ROCKET RANCH

Episode 1: Mars

June 2018

@NASAKennedy
#NASARocketRanch

New episodes every month!

1
00:00:04,130 --> 00:00:07,810
Joshua Santora (Host): The soil beneath your
feet, the food on your table, the roof over

2
00:00:07,810 --> 00:00:11,220
your head...these are luxuries on Mars.

3
00:00:11,220 --> 00:00:14,920
Getting there isn’t a problem, it’s surviving
once you land.

4
00:00:14,920 --> 00:00:17,790
Launch Countdown Sequence: EGS Program Chief
Engineer, verify no constraints to launch.

5
00:00:17,790 --> 00:00:19,710
EGS Chief Engineer team has no constraints.

6
00:00:19,710 --> 00:00:20,710
I copy that.

7
00:00:20,710 --> 00:00:21,710
You are clear to launch.

8
00:00:21,710 --> 00:00:23,990
Five, four, three, two, one, and lift-off.

9
00:00:23,990 --> 00:00:27,410
All clear.

10
00:00:27,410 --> 00:00:41,110
Now passing through max q, maximum dynamic
pressure.

11
00:00:41,110 --> 00:00:42,110
Welcome to space.

12
00:00:42,110 --> 00:00:43,110

Host: Welcome to the rocket ranch.

13
00:00:43,110 --> 00:00:44,110
I’m Joshua Santora.

14
00:00:44,110 --> 00:00:48,110
While our current focus is on the Moon, it
is our stepping stone to the Red Planet.

15
00:00:48,110 --> 00:00:51,990
In this episode we’ll sit down with scientists
and engineers exploring our planetary neighbor

16
00:00:51,990 --> 00:00:55,010
and preparing for the survival of those who
brave the journey.

17
00:00:55,010 --> 00:00:59,480
First up, a trajectory analyst plotting million
mile journeys to the Red Planet and beyond.

18
00:00:59,480 --> 00:01:03,870
Next, we’ll hear from two plant researchers
who are figuring out how to grow food in space

19
00:01:03,870 --> 00:01:05,030
and on alien planets.

20
00:01:05,030 --> 00:01:09,420
And finally, we’ll dig deep into the daunting
challenges that still lie ahead before humans

21
00:01:09,420 --> 00:01:16,179
can set foot on Mars.

22
00:01:16,179 --> 00:01:19,200
Insight is a Mars lander designed to give
the Red Planet its first thorough check-up

23

00:01:19,200 --> 00:01:21,929
since it formed 4.5 billion years ago.

24
00:01:21,929 --> 00:01:27,240
It is the first outer space robotic explorer
to study in depth the inner-space of mars--

25
00:01:27,240 --> 00:01:29,299
its crust, mantle, and core.

26
00:01:29,299 --> 00:01:33,939
A few days before the insight launch, Kennedy’s
Amanda Griffin sat down with trajectory analyst

27
00:01:33,939 --> 00:01:38,569
Caley Burke of NASA’s Launch Services Program
to find out what it takes to send a spacecraft

28
00:01:38,569 --> 00:01:39,569
to the red planet.

29
00:01:39,569 --> 00:01:43,859
Amanda Griffin (Host): So, Caley, tell us
a little bit about your role for Insight.

30
00:01:43,859 --> 00:01:48,259
Caley Burke: my role is the trajectory analyst
here at the Launch Services Program.

31
00:01:48,259 --> 00:01:52,491
And so, my job’s to make sure that the rocket
drops the spacecraft off at the right place

32
00:01:52,491 --> 00:01:54,400
and time in space.

33
00:01:54,400 --> 00:02:00,060
And so, we get these targets from the spacecraft
team, who look at where they’re going, um,

34
00:02:00,060 --> 00:02:01,979
and what the capabilities of the rocket is.

35
00:02:01,979 --> 00:02:06,079
And so, I’m there to make sure that that
rocket performs as it needs to together with

36
00:02:06,079 --> 00:02:07,579
the launch vehicle company.

37
00:02:07,579 --> 00:02:09,540
Host: that sounds like a lotta math to me.

38
00:02:09,540 --> 00:02:10,540
Caley Burke: It is.

39
00:02:10,540 --> 00:02:11,540
There’s a lot of equations.

40
00:02:11,540 --> 00:02:15,781
Um, those of you who are familiar with “hidden
figures,” um, she developed a lot of the

41
00:02:15,781 --> 00:02:18,280
math that we use in our computer programs.

42
00:02:18,280 --> 00:02:21,230
But, um, we have to consider these really
complex journeys.

43
00:02:21,230 --> 00:02:23,920
You know, it’s not just doing an equation
once.

44
00:02:23,920 --> 00:02:28,060
Um, we’re always trying to-to make it as
optimal as possible, and so there’s all

45

00:02:28,060 --> 00:02:29,220
these levers you have to push.

46
00:02:29,220 --> 00:02:31,540
You know, I think of it as planning a summer
vacation.

47
00:02:31,540 --> 00:02:34,890
You know, how many different summer vacations
are out there?

48
00:02:34,890 --> 00:02:39,410
There's millions of ideas and so you have
to kinda tailor it down to a reasonable one.

49
00:02:39,410 --> 00:02:42,700
Say, like, okay, we're going on a camping
trip and we're gonna go in the summer.

50
00:02:42,700 --> 00:02:45,350
You start paring it down and finding the best
one.

51
00:02:45,350 --> 00:02:51,030
Host: So, speaking of all of these possibilities,
I understand Insight has a lot of launch attempts,

52
00:02:51,030 --> 00:02:55,820
and that's a paring down from like an endless--
seemingly endless possibility.

53
00:02:55,820 --> 00:02:57,090
Caley Burke: There are.

54
00:02:57,090 --> 00:03:02,010
The jet propulsion lab, they do these things
called pork chop plots, and so they consider

55
00:03:02,010 --> 00:03:05,590
many months they could launch and many months

they could land on mars.

56
00:03:05,590 --> 00:03:06,750
And they look at different conditions.

57
00:03:06,750 --> 00:03:09,910
They’re saying, okay, you know, how fast
does the rocket need to get the spacecraft

58
00:03:09,910 --> 00:03:10,910
going?

59
00:03:10,910 --> 00:03:12,420
How fast is it is-- if we arrive at mars?

60
00:03:12,420 --> 00:03:15,530
You don’t want the spacecraft crashing like
an egg and breaking on mars.

61
00:03:15,530 --> 00:03:16,530
Host: No.

62
00:03:16,530 --> 00:03:19,280
Caley Burke: Yeah, we want a little bit softer
of a landing.

63
00:03:19,280 --> 00:03:22,450
Um, what’s the weather conditions gonna
be like when they get there?

64
00:03:22,450 --> 00:03:26,202
We wanna get communication during landing,
so are the right satellites in place or are

65
00:03:26,202 --> 00:03:29,380
we looking back at earth at that time in the
landing site?

66
00:03:29,380 --> 00:03:34,880

So there’s all these considerations they
put into, and then they get it down to, um,

67
00:03:34,880 --> 00:03:37,990
what they consider their ideal number of launch
days.

68
00:03:37,990 --> 00:03:42,400
And so, we’re-- have 35 days we’re looking
at that we’re launching, but only one day

69
00:03:42,400 --> 00:03:43,980
that we’re gonna land.

70
00:03:43,980 --> 00:03:49,040
And so, that was all pared down, but then
once we get there, um, we don’t have just

71
00:03:49,040 --> 00:03:51,740
35 opportunities, you know, one per day.

72
00:03:51,740 --> 00:03:57,700
We actually have a two-hour window that we’re
able to do on each day, and so that’s 25

73
00:03:57,700 --> 00:03:58,700
opportunities.

74
00:03:58,700 --> 00:04:01,530
So there’s 875 possible ones we analyzed.

75
00:04:01,530 --> 00:04:02,530
Host: Wow.

76
00:04:02,530 --> 00:04:03,530
Caley Burke: Yeah.

77
00:04:03,530 --> 00:04:07,630
And so a couple of those, um, we’ve already

said that they don’t meet the requirements,

78
00:04:07,630 --> 00:04:11,480
which we have so many it’s not a problem
to have a few that we lose.

79
00:04:11,480 --> 00:04:17,010
I mean, it’s great to have large windows
because if there’s any weather conditions,

80
00:04:17,010 --> 00:04:22,020
if the range is clearing, if there’s a mechanical
issue on the rocket, we have time to possibly

81
00:04:22,020 --> 00:04:25,270
fix it so that we don’t have to completely
scrub that day, but—

82
00:04:25,270 --> 00:04:27,210
Host: And I know in Florida we often have
weather conditions.

83
00:04:27,210 --> 00:04:28,210
Caley Burke: Yeah.

84
00:04:28,210 --> 00:04:30,260
Host: But the insight is launching from the
west coast.

85
00:04:30,260 --> 00:04:31,260
Caley Burke: mm-hmm.

86
00:04:31,260 --> 00:04:33,380
Host: So you’re talkin’ about all the
considerations you guys have to take into

87
00:04:33,380 --> 00:04:34,380
account.

88

00:04:34,380 --> 00:04:36,030
So to launch from California, what’s different?

89
00:04:36,030 --> 00:04:41,170
Caley Burke: So as a trajectory analyst, um,
the main thing that I have to make sure is,

90
00:04:41,170 --> 00:04:45,580
uh, first of all, I have to make sure my computer
program puts us at the right l-launch site.

91
00:04:45,580 --> 00:04:48,310
That, um, sometimes you get a trajectory--
Host: that helps.

