1
00:00:01,000 --> 00:00:02,135
- Good evening
ladies and gentlemen,

2
00:00:02,168 --> 00:00:04,103
how's everyone doin' tonight?

3
00:00:04,136 --> 00:00:05,204
- [Audience Member]
Good, how are you?

4
00:00:05,237 --> 00:00:06,839
- Good, I'm well
thank you for asking!

5
00:00:06,872 --> 00:00:07,940
(audience applauding)
Thanks for coming out

6
00:00:07,973 --> 00:00:09,075
to visit us tonight.

7
00:00:09,108 --> 00:00:10,043
We are absolutely
grateful for your

8
00:00:10,076 --> 00:00:12,278
participation and interest.

9
00:00:12,311 --> 00:00:15,181
Like the Mars Rover,
Charles Elachi's curiosity

10
00:00:15,214 --> 00:00:17,050
knows no bounds.

11
00:00:17,083 --> 00:00:20,286
In his 46 year career at JPL
as a world leading reasearcher

12
00:00:20,319 --> 00:00:23,122
in radar science and
eventual Director

13
00:00:23,155 --> 00:00:25,892
of the Jet Propulsion
Laboratory, he has spent

14
00:00:25,925 --> 00:00:29,028
his entire career as
a modern day Magellan.

15
00:00:29,061 --> 00:00:32,065
With the landing of the
latest rover in August 2012,

16
00:00:32,098 --> 00:00:33,900
he oversaw one of
the most challenging

17
00:00:33,933 --> 00:00:36,903
engineering feats since
the Apollo moon landing.

18
00:00:36,936 --> 00:00:39,906
To quote him from a
post-landing press conference,

19
00:00:39,939 --> 00:00:42,041
"I could only think of the
words of Teddy Roosevelt

20
00:00:42,074 --> 00:00:44,177
"as I was sitting there,
'It is far better to dare

21
00:00:44,210 --> 00:00:47,080
"mighty things, even
though we might fail,

22
00:00:47,113 --> 00:00:49,115
"than to stay in a twilight
that knows neither victory

23
00:00:49,148 --> 00:00:52,752
"nor defeat,' and the
team brought us victory."

24
00:00:52,785 --> 00:00:54,087
Yeah they did.

25
00:00:54,120 --> 00:00:57,123
Tonight, Dr. Elachi will
discuss that particular victory,

26
00:00:57,156 --> 00:00:59,192
his storied career
in space exploration,

27
00:00:59,225 --> 00:01:01,227
and the remarkable
work that JPL is doing

28
00:01:01,260 --> 00:01:04,197
as it monitors it's existing
19 spacecraft across

29
00:01:04,230 --> 00:01:08,201
the solar system, and prepares
for the next generation.

30
00:01:08,234 --> 00:01:10,903
Some additional details
about our esteemed guest.

31
00:01:10,936 --> 00:01:13,272
From 2001 to 2016,
he was the Director

32
00:01:13,305 --> 00:01:15,274
of the Jet Propulsion
Laboratory.

33
00:01:15,307 --> 00:01:17,310
He is currently a professor
of electrical engineering

34
00:01:17,343 --> 00:01:19,312
and planetary science
at the California

35
00:01:19,345 --> 00:01:21,247
Institute of Technology.

36
00:01:21,280 --> 00:01:24,317
In his career at JPL,
Dr. Elachi was a leader

37
00:01:24,350 --> 00:01:27,253
in developing the field of
spaceborn imaging radar,

38
00:01:27,286 --> 00:01:29,288
the principal investigator
on numerous research

39
00:01:29,321 --> 00:01:30,957
and development studies,

40
00:01:30,990 --> 00:01:33,259
and flight projects,
sponsored by NASA,

41
00:01:33,292 --> 00:01:35,828
and he is currently
the Team Leader

42
00:01:35,861 --> 00:01:37,563

of the Cassini Titan
radar experiment,

43
00:01:37,596 --> 00:01:38,831
and a co-investigator

44
00:01:38,864 --> 00:01:42,201
on the Rosetta Comet
Nucleus Sounder experiment.

45
00:01:42,234 --> 00:01:45,004
He is the author of
over 230 publications,

46
00:01:45,037 --> 00:01:47,039
and the holder of
several patents.

47
00:01:47,072 --> 00:01:49,108
The recipient of numerous
honors, he was named

48
00:01:49,141 --> 00:01:52,778
one of America's best leaders
by US News and World Report,

49
00:01:52,811 --> 00:01:54,981
and the Center for Public
Leadership at Harvard

50
00:01:55,014 --> 00:01:58,117
University's Kennedy School
of Government in 2006.

51
00:01:58,150 --> 00:02:00,953
He also has an asteroid named
after him in recognition

52
00:02:00,986 --> 00:02:04,056
of his contributions

to space exploration.

53
00:02:04,089 --> 00:02:05,191
(cheerful laughter)

54
00:02:05,224 --> 00:02:06,292
Ladies and gentlemen,
please help me welcome

55
00:02:06,325 --> 00:02:08,261
tonight's guest,
Dr. Charles Elachi.

56
00:02:08,294 --> 00:02:11,865
(audience applauding)

57
00:02:13,132 --> 00:02:14,134
- Thank you.

58
00:02:19,138 --> 00:02:21,040
Thank you very much for
the nice introduction,

59
00:02:21,073 --> 00:02:23,910
and good to see all of you here.

60
00:02:25,277 --> 00:02:28,247
When you think about it, for
literally thousands of years,

61
00:02:28,280 --> 00:02:30,950
our ancestors kind of
looked up at the sky

62
00:02:30,983 --> 00:02:33,853
and wondered about
all these stars,

63
00:02:33,886 --> 00:02:36,856

what's on them, how
they came about,

64
00:02:36,889 --> 00:02:38,191
and particularly they
noticed that some of them

65
00:02:38,224 --> 00:02:42,061
actually do move, and these
turned out to be the planets.

66
00:02:42,094 --> 00:02:43,863
And one of them was
a little bit more

67
00:02:43,896 --> 00:02:46,966
reddish than others, you
know, which was Mars,

68
00:02:46,999 --> 00:02:50,937
and people wondered
what's on that star?

