31,779 --> 00:33:32,909
win for NASA.

572
00:33:32,909 --> 00:33:36,779
And we really see that as a benefit for all
mankind because the more companies that enter

573
00:33:36,779 --> 00:33:41,409
the field, the more competition there is and
so that actually will drive costs down and

574
00:33:41,409 --> 00:33:43,870
make commercial space more accessible for
most people.

575
00:33:43,870 --> 00:33:49,399
So, over time, the cost of flying into space
will take a huge plummet and that’s awesome

576
00:33:49,399 --> 00:33:53,269
because then everyone will get a chance to
hopefully some day vacation in space, visit

577
00:33:53,269 --> 00:33:55,049
the moon or even further than that.

578
00:33:55,049 --> 00:33:58,419
So we’re excited for all these commercial
companies and a growing field.

579
00:33:58,419 --> 00:33:59,419
[Sound Effect]

580
00:33:59,419 --> 00:34:03,100
Mike, we had a chance to sit down with Dr.
Phil Metzger and talk about the WINE project.

581
00:34:03,100 --> 00:34:10,109
Is this an exceptional project, or is this
par for the course when it comes to SBIR and

582
00:34:10,109 --> 00:34:11,109
STTR?

583
00:34:11,109 --> 00:34:16,599
It's a great question, because the SBIR Program
has been responsible for bringing forward

584
00:34:16,599 --> 00:34:20,669

a lot of really amazing companies and teams
doing remarkable projects.

585
00:34:20,669 --> 00:34:26,280
So, we're lucky to say that, yeah, there are
quite a few like this WINE project that really

586
00:34:26,280 --> 00:34:27,750
knock it out of the park.

587
00:34:27,750 --> 00:34:32,129
And it's hats off to the small businesses
that put all the effort in for this program,

588
00:34:32,129 --> 00:34:33,129
that's for sure.

589
00:34:33,129 --> 00:34:39,960
So, you mentioned that we're looking for research
projects that we could see some commercial

590
00:34:39,960 --> 00:34:41,250
application.

591
00:34:41,250 --> 00:34:42,270
Is that a priority for us?

592
00:34:42,270 --> 00:34:49,600
Are we really helping to kind of kick-start
these commercial deliverables or products

593
00:34:49,600 --> 00:34:51,369
or however you want to describe it?

594
00:34:51,369 --> 00:34:57,279
We try in general to make sure that the company's
participation in the SBIR Program is something

595
00:34:57,279 --> 00:35:00,950

that's gonna benefit them in the commercial
world as well as the government world.

596
00:35:00,950 --> 00:35:06,800
And there's a couple different ways how that
happens and why we would want it to happen.

597
00:35:06,800 --> 00:35:11,559
It helps in the commercial world in the sense
that, we're interested in making sure that

598
00:35:11,559 --> 00:35:17,660
these small businesses are functional and
available to us for future use as suppliers.

599
00:35:19,660 --> 00:35:18,660
Interesting.

600
00:35:19,660 --> 00:35:23,740
So, a good way of saying it for the SBIR Program
-- in fact, this kind of leans towards it.

601
00:35:23,740 --> 00:35:28,200
A good way of looking at the SBIR Program
is, for NASA, we're trying to build pockets

602
00:35:28,200 --> 00:35:31,329
of the industry that we know we're gonna need
in the near future.

603
00:35:31,329 --> 00:35:32,329
Huh.

604
00:35:32,329 --> 00:35:39,039
So, while we know that there's suppliers of
-- or prime contractors and established suppliers

605
00:35:39,039 --> 00:35:42,580
of different types of technology, if we can
see that, a few years down the road, we're

606
00:35:42,580 --> 00:35:47,450
gonna need some new category or class of sensors
or what have you, it's worth it for us to

607
00:35:47,450 --> 00:35:52,890
put some seed money out through the SBIR program,
work with small businesses, and collaboratively

608
00:35:52,890 --> 00:35:56,329
try to develop that little niche in the industry
and see if we can grow it.

609
00:35:56,329 --> 00:35:58,720
Can you talk about kind of the process?