92
00:04:48,310 --> 00:04:51,060
Caley Burke: --and you’re like, “hmm,
that’s not in the right place.”

93
00:04:51,060 --> 00:04:53,230
But usually it’s pretty obvious at that
point.

94
00:04:53,230 --> 00:04:57,040
Um, but a-a big thing that’s an indicator
is what directions you can launch.

95
00:04:57,040 --> 00:05:01,050
So, each launch site we work at the range
to figure out what are the safe directions

96
00:05:01,050 --> 00:05:02,440
we don’t endanger the public?

97
00:05:02,440 --> 00:05:03,440
Host: Sure.

98
00:05:03,440 --> 00:05:06,740
Caley Burke: And so, here from Florida, we
launch east safely, and we can go somewhat

99
00:05:06,740 --> 00:05:08,490
to the north and somewhat from the south.

100
00:05:08,490 --> 00:05:13,400
But from Vandenberg, um, if they launch east
they’re flying over people, and so we don’t

101
00:05:13,400 --> 00:05:14,400
want that.

102
00:05:14,400 --> 00:05:18,840
So we can launch to the southeast, as we are
for, um, insight, and then we can continue

103
00:05:18,840 --> 00:05:21,720
going west and, uh, launch safely.

104
00:05:21,720 --> 00:05:26,510
But, uh, we wanna make sure that everything
happens with the rocket, uh, we don’t endanger

105
00:05:26,510 --> 00:05:28,340
anybody and nothing drops on somebody.

106
00:05:28,340 --> 00:05:30,150
If-- it’s a low risk as possible.

107
00:05:30,150 --> 00:05:32,680
Host: I’m sure we all appreciate that.

108
00:05:32,680 --> 00:05:41,889
Insight Launch Sequence: Lift-off of the Atlas
V, launching the first interplanetary mission

109
00:05:41,889 --> 00:05:46,190
from the west coast, and NASA’s Insight,
the first outer space robotic explorer to

110
00:05:46,190 --> 00:05:47,190
study the interior of Mars.

111
00:05:47,190 --> 00:05:49,470
Host: Speaking of risk, once you get to mars,
or near mars, we’ve heard a lot about planetary

112
00:05:49,470 --> 00:05:50,470
protection.

113
00:05:50,470 --> 00:05:51,470
Caley Burke: mm-hmm.

114
00:05:51,470 --> 00:05:54,400
Host: So what is that and what is your team
doing to try to help mitigate that at Mars?

115
00:05:54,400 --> 00:05:59,060
Caley Burke: So we have somebody here at NASA
who’s called the planetary protection officer.

116
00:05:59,060 --> 00:06:03,630
Um, which after a nine-year-old applied, I
now-- jokingly, it’s the guardian of the

117
00:06:03,630 --> 00:06:04,630
galaxy.

118
00:06:04,630 --> 00:06:06,800
Um, that’s who-- why he said he’d be great.

119
00:06:06,800 --> 00:06:11,640
But the planetary protection officer, um,
looks to both protect earth from any microbes

120
00:06:11,640 --> 00:06:12,930
we bring from space.

121

00:06:12,930 --> 00:06:13,930
Host: Okay.

122
00:06:13,930 --> 00:06:16,419
Caley Burke: And then, we also consider Mars
and Europa, where we think there might be

123
00:06:16,419 --> 00:06:21,620
life, we wanna protect them from any earth
bugs and basically creating life somewhere

124
00:06:21,620 --> 00:06:22,960
as opposed to finding it.

125
00:06:22,960 --> 00:06:23,960
Host: Sure.

126
00:06:23,960 --> 00:06:27,860
Caley Burke: So, we do that, um, with Insight
in a couple different ways.

127
00:06:27,860 --> 00:06:33,150
So, one, is the spacecraft, which we-we plan
to have land on Mars, has been very specially

128
00:06:33,150 --> 00:06:34,150
cleaned.

129
00:06:34,150 --> 00:06:37,910
There’s a whole team that is working to
make sure that there’s as few microbes as

130
00:06:37,910 --> 00:06:39,500
possible, if any.

131
00:06:39,500 --> 00:06:42,020
Um, but we don’t do that with the rocket.

132
00:06:42,020 --> 00:06:45,930

And so, we actually aim the trajectory a little
bit away from Mars.

133
00:06:45,930 --> 00:06:47,440
We don’t aim it straight at Mars.

134
00:06:47,440 --> 00:06:48,440
Host: Okay.

135
00:06:48,440 --> 00:06:53,170
Caley Burke: Um, so that if, um, it doesn’t
perform as it should, or even if the spacecraft

136
00:06:53,170 --> 00:06:56,450
doesn’t perform as it should, we don’t
pollute Mars.

137
00:06:56,450 --> 00:07:00,610
And so, what that means is the spacecraft
has to carry extra fuel to account for that

138
00:07:00,610 --> 00:07:03,010
correction, but they already have to do corrections.

139
00:07:03,010 --> 00:07:07,600
They just have more fuel that they need to
get closer to mars than if we could go straight

140
00:07:07,600 --> 00:07:08,600
at it.

141
00:07:08,600 --> 00:07:09,880
Host: So many things you have to think about.

142
00:07:09,880 --> 00:07:12,150
So, what it-- it’s gonna land in November,
correct?

143
00:07:12,150 --> 00:07:13,150

Caley Burke: Yes.

144
00:07:13,150 --> 00:07:15,080
Host: So what do the next seven months have
in store for you?

145
00:07:15,080 --> 00:07:20,330
Caley Burke: So for me, um, it’s really
about that 90 minutes that starts at lift-off

146
00:07:20,330 --> 00:07:21,600
to when we separate.

147
00:07:21,600 --> 00:07:25,340
Um, and that’s-- it varies a little bit
day-by-day and time-by-time.

148
00:07:25,340 --> 00:07:31,740
Um, but once insight separates, followed shortly
by the Marcos, you know, I’m clapping and

149
00:07:31,740 --> 00:07:32,740
celebrating.

150
00:07:32,740 --> 00:07:34,270
Host: And the Marcos are CubeSat’s?

151
00:07:34,270 --> 00:07:35,710
Caley Burke: The Marcos, they are CubeSat’s.

152
00:07:35,710 --> 00:07:39,910
They’re each the size of a b-briefcase and
they’re going along with insight to mars.

153
00:07:39,910 --> 00:07:44,000
They’re gonna be doing communications with
it as it goes through the landing, which is

154
00:07:44,000 --> 00:07:47,860

such a dangerous point that if something were
to happen during landing, we’d like as much

155
00:07:47,860 --> 00:07:50,710
data as possible so we can figure out what
went wrong.

156
00:07:50,710 --> 00:07:56,270
Um, but once insight and the Marcos separate,
um, then I’m gonna clap and cheer.

157
00:07:56,270 --> 00:08:01,770
And I began a process of data analysis, but
all the systems I’m involved with have flown

158
00:08:01,770 --> 00:08:02,950
and have done their jobs.

159
00:08:02,950 --> 00:08:05,440
Host: So you can breathe easy about an hour
and a half after launch?

160
00:08:05,440 --> 00:08:07,610
Caley Burke: Yeah, about an hour and a half,
I’ll breathe easy.

161
00:08:07,610 --> 00:08:11,960
Um, but I’ll really-- I’ll breathe easy
once I get the data and I do the calculation

162
00:08:11,960 --> 00:08:13,100
and we’ve met the requirement.

163
00:08:13,100 --> 00:08:14,100
Host: Fair enough.

164
00:08:14,100 --> 00:08:16,280
Caley Burke: Um, but, you know, it’s tough.

165

00:08:16,280 --> 00:08:21,020
If anything goes wrong at any part of the
system, it’s very-- it’s devastating.

166
00:08:21,020 --> 00:08:26,900
But, um, but you do wanna check, you know,
that you’ve put it on the right path, and

167
00:08:26,900 --> 00:08:30,890
hopefully it doesn’t have to use a ton of
fuel to correct for launch vehicle errors,

168
00:08:30,890 --> 00:08:36,200
because the spacecraft has budgeted a certain
amount of their fuel for the launch vehicle

169
00:08:36,200 --> 00:08:37,529
errors, because we know they exist.

170
00:08:37,529 --> 00:08:38,909
It’s not gonna be a perfect shot.

171
00:08:38,909 --> 00:08:40,539
They’re gonna have to make corrections.

172
00:08:40,539 --> 00:08:43,090
Host: And so, on launch day you’re gonna
be here at Kennedy watching?

173
00:08:43,090 --> 00:08:44,090
Caley Burke: I am.

174
00:08:44,090 --> 00:08:45,270
So I do have a role.

175
00:08:45,270 --> 00:08:48,830
I’ll be flight dynamics for NASA, but it’s
not a critical role.

176

00:08:48,830 --> 00:08:52,140
And so, I’m here at Hangar AE in Cape Canaveral
working on it.

177
00:08:52,140 --> 00:08:56,240
So I’ll be looking at the data, I’ll have
my headset on and I can talk with the chief

178
00:08:56,240 --> 00:09:02,300
engineer, and so I’m ready to make sure,
um, as we launch-- because we have all those

179
00:09:02,300 --> 00:09:06,200
times that we can launch, but the amount of
fuel for each of them is a little different.

180
00:09:06,200 --> 00:09:11,610
So we’ll be looking at the weather conditions
and all that stuff and making sure that, um,

181
00:09:11,610 --> 00:09:14,600
for everything that’s going on for that
time, we have enough fuel.