69
00:02:50,970 --> 00:02:52,138
And when you think
about it, also even

70
00:02:52,171 --> 00:02:54,073
few hundred years
ago, we didn't know

71
00:02:54,106 --> 00:02:56,209
that there was a
Uranus, or a Neptune,

72
00:02:56,242 --> 00:02:59,178
we didn't know about
the rings of Saturn.

73
00:02:59,211 --> 00:03:02,982

We didn't know about the
satellite around Jupiter.

74
00:03:03,015 --> 00:03:05,918
And here in one
generation, we have visited

75
00:03:05,951 --> 00:03:08,154
each and every one
of those planets.

76
00:03:08,187 --> 00:03:10,256
When you think about
it, isn't that amazing?

77
00:03:10,289 --> 00:03:13,226
That we have done in one
generation what people

78
00:03:13,259 --> 00:03:16,929
have dreamt about for thousands
and thousands of years.

79
00:03:16,962 --> 00:03:18,130
In one generation.

80
00:03:18,163 --> 00:03:20,066
Not only we visited
them, but on some of them

81
00:03:20,099 --> 00:03:22,034
we have rovers, some of
them we have landers,

82
00:03:22,067 --> 00:03:24,003
some of them we have probes.

83
00:03:24,036 --> 00:03:27,840
So what I'm going to do today
is to kind of describe to you,

84
00:03:27,873 --> 00:03:29,242
why do we explore?

85
00:03:29,275 --> 00:03:31,143
Why is it something
really exciting?

86
00:03:31,176 --> 00:03:32,845
What have we learned?

87
00:03:32,878 --> 00:03:34,947
And what are some
of the future things

88
00:03:34,980 --> 00:03:37,950
that we're planning to do,
what is the future holding

89
00:03:37,983 --> 00:03:40,019
for particularly this
great institution,

90
00:03:40,052 --> 00:03:43,756
which was elite players
in making that happen.

91
00:03:43,789 --> 00:03:46,192
Now before I start on that,
I thought because I always

92
00:03:46,225 --> 00:03:49,895
get asked question, "How
did you end in this field?

93
00:03:49,928 --> 00:03:51,998
"How did you end coming to JPL?"

94
00:03:52,031 --> 00:03:54,900

So I thought I'll start
with one or two charts

95
00:03:54,933 --> 00:03:57,236
to kind of tell you a little
bit about my background,

96
00:03:57,269 --> 00:04:01,173
and when did I get
involved in space.

97
00:04:01,206 --> 00:04:03,943
So you look at that
picture to the left.

98
00:04:03,976 --> 00:04:07,213
That kid who is kind of looking
like a little bit upset?

99
00:04:07,246 --> 00:04:09,315
That's me.
(audience laughing)

100
00:04:09,348 --> 00:04:12,051
And maybe that was my
first experience with space

101
00:04:12,084 --> 00:04:14,186
because my mom dressed
me like an angel

102
00:04:14,219 --> 00:04:16,922
because it was my
brother first communion,

103
00:04:16,955 --> 00:04:19,158
that my brother is the
guy in front of me.

104
00:04:19,191 --> 00:04:22,161

And I was very unhappy because
I was dressed in a dress

105
00:04:22,194 --> 00:04:24,930
instead of pants.
(audience laughing)

106
00:04:24,963 --> 00:04:27,933
So I used to hate that
picture, but now I love it.

107
00:04:27,966 --> 00:04:29,969
So that was my first
introduction to space,

108
00:04:30,002 --> 00:04:32,138
I was born in Lebanon.

109
00:04:32,171 --> 00:04:35,141
Then I wanted my undergraduate
education in France,

110
00:04:35,174 --> 00:04:37,176
so you see that in the middle.

111
00:04:37,209 --> 00:04:41,113
Then I came to Caltech
for my graduate degree,

112
00:04:41,146 --> 00:04:43,983
and at the right that
was my first team here,

113
00:04:44,016 --> 00:04:47,053
and I see one of them is here,
Joby, where are you Joby?

114
00:04:47,086 --> 00:04:50,122
There you are, so she's the
lady sitting with the red dress.

115
00:04:50,155 --> 00:04:51,424
So you can see when
I was younger

116
00:04:51,457 --> 00:04:52,892
I used to have
a mustache,

117
00:04:52,925 --> 00:04:54,827
I used to have a lot of hair.

118
00:04:54,860 --> 00:04:56,829
When I showed the
picture in the middle

119
00:04:56,862 --> 00:04:59,899
to my younger daughter,
she kind of slipped,

120
00:04:59,932 --> 00:05:02,268
she said, "Dad, you used to
look pretty good before!"

121
00:05:02,301 --> 00:05:03,869
(audience laughing)

122
00:05:03,902 --> 00:05:05,137
I told her, "What do
you mean?" I said.

123
00:05:05,170 --> 00:05:07,306
"Oh, sorry sorry, but now
you are very distinguished."

124
00:05:07,339 --> 00:05:10,042
So she corrected
herself very quickly.

125

00:05:10,075 --> 00:05:12,845
So anyways, I did my
undergraduate at Caltech,

126
00:05:12,878 --> 00:05:17,083
and started working here at
JPL as a summer student first,

127
00:05:17,116 --> 00:05:20,119
and as a part time academic,
like many of the people

128
00:05:20,152 --> 00:05:23,289
sitting here, and then I
was offered a job as a TI

129
00:05:23,322 --> 00:05:26,192
working for couple of
years, and 48 years later

130
00:05:26,225 --> 00:05:27,960
I was still here.

131
00:05:30,095 --> 00:05:33,299
Now let me go to the
original topic of about

132
00:05:33,332 --> 00:05:36,068
when you look in the sky,
I'm sure you can count

133
00:05:36,101 --> 00:05:38,003
hundred of stars.

134
00:05:38,036 --> 00:05:40,773
But in reality, when you
look through a telescope,

135
00:05:40,806 --> 00:05:43,042
particularly a telescope

like the Hubble telescope,

136
00:05:43,075 --> 00:05:46,846
you'd be amazed of how
many stars and galaxies

137
00:05:46,879 --> 00:05:48,114
are in the sky.

