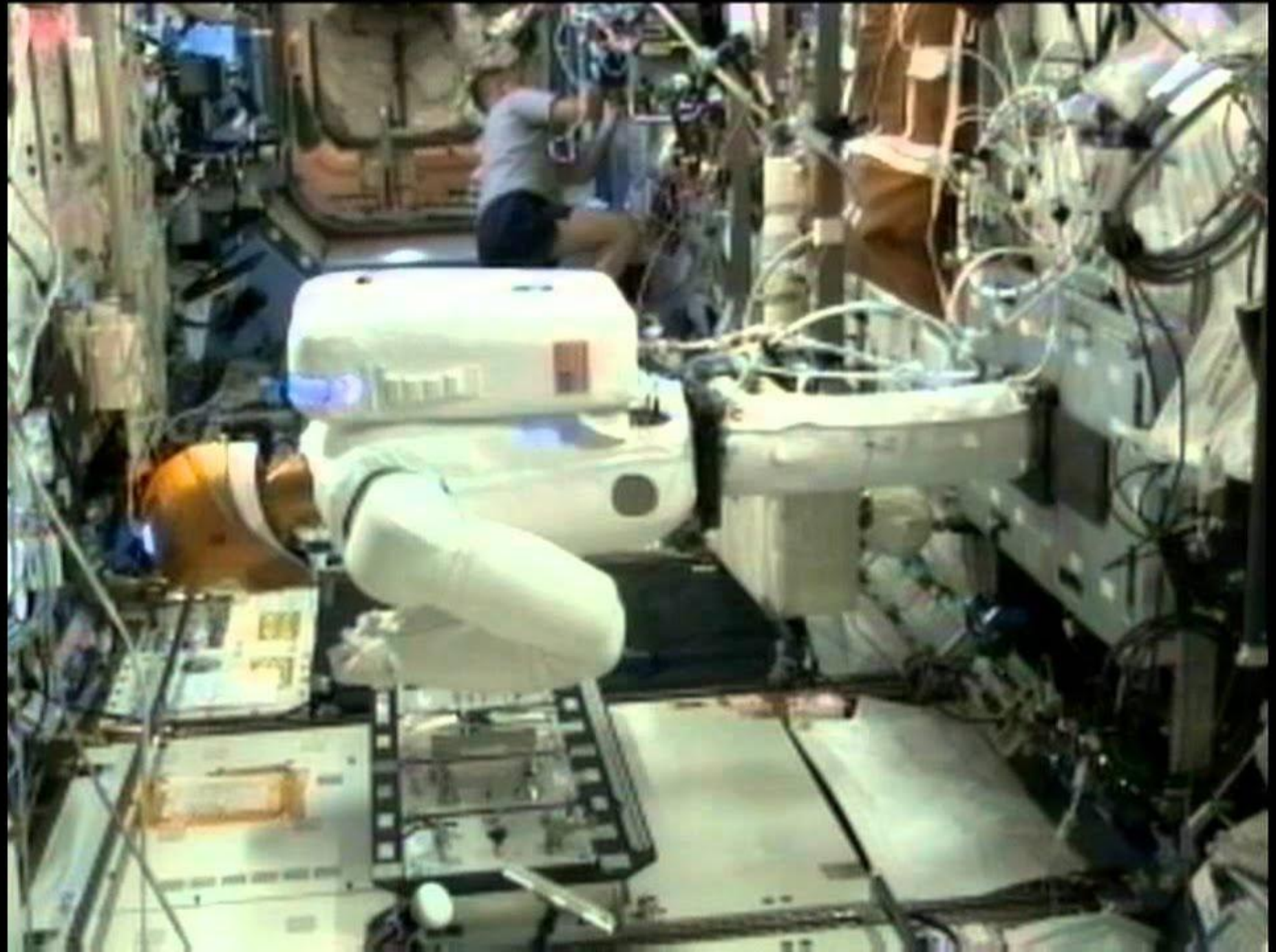

1
00:00:02,068 --> 00:00:03,836
>> Early today as we mentioned,

2
00:00:03,836 --> 00:00:06,305
space station commander
Kevin Ford was at work

3
00:00:06,305 --> 00:00:07,973
in the Destiny Laboratory.