182
00:09:14,600 --> 00:09:16,880
Now, for Insight, it’s not-- that’s not
a big concern.

183
00:09:16,880 --> 00:09:18,960
We have quite a bit of fuel on this mission.

184
00:09:18,960 --> 00:09:25,610
Um, but then, after it launches I’m looking
to see how the different numbers and parameters

185
00:09:25,610 --> 00:09:27,790
look to what we call the nominal trajectory.

186
00:09:27,790 --> 00:09:30,640
And so, that’s the one where everything

is just as we modeled.

187
00:09:30,640 --> 00:09:31,930
But let’s say we’re off nominal.

188
00:09:31,930 --> 00:09:37,000
I’m there to let our chief engineer know,
you know, if we can recover, if this is within

189
00:09:37,000 --> 00:09:40,950
the bounds we’ve modeled, that it’s just--
it’s an off nominal day, but the rocket’s

190
00:09:40,950 --> 00:09:42,080
still getting where it needs to.

191
00:09:42,080 --> 00:09:44,140
Host: All right, well let’s all hope for
a nominal day then.

192
00:09:44,140 --> 00:09:45,140
Caley Burke: Yeah, that’d be great.

193
00:09:45,140 --> 00:09:47,120
Host: And good luck to you and Insight.

194
00:09:47,120 --> 00:09:49,710
Caley Burke: Thank you.

195
00:09:49,710 --> 00:09:54,240
Thankfully, all calls were nominal and insight
successfully launched from Vandenberg on May

196
00:09:54,240 --> 00:09:58,070
5th, and Caley was able to relax just a few
hours later.

197
00:09:58,070 --> 00:10:02,070
At the time of this recording, the spacecraft

is already more than 6 million miles from

198
00:10:02,070 --> 00:10:05,220
Earth and is scheduled to arrive at the Red
Planet on November 26th.

199
00:10:05,220 --> 00:10:07,800
Happy trails.

200
00:10:07,800 --> 00:10:17,060
Dr. Gioia Massa: We've seen the movie “The
Martian”, and Mark Watney uses his botany

201
00:10:17,060 --> 00:10:18,460
skills to save his life.

202
00:10:18,460 --> 00:10:19,460
We will need plants to survive on mars.

203
00:10:19,460 --> 00:10:21,740
Host: So that was our own Mark Watney, Dr.
Gioia Massa.

204
00:10:21,740 --> 00:10:23,750
She's a scientist here at Kennedy Space
Center.

205
00:10:23,750 --> 00:10:25,800
Her research is growing food in space.

206
00:10:25,800 --> 00:10:29,020
And also with us is Ralph Fritsche, who works
on long duration food production.

207
00:10:29,020 --> 00:10:31,300
We'll get to what that means a little bit
later.

208
00:10:31,300 --> 00:10:33,450

So, Gioia, tell us a little bit about what
you’ve been working on.

209
00:10:33,450 --> 00:10:38,430
Dr. Gioia Massa: So we work on food production
to help grow food for the astronauts.

210
00:10:38,430 --> 00:10:42,700
We’re growing fresh vegetables right now
on the International Space Station to supplement

211
00:10:42,700 --> 00:10:44,370
the astronauts’ diet.

212
00:10:44,370 --> 00:10:48,840
You can bring a lot of food with you when
you go, and we do that on Space Station, and

213
00:10:48,840 --> 00:10:50,240
the packaged food is really good.

214
00:10:50,240 --> 00:10:56,630
There’s a lot of variety, but over time
vac-packaged food loses its nutritional quality.

215
00:10:56,630 --> 00:11:00,930
And so, one of the things that’s really
important is to figure out how to grow fresh

216
00:11:00,930 --> 00:11:03,839
vegetables to supplement that packaged diet.

217
00:11:03,839 --> 00:11:07,800
And doing that without gravity and without,
you know, the sun, and all the other things

218
00:11:07,800 --> 00:11:10,370
we take for granted on earth is kind of a
challenge.

219
00:11:10,370 --> 00:11:11,370
>>

220
00:11:11,370 --> 00:11:12,370
Host: So how exactly do you do that?

221
00:11:12,370 --> 00:11:16,220
The Space Station, as, you know, many of our
listeners probably know, is 225, 250 miles

222
00:11:16,220 --> 00:11:17,220
above Earth.

223
00:11:17,220 --> 00:11:19,540
So, you know, we have microgravity.

224
00:11:19,540 --> 00:11:22,920
It doesn’t have sunshine to the plant, so
how do you-- how do you take care of that?

225
00:11:22,920 --> 00:11:27,190
Dr. Gioia Massa: Well, we do a lot of our
growing in what we call controlled environments.

226
00:11:27,190 --> 00:11:29,320
So we’re actually controlling the light.

227
00:11:29,320 --> 00:11:33,350
We use LED’s, light emitting diodes, to
provide the light for plants, and we have

228
00:11:33,350 --> 00:11:37,260
a lot of research on that here at Kennedy
Space Center, figuring out what’s the best

229
00:11:37,260 --> 00:11:42,460
light recipe to give the plants to get them
to grow well and to taste good and to be very

230
00:11:42,460 --> 00:11:43,460
nutritious.

231
00:11:43,460 --> 00:11:44,800
Host: Have you figured out that light recipe
yet?

232
00:11:44,800 --> 00:11:48,390
Dr. Gioia Massa: It differs for every single
plant we grow, so it’s a big challenge,

233
00:11:48,390 --> 00:11:49,390
actually.

234
00:11:49,390 --> 00:11:50,390
We have to do a lot of research.

235
00:11:50,390 --> 00:11:54,320
Um, the other thing that we’re working a
lot on is water delivery.

236
00:11:54,320 --> 00:11:57,110
Delivering water to plants without gravity
is a real challenge.

237
00:11:57,110 --> 00:12:01,120
And plant roots don’t just need water, but
they also need oxygen.

238
00:12:01,120 --> 00:12:04,240
And in space, air and water just don’t mix
very well.

239
00:12:04,240 --> 00:12:07,170
You may have seen the video of the astronaut
wringing out the wet washcloth.

240
00:12:07,170 --> 00:12:08,170
Host: mm-hmm.

241
00:12:08,170 --> 00:12:10,850
Dr. Gioia Massa: Where the water crawls around
his hand, you know.

242
00:12:10,850 --> 00:12:13,269
It’s surface, um, surface tension.

243
00:12:13,269 --> 00:12:17,120
And so, if you think of that as a plant root,
it just gets drowned in water.

244
00:12:17,120 --> 00:12:20,550
So we have to figure out the right way to
do a lot of water and air balancing.

245
00:12:20,550 --> 00:12:23,800
And-and actually, that’s one of the things
we’re working on with food production.

246
00:12:23,800 --> 00:12:25,020
Ralph can talk more about that.

247
00:12:25,020 --> 00:12:27,440
Ralph Fritsche: Yeah, that’s where I come
in.

248
00:12:27,440 --> 00:12:30,019
Um, we have the plant scientists and we also
have engineers.

249
00:12:30,019 --> 00:12:34,850
And I think the real challenge is to take
the knowledge that the scientists have in

250
00:12:34,850 --> 00:12:39,890
how to grow plants and kind of merge that
with the engineering expertise that the talent

251

00:12:39,890 --> 00:12:42,200
we have here at KSC can provide.

252
00:12:42,200 --> 00:12:46,420
It-it’s interesting that you get to a certain
point with the plant scientists where their

253
00:12:46,420 --> 00:12:48,560
engineering skills tend to run out.

254
00:12:48,560 --> 00:12:50,959
You’re at the fringe of-- the boundary of
their knowledge.

255
00:12:50,959 --> 00:12:53,990
And then you have the engineers come along
and-and they really-- most-- for the most

256
00:12:53,990 --> 00:12:57,880
part know little to nothing about plants,
unless they grew on a farm.

257
00:12:57,880 --> 00:13:02,860
So it’s trying to merge those two cultures
into a successful collaboration that really

258
00:13:02,860 --> 00:13:04,600
enables us to push forward.

259
00:13:04,600 --> 00:13:07,100
And water delivery right now is our first
challenge.

260
00:13:07,100 --> 00:13:08,260
Host: you’ve had successes.

261
00:13:08,260 --> 00:13:09,500
I’ve seen astronauts eating lettuce.

262

00:13:09,500 --> 00:13:11,180
Astronauts on the Space Station: that’s
awesome.

263
00:13:11,180 --> 00:13:12,640
It’s good-- tastes good?

264
00:13:12,640 --> 00:13:13,640
Yeah.

265
00:13:13,640 --> 00:13:14,640
I like that.

266
00:13:14,640 --> 00:13:15,910
Kind of like arugula.

267
00:13:15,910 --> 00:13:20,650
Host: I know here on earth we-we’ve kinda
had a lot of scares with lettuce lately.

268
00:13:20,650 --> 00:13:22,980
Um, are there the same concerns in space?

269
00:13:22,980 --> 00:13:24,570
Dr. Gioia Massa: Actually, no.

270
00:13:24,570 --> 00:13:28,790
There are some food safety concerns in space,
‘cause we have to worry about what microorganisms

271
00:13:28,790 --> 00:13:31,680
might be in the environment just kinda floating
around.

272
00:13:31,680 --> 00:13:35,750
But most of the lettuce concerns or the food
safety scares we have on earth are from things

273
00:13:35,750 --> 00:13:38,320

like animals getting into the field.

274
00:13:38,320 --> 00:13:42,830
So we don’t really have any of those issues,
but we do have to, you know, do due diligence.