138
00:05:48,147 --> 00:05:50,783
This picture here which was
taken with the Hubble telescope

139
00:05:50,816 --> 00:05:54,019
that correspond to an area
about the size of a dime

140
00:05:54,052 --> 00:05:56,889
at the end of your hand,
that's about the area

141
00:05:56,922 --> 00:05:58,758
that you see in here.

142
00:05:58,791 --> 00:06:00,893
And literally you
are seeing billions

143
00:06:00,926 --> 00:06:03,896
and billions of
stars and galaxies.

144
00:06:03,929 --> 00:06:06,899
So when you think about it,
it's an amazing universe

145
00:06:06,932 --> 00:06:08,901
that we live in.

146

00:06:08,934 --> 00:06:11,170
And if you zoom in a
little bit on that picture

147
00:06:11,203 --> 00:06:13,038
so that you see some
of the galaxies,

148
00:06:13,071 --> 00:06:15,107
it's a very active universe.

149
00:06:15,140 --> 00:06:18,110
So you see actually galaxies
which are interacting,

150
00:06:18,143 --> 00:06:20,045
you see stars which are forming,

151
00:06:20,078 --> 00:06:22,181
you see stars which
are basically dying.

152
00:06:22,214 --> 00:06:25,951
So we do live in a
very active universe.

153
00:06:25,984 --> 00:06:29,188
And some how in one
of those galaxies,

154
00:06:29,221 --> 00:06:32,124
is kind of similar to
our Milky Way galaxies.

155
00:06:32,157 --> 00:06:36,929
Around one of those little
stars, we have planets.

156
00:06:36,962 --> 00:06:40,866
Somehow they came about, and

this is our solar system.

157
00:06:40,899 --> 00:06:42,902
So you see the Earth
and Mars and Venus,

158
00:06:42,935 --> 00:06:45,204
and somehow on one
of those planets,

159
00:06:45,237 --> 00:06:47,072
there was all the
right ingredients,

160
00:06:47,105 --> 00:06:48,874
the right temperature,

161
00:06:48,907 --> 00:06:53,045
that basically led to cells
which formed, and those cells

162
00:06:53,078 --> 00:06:55,948
led to the life that
we are familiar with.

163
00:06:55,981 --> 00:06:58,117
So when you think
about it, it's amazing.

164
00:06:58,150 --> 00:07:00,920
How did it start from the
beginning of that universe

165
00:07:00,953 --> 00:07:03,889
about 14 billion years
ago, and here we have

166
00:07:03,922 --> 00:07:06,225
people like you and
I sitting down having

167
00:07:06,258 --> 00:07:08,127
this conversation tonight.

168
00:07:08,160 --> 00:07:11,030
So don't you wonder,
how did that came about?

169
00:07:11,063 --> 00:07:14,834
And particularly on our
planet after 3.8 billion years

170
00:07:14,867 --> 00:07:17,069
of evolution, guess
what it produced?

171
00:07:17,102 --> 00:07:19,038
Produced JPL!
(audience laughing)

172
00:07:19,071 --> 00:07:23,843
So people don't appreciate
that JPL took 3.8 billion years

173
00:07:23,876 --> 00:07:26,278
to actually evolve and
be where we are here,

174
00:07:26,311 --> 00:07:30,049
and more important, the
employees at JPL through all

175
00:07:30,082 --> 00:07:34,019
that evolution, had
a certain attitude.

176
00:07:34,052 --> 00:07:35,921
Guess which one in this picture,

177

00:07:35,954 --> 00:07:37,923
there is one guy
who's a JPL employee.

178
00:07:37,956 --> 00:07:40,860
(audience laughing)

179
00:07:40,893 --> 00:07:42,962
But the point I want to
make about this picture,

180
00:07:42,995 --> 00:07:45,030
this is from the
early days of JPL,

181
00:07:45,063 --> 00:07:47,933
is while everybody is
looking in this direction,

182
00:07:47,966 --> 00:07:49,101
the JPL employee is looking

183
00:07:49,134 --> 00:07:50,936
in that direction.
(audience laughing)

184
00:07:50,969 --> 00:07:52,838
And that has a
meaning behind it,

185
00:07:52,871 --> 00:07:55,174
because we don't go
where other people go.

186
00:07:55,207 --> 00:07:57,810
We try to look at
things differently,

187
00:07:57,843 --> 00:08:00,880
we look at things out of

the box, and we are looking

188
00:08:00,913 --> 00:08:02,882
at things that
nobody else looks at,

189
00:08:02,915 --> 00:08:04,917
and we try to make them reality.

190
00:08:04,950 --> 00:08:07,052
Now, one thing I want to
make sure for particularly

191
00:08:07,085 --> 00:08:09,088
the young JPL employees
here, don't try to come

192
00:08:09,121 --> 00:08:11,891
with that dress code,
that's not the normal

193
00:08:11,924 --> 00:08:13,259
dress code you know.

194
00:08:15,227 --> 00:08:18,130
So now what I'm going to
show you, that just looking

195
00:08:18,163 --> 00:08:21,066
at the last 15 years,
actually what this

196
00:08:21,099 --> 00:08:23,202
great institution
has accomplished.

197
00:08:23,235 --> 00:08:25,271
So I'm going to show
you a very short video

198
00:08:25,304 --> 00:08:28,140
which show you about every
launch, and every activity,

199
00:08:28,173 --> 00:08:31,143
and every encounter which
happened just in 15 years.

200
00:08:31,176 --> 00:08:33,346
So if we can get that video.

201
00:08:37,015 --> 00:08:40,286
(dramatic inspiring music)

202
00:09:58,964 --> 00:10:03,035
(staticky mumbled speaking)
(cheerful applause)

203
00:12:17,302 --> 00:12:19,905
(enthusiastic cheering)

204
00:12:19,938 --> 00:12:22,241
A fantastic demonstration
of what our nation

205
00:12:22,274 --> 00:12:25,844
and our agency can do. I
could only think of the words

206
00:12:25,877 --> 00:12:28,180
of Teddy Roosevelt as
I was sitting there,

207
00:12:28,213 --> 00:12:30,949
"It is far better to dare
mighty things even though

208
00:12:30,982 --> 00:12:33,919
we might fail, than

to stay in a twilight

209
00:12:33,952 --> 00:12:36,188
that knows neither
victory nor defeat."