610
00:35:58,720 --> 00:36:03,789
So, whether it be for WINE or for any SBIR
-- I would assume the process is similar -- what

611
00:36:03,789 --> 00:36:07,460
do they go through from a NASA perspective
to develop this technology and get it ready

612
00:36:07,460 --> 00:36:08,460
for flight?

613
00:36:08,460 --> 00:36:09,460
Sure.

614
00:36:09,460 --> 00:36:14,470
The NASA SBIR process is actually something
that has a couple different phases.

615
00:36:14,470 --> 00:36:22,109
The first part is Phase I, where we send out
the solicitation to the general public and

616
00:36:22,109 --> 00:36:23,109

to industry.

617
00:36:23,109 --> 00:36:26,400
And any company or any person who's starting
a company, even, can apply.

618
00:36:26,400 --> 00:36:33,580
And they're applying for a Phase I award,
which is $125,000 for 6 months' or 13 months'

619
00:36:33,580 --> 00:36:37,880
worth of work, depending on whether it's the
SBIR Program or STTR Program.

620
00:36:37,880 --> 00:36:43,380
But that Phase I, what that's basically doing
is, that is -- what NASA's asking for, I should

621
00:36:43,380 --> 00:36:47,270
say, is something of a technology-development
plan.

622
00:36:47,270 --> 00:36:48,770
You think you have an idea.

623
00:36:48,770 --> 00:36:54,039
How would you develop the idea if you had
funds, and what kind of preliminary work can

624
00:36:54,039 --> 00:36:59,980
you do up front to validate or better plan
for it or even disprove the concept?

625
00:36:59,980 --> 00:37:02,670
That's kind of what the Phase I work does.

626
00:37:02,670 --> 00:37:08,029
And then what happens is, at the end of the
Phase I period, the company submits a final

627
00:37:08,029 --> 00:37:11,029
report, and they're also invited to apply
for Phase II.

628
00:37:11,029 --> 00:37:14,710
So, you don't get to Phase II unless you've
been awarded a Phase I.

629
00:37:14,710 --> 00:37:15,710
Okay.

630
00:37:15,710 --> 00:37:17,240
And the Phase II is sort of follow-on work.

631
00:37:17,240 --> 00:37:19,529
So that's the second stage of the work.

632
00:37:19,529 --> 00:37:22,779
The nice thing about Phase II is, it's a bit
more time.

633
00:37:22,779 --> 00:37:26,260
It's two years' worth of duration, and it's
also $750,000.

634
00:37:26,260 --> 00:37:31,559
So, between those two, you're close to $1
million worth of funding that NASA has provided

635
00:37:31,559 --> 00:37:35,230
to the small business to pursue that particular
technology.

636
00:37:35,230 --> 00:37:41,510
So, the World Is Not Enough project, the WINE
project, has proceeded through Phase II, and

637
00:37:41,510 --> 00:37:44,900
has gotten to where they've been able to develop

hardware.

638
00:37:44,900 --> 00:37:47,619
And that's the exciting part about the Phase
II project.

639
00:37:47,619 --> 00:37:52,080
By the end of Phase II, NASA is generally
expecting to see some sort of hardware that

640
00:37:52,080 --> 00:37:54,710
will be delivered or a software prototype,
something like that.

641
00:37:54,710 --> 00:37:57,430
Some sort of proof of the technology.

642
00:37:57,430 --> 00:38:02,650
And between those different phases, it pretty
systematically helps bring the companies up

643
00:38:02,650 --> 00:38:06,980
-- in terms of developing their technology,
up through the Technology Readiness Levels.

644
00:38:06,980 --> 00:38:12,450
Mike, the STTR Program being different, and
that it incorporates universities -- and I

645
00:38:12,450 --> 00:38:17,289
think there's part of me that's continuously
impressed by the fact that we do have university

646
00:38:17,289 --> 00:38:20,839
students really contributing to NASA missions.

647
00:38:20,839 --> 00:38:23,380
Can you talk about the value of those students?

648

00:38:23,380 --> 00:38:27,750
Like, is it more learning for them, or is
it more value for us?

649
00:38:27,750 --> 00:38:32,089
The approach that has really worked well in
the past, and I think is the reason why the

650
00:38:32,089 --> 00:38:37,280
STTR Program is structured the way it is,
is that not only do you need to find groups

651
00:38:37,280 --> 00:38:41,500
of people who are capable of coming up with
innovative solutions, but you also need to

652
00:38:41,500 --> 00:38:43,609
think of it more like a process.