275
00:13:42,830 --> 00:13:47,070
We-we don’t want to put the astronauts at
risk, so we wanna make sure that the food

276
00:13:47,070 --> 00:13:48,070
is safe to eat.

277
00:13:48,070 --> 00:13:52,270
And we’re also looking at new ways to clean
the produce, because, you know, you-- it’s--

278
00:13:52,270 --> 00:13:55,899
just like it’s hard to wash or, to water
plants, it’s also really hard to wash your

279
00:13:55,899 --> 00:13:57,279
vegetables in space.

280
00:13:57,279 --> 00:13:59,850
Uh, so we have, um, groups working on that
as well.

281
00:13:59,850 --> 00:14:04,370
Host: so for the space station, it makes sense
that, you know, we can send resupply missions

282
00:14:04,370 --> 00:14:06,760
up often so they have, uh, a food supply.

283
00:14:06,760 --> 00:14:11,029
So, when we go to further destinations like
Mars, where it takes six to nine months to

284

00:14:11,029 --> 00:14:13,560
get there, why is your work so important?

285
00:14:13,560 --> 00:14:19,930
Ralph Fritsche: So right now, I think we’re
kind of, um, really at the benefit of having

286
00:14:19,930 --> 00:14:21,450
this close proximity to the earth.

287
00:14:21,450 --> 00:14:25,740
We don’t worry so much about the food that
we are growing, uh, because it’s not really

288
00:14:25,740 --> 00:14:30,170
being required to s-- really supply additional
calories and nutrition to the crew.

289
00:14:30,170 --> 00:14:35,279
Right now, it’s been primarily research
and as an additive just to demonstrate a capability.

290
00:14:35,279 --> 00:14:40,070
But the further away we go, the more important
and critical having that food as part of--

291
00:14:40,070 --> 00:14:43,690
that we grow as part of the system, uh, capability
requirements.

292
00:14:43,690 --> 00:14:49,940
It-it takes a lot of energy and a lot of money
to get food sent from the ground up into deep

293
00:14:49,940 --> 00:14:50,940
space.

294
00:14:50,940 --> 00:14:56,980
Uh, we know that a crew of six, one-year stay
on mars, its 26,000 pounds of food, 31 cubic

295
00:14:56,980 --> 00:14:58,709
meters of volume.

296
00:14:58,709 --> 00:15:04,130
And when I look at the next vehicle that we’re
planning on putting up in, um, cis-lunar space,

297
00:15:04,130 --> 00:15:09,520
the lunar orbital platform, the gateway, that
internal volume is only 51 cubic meters.

298
00:15:09,520 --> 00:15:15,180
So if we think about the amount of space required
and the weight, uh, required to get off the

299
00:15:15,180 --> 00:15:19,720
ground to get to Mars, to get on the surface
of Mars, to feed crews, we’re not gonna

300
00:15:19,720 --> 00:15:21,020
be able to sustain that.

301
00:15:21,020 --> 00:15:25,610
We really, for the long haul, need to be able
to come up with a bio-regenerative capability

302
00:15:25,610 --> 00:15:27,861
where we can really truly start looking at
Earth independence.

303
00:15:27,861 --> 00:15:32,730
And so, you’re gonna see a transition from
the pick and eat type of crops that we grow

304
00:15:32,730 --> 00:15:37,709
now into the staple crops, which really supply
our calories, so that we can kind of offload

305

00:15:37,709 --> 00:15:40,089
that weight penalty for bringing things from
earth.

306
00:15:40,089 --> 00:15:43,390
Host: so pick and eat-- so Gioia, can you
talk a little about the difference between

307
00:15:43,390 --> 00:15:44,390
those?

308
00:15:44,390 --> 00:15:45,390
>>

309
00:15:45,390 --> 00:15:46,410
Dr. Gioia Massa: Yeah, so pick and eat are
your fresh vegetables, things that you can

310
00:15:46,410 --> 00:15:47,570
pick and eat directly.

311
00:15:47,570 --> 00:15:48,959
So your salad crops.

312
00:15:48,959 --> 00:15:54,070
We work a lot with leafy greens, um, small
fruits like tomatoes and peppers, um, maybe

313
00:15:54,070 --> 00:15:57,279
some herbs like basil that you could add to
the packaged food.

314
00:15:57,279 --> 00:16:01,000
Um, maybe even some root crops, like a radish
or a carrot.

315
00:16:01,000 --> 00:16:05,220
Uh, those are a little harder because, you
know, without gravity it gets to be a challenge

316
00:16:05,220 --> 00:16:07,149
to-to-to harvest the roots well.

317
00:16:07,149 --> 00:16:08,149
>>

318
00:16:08,149 --> 00:16:09,230
Host: And you mentioned growing fast and-and
flavors.

319
00:16:09,230 --> 00:16:12,519
And I know, uh, Ralph, you guys have been
testing microgreens.

320
00:16:12,519 --> 00:16:16,850
Ralph Fritsche: Uh, advantages of microgreens
is it doesn’t take much in the way of resources

321
00:16:16,850 --> 00:16:22,550
to grow them, and they are very dense in their
nutrition, uh, they require less light.

322
00:16:22,550 --> 00:16:26,680
So everything with more-- growing microgreens
is pretty much a positive so far.

323
00:16:26,680 --> 00:16:27,839
They have a lot of flavor.

324
00:16:27,839 --> 00:16:31,610
You can add them to the diet as an augmentation
to meals, um--

325
00:16:31,610 --> 00:16:34,950
Host: And I hear that the astronauts really
love things that have a little punch of flavor.

326
00:16:34,950 --> 00:16:38,779
Ralph Fritsche: Yeah, and we can-- anything

that you can grow as a typical salad crop

327
00:16:38,779 --> 00:16:40,500
can be grown as a microgreen.

328
00:16:40,500 --> 00:16:41,889
You just harvest it earlier.

329
00:16:41,889 --> 00:16:46,250
Uh, we've been experimenting with wasabi,
things that have a real kick to them.

330
00:16:46,250 --> 00:16:49,769
There's also some, uh, microgreens that
we grow that taste like green apples.

331
00:16:49,769 --> 00:16:54,130
So we can add a lot of variety of flavor,
as well as the nutrients, into the diet by

332
00:16:54,130 --> 00:16:57,650
growing something that's simple, that doesn't
take up much space, and doesn't require

333
00:16:57,650 --> 00:17:01,161
much of the, uh, consumable resources that
we have to bring along.

334
00:17:01,161 --> 00:17:02,620
Host: Yeah, I imagine seeds are quite light.

335
00:17:02,620 --> 00:17:05,929
Ralph Fritsche: Seeds are light when compared
to some of the hardware components that we

336
00:17:05,929 --> 00:17:07,010
have to bring up, yeah.

337
00:17:07,010 --> 00:17:08,939

And we can pack a lot of ‘em in a small
space.

338
00:17:08,939 --> 00:17:09,939
Host: mm-hmm.

339
00:17:09,939 --> 00:17:13,630
Dr. Gioia Massa: So, one of the things we
have to figure out is how seeds do over long

340
00:17:13,630 --> 00:17:17,620
durations, especially when they’re exposed
to some of the radiation we may get on the

341
00:17:17,620 --> 00:17:18,810
way to-- the way to Mars, so--

342
00:17:18,810 --> 00:17:19,810
Ralph Fritsche: Big thing, radiation.

343
00:17:19,810 --> 00:17:20,850
Dr. Gioia Massa: Yeah, radiation’s big.

344
00:17:20,850 --> 00:17:25,290
Ralph Fritsche: Everything we’ve done, um,
in terms of growing plants for food in recent

345
00:17:25,290 --> 00:17:28,980
years has all been done in low earth orbit,
in the protective environment of the radiation

346
00:17:28,980 --> 00:17:31,130
belts that we have here, the Van Allen belts.

347
00:17:31,130 --> 00:17:35,330
We don’t know what the effect of that radiation
environment, the cosmic rays are gonna have

348
00:17:35,330 --> 00:17:37,860

long term on the seeds or the plants that
we grow.

349
00:17:37,860 --> 00:17:42,200
So we’re gonna be looking at multi-generational
studies to really observe those effects, and

350
00:17:42,200 --> 00:17:46,390
that’s why we need to start that kinda research
as soon as we can and why we’re really hoping

351
00:17:46,390 --> 00:17:48,670
to get something incorporated onto the Gateway.

352
00:17:48,670 --> 00:17:52,580
Host: What would, like, a greenhouse look
like on Mars, like, given the radiation concerns?

353
00:17:52,580 --> 00:17:53,580
>>

354
00:17:53,580 --> 00:17:55,910
Dr. Gioia Massa: Well, you’ll probably be
underground.

355
00:17:55,910 --> 00:17:59,180
Um, you know, i think you’ll wanna be protected
somehow.

356
00:17:59,180 --> 00:18:04,190
So maybe in the early period, you know, when
you’re just there, you might be in a habitat,

357
00:18:04,190 --> 00:18:08,670
something that would launch on a rocket, and
maybe you’ll have, um, you know, a habitat

358
00:18:08,670 --> 00:18:13,480
that’s outfitted just for plant growth that
could provide those-those crops for the crew.

359
00:18:13,480 --> 00:18:18,080
But later on, you'll probably be-- I'd
either pile dirt over the top of it, or you'll

360
00:18:18,080 --> 00:18:19,080
be in a cave.

361
00:18:19,080 --> 00:18:20,179
Ralph Fritsche: Regolith, Gioia, it's regolith.