210
00:12:36,221 --> 00:12:38,757
And the team brought us victory.

211
00:12:38,790 --> 00:12:40,859
- [Obama] I just wanted to
call and say congratulations

212
00:12:40,892 --> 00:12:43,028
to the entire Mars
Science Laboratory team,

213
00:12:43,061 --> 00:12:44,963
and really all of JPL.

214
00:12:44,996 --> 00:12:46,865
You guys should be
remarkably proud.

215
00:12:46,898 --> 00:12:49,101
And this is the kind
of thing that inspires

216
00:12:49,134 --> 00:12:51,137
kids across the country.

217
00:14:56,127 --> 00:14:57,195
- Anyway, when you
think about it,

218
00:14:57,228 --> 00:15:01,867
it's amazing.
(audience applauding)

219

00:15:03,935 --> 00:15:06,038
It's amazing what our
nation and this institution

220
00:15:06,071 --> 00:15:08,307
has done in the last 15 years.

221
00:15:08,340 --> 00:15:10,943
Usually when people ask me,

222
00:15:10,976 --> 00:15:12,945
"How many employees
are there at JPL?"

223
00:15:12,978 --> 00:15:14,880
And I'm, "Employees, we
don't have any employees,

224
00:15:14,913 --> 00:15:16,848
"we have 6000 explorers!"

225
00:15:16,881 --> 00:15:19,818
Because that's what
people actually do here.

226
00:15:19,851 --> 00:15:21,820
And the other thing, I
mean I didn't come up

227
00:15:21,853 --> 00:15:24,823
with this title about the
Golden Age of Exploration,

228
00:15:24,856 --> 00:15:26,892
I was showing the
video to Jim Cameron

229
00:15:26,925 --> 00:15:28,961
who is the ultimate storyteller,

230
00:15:28,994 --> 00:15:30,162
and at the end what they said,

231
00:15:30,195 --> 00:15:32,864
"You know this was a
golden age of exploration."

232
00:15:32,897 --> 00:15:34,866
You know, when he saw the thing.

233
00:15:34,899 --> 00:15:36,201
So now what I am going
to do is tell you

234
00:15:36,234 --> 00:15:38,036
a little bit about
some of these missions.

235
00:15:38,069 --> 00:15:40,138
I cannot go through
all of them otherwise

236
00:15:40,171 --> 00:15:42,908
you won't go home tonight,
so I'm going to start

237
00:15:42,941 --> 00:15:46,011
by talking about probably
one of the most exciting,

238
00:15:46,044 --> 00:15:49,181
and in many peoples mind,
the most exciting missions

239
00:15:49,214 --> 00:15:53,018
that JPL is conducting, and
that's the Cassini mission.

240
00:15:53,051 --> 00:15:57,055

And the Cassini is not just
spacecraft which visited Saturn,

241
00:15:57,088 --> 00:16:01,994
but it really explored over
a period of almost 13 years,

242
00:16:02,027 --> 00:16:05,197
explored the whole system,
which is around Saturn.

243
00:16:05,230 --> 00:16:08,133
Now Saturn is a beautiful
planet, everybody knows about it

244
00:16:08,166 --> 00:16:11,003
because of the rings and
they look great and you see

245
00:16:11,036 --> 00:16:14,106
that's a more detailed
picture of the rings,

246
00:16:14,139 --> 00:16:18,210
but there is more fundamental
reason for exploring Saturn

247
00:16:18,243 --> 00:16:21,847
is because by analyzing
the rings and understanding

248
00:16:21,880 --> 00:16:24,049
the satellites around
Saturn, it shed light

249
00:16:24,082 --> 00:16:27,285
about how our own solar
system actually formed.

250
00:16:27,318 --> 00:16:29,855

One of the key theories
about the formation

251
00:16:29,888 --> 00:16:32,891
of our solar system is
when a dust cloud collapsed

252
00:16:32,924 --> 00:16:35,827
and formed the sun, there
was a lot of dust around it,

253
00:16:35,860 --> 00:16:38,096
so there were rings around
it, and the particles

254
00:16:38,129 --> 00:16:40,932
in those rings agglomerated
together and they became rocks

255
00:16:40,965 --> 00:16:42,934
and they became bigger
rocks, and bigger rocks,

256
00:16:42,967 --> 00:16:46,138
and they became the
planets that we are.

257
00:16:47,238 --> 00:16:49,908
So by watching Saturn
rings, it could give us

258
00:16:49,941 --> 00:16:53,045
some insight about
how our own planet

259
00:16:53,078 --> 00:16:55,981
and how our own solar
system actually formed.

260
00:16:56,014 --> 00:16:58,850

Now to make you believe me,
you can see in that picture

261
00:16:58,883 --> 00:17:00,952
what looks like a small
satellite is forming

262
00:17:00,985 --> 00:17:03,922
just at the edge of that ring.

263
00:17:03,955 --> 00:17:06,258
And if you zoom a little
bit more in some other one,

264
00:17:06,291 --> 00:17:09,261
you actually see in those
gaps that is on Saturn,

265
00:17:09,294 --> 00:17:11,997
actually small
satellites is forming.

266
00:17:12,030 --> 00:17:14,132
So it's in a sense we
are doing an experiment,

267
00:17:14,165 --> 00:17:17,969
by watching Saturn, it's
like you are in your lab

268
00:17:18,002 --> 00:17:20,939
doing an experiment of
forming a planetary system,

269
00:17:20,972 --> 00:17:23,308
and that's actually what's
happening on Saturn.

270
00:17:23,341 --> 00:17:27,079
Of course, our solar system

took many billions of years

271
00:17:27,112 --> 00:17:29,247
to form, and here we have
been watching it only

272
00:17:29,280 --> 00:17:33,952
for 14 years, but it gives
us some idea about it.