653
00:38:43,609 --> 00:38:45,380
Where do these people come from?

654
00:38:45,380 --> 00:38:51,109
And if they're going to grow into big companies,
how do you supply them with people who have

655
00:38:51,109 --> 00:38:52,319
familiarity in those fields?

656
00:38:52,319 --> 00:38:55,369
But also, you're not just growing companies.

657
00:38:55,369 --> 00:38:59,720
You're growing whole areas of thought and
development, and a lot of times the academic

658
00:38:59,720 --> 00:39:03,010
world is critical for that.

659

00:39:03,010 --> 00:39:09,329
At NASA, we pay a lot of attention to technology
ecosystems, as I would call it, where the

660
00:39:09,329 --> 00:39:13,490
different elements that are needed in a particular
region in order to support technology development,

661
00:39:13,490 --> 00:39:19,720
it's very hard for a small business by itself
to really be able to thrive in some of these

662
00:39:19,720 --> 00:39:21,940
demanding worlds if you don't have some kind
of support.

663
00:39:21,940 --> 00:39:28,029
And a lot of times, the nearest university
or research institute can be just the critical

664
00:39:28,029 --> 00:39:30,329
lifeline that a small business would need.

665
00:39:30,329 --> 00:39:31,920
And we want to try to encourage that.

666
00:39:31,920 --> 00:39:35,250
That's part of why we have the STTR Program.

667
00:39:35,250 --> 00:39:41,210
We've found it to be extremely powerful for
small businesses to make an effort to reach

668
00:39:41,210 --> 00:39:45,920
out and interact with the universities, particularly
if they're doing technology development, because

669
00:39:45,920 --> 00:39:50,400
it is the exchange of ideas that is pretty
staggering.

670
00:39:50,400 --> 00:39:54,319
And small businesses also don't realize that
sometimes there are more opportunities than

671
00:39:54,319 --> 00:39:58,740
just our STTR Program that require a combined
team.

672
00:39:58,740 --> 00:40:04,210
And it's a real vibrant part of the research
part, and there's

673
00:40:04,210 --> 00:40:07,590
nothing but benefit to get if people can team
up like that.

674
00:40:07,590 --> 00:40:08,590
All right.

675
00:40:08,590 --> 00:40:09,839
Mike, that's all the time we have for today.

676
00:40:09,839 --> 00:40:11,299
Thank you so much for being here.

677
00:40:11,299 --> 00:40:13,250
I am incredibly excited.

678
00:40:13,250 --> 00:40:16,990
Obviously an exciting time for SBIR as we
look to return to the moon.

679
00:40:16,990 --> 00:40:18,769
Thanks for joining me.

680
00:40:18,769 --> 00:40:21,170
Thank you.

681
00:40:21,170 --> 00:40:24,589
I’m Joshua Santora, and that’s our show.

682
00:40:24,589 --> 00:40:26,369
Thanks for stoppin’ by the rocket ranch.

683
00:40:26,369 --> 00:40:30,240
And special thanks to our guests Mike Vinje
and Dr. Phil Metzger.

684
00:40:30,240 --> 00:40:36,490
To learn more about SBIR and STTR visit sbir.nasa.gov.

685
00:40:36,490 --> 00:40:41,920
To learn more about how NASA technology benefits
life on earth, check out the 2019 NASA Spinoff

686
00:40:41,920 --> 00:40:46,980
magazine, which is out now, at spinoff.nasa.gov.

687
00:40:46,980 --> 00:40:50,599
And to learn more about everything going on
at the Kennedy Space Center, go to nasa.gov/kennedy.

688
00:40:50,599 --> 00:40:55,779
Check out NASA’s other podcasts to learn
more about what’s happening at all of our

689
00:40:55,779 --> 00:40:59,049
centers at nasa.gov/podcasts.

690
00:40:59,049 --> 00:41:04,670
A special shout-out to our producer, John
Sackman, our soundman Lorne Mathre, editor

691
00:41:04,670 --> 00:41:08,349
Michelle Stone, and our production manager,
Leejay Lockhart.