362
00:18:20,179 --> 00:18:21,179
Dr. Gioia Massa: Yeah.

363
00:18:21,179 --> 00:18:23,549
Uh, over-- or you'll be in maybe a lava
tube cave.

364
00:18:23,549 --> 00:18:27,470
So you'd protect the crew and the plants
from-from the radiation that's hittin'

365
00:18:27,470 --> 00:18:28,470
surface.

366
00:18:28,470 --> 00:18:31,250
It would also protect from things like dust,
micrometeorite impacts.

367
00:18:31,250 --> 00:18:34,720
You know, there's a lot of hazards on-on-on
the planet.

368
00:18:34,720 --> 00:18:39,760
Um, and then, you know, you'd be using either
electric light, like LED's, or maybe you

369
00:18:39,760 --> 00:18:45,100
can use some light piping where you have a

concentrating mirror, like a parabolic shaped

370
00:18:45,100 --> 00:18:49,300
mirror that will concentrate the sun and pipe
it underground through fiber optics.

371
00:18:49,300 --> 00:18:55,480
But, um, you gotta remember the sun on Mars
is-is 43-percent of what it is on Earth, so--

372
00:18:55,480 --> 00:18:57,120
and that’s even without a dust storm.

373
00:18:57,120 --> 00:19:02,020
So you know, you’d have to have a lot of
area that you concentrate to-to get enough

374
00:19:02,020 --> 00:19:03,020
sun to grow plants.

375
00:19:03,020 --> 00:19:05,730
Host: So, I read “The Martian”, I saw
the movie.

376
00:19:05,730 --> 00:19:06,880
I’m sure you have, too.

377
00:19:06,880 --> 00:19:07,880
Dr. Gioia Massa: Mm-hmm.

378
00:19:07,880 --> 00:19:08,880
Host: So mark Watney--

379
00:19:08,880 --> 00:19:10,330
Ralph Fritsche: Wait, what was that-- what
was that movie?

380
00:19:10,330 --> 00:19:14,350
Host: Uh, Mark Watney, you know, grew potatoes

in that regolith.

381
00:19:14,350 --> 00:19:16,270
Um, are potatoes a good option?

382
00:19:16,270 --> 00:19:19,890
Ralph Fritsche: So, when it comes to what
he did in terms of growing the potatoes on

383
00:19:19,890 --> 00:19:23,380
mars, um, once again, Hollywood takes a lot
of liberties.

384
00:19:23,380 --> 00:19:27,440
Uh, we appreciate their efforts in showing
the potential possibility, but, no, you couldn't

385
00:19:27,440 --> 00:19:32,669
grow potatoes or pretty much anything with
straight up Martian regolith the way he used

386
00:19:32,669 --> 00:19:33,669
it.

387
00:19:33,669 --> 00:19:38,620
Uh, regolith contains perchlorates and other
things that are not conducive to plant growth

388
00:19:38,620 --> 00:19:40,549
or human consumption.

389
00:19:40,549 --> 00:19:44,100
So we would have to remediate those things,
get those things out of the regolith before

390
00:19:44,100 --> 00:19:49,460
you could actually even consider adding nutrients
to the regolith that would facilitate plant

391

00:19:49,460 --> 00:19:50,460
growth.

392
00:19:50,460 --> 00:19:53,020
So the way it’s depicted in the movie, not
so much.

393
00:19:53,020 --> 00:19:56,250
Dr. Gioia Massa: But potatoes are a good candidate
crop.

394
00:19:56,250 --> 00:19:59,650
They’re very nutritious, they’re very
productive, um, and we’ve actually worked

395
00:19:59,650 --> 00:20:03,600
for a long time here at Kennedy Space Center
on potatoes, especially our colleague dr.

396
00:20:03,600 --> 00:20:05,510
Ray Wheeler, who’s a potato expert.

397
00:20:05,510 --> 00:20:08,450
You know, right now on space station, we don’t
have any way to cook anything.

398
00:20:08,450 --> 00:20:10,200
We don’t even have a microwave.

399
00:20:10,200 --> 00:20:13,789
So we’re really just focusing on things
you can pick and eat fresh, but as soon as

400
00:20:13,789 --> 00:20:19,030
we had a microwave or an oven or a way to
cook, crops like white potato and sweet potato

401
00:20:19,030 --> 00:20:21,420
become a really good source of food.

402
00:20:21,420 --> 00:20:24,380
Um, and they’re easy to grow and-and they’re
kinda fun.

403
00:20:24,380 --> 00:20:29,140
Host: So, can you speak a little bit about
the psychological benefits of growing things.

404
00:20:29,140 --> 00:20:33,130
Like, when you’re going on a six to nine-month
mission to Mars, like, how important is that

405
00:20:33,130 --> 00:20:34,370
to see something green growing?

406
00:20:34,370 --> 00:20:37,560
Dr. Gioia Massa: Well, I think it would be
really important, but I’m a little biased.

407
00:20:37,560 --> 00:20:40,200
Um, you know, it-- we don’t really know.

408
00:20:40,200 --> 00:20:44,660
We don’t have great data on that yet, but
there are a lot of anecdotal evidence from

409
00:20:44,660 --> 00:20:49,179
the astronauts saying how much they like growing
the plants, how much they really enjoy seeing

410
00:20:49,179 --> 00:20:52,330
them in that environment of the Space Station,
which is very synthetic.

411
00:20:52,330 --> 00:20:55,110
It’s all plastic and metal and cables and
wires.

412
00:20:55,110 --> 00:20:59,679

Um, so I think having that little piece of
Earth with you when you’re living and working

413
00:20:59,679 --> 00:21:04,809
in a stressful environment, especially when
you’re so far from home on Mars that, you

414
00:21:04,809 --> 00:21:09,200
know, it’s just a-a dot in the sky, I think
that’s gonna be really important.

415
00:21:09,200 --> 00:21:12,669
But then there’s the-the-the downside--
you know, what happens if you get too attached

416
00:21:12,669 --> 00:21:14,000
to your plants and they-they die?

417
00:21:14,000 --> 00:21:17,340
Or you know, you have an insect or-- not insect,
a disease outbreak.

418
00:21:17,340 --> 00:21:19,080
Hopefully we won’t bring any insects.

419
00:21:19,080 --> 00:21:22,220
Then, you know, then that could be psychologically
detrimental.

420
00:21:22,220 --> 00:21:24,020
So we have to look at all of that.

421
00:21:24,020 --> 00:21:28,540
We’re gonna be startin’ to collect some
data on the psychological benefit or not of

422
00:21:28,540 --> 00:21:31,270
plants in space in the next couple of years
on ISS.

423
00:21:31,270 --> 00:21:35,549
We’ll be doing questionnaires and surveys
of the crew and actually collect some data

424
00:21:35,549 --> 00:21:36,549
on this.

425
00:21:36,549 --> 00:21:37,549
So hopefully we’ll know more.

426
00:21:37,549 --> 00:21:38,549
Host: That sounds really cool.

427
00:21:38,549 --> 00:21:39,549
>>

428
00:21:39,549 --> 00:21:40,610
Ralph Fritsche: But, you know, you can do
some extrapolation, and-and this is not scientific

429
00:21:40,610 --> 00:21:45,669
at all, but we know from the food technology
folks in Houston who we kind of support in

430
00:21:45,669 --> 00:21:49,360
terms with our food production activities,
they’re very concerned about the quality

431
00:21:49,360 --> 00:21:51,850
of the diet from a palatability standpoint.

432
00:21:51,850 --> 00:21:55,030
Is the crew gonna like whatever we grow so
that they would eat it?

433
00:21:55,030 --> 00:21:58,720
Uh, and they’re very concerned from the
perspective that the crew has to give up a

434
00:21:58,720 --> 00:22:03,919
lot of the comforts of home just going on
spaceflight, and so the thought of sacrificing

435
00:22:03,919 --> 00:22:08,429
the quality and the enjoyment they get from
their diet with that sense of taste is something

436
00:22:08,429 --> 00:22:09,650
that they don’t wanna have to give up.

437
00:22:09,650 --> 00:22:14,480
Dr. Gioia Massa: They found that people eating
the same diets for long times get-get menu

438
00:22:14,480 --> 00:22:15,480
fatigue.

439
00:22:15,480 --> 00:22:16,480
Ralph Fritsche: Unless it’s my son.

440
00:22:16,480 --> 00:22:17,500
He likes chicken fingers every day.

441
00:22:17,500 --> 00:22:19,380
Host: I think that’s everyone’s child.

442
00:22:19,380 --> 00:22:20,429
Dr. Gioia Massa: Yeah, but--

443
00:22:20,429 --> 00:22:21,429
Ralph Fritsche: There’s our solution.

444
00:22:21,429 --> 00:22:24,560
Dr. Gioia Massa: If we don’t have chicken
fingers, um, you know, you might get a little

445
00:22:24,560 --> 00:22:29,040

bored eating the same diet year in, year out,
you know, on maybe a two week cycle, even

446
00:22:29,040 --> 00:22:30,169
though it’s a really good diet.

447
00:22:30,169 --> 00:22:35,580
And so having this fresh produce to make it
more interesting to-to give you more options

448
00:22:35,580 --> 00:22:37,650
of things that you can make could be really
good, too.

449
00:22:37,650 --> 00:22:40,660
Ralph Fritsche: and-and that’s another interesting
challenge we have where we’re constantly

450
00:22:40,660 --> 00:22:46,250
approached by people who have potential food
production solutions, but the product that

451
00:22:46,250 --> 00:22:49,610
they’re developing is not something that
you would traditionally find appealing, let’s

452
00:22:49,610 --> 00:22:51,460
say, in a regular diet.