273
00:17:33,985 --> 00:17:36,288
Now just to tell you about
some of the major discoveries,

274
00:17:36,321 --> 00:17:40,859
this is a satellite of
Saturn called Titan,

275
00:17:40,892 --> 00:17:42,194
it's about the size of our moon.

276
00:17:42,227 --> 00:17:46,898
It's a very big satellite,
it has cloud all around it.

277
00:17:46,931 --> 00:17:49,968
But what's amazing, and it
has about the same pressure

278
00:17:50,001 --> 00:17:52,804
as the Earth here, so
if you are on Titan

279
00:17:52,837 --> 00:17:55,040
it's about the same
pressure, but the atmosphere

280
00:17:55,073 --> 00:17:58,076
is mostly made of
methane and hydrocarbon,

281
00:17:58,109 --> 00:18:00,078
and it's much colder than here,

282
00:18:00,111 --> 00:18:02,848
but when we looked
at it in more detail,

283
00:18:02,881 --> 00:18:05,283
we actually found
something very similar.

284
00:18:05,316 --> 00:18:07,252
You look at the picture on
the right at the south pole

285
00:18:07,285 --> 00:18:10,155
on Titan, and it
has lakes on it.

286
00:18:10,188 --> 00:18:13,058
And these are lakes which are
the size of the Great lakes.

287
00:18:13,091 --> 00:18:15,894
So actually, if I show
you a series of pictures,

288
00:18:15,927 --> 00:18:19,831
actually it look like
it rains on Titan,

289
00:18:19,864 --> 00:18:22,934
that liquid goes into
rivers, rivers go into ocean,

290
00:18:22,967 --> 00:18:25,003
then they evaporate, they
go up in the atmosphere,

291
00:18:25,036 --> 00:18:26,138
there are the clouds,

292
00:18:26,171 --> 00:18:29,107
so it's very similar
to our own planet,

293
00:18:29,140 --> 00:18:31,943
except it's all
made of hydrocarbon.

294
00:18:31,976 --> 00:18:33,311
You know, the rain
is not made of water,

295
00:18:33,344 --> 00:18:36,181
it's made of kind of
gasoline if you want.

296
00:18:36,214 --> 00:18:38,984
So I keep jokingly tell
people, if you live on Titan,

297
00:18:39,017 --> 00:18:40,785
you don't need to go
to the gas station,

298
00:18:40,818 --> 00:18:42,988
you can just go to the
nearest lake and take a bucket

299
00:18:43,021 --> 00:18:45,757
and you can fill
your car with it.

300
00:18:45,790 --> 00:18:48,994
And then on the picture
to the left, we saw desert

301

00:18:49,027 --> 00:18:51,129
sand dunes, similar to
what you see in the Sahara

302
00:18:51,162 --> 00:18:54,966
and the tropical, or
in the dry arid regions

303
00:18:54,999 --> 00:18:56,201
around our planet.

304
00:18:56,234 --> 00:19:00,038
So here you have a satellite
which have a lot of similarity.

305
00:19:00,071 --> 00:19:03,175
Not identical, but a lot of
similarity to our own planet,

306
00:19:03,208 --> 00:19:06,278
and number of scientists
believe that this could be

307
00:19:06,311 --> 00:19:09,948
a prebiotic planet, that mean
a planet which have organic

308
00:19:09,981 --> 00:19:14,252
material, and maybe it was
early way of how life started.

309
00:19:14,285 --> 00:19:16,821
And some people think there
might be life different

310
00:19:16,854 --> 00:19:18,990
than ours which
doesn't require water.

311
00:19:19,023 --> 00:19:20,892

You know, actually
you can, but you have

312
00:19:20,925 --> 00:19:23,128
all the hydrocarbon
which exist on it.

313
00:19:23,161 --> 00:19:26,131
So now we are starting to
think about future missions

314
00:19:26,164 --> 00:19:30,235
of possibly put boats in
those lakes, go sailing,

315
00:19:30,268 --> 00:19:32,137
have possibly balloons
in the atmosphere

316
00:19:32,170 --> 00:19:35,240
to explore it more in
detail, rover on that planet.

317
00:19:35,273 --> 00:19:37,309
So this is one example
of the kind of things

318
00:19:37,342 --> 00:19:40,278
that we'll be doing,
or our nation and NASA

319
00:19:40,311 --> 00:19:43,848
will be doing over the
next couple decades.

320
00:19:43,881 --> 00:19:46,218
Another interesting
satellite of Saturn,

321
00:19:46,251 --> 00:19:48,987

this one is much smaller,
is called Enceladus,

322
00:19:49,020 --> 00:19:51,089
and it's all made of
ice on the surface,

323
00:19:51,122 --> 00:19:53,892
we know that from what
we call spectroscopy,

324
00:19:53,925 --> 00:19:55,293
but what was very
puzzling, as you see

325
00:19:55,326 --> 00:19:58,230
those blue stripes
at the bottom.

326
00:19:58,263 --> 00:20:02,033
So when we flew by those blue
stripes, also on Cassini,

327
00:20:02,066 --> 00:20:05,103
by using what we call a
thermal infrared instrument

328
00:20:05,136 --> 00:20:08,139
which measures the heat,
we find that those stripes

329
00:20:08,172 --> 00:20:10,976
actually are warmer than
the environment around them.

330
00:20:11,009 --> 00:20:12,277
So that was very intriguing.

331
00:20:12,310 --> 00:20:15,947
But then Cassini looked

back toward those stripes

332
00:20:15,980 --> 00:20:19,084
and we actually saw geysers
shooting out of those stripes,

333
00:20:19,117 --> 00:20:22,120
so it's like you are up in
Yellowstone and these geysers

334
00:20:22,153 --> 00:20:24,856
are shooting up,
except these geysers

335
00:20:24,889 --> 00:20:27,058
are like 50 kilometers high.

336
00:20:27,091 --> 00:20:29,928
So they are higher than when
you are flying on an airplane.

337
00:20:29,961 --> 00:20:32,097
You know, you will see
geysers shooting up.