4
00:00:07,973 --> 00:00:12,244
He powered up the
Robonaut experiment and set

5
00:00:12,244 --> 00:00:15,915
up the cameras so we could
record Robonaut's actions during

6
00:00:15,915 --> 00:00:18,784
ground commanded activities.

7
00:00:18,784 --> 00:00:22,121
That's got started on-
board the station last year.

8
00:00:22,121 --> 00:00:25,191
This experiment is ongoing.

9
00:00:25,191 --> 00:00:28,694
Right now Ford is disassembling
Robonaut and preparing

10
00:00:28,694 --> 00:00:31,464
to stow it before its
next work session.

11
00:00:31,464 --> 00:00:34,133
In order to learn more about
this robot and its work

12
00:00:34,133 --> 00:00:35,968
on the station, I'm joined here

13
00:00:35,968 --> 00:00:39,305
in the flight control room this
morning by Dr. Ron Diffler.

14
00:00:39,305 --> 00:00:42,074
He is the Robonaut
project lead based here

15
00:00:42,074 --> 00:00:43,776
at the Johnson Space
Center in Houston.

16
00:00:43,776 --> 00:00:44,477
Good morning.

17
00:00:44,477 --> 00:00:45,544
Thanks for being here.

18
00:00:45,544 --> 00:00:46,612
>> Dr. Ron Diffler:
Well, thank you Pat.

19
00:00:46,612 --> 00:00:48,280
>> How and when did
you become involved

20
00:00:48,280 --> 00:00:49,849
in the Robonaut project?

21
00:00:49,849 --> 00:00:51,584
>> Dr. Ron Diffler: I
started in the late 1990s.

22
00:00:51,584 --> 00:00:54,386
My first job was actually

working on the design

23
00:00:54,386 --> 00:00:57,823
of the form and the hand.

24
00:00:57,823 --> 00:00:59,992
After we completed the design
of it, I worked quite a bit

25
00:00:59,992 --> 00:01:01,393
on the control system.

26
00:01:01,393 --> 00:01:04,897
Later on the project I became
the hand subsystem lead then

27
00:01:04,897 --> 00:01:08,234
moved on to become first
deputy project lead

28
00:01:08,234 --> 00:01:11,971
and the project lead
in the early 2000s.

29
00:01:11,971 --> 00:01:14,039
>> When did the design
really get started?

30
00:01:14,039 --> 00:01:16,242
>> Well, that was for the
first Robonaut, Robonaut 1,

31
00:01:16,242 --> 00:01:18,444
which is not in space.

32
00:01:18,444 --> 00:01:20,346
It was a prototype
for the ground.

33

00:01:20,346 --> 00:01:24,116
We started working on
Robonaut 2 in 2007.

34
00:01:24,116 --> 00:01:26,685
That was the beginning of our
partnership with General Motors.

35
00:01:26,685 --> 00:01:30,022
>> Just to give a sense of
how long it sometimes take s

36
00:01:30,022 --> 00:01:31,423
for these things to develop.

37
00:01:31,423 --> 00:01:32,992
How was a partnership

38
00:01:32,992 --> 00:01:35,594
with General Motors
helped in the development?

39
00:01:35,594 --> 00:01:36,996
>> Dr. Ron Diffler: Oh, it's
been an excellent partnership.

40
00:01:36,996 --> 00:01:39,999
It's allowed us to combine our
resources with General Motors

41
00:01:39,999 --> 00:01:41,567
to build a better
Robonaut system.

42
00:01:41,567 --> 00:01:42,835
The one that we have in space

43
00:01:42,835 --> 00:01:44,236
that we could have
done independently.