453
00:22:51,460 --> 00:22:52,460
Host: Hmm, yeah.

454
00:22:52,460 --> 00:22:55,210
Ralph Fritsche: Even though it might be highly
nutritious, uh, we’ve seen articles in the

455
00:22:55,210 --> 00:22:57,110
press recently about cockroach milk.

456

00:22:57,110 --> 00:23:01,200
Um, yeah, it might be really good for you,
but how do you provide that to someone and

457
00:23:01,200 --> 00:23:02,200
have them eat it?

458
00:23:02,200 --> 00:23:05,799
Host: And I understand you’re also working
with kids to help you decide the next crops

459
00:23:05,799 --> 00:23:06,799
to grow?

460
00:23:06,799 --> 00:23:10,030
Dr. Gioia Massa: Yeah, we have a wonderful
program with the Fairchild Tropical Botanic

461
00:23:10,030 --> 00:23:15,700
Garden in Miami, and they have about 150 or
more, uh, middle schools and high schools,

462
00:23:15,700 --> 00:23:19,990
and those students are involved with testing
new crops for us for space.

463
00:23:19,990 --> 00:23:25,140
Student: Hi, my name is Giselle and I’m
a 12th grade student at biotech high school.

464
00:23:25,140 --> 00:23:26,900
My question is for Ricky.

465
00:23:26,900 --> 00:23:29,789
If you could grow any food plant on ISS, what
would it be?

466
00:23:29,789 --> 00:23:33,070
Ricky Arnold (astronaut): well, if I had my
choice, it would be a barbeque plant.

467
00:23:33,070 --> 00:23:36,890
But, uh, since they don’t exist on Earth,
uh, I’ll have to go with a, uh, some kinda

468
00:23:36,890 --> 00:23:37,890
fresh fruit.

469
00:23:37,890 --> 00:23:42,280
Dr. Gioia Massa: so if you can get, you know,
100 schools to grow one type of plant really

470
00:23:42,280 --> 00:23:46,600
well, when you have some kids watering not
enough and some overwatering, and some classrooms

471
00:23:46,600 --> 00:23:50,670
cold and some hot-- if that plant grows really
well in that many schools, it’s probably

472
00:23:50,670 --> 00:23:52,390
a really good candidate for space.

473
00:23:52,390 --> 00:23:54,130
So we’re really excited.

474
00:23:54,130 --> 00:23:58,260
They’re generating a lot of data, they’re
feeding it to us on Google Sheets, they have

475
00:23:58,260 --> 00:24:03,890
a statistician involved as well, and so we’re
actually going to be flying two of the species

476
00:24:03,890 --> 00:24:07,260
that they down-selected on the International
Space Station.

477
00:24:07,260 --> 00:24:08,260

Host: That’s amazing.

478
00:24:08,260 --> 00:24:09,260
Dr. Gioia Massa: Yeah.

479
00:24:09,260 --> 00:24:10,260
Host: Where kids get to be part of, you know,
NASA.

480
00:24:10,260 --> 00:24:11,260
Dr. Gioia Massa: Yeah, they are so valuable.

481
00:24:11,260 --> 00:24:12,260
Yeah.

482
00:24:12,260 --> 00:24:13,260
Host: That’s awesome.

483
00:24:13,260 --> 00:24:17,940
That sounds like you guys have so many challenges
between oxygen, and water, and radiation,

484
00:24:17,940 --> 00:24:19,960
and what kind of soil do you grow it in in
space, and-and mass.

485
00:24:19,960 --> 00:24:21,789
Ralph Fritsche: We’ll have ‘em all solved
by next week.

486
00:24:21,789 --> 00:24:22,820
It’s no problem.

487
00:24:22,820 --> 00:24:23,820
Host: Excellent.

488
00:24:23,820 --> 00:24:26,640
Dr. Gioia Massa: We have a lot of interns,
so that helps.

489
00:24:26,640 --> 00:24:27,640
Host: I love it.

490
00:24:27,640 --> 00:24:31,520
So, my last question, you guys: would you
go to Mars and be that crazy botanist on Mars?

491
00:24:31,520 --> 00:24:36,600
Dr. Gioia Massa: A few years ago I might’ve,
but now I think I’m pretty earthbound.

492
00:24:36,600 --> 00:24:42,330
You know, I would like to go to space at some
point, but, um, I’d- I think Mars is a little-little

493
00:24:42,330 --> 00:24:43,330
far away for me.

494
00:24:43,330 --> 00:24:44,330
Host: Ralph?

495
00:24:44,330 --> 00:24:47,809
Ralph Fritsche: I am strangely drawn to Mars,
but I’m not a botanist, so I guess I can’t

496
00:24:47,809 --> 00:24:48,809
go.

497
00:24:48,809 --> 00:24:49,809
>>

498
00:24:49,809 --> 00:24:50,809
Host: You can still go.

499
00:24:50,809 --> 00:24:51,809
We still need project managers.

500

00:24:51,809 --> 00:24:57,220
Dr. Gioia Massa: Just don’t open the airlock.

501
00:24:57,220 --> 00:25:11,480
Rob Mueller: Kennedy Space Center is one of
the world’s, uh, premier spaceports, but

502
00:25:11,480 --> 00:25:17,570
we also envision spaceports on other planetary
surfaces-- uh, Mars, uh, the Moon, and even

503
00:25:17,570 --> 00:25:18,950
asteroids and beyond.

504
00:25:18,950 --> 00:25:22,850
Joshua Santora (Host): All right, so I am
here today in the booth with Rob Mueller.

505
00:25:22,850 --> 00:25:25,000
Uh, Rob, what’s your official title here?

506
00:25:25,000 --> 00:25:30,130
Rob Mueller: I am a senior technologist in
the NASA Kennedy Space Center Swamp Works

507
00:25:30,130 --> 00:25:31,409
innovation environment.

508
00:25:31,409 --> 00:25:35,600
Essentially, we’re developing the technologies
that are required to operate in space-- for

509
00:25:35,600 --> 00:25:37,150
humans to operate in space.

510
00:25:37,150 --> 00:25:42,700
Speaker: Robert, let me add my congratulations,
uh, to Jim Bridenstine as the new administrator

511

00:25:42,700 --> 00:25:43,700
of NASA.

512
00:25:43,700 --> 00:25:48,450
Jim Bridenstine: The reason we go to the Moon
is because we wanna land Americans on the

513
00:25:48,450 --> 00:25:49,850
surface of Mars.

514
00:25:49,850 --> 00:25:55,419
And the technologies, the capabilities, the
in situ resource utilization that we develop

515
00:25:55,419 --> 00:25:58,270
for the Moon will ultimately get us to Mars.

516
00:25:58,270 --> 00:26:00,720
It’s also why the Gateway is so important.

517
00:26:00,720 --> 00:26:07,070
Having, uh, an-an orbital outpost around the
Moon gives us more access to more parts of

518
00:26:07,070 --> 00:26:09,510
the solar system than ever before.

519
00:26:09,510 --> 00:26:14,540
Host: Okay, so we have rockets that can get
people to Mars today.

520
00:26:14,540 --> 00:26:19,309
Uh, maybe not a lot of stuff with them, but--
so you strap me in in a rocket, I got a spacesuit

521
00:26:19,309 --> 00:26:23,820
on, I got some food and some water-- how successful
of a mission is this to Mars?

522

00:26:23,820 --> 00:26:27,549
Rob Mueller: Well, first of all, you have
to realize this is not a short trip.

523
00:26:27,549 --> 00:26:28,549
Host: Okay.

524
00:26:28,549 --> 00:26:33,590
Rob Mueller: And to-to compound that, once
you get there, you can’t come home right

525
00:26:33,590 --> 00:26:34,590
away.

526
00:26:34,590 --> 00:26:39,270
If you had an emergency, the planets aren’t
lined up the way the orbits work.

527
00:26:39,270 --> 00:26:46,200
And so it’s very difficult to come back
from Mars, uh, without using a lot of propellant.

528
00:26:46,200 --> 00:26:51,860
And so, essentially, in the trajectory that
we have planned, you would go there.

529
00:26:51,860 --> 00:26:57,409
Uh, it’s called a conjunction class trajectory
and it would take you six to eight months

530
00:26:57,409 --> 00:27:02,330
to travel to Mars, and then, uh, you're committed
to being on Mars for one and a half years,

531
00:27:02,330 --> 00:27:03,920
and then you can come back.

532
00:27:03,920 --> 00:27:08,270
So it’s a two and a half year round trip
journey, and, uh, that’s what you’re signing

533
00:27:08,270 --> 00:27:09,270
up for.

534
00:27:09,270 --> 00:27:12,460
And-and so, that’s-that’s a big difference
between the Moon and Mars.

535
00:27:12,460 --> 00:27:14,230
The Moon is three days journey.

536
00:27:14,230 --> 00:27:16,190
Uh, we did it during the Apollo missions.

537
00:27:16,190 --> 00:27:18,460
If there’s an emergency, as like in Apollo
13.

538
00:27:18,460 --> 00:27:25,299
Apollo 13 clip: your black team of flight
controllers is now in station in mission control

539
00:27:25,299 --> 00:27:31,250
center, looking at possible alternate missions,
as we have an apparent serious oxygen leak

540
00:27:31,250 --> 00:27:34,169
in the cryogenic oxygen in the service module.

541
00:27:34,169 --> 00:27:40,929
Rob Mueller: Uh, you can come back home relatively
easily as compared to Mars.