338
00:20:32,130 --> 00:20:35,033
And being the typical
JPL's always look

339
00:20:35,066 --> 00:20:37,969
in the different direction,
actually the team here,

340
00:20:38,002 --> 00:20:41,840
which was an amazing team,
actually targeted Cassini

341
00:20:41,873 --> 00:20:44,209
to fly through one of those
plumes, and they found

342
00:20:44,242 --> 00:20:46,244
that actually it's water ice,

343
00:20:46,277 --> 00:20:48,980
and it has organic
material in it.

344
00:20:49,013 --> 00:20:53,051
So now one theory is that
possibly these geysers

345
00:20:53,084 --> 00:20:55,987
are coming out from an
ocean below that ice,

346
00:20:56,020 --> 00:20:58,923
which is liquid, and
then as soon as you say

347
00:20:58,956 --> 00:21:02,294
a liquid ocean of H2O,
then people will be say,

348
00:21:02,327 --> 00:21:05,063
"Could there be
life in it today?"

349
00:21:05,096 --> 00:21:09,000
Now you will say, "Well
but Enceladus is way out,

350
00:21:09,033 --> 00:21:10,935
"how could it be
liquid water in it?"

351
00:21:10,968 --> 00:21:13,938
Well it turn out as
Enceladus goes around Saturn,

352
00:21:13,971 --> 00:21:17,842
you have this big planet,
and it creates tides,

353
00:21:17,875 --> 00:21:20,211
so you have the ice is
being pumped back and forth

354
00:21:20,244 --> 00:21:22,213
back and forth for
billions of years,

355
00:21:22,246 --> 00:21:24,883
and that generates heat
and that's what melted

356
00:21:24,916 --> 00:21:26,284
the ice below the surface.

357
00:21:26,317 --> 00:21:28,286
So now one mission
people are thinking about

358
00:21:28,319 --> 00:21:32,090
is actually to go fly a
spacecraft which will go fly

359
00:21:32,123 --> 00:21:34,225
through those plumes,
collect samples,

360
00:21:34,258 --> 00:21:36,261
and possibly bring
them back to Earth,

361
00:21:36,294 --> 00:21:39,164
and then you can analyze the
composition of those samples.

362

00:21:39,197 --> 00:21:41,966
So that's another example
of these far out missions

363
00:21:41,999 --> 00:21:44,002
that we are thinking about.

364
00:21:44,035 --> 00:21:47,005
Now this one is one of
my favorite pictures.

365
00:21:47,038 --> 00:21:50,141
This is a picture of
Saturn, taken from Cassini

366
00:21:50,174 --> 00:21:54,112
when it was behind Saturn
relative to the sun.

367
00:21:54,145 --> 00:21:57,782
So Saturn was blocking the
sun, and when you do that,

368
00:21:57,815 --> 00:22:00,852
you can see very faint light
around it, so it's the same,

369
00:22:00,885 --> 00:22:03,855
now I barely can see you
because the light is in my face,

370
00:22:03,888 --> 00:22:07,192
but if I block it I can
see you much better.

371
00:22:07,225 --> 00:22:11,062
So basically from that
picture, actually what you see

372
00:22:11,095 --> 00:22:13,298

those two little
dots, that's us.

373
00:22:13,331 --> 00:22:16,134
That's the Earth and
the moon next to it.

374
00:22:16,167 --> 00:22:19,237
So that little dot, is all
of you live on this dot,

375
00:22:19,270 --> 00:22:21,906
all your friends,
all your neighbors,

376
00:22:21,939 --> 00:22:25,043
all the people you like, all
the people you don't like.

377
00:22:25,076 --> 00:22:27,879
They are all living
on that little dot.

378
00:22:27,912 --> 00:22:30,248
So that give you a
perspective of our position

379
00:22:30,281 --> 00:22:32,150
in this solar system.

380
00:22:33,184 --> 00:22:36,221
Just imagine in the universe.

381
00:22:36,254 --> 00:22:40,792
Now, Cassini have been
flying for almost 13 years,

382
00:22:42,160 --> 00:22:45,830
but unfortunately in September
it's coming to an end,

383
00:22:45,863 --> 00:22:48,166
so it's going to be a
bittersweet kind of moment,

384
00:22:48,199 --> 00:22:52,036
because basically all the
fuel on it have been consumed,

385
00:22:52,069 --> 00:22:54,873
but again the imaginative
team said, "Well we're not

386
00:22:54,906 --> 00:22:56,908
"going to crash without
a big celebration,

387
00:22:56,941 --> 00:22:58,243
"we are going to
figure out a way

388
00:22:58,276 --> 00:23:00,945
"of how to we get
even more science."

389
00:23:00,978 --> 00:23:03,047
So they came up with
the idea of actually

390
00:23:03,080 --> 00:23:06,851
bringing the spacecraft
very very close to Saturn,

391
00:23:06,884 --> 00:23:09,821
and fly between
Saturn and the rings,

392
00:23:09,854 --> 00:23:12,257
and really coming
close to Saturn.

393
00:23:13,991 --> 00:23:16,194
And that's what you see is
happening as we speak today,

394
00:23:16,227 --> 00:23:19,264
we are coming every few
days, we are coming diving

395
00:23:19,297 --> 00:23:23,868
between the rings and
Saturn itself, and getting

396
00:23:23,901 --> 00:23:27,305
some amazing perspective about
Saturn and about what exists

397
00:23:27,338 --> 00:23:31,009
between the planet
itself and the rings.

398
00:23:31,042 --> 00:23:34,012
And then on September
15, is actually we will

399
00:23:34,045 --> 00:23:36,214
crash the spacecraft
into Saturn.

400
00:23:36,247 --> 00:23:38,116
Now you say, "Why in the
heck are you doing that,

401
00:23:38,149 --> 00:23:39,951
I mean this is a
great spacecraft?"

402
00:23:39,984 --> 00:23:42,187
Well, one thing we want
to make sure is that

403
00:23:42,220 --> 00:23:45,824
once we lose control of
it, when all the propellant

404
00:23:45,857 --> 00:23:48,793
is consumed and we lose
control of it, it doesn't end

405
00:23:48,826 --> 00:23:53,097
at some future time crashing
into Titan or in Enceladus,

406
00:23:53,130 --> 00:23:55,166
and carry some of
our microbes with it.