44
00:01:44,236 --> 00:01:47,006
By pulling our resources,
we took advantage of that.

45
00:01:47,006 --> 00:01:48,841
The skills in both areas.

46
00:01:48,841 --> 00:01:51,710
And it allowed us to produce a
system that's been doing very

47
00:01:51,710 --> 00:01:53,112
well on orbit.

48
00:01:53,112 --> 00:01:56,448
>> How would you describe the
overall goals of this project?

49
00:01:56,448 --> 00:01:58,317
What are you trying
to accomplish

50
00:01:58,317 --> 00:02:00,119
with the Robonaut in space?

51
00:02:00,119 --> 00:02:01,554
>> Dr. Ron Diffler: Well, our
goals provide another tool

52
00:02:01,554 --> 00:02:04,023
for the space station community.

53
00:02:04,023 --> 00:02:06,659
As my boss likes to say,
another pair of hands to help

54
00:02:06,659 --> 00:02:09,595
out on-board the space station.

55
00:02:09,595 --> 00:02:11,664
We have the Robonaut
up there right now,

56
00:02:11,664 --> 00:02:14,567
and as a fixed system
on a stanchion.

57
00:02:14,567 --> 00:02:15,935
Just an upper body.

58
00:02:15,935 --> 00:02:18,304
And we're going through a
variety of tests to verify

59
00:02:18,304 --> 00:02:20,706
that it can perform the
way we expect it to do.

60
00:02:20,706 --> 00:02:23,475
To do many of the tasks that it
was able to do on the ground.

61
00:02:23,475 --> 00:02:26,512
This is all a precursor for
later having the robot go mobile

62
00:02:26,512 --> 00:02:29,248
and helping inside
the space station.

63
00:02:29,248 --> 00:02:30,916
>> But how has it gone so far?

64
00:02:30,916 --> 00:02:31,984
[inaudible]

65
00:02:31,984 --> 00:02:33,252

>> Dr. Ron Diffler:
It's gone very well.

66
00:02:33,252 --> 00:02:38,824
We -- as you mentioned it
was sent up there in 2011

67
00:02:38,824 --> 00:02:40,759
and actually -- I'm
sorry -- 2011.

68
00:02:40,759 --> 00:02:42,828
We've been working with
it now on space station

69
00:02:42,828 --> 00:02:44,697
for a little more than a year.

70
00:02:44,697 --> 00:02:46,565
We went through checkout,
which went very well.

71
00:02:46,565 --> 00:02:48,434
We have completed
three space tasks.

72
00:02:48,434 --> 00:02:50,169
We've done our first
interaction with the crew.

73
00:02:50,169 --> 00:02:53,672
Human robot interaction,
which is a big thing for us.

74
00:02:53,672 --> 00:02:55,140
We've been working on
the task panel some

75
00:02:55,140 --> 00:02:57,009
of which you saw

that activity today.

76
00:02:57,009 --> 00:02:59,578
We've also had a chance to work
with our first tool on station.

77
00:02:59,578 --> 00:03:01,447
Actually an air flow meter.

78
00:03:01,447 --> 00:03:03,682
With that device, we're
able to send back data

79
00:03:03,682 --> 00:03:05,251
that normally isn't
received on the ground.

80
00:03:05,251 --> 00:03:07,186
Which is a great thing to help

81
00:03:07,186 --> 00:03:09,488
out providing even more
information back to the crew,

82
00:03:09,488 --> 00:03:12,591
back to the support personnel
that are helping the crew

83
00:03:12,591 --> 00:03:13,926
to perform their tasks in space.

84
00:03:13,926 --> 00:03:15,995
>> What was the task
with the air flow meter?

85
00:03:15,995 --> 00:03:18,230
What did Robonaut
have to actually do?

86

00:03:18,230 --> 00:03:19,632
>> Dr. Ron Diffler: Well,

87
00:03:19,632 --> 00:03:23,369
normally a few times a year the
crew uses a wand and a meter,

88
00:03:23,369 --> 00:03:26,005
and they measure the air flow
coming out through the vents

89
00:03:26,005 --> 00:03:28,040
in various parts of
the space station.