542
00:27:40,929 --> 00:27:43,940
So those-those are the big differences between
the Moon and Mars.

543
00:27:43,940 --> 00:27:46,990
Then, when you get to Mars, there’s, uh,

an atmosphere.

544
00:27:46,990 --> 00:27:53,090
It’s about 1% of the Earth’s atmosphere
in density, and, uh, uh, you would think that

545
00:27:53,090 --> 00:27:57,220
that’s a good thing, uh, and it’s-it’s
good and bad.

546
00:27:57,220 --> 00:28:02,429
When you try to land on Mars and you come
into the atmosphere, it helps because it provides

547
00:28:02,429 --> 00:28:04,150
friction, which slows you down.

548
00:28:04,150 --> 00:28:10,740
However, that friction creates heat, and then
that will cause problems for your spacecraft,

549
00:28:10,740 --> 00:28:13,590
and so you need heat shields and those kind
of things.

550
00:28:13,590 --> 00:28:19,210
But the atmosphere isn’t dense enough to
really slow you down, so you need more time.

551
00:28:19,210 --> 00:28:23,299
In fact, there’s many places on Mars where
we cannot land today because the altitude

552
00:28:23,299 --> 00:28:24,299
is too high.

553
00:28:24,299 --> 00:28:25,299
You don’t have enough time to land.

554

00:28:25,299 --> 00:28:28,070
The parachute’s open but you’re still
going too fast.

555
00:28:28,070 --> 00:28:32,411
So we land in the valleys on Mars and low
areas, and that’s just a reality of going

556
00:28:34,570 --> 00:28:33,411
to Mars.

557
00:28:34,570 --> 00:28:37,010
Host: What kind of things do we have to consider
before we go?

558
00:28:37,010 --> 00:28:40,460
Rob Mueller: Well, let’s start with what
we can do today.

559
00:28:40,460 --> 00:28:46,920
Today, the largest object we’ve landed on
Mars had-had a roughly 1,000 kilograms, a

560
00:28:46,920 --> 00:28:49,820
little bit under 1,000 kilograms, the-the
Mars Science Lab.

561
00:28:49,820 --> 00:28:52,720
That’s what we’re able to land on Mars
today.

562
00:28:52,720 --> 00:28:57,140
In the future, the payloads we’re going
to have to land on Mars for human exploration

563
00:28:57,140 --> 00:29:03,990
will be between 20 and 40 metric tons, so
20,000 to 40,000 kilograms per landing, and

564
00:29:03,990 --> 00:29:06,080

there will be multiple landings required.

565
00:29:06,080 --> 00:29:11,419
So that’s 20 to 40 times the capability
of the systems we have today for landing on

566
00:29:11,419 --> 00:29:12,419
Mars.

567
00:29:12,419 --> 00:29:14,160
Then, you have to consider the humans.

568
00:29:14,160 --> 00:29:16,930
The humans need to survive.

569
00:29:16,930 --> 00:29:18,590
That is, uh, important.

570
00:29:18,590 --> 00:29:19,590
Host: Pretty critical.

571
00:29:19,590 --> 00:29:24,299
Rob Mueller: And so, we’d like to not only
have them survive, but-but really do well

572
00:29:24,299 --> 00:29:25,720
in space.

573
00:29:25,720 --> 00:29:28,789
But we’re still learning about that, and
that’s one of the reasons we have the International

574
00:29:28,789 --> 00:29:30,159
Space Station.

575
00:29:30,159 --> 00:29:33,020
When we have a-a journey to Mars, it takes
six months.

576
00:29:33,020 --> 00:29:37,429
In those six months, when you land, the first
thing that could happen is you’ll have to

577
00:29:37,429 --> 00:29:38,650
do rehab.

578
00:29:38,650 --> 00:29:43,419
And so, you’ll spend four to six weeks doing
rehab before you can ever walk on the surface

579
00:29:43,419 --> 00:29:44,610
of Mars.

580
00:29:44,610 --> 00:29:49,570
But on the other hand, you have to plug your
spacecraft into the power plant right away

581
00:29:49,570 --> 00:29:51,390
or your batteries will run down.

582
00:29:51,390 --> 00:29:55,831
So now you have this dilemma-- you’re too
weak to do a spacewalk on Mars because there’s

583
00:29:55,831 --> 00:30:00,900
a gravity environment because you’ve turned
into, uh, some kind of jellyfish on the way

584
00:30:00,900 --> 00:30:04,240
to going to Mars, and you have to do rehab.

585
00:30:04,240 --> 00:30:11,600
So first, we have to figure out the biological
and physiological, uh, issues with human health,

586
00:30:11,600 --> 00:30:16,049
and, uh, that’s what we’re doing today
in the international space station.

587
00:30:16,049 --> 00:30:22,840
Uh, once we know a crew can be healthy and
arrive at mars, and we have the landing systems,

588
00:30:22,840 --> 00:30:29,230
and we have, uh, done all the technology development
required to land on the surface of mars reliably--

589
00:30:29,230 --> 00:30:33,159
uh, we have to land in the same spot every
time.

590
00:30:33,159 --> 00:30:34,750
So it’s one thing landing on mars.

591
00:30:34,750 --> 00:30:39,929
It’s another thing landing one spacecraft
next to another spacecraft within, let’s

592
00:30:39,929 --> 00:30:42,169
say, 100 meters of each other.

593
00:30:42,169 --> 00:30:45,539
And, uh, and we also need propellant to come
home.

594
00:30:45,539 --> 00:30:51,390
Uh, one of the things about our mars architecture
is we need about 30 tons of propellant to

595
00:30:51,390 --> 00:30:52,559
come home.

596
00:30:52,559 --> 00:30:58,039
And when-when it takes a-a gear ratio, a ratio
of 11 to 1 of the mass in low earth orbit

597
00:30:58,039 --> 00:31:02,929

to the mass you land on mars, so it’s-it’s
not 30 tons anymore, it’s 330 tons in low

598
00:31:02,929 --> 00:31:03,929
earth orbit.

599
00:31:03,929 --> 00:31:06,840
And it’s-it’s even more on the surface
of the earth on a launch pad.

600
00:31:06,840 --> 00:31:11,630
So when you, uh, work out all the numbers,
you really can’t afford to bring all that

601
00:31:11,630 --> 00:31:16,419
propellant to mars to come home, so you have
to make it on mars.

602
00:31:16,419 --> 00:31:21,370
And how we make it is we make it from the
water and the carbon dioxide in the atmosphere.

603
00:31:21,370 --> 00:31:26,890
We combine the two using the sabatier process
and we make methane and oxygen, and those

604
00:31:26,890 --> 00:31:29,490
are our propellants for coming home from mars.

605
00:31:29,490 --> 00:31:34,059
So it’s not just a-a pleasure cruise out
there, and it’s-it’s-it’s not for fun.

606
00:31:34,059 --> 00:31:37,440
This is really advancing science in the solar
system.

607
00:31:37,440 --> 00:31:38,440
>>

608
00:31:38,440 --> 00:31:39,860
Host: So you talked about local resources.

609
00:31:39,860 --> 00:31:42,820
I assume you mean things we’d find on the
Moon or Mars.

610
00:31:42,820 --> 00:31:46,750
What I know of Mars, there’s no active streams,
there’s no trees growing.

611
00:31:46,750 --> 00:31:50,000
So what does local resources mean, and how
useful is that for us?

612
00:31:50,000 --> 00:31:53,670
Rob Mueller: Well, it seems like that when
you first look at it.

613
00:31:53,670 --> 00:31:55,950
Host: So-so are-are there trees on mars?

614
00:31:55,950 --> 00:32:00,880
there-there’s absolutely everything that’s
in a tree is on mars.

615
00:32:00,880 --> 00:32:01,880
Host: Okay.

616
00:32:01,880 --> 00:32:07,580
Rob Mueller: So what you have to do is you
have to break everything down into its fundamental

617
00:32:07,580 --> 00:32:08,580
elements.

618
00:32:08,580 --> 00:32:14,510
Uh, we need far more education and far more
science and technology in order to achieve

619
00:32:14,510 --> 00:32:18,340
the pioneering goals we have to expand civilization
into space.

620
00:32:18,340 --> 00:32:23,090
And so what you have to think about is the
periodic table of elements.

621
00:32:23,090 --> 00:32:24,529
So those are your building blocks.

622
00:32:24,529 --> 00:32:26,460
Host: So not trees anymore, not bricks.

623
00:32:26,460 --> 00:32:28,470
We’re talkin’ like, molecular level here.

624
00:32:28,470 --> 00:32:29,470
Rob Mueller: That’s right.

625
00:32:29,470 --> 00:32:35,270
So if-if you think of the elements as being
your trees and-and your rocks and-and everything

626
00:32:35,270 --> 00:32:41,890
else that they use to-to build things, and
so we can look at this at-at a, uh, maybe

627
00:32:41,890 --> 00:32:46,590
not molecular level yet, but at-- certainly
at an elemental level.

628
00:32:46,590 --> 00:32:52,620
And then with the use of chemical engineering
and other sciences, we can take these elements,

629
00:32:52,620 --> 00:32:57,100
we can use the-the minerals-- so, in space

we have a lot of rocks that have minerals.

630
00:32:57,100 --> 00:33:00,950
We can break down the minerals, which are
compounds, break down the compounds into elements,

631
00:33:00,950 --> 00:33:05,110
recombine them into new things, and those
are the resources we will use.

632
00:33:05,110 --> 00:33:09,160
So what I like to say is we have a lot of
energy in space from the sun.