407
00:23:55,199 --> 00:23:58,069
We want to make sure those
satellites are very pristine,

408
00:23:58,102 --> 00:24:00,805
so if we go to explore
for life in them

409
00:24:00,838 --> 00:24:03,107
we don't find the life
that we took with us here.

410
00:24:03,140 --> 00:24:05,310
So that's part of the reason
we actually will crash it.

411
00:24:05,343 --> 00:24:08,279
So it doesn't mean that people
are not doing a good job,

412
00:24:08,312 --> 00:24:10,915
just mean that we
on purpose did that.

413
00:24:10,948 --> 00:24:13,084
So that happen
September 15, I think

414
00:24:13,117 --> 00:24:15,153
at 2:30am in the morning.

415
00:24:16,921 --> 00:24:19,824
The other great mission that
is ongoing now is called Juno,

416
00:24:19,857 --> 00:24:22,193
and that's a mission
going exploring Jupiter.

417
00:24:22,226 --> 00:24:25,296
It got there about a
year ago, and basically

418
00:24:25,329 --> 00:24:29,033
what that mission does by
using microwave radiation,

419
00:24:29,066 --> 00:24:33,071
it can probe deep into
the atmosphere of Jupiter

420
00:24:33,104 --> 00:24:36,808
and see what's internal
composition of that planet.

421
00:24:36,841 --> 00:24:40,812
And to do that, it comes and
fly very very close to Jupiter,

422
00:24:40,845 --> 00:24:43,047
even in the radiation belt,
and then it goes far out,

423
00:24:43,080 --> 00:24:44,883
and then come back in.

424
00:24:44,916 --> 00:24:46,818
And it has a camera
on it, and I picked

425
00:24:46,851 --> 00:24:48,119
one of those pictures.

426
00:24:48,152 --> 00:24:51,055
Look at the amazing picture
of what you actually can see,

427
00:24:51,088 --> 00:24:54,859
all these are basically
hurricanes which are happening,

428
00:24:54,892 --> 00:24:57,195
each one of them is
the size of our planet.

429
00:24:57,228 --> 00:25:00,999
So this is a very dynamic
planet, and that will

430
00:25:01,032 --> 00:25:04,002
give us insight in actually
the atmospheric dynamic

431
00:25:04,035 --> 00:25:06,237
and how hurricane form,
how they dissipate,

432
00:25:06,270 --> 00:25:08,006
how they interact.

433
00:25:08,039 --> 00:25:12,176
So in addition to seeing deep

into the inside of Jupiter,

434
00:25:12,209 --> 00:25:15,079
also is giving us a new
insight about the atmospheric

435
00:25:15,112 --> 00:25:17,248
dynamic around it.

436
00:25:17,281 --> 00:25:20,218
And these are some of
the more recent pictures

437
00:25:20,251 --> 00:25:23,855
that were acquired
with that mission.

438
00:25:23,888 --> 00:25:26,224
Now around Jupiter there is
another satellite which is

439
00:25:26,257 --> 00:25:29,994
very exciting, kind of like
Enceladus except much bigger,

440
00:25:30,027 --> 00:25:31,930
and it's called Europa.

441
00:25:31,963 --> 00:25:33,932
And as you can see
from that picture,

442
00:25:33,965 --> 00:25:37,769
Europa is made of ice, we
have known that from Galileo,

443
00:25:37,802 --> 00:25:39,070
and even from Voyager,

444

00:25:39,103 --> 00:25:41,239
and you see that brown
material, and when I say ice

445
00:25:41,272 --> 00:25:43,007
I mean H2O ice,

446
00:25:43,040 --> 00:25:45,944
it's the thing you put in
your drink when you are

447
00:25:45,977 --> 00:25:50,048
making a martini or something,
that kind of ice, H2O.

448
00:25:50,081 --> 00:25:53,184
But you see also these
fractures and all these cracks

449
00:25:53,217 --> 00:25:56,154
which are on it, and when
you look at it a little bit

450
00:25:56,187 --> 00:25:59,891
more detail, what that
remind me at the top,

451
00:25:59,924 --> 00:26:03,895
is if you fly from here to
Europe over the North Pole,

452
00:26:03,928 --> 00:26:07,065
you see these icebergs
which are floating.

453
00:26:07,098 --> 00:26:09,300
So that's exactly what is
here, it looks like big

454
00:26:09,333 --> 00:26:12,103

iceberg which are
floating on the surface,

455
00:26:12,136 --> 00:26:13,905
and if you look
carefully you can trace

456
00:26:13,938 --> 00:26:15,974
some of those features,
you trace them to the edge

457
00:26:16,007 --> 00:26:18,042
of an iceberg, and
then they re displaced.

458
00:26:18,075 --> 00:26:21,112
So that indicate that actually
that the ice is moving,

459
00:26:21,145 --> 00:26:24,215
which implies that most likely
there is an ocean below it,

460
00:26:24,248 --> 00:26:26,951
and then from measurement
of the gravity field

461
00:26:26,984 --> 00:26:29,120
and magnetic measurement,
people have concluded

462
00:26:29,153 --> 00:26:31,889
that actually there is
a thin layer of ice,

463
00:26:31,922 --> 00:26:34,258
thin meaning anywhere
between few hundred meters

464
00:26:34,291 --> 00:26:37,962

to few tens of kilometers,
and then there is a deep ocean

465
00:26:37,995 --> 00:26:40,798
below that, which
all made of H2O.

466
00:26:40,831 --> 00:26:42,800
So again that brings
the same question,

467
00:26:42,833 --> 00:26:47,005
could there be life if there
is actually an H2O ocean now,

468
00:26:47,038 --> 00:26:49,140
could there be life
actually in that ocean?

469
00:26:49,173 --> 00:26:52,076
Again today, not past
life, but life today.

470
00:26:52,109 --> 00:26:54,979
So that's the next major
mission that they planned,

471
00:26:55,012 --> 00:26:57,081
or one of the next major
mission being planned,

472
00:26:57,114 --> 00:26:59,117
is a mission to go to Europa.