90
00:03:28,040 --> 00:03:29,508
Actually a perfect
job for a robot.

91
00:03:29,508 --> 00:03:31,243
Nothing can hold
something still better

92
00:03:31,243 --> 00:03:33,379
than a robot as you
might expect.

93
00:03:33,379 --> 00:03:35,881
In this case, we had the robot
hold the wand and the meter.

94
00:03:35,881 --> 00:03:38,217
And what was unique about
this particular situation,

95
00:03:38,217 --> 00:03:41,453
is that normally the crew
averages out the values they see

96
00:03:41,453 --> 00:03:44,957

on the meter and then sends down
a few numbers to the ground.

97
00:03:44,957 --> 00:03:46,725
Here the people on the
ground were able to look

98
00:03:46,725 --> 00:03:49,428
through the robot's eyes using
the robot's camera system

99
00:03:49,428 --> 00:03:53,299
and see real-time data
coming through the air vents.

100
00:03:53,299 --> 00:03:55,367
And that was really cool because
that was data they had never

101
00:03:55,367 --> 00:03:57,169
seen before.

102
00:03:57,169 --> 00:04:00,539
>> We've seen video of
where today and yesterday

103
00:04:00,539 --> 00:04:02,741
of the view from Robonaut's eye.

104
00:04:02,741 --> 00:04:05,210
Is the point of that
to allow the ground

105
00:04:05,210 --> 00:04:07,146
to see what Robonaut sees?

106
00:04:07,146 --> 00:04:10,783
Or is it registering data
that's recorded itself?

107
00:04:10,783 --> 00:04:11,850
>> Dr. Ron Diffler: Well,

108
00:04:11,850 --> 00:04:13,218
there's actually
multiple cameras systems.

109
00:04:13,218 --> 00:04:14,853
The ones we're seeing on the
ground right now are the ones

110
00:04:14,853 --> 00:04:18,357
that we would use when a person
directly controls the robot.

111
00:04:18,357 --> 00:04:19,958
That can be done a
couple of different ways.

112
00:04:19,958 --> 00:04:21,927
On the ground we are
performing experiments,

113
00:04:21,927 --> 00:04:24,330
and people on the ground can see
the robot perform their tasks

114
00:04:24,330 --> 00:04:25,597
with real-time data.

115
00:04:25,597 --> 00:04:28,367
And of course, that allows
for a more expedited task.

116
00:04:28,367 --> 00:04:31,337
Also, when the crew will

117
00:04:31,337 --> 00:04:34,473
in the future don what we

call teleoperation gear.

118
00:04:34,473 --> 00:04:36,909
They wear a variety of
gloves and other sensors.

119
00:04:36,909 --> 00:04:38,210
And as they move
around the robot,

120
00:04:38,210 --> 00:04:39,378
we'll track their position.

121
00:04:39,378 --> 00:04:42,181
When they're doing that,
they'll be able to put

122
00:04:42,181 --> 00:04:44,450
on a helmet-like
device, and they'll see

123
00:04:44,450 --> 00:04:46,418
through those same robot eyes.

124
00:04:46,418 --> 00:04:48,253
They can have a good perspective

125
00:04:48,253 --> 00:04:51,890
as they're performing tasks
basically made into the robot.

126
00:04:51,890 --> 00:04:54,093
>> They're controlling
the robot's actions

127
00:04:54,093 --> 00:04:55,160
with their own actions.

128
00:04:55,160 --> 00:04:56,362

>> Dr. Ron Diffler:
That's correct.

129
00:04:56,362 --> 00:04:59,098
>> That sounds like that
would have application

130
00:04:59,098 --> 00:05:02,801
for using it anywhere in the
station or outside the station.