633
00:33:09,160 --> 00:33:14,280
We’ll have a lot of resources in space in
all the rocks and minerals that we have out

634
00:33:14,280 --> 00:33:15,280
there.

635
00:33:15,280 --> 00:33:18,660
What we’re missing is the technologies,
so we’ll have to be clever.

636
00:33:18,660 --> 00:33:20,290
We have to invent new technologies.

637
00:33:20,290 --> 00:33:21,970
Host: Where are we in that process?

638
00:33:21,970 --> 00:33:23,730
Um, how far-- are we doing this yet?

639
00:33:23,730 --> 00:33:25,650
Are we just thinking about it?

640
00:33:25,650 --> 00:33:26,650
Where are we?

641
00:33:26,650 --> 00:33:30,669
Rob Mueller: Well, at the beginning of the
show, you asked me where I work.

642
00:33:30,669 --> 00:33:34,350
And I work in a lab dedicated to doing this,
to developing these technologies.

643
00:33:34,350 --> 00:33:40,320
It’s called Swamp Works, and it requires
a lot of imagination, a lot of creativity,

644
00:33:40,320 --> 00:33:43,510
and so you have to set up an environment which
is conducive to that.

645
00:33:43,510 --> 00:33:44,950
And, uh, it’s-it’s difficult.

646
00:33:44,950 --> 00:33:48,770
You’re really pushing the envelope of what’s
feasible.

647
00:33:48,770 --> 00:33:53,100
Uh, what we’re doing is we’re looking
at ways of using these resources.

648
00:33:53,100 --> 00:33:55,669
One good example is, uh, 3D printing.

649
00:33:55,669 --> 00:34:00,740
This is a new technology that’s, uh, barely
20 years old and, uh, it’s-it’s really

650
00:34:00,740 --> 00:34:02,370
changing the world.

651
00:34:02,370 --> 00:34:08,069

And it’s, uh, allowing us to look at new
ways of manufacturing, uh, objects and structures.

652
00:34:08,069 --> 00:34:12,359
And so what we do is we actually use the local
regolith, which is the crushed rock covering

653
00:34:12,359 --> 00:34:19,000
the surface of planetary bodies, and we use
that crushed rock, and we make a concrete

654
00:34:19,000 --> 00:34:20,200
material out of it.

655
00:34:20,200 --> 00:34:23,529
And, uh, we actually 3D print with concrete.

656
00:34:23,529 --> 00:34:28,509
And we also have reinforcements in there which
are basalt fiber, basalt glass fiber.

657
00:34:28,509 --> 00:34:33,730
So by doing this, suddenly all these things
become feasible which before were not feasible.

658
00:34:33,730 --> 00:34:35,099
Now, where are-are we on that?

659
00:34:35,099 --> 00:34:36,619
We can’t do it yet today.

660
00:34:36,619 --> 00:34:40,879
Uh, typically, at NASA we have something called
technology readiness level.

661
00:34:40,879 --> 00:34:42,399
It goes from 1 to 9.

662
00:34:42,399 --> 00:34:47,829

At 1 it’s just a-a basic principle that’s
observed or formulated, and 9 has been in

663
00:34:47,829 --> 00:34:48,829
space.

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00:34:48,829 --> 00:34:51,869
So we call this the-the ladder of technology
development.

665
00:34:51,869 --> 00:34:56,379
And you have to go from one rung of the ladder
to the next rung of the ladder, and that’s

666
00:34:56,379 --> 00:34:58,049
how the technology’s developed.

667
00:34:58,049 --> 00:35:02,999
And usually, at TRL 6, we’re ready for--
to be considered for a flight.

668
00:35:02,999 --> 00:35:04,720
That’s when it’s developed for a flight.

669
00:35:04,720 --> 00:35:07,579
So typically, from 1 to 6 you’re in the
lab.

670
00:35:07,579 --> 00:35:11,520
And currently, these technologies like 3D
printing with regolith, that’s at about

671
00:35:11,520 --> 00:35:15,440
TRL 4, I would say, and that’s happening
in the lab.

672
00:35:15,440 --> 00:35:19,799
Once we’ve developed in the lab, we’ve
proven that it works, then we can go and make

673
00:35:19,799 --> 00:35:22,899
a real system out of it for space.

674
00:35:22,899 --> 00:35:23,899
>>

675
00:35:23,899 --> 00:35:27,490
Host: So just takin’ that one, for instance--
obviously you can’t predict the future,

676
00:35:27,490 --> 00:35:31,009
but as-as the pace is going and as things
are developing, when-when do you hope to see

677
00:35:31,009 --> 00:35:32,529
that technology in space?

678
00:35:32,529 --> 00:35:36,940
Rob Mueller: I would say realistically, it’s
five to ten years away.

679
00:35:36,940 --> 00:35:41,450
Uh, a lot of it depends on the desire to do
this.

680
00:35:41,450 --> 00:35:46,759
If we made it a priority, then we would put
more resources on, more people on it, and,

681
00:35:46,759 --> 00:35:48,420
uh, we’d work it harder.

682
00:35:48,420 --> 00:35:52,390
So a lot of it just depends on-on how much
of a priority it is.

683
00:35:52,390 --> 00:35:54,279
Uh, we’d like to see it happen.

684
00:35:54,279 --> 00:35:56,059
Uh, we think it’s a game changer.

685
00:35:56,059 --> 00:36:01,799
And, uh, so within five to ten years, we could
do it, and we would probably test it on Earth

686
00:36:01,799 --> 00:36:02,799
first.

687
00:36:02,799 --> 00:36:08,869
And as a-a nice side benefit of this, a spinoff,
we would be able to build houses on earth

688
00:36:08,869 --> 00:36:11,900
quicker and cheaper, and they would be hurricane
proof.

689
00:36:11,900 --> 00:36:14,920
So these are all very beneficial things on
Earth here as well.

690
00:36:14,920 --> 00:36:19,690
Host: So this technology not just good for
the Moon or Mars, but it can be used here

691
00:36:19,690 --> 00:36:20,690
as well?

692
00:36:20,690 --> 00:36:21,690
Rob Mueller: Absolutely.

693
00:36:21,690 --> 00:36:25,319
It’s-it’s something where you can use
local materials anywhere you are and then

694
00:36:25,319 --> 00:36:26,650
make a structure out of it.

695
00:36:26,650 --> 00:36:29,170
And it also gives the architects design freedom.

696
00:36:29,170 --> 00:36:34,309
So now you can make structures that aren’t
just shaped like a square or a rectangle.

697
00:36:34,309 --> 00:36:37,480
All kinds of new shapes are possible, new
combinations.

698
00:36:37,480 --> 00:36:38,859
And so it frees the imagination.

699
00:36:38,859 --> 00:36:42,420
And, uh, this is what we call design freedom.

700
00:36:42,420 --> 00:36:46,009
And once you have that, you can also create
structures that are stronger.

701
00:36:46,009 --> 00:36:54,809
Uh, so as we know, we have, uh, severe weather
events-- uh, tornadoes, hurricanes, earthquakes,

702
00:36:54,809 --> 00:36:55,859
floods.

703
00:36:55,859 --> 00:37:02,130
These will all require structures that are
much stronger and, uh, can bear the brunt

704
00:37:02,130 --> 00:37:04,000
of these natural phenomena.

705
00:37:04,000 --> 00:37:07,980
And so we-we can do this with new materials
and new technologies.

706
00:37:07,980 --> 00:37:10,410
And the cost will go down because of automation.

707
00:37:10,410 --> 00:37:17,029
So you combine all those three things, and
you really have a completely new way of addressing

708
00:37:17,029 --> 00:37:19,009
the need for shelter.

709
00:37:19,009 --> 00:37:20,619
And everybody needs shelter on Earth.

710
00:37:20,619 --> 00:37:21,619
Host: Awesome.

711
00:37:21,619 --> 00:37:23,769
Rob, uh, thanks for bein' here today.

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00:37:23,769 --> 00:37:27,190
Excited to see your progress in the coming
years, and excited to see this stuff get used

713
00:37:27,190 --> 00:37:28,329
on Mars someday.

714
00:37:28,329 --> 00:37:33,209
Rob Mueller: Yeah, we hope to use it very
soon on Earth and test it here, and then we'll

715
00:37:33,209 --> 00:37:36,380
go out into the exciting solar system.

716
00:37:36,380 --> 00:37:38,630
Joshua Santora (Host): That's our show.

717
00:37:38,630 --> 00:37:40,829
Thanks for stoppin' by the rocket ranch.

718
00:37:40,829 --> 00:37:44,940
And special thanks to our guests, our sherpa
on our path to mars, Caley Burke, our plant

719
00:37:44,940 --> 00:37:50,219
people, Dr. Gioia Massa and Ralph Fritsche,
and technology guru Rob Mueller.

720
00:37:50,219 --> 00:37:55,329
To learn more about all things Mars, you can
head to mars.nasa.gov.

721
00:37:55,329 --> 00:37:58,229
There are also several NASA podcasts you can
check out to learn more about the science

722
00:37:58,229 --> 00:38:00,900
happening all over our centers at nasa.gov/podcasts.

723
00:38:00,900 --> 00:38:06,180
And shout-out to my colleague Amanda Griffin,
who helped with the interviews, our sound

724
00:38:06,180 --> 00:38:12,150
man Lorne Mathre, editor Frankie Martin, and
our producer, Jessica Landa.

725
00:38:12,150 --> 00:38:14,650
Tune in next month to hear our episode all
about traveling to the sun.