131
00:05:02,801 --> 00:05:04,603
>> Dr. Ron Diffler: Actually
that's the biggest value will be

132
00:05:04,603 --> 00:05:08,540
when we have the crew person
controlling the robot directly

133
00:05:08,540 --> 00:05:10,142
when the robot is on the
outside of the station,

134
00:05:10,142 --> 00:05:12,111
which is something we're
planning in the future.

135
00:05:12,111 --> 00:05:14,646
We'll do experiments
inside the station

136
00:05:14,646 --> 00:05:16,915
where we'll practice
this technique.

137
00:05:16,915 --> 00:05:18,250
Where the human and the --

138
00:05:18,250 --> 00:05:20,119
the crew person and the robot

are right near each other.

139
00:05:20,119 --> 00:05:22,054
As we develop that and be
sure that it works well

140
00:05:22,054 --> 00:05:23,622
in the zero G environment.

141
00:05:23,622 --> 00:05:26,825
>> The development is
being done in small steps.

142
00:05:26,825 --> 00:05:29,895
Because you said you've been
working on it for years.

143
00:05:29,895 --> 00:05:30,996
>> Dr. Ron Diffler: A
little more than a year.

144
00:05:30,996 --> 00:05:34,800
And we've been increasing
the difficulty

145
00:05:34,800 --> 00:05:36,135
of the tasks essentially.

146
00:05:36,135 --> 00:05:38,036
We've been adding to the
capability of the robot

147
00:05:38,036 --> 00:05:40,439
over time by trying out
different subsystems.

148
00:05:40,439 --> 00:05:42,841
Initially, we were just
controlling it and having it go

149
00:05:42,841 --> 00:05:44,243
to predefined positions.

150
00:05:44,243 --> 00:05:47,045
Today's experiment, as a matter
of fact, involved the use

151
00:05:47,045 --> 00:05:47,746
of machine [inaudible].

152
00:05:47,746 --> 00:05:49,081
We are using the robot.

153
00:05:49,081 --> 00:05:51,316
Other set of cameras,
machine vision cameras,

154
00:05:51,316 --> 00:05:53,752
to find locations
where objects are.

155
00:05:53,752 --> 00:05:56,488
And the robot drives its
hand to those locations.

156
00:05:56,488 --> 00:05:59,825
We're doing initial work with
that right now to calibrate

157
00:05:59,825 --> 00:06:01,927
and verify the vision
system is working properly

158
00:06:01,927 --> 00:06:03,595
and adjust it accordingly.

159
00:06:03,595 --> 00:06:06,031
Later we'll incorporate that
machine vision technology

160
00:06:06,031 --> 00:06:09,334
and the robot will do tasks in
a more automated fashion using

161
00:06:09,334 --> 00:06:12,070
that sensor information
coming from the cameras.

162
00:06:12,070 --> 00:06:13,839
>> And I think that
that sounds like it --

163
00:06:13,839 --> 00:06:18,110
the Robonaut would be able to
be a lot more useful to the crew

164
00:06:18,110 --> 00:06:19,878
if it could perform
automated tasks.

165
00:06:19,878 --> 00:06:21,880
They'd be given tasks
and allowed

166
00:06:21,880 --> 00:06:23,315
to go about it's business.

167
00:06:23,315 --> 00:06:24,016
>> Dr. Ron Diffler: Absolutely.

168
00:06:24,016 --> 00:06:25,217
We see a progression.

169
00:06:25,217 --> 00:06:27,386
Right now we're controlling
many of the motions

170
00:06:27,386 --> 00:06:29,421

in a very definitive manner.

171
00:06:29,421 --> 00:06:32,491
Controlling each part of
the task very precisely.

172
00:06:32,491 --> 00:06:35,527
We later expect to go to
a more semiautonomous mode

173
00:06:35,527 --> 00:06:38,530
where the ground personnel
would be doing more supervision.

174
00:06:38,530 --> 00:06:40,933
And then as time goes on
and we gain more confidence

175
00:06:40,933 --> 00:06:42,734
in the system and
everything is proven out,

176
00:06:42,734 --> 00:06:45,537
we go to even more
autonomous type mode.

177
00:06:45,537 --> 00:06:48,440
Where there'd be less
supervision from the ground.

178
00:06:48,440 --> 00:06:51,810
>> Why is the Robonaut only
an upper body right now?

179
00:06:51,810 --> 00:06:53,512
>> Dr. Ron Diffler: Well,
when we first started our work

180
00:06:53,512 --> 00:06:56,014
with General Motors, our

focus was on manipulation.

181
00:06:56,014 --> 00:06:57,483
The ability to perform tasks

182
00:06:57,483 --> 00:06:59,284
that currently only
humans can perform.

183
00:06:59,284 --> 00:07:02,654
So we start working with that
part of the body that's involved

184
00:07:02,654 --> 00:07:03,689
in those types of tasks.

185
00:07:03,689 --> 00:07:06,091
The upper body --
arms, hands, a head.

186
00:07:06,091 --> 00:07:07,726
To have sensor systems in it

187
00:07:07,726 --> 00:07:10,496
so that you can see
what you're doing.

188
00:07:10,496 --> 00:07:12,364
Now, we're looking
towards the future

189
00:07:12,364 --> 00:07:14,032
where we'll need to go mobile.

190
00:07:14,032 --> 00:07:15,834
If we're going to be
helping the crew both inside

191
00:07:15,834 --> 00:07:18,370

and outside the space
station, we need that mobility.

192
00:07:18,370 --> 00:07:20,639
We're working on a pair of
what we call "climbing legs."

193
00:07:20,639 --> 00:07:23,609
Which will -- we'll add to
the upper body of the robot

194
00:07:23,609 --> 00:07:26,879
and allow it to move throughout
the inside of station initially

195
00:07:26,879 --> 00:07:29,181
and then eventually
outside the station.

196
00:07:29,181 --> 00:07:32,017
And perform the kinds of
tasks that we're testing

197
00:07:32,017 --> 00:07:34,386
out capabilities for right
now on our task board

198
00:07:34,386 --> 00:07:36,121
and with the tools
I mentioned earlier.

199
00:07:36,121 --> 00:07:39,224
>> It occurred to me that if it
had legs you could probably make

200
00:07:39,224 --> 00:07:40,292
it walk.

201
00:07:40,292 --> 00:07:41,493
You just couldn't

keep it on the ground.

202
00:07:41,493 --> 00:07:44,463
Couldn't keep it down on
the floor of the station.

203
00:07:44,463 --> 00:07:45,364
>> Dr. Ron Diffler: And
that's why we call these

204
00:07:45,364 --> 00:07:46,565
"climbing legs."

205
00:07:46,565 --> 00:07:47,900
Because our protocol will
be that we will be move

206
00:07:47,900 --> 00:07:50,168
from one fixed location
to another.

207
00:07:50,168 --> 00:07:53,472
The robot will always
have one leg in contact

208
00:07:53,472 --> 00:07:56,341
so that it will be grounded
as it's performing its task.

209
00:07:56,341 --> 00:07:59,344
>> Looking ahead, what's the
next step or the next couple

210
00:07:59,344 --> 00:08:01,680
of steps in the development
in the testing?

211
00:08:01,680 --> 00:08:02,948
>> Dr. Ron Diffler: Well,
we're continuing to work

212
00:08:02,948 --> 00:08:05,951
with our task board integrating
first our vision data.

213
00:08:05,951 --> 00:08:07,619
Some of which we're
working on today.

214
00:08:07,619 --> 00:08:09,454
We'll be adding more
force information

215
00:08:09,454 --> 00:08:10,822
to performing our tasks.

216
00:08:10,822 --> 00:08:13,559
Just like a human, we use a
variety of sensor information

217
00:08:13,559 --> 00:08:16,061
to perform our tasks --
vision, force data [inaudible].

218
00:08:16,061 --> 00:08:20,165
Testing out those
capabilities on the robot.

219
00:08:20,165 --> 00:08:22,401
We'll be adding more
tools to our repertoire.

220
00:08:22,401 --> 00:08:25,170
We hope to be using
a tether hook.

221
00:08:25,170 --> 00:08:27,506
That's our early
practice when we go EDA.

222
00:08:27,506 --> 00:08:30,842
Then, of course, we'll
be sending up the legs

223
00:08:30,842 --> 00:08:34,413
and then a battery backpack
so we can be untethered

224
00:08:34,413 --> 00:08:35,747
and start moving in the station.

225
00:08:35,747 --> 00:08:39,184
We expect to send those up
in the later part of 2013

226
00:08:39,184 --> 00:08:42,387
and start performing our
first tests in early 2014.

227
00:08:42,387 --> 00:08:45,824
The robot checking out its
lower body and starting

228
00:08:45,824 --> 00:08:48,827
to move throughout
the space station.

229
00:08:48,827 --> 00:08:50,162
>> Awkward.

230
00:08:50,162 --> 00:08:54,700
It was becoming self-aware
and discovering it's own self.

231
00:08:54,700 --> 00:08:55,834
>> Dr. Ron Diffler: It'll be --

232
00:08:55,834 --> 00:08:57,202
we'll be working with it

to checkout to be sure

233
00:08:57,202 --> 00:08:59,471
that all the new parts
we're sending up work well.

234
00:08:59,471 --> 00:09:01,807
But right now its conscious
is pretty much limited

235
00:09:01,807 --> 00:09:03,475
to what we tell it to do.

236
00:09:03,475 --> 00:09:05,911
>> You given any thought
to giving it a voice?

237
00:09:05,911 --> 00:09:07,312
>> Dr. Ron Diffler:
We haven't actually.

238
00:09:07,312 --> 00:09:09,147
As a matter of fact, when you're
wearing the teleoperation gear,

239
00:09:09,147 --> 00:09:10,882
which I mentioned earlier,
and you're wearing the helmet,

240
00:09:10,882 --> 00:09:12,451
you'll also have a microphone.

241
00:09:12,451 --> 00:09:14,353
This allows the person,
the crew person,

242
00:09:14,353 --> 00:09:16,688
to command the robot
to change mode.

243
00:09:16,688 --> 00:09:18,423
For example, if they're
performing a task and they want

244
00:09:18,423 --> 00:09:20,859
to rest, they can tell the
robot to freeze its limbs.

245
00:09:20,859 --> 00:09:22,561
And the robot's limbs
will start moving

246
00:09:22,561 --> 00:09:24,029
and the crew person can stop.

247
00:09:24,029 --> 00:09:26,665
So we do have a voice
interaction system integrated,

248
00:09:26,665 --> 00:09:29,601
but we only use it right now
when we're doing teleoperation.

249
00:09:29,601 --> 00:09:33,338
>> So the look ahead then it
may be this time next year

250
00:09:33,338 --> 00:09:36,975
or roughly, where we could
see it really interacting

251
00:09:36,975 --> 00:09:39,044
with the crew members
and performing tasks.

252
00:09:39,044 --> 00:09:40,445
>> Dr. Ron Diffler: We'll
definitely see it starting

253

00:09:40,445 --> 00:09:43,949
to take its first steps in that
climbing process I mentioned.

254
00:09:43,949 --> 00:09:46,418
>> Ron, it's fascinating,
and it's great to watch.

255
00:09:46,418 --> 00:09:49,187
And I really appreciate you're
helping get us up to speed

256
00:09:49,187 --> 00:09:50,389
on what's going on with it.

257
00:09:50,389 --> 00:09:51,223
Thank you very much.

258
00:09:51,223 --> 00:09:52,624
>> Dr. Ron Diffler: My pleasure.

259
00:09:52,624 --> 00:09:55,193
>> Ron Diffler is the -- Dr. Ron
Diffler is the Robonaut project