473
00:26:59,150 --> 00:27:02,153
First to put an
orbiter around Jupiter,

474
00:27:02,186 --> 00:27:05,857
fly through a series of

fly by of Europa, and using

475
00:27:05,890 --> 00:27:09,894
a very high resolution
cameras and a sounder,

476
00:27:09,927 --> 00:27:13,831
you know a radar sounder,
determine how thick that ice is,

477
00:27:13,864 --> 00:27:15,833
and where is it the thinnest.

478
00:27:15,866 --> 00:27:18,970
And then shortly after that
we'll be putting a lander

479
00:27:19,003 --> 00:27:22,974
on the surface so we can analyze
what is that ice made of,

480
00:27:23,007 --> 00:27:26,110
how hard it is, is there
any organic material in it,

481
00:27:26,143 --> 00:27:28,112
and guess why we are doing that?

482
00:27:28,145 --> 00:27:31,282
Because after that we want
to land on it, drill our way

483
00:27:31,315 --> 00:27:34,952
down through that ice, and
put a submarine in that ocean

484
00:27:34,985 --> 00:27:37,088
and see what is
that ocean made of,

485
00:27:37,121 --> 00:27:38,923
is there life in that ocean?

486
00:27:38,956 --> 00:27:42,860
And people are already working
on actually what I call

487
00:27:42,893 --> 00:27:46,798
a upside down rover, which
are down in the ocean,

488
00:27:46,831 --> 00:27:49,901
where actually you put
the rover through the ice,

489
00:27:49,934 --> 00:27:52,770
the rover floats up,
and drive at the bottom

490
00:27:52,803 --> 00:27:54,772
of the ice upside down.

491
00:27:54,805 --> 00:27:57,175
And that, Kevin Hand, is
one of the scientists here

492
00:27:57,208 --> 00:27:59,977
working with a team of
engineers who are actually,

493
00:28:00,010 --> 00:28:01,946
they are doing this in Alaska.

494
00:28:01,979 --> 00:28:04,982
So they went through lakes
which are actually frozen,

495
00:28:05,015 --> 00:28:07,919
and they drilled the

hole, they put that rover

496
00:28:07,952 --> 00:28:11,155
upside down in it, and we
control it from JPL here.

497
00:28:11,188 --> 00:28:13,925
So this is kind of the
early technology that

498
00:28:13,958 --> 00:28:17,028
possibly 15 years from now you
probably will read about it

499
00:28:17,061 --> 00:28:20,298
that we are doing
that on Europa.

500
00:28:20,331 --> 00:28:23,901
Now, so that's one major
emphasis that JPL is doing,

501
00:28:23,934 --> 00:28:24,902
is potentially
looking up

502
00:28:24,935 --> 00:28:28,139
present life in
our solar system.

503
00:28:28,172 --> 00:28:30,141
But also there is a lot
of interest on Mars,

504
00:28:30,174 --> 00:28:32,176
and Mars has interest
for a variety of reason,

505
00:28:32,209 --> 00:28:35,012
and one historic, you know

people in science fiction

506
00:28:35,045 --> 00:28:36,914
stories, it's a place
where potentially

507
00:28:36,947 --> 00:28:40,084
we might be able to travel
some time in the future,

508
00:28:40,117 --> 00:28:43,187
but also Mars has a lot
of similarity with Earth.

509
00:28:43,220 --> 00:28:46,224
It has differences, but it
has a lot of similarity also.

510
00:28:46,257 --> 00:28:48,993
Mars is about one quarter
the size of Earth,

511
00:28:49,026 --> 00:28:50,962
so if you look at the
land mass on Earth,

512
00:28:50,995 --> 00:28:53,231
if you forget the oceans,
that's about the same area

513
00:28:53,264 --> 00:28:56,134
as Mars, so it's a
fairly large place.

514
00:28:56,167 --> 00:28:58,202
It has polar caps, you
can see the polar cap

515
00:28:58,235 --> 00:29:01,005
at the bottom in this case.

516
00:29:01,038 --> 00:29:03,107
The day on Mars is
a little bit longer

517
00:29:03,140 --> 00:29:06,010
than a day on Earth, few
tens of minutes longer.

518
00:29:06,043 --> 00:29:09,080
The year on Mars is
about two years on Earth.

519
00:29:09,113 --> 00:29:12,216
Mars has an atmosphere, not
as thick as our atmosphere,

520
00:29:12,249 --> 00:29:14,051
but it has an atmosphere.

521
00:29:14,084 --> 00:29:17,221
And then if you zoom on it,
Mars has a lot of similarity,

522
00:29:17,254 --> 00:29:20,124
you look at the geology on
Mars, it looks very similar.

523
00:29:20,157 --> 00:29:22,293
Sometime I give this as
a test to the audience,

524
00:29:22,326 --> 00:29:24,228
tell them guess which
one is the Grand Canyon

525
00:29:24,261 --> 00:29:26,197
and which one is
a canyon on Mars.

526
00:29:26,230 --> 00:29:27,999
You know, if I don't
tell you, you might,

527
00:29:28,032 --> 00:29:30,935
I'll bet you half of you think
it's the one on the right

528
00:29:30,968 --> 00:29:32,170
is on Earth, half of
you will think the one

529
00:29:32,203 --> 00:29:33,971
on the left is on Earth,

530
00:29:34,004 --> 00:29:37,909
so I will have a test
coming up, so hold on.

531
00:29:37,942 --> 00:29:40,311
You look at volcanoes, we
have volcanoes on Earth,

532
00:29:40,344 --> 00:29:42,046
you have volcanoes on Mars.

533
00:29:42,079 --> 00:29:44,182
That's Mount
Olympus, it's higher

534
00:29:44,215 --> 00:29:47,018
than the Himalayas at
Mount Everest on Earth,

535
00:29:47,051 --> 00:29:50,288
and clearly even that now
it's extinct, but clearly

536
00:29:50,321 --> 00:29:52,957

at an earlier time on
Mars when the volcano

537
00:29:52,990 --> 00:29:55,960
was forming, there was a
lot of volcanic activity

538
00:29:55,993 --> 00:29:57,195
happening on that planet.

539
00:29:57,228 --> 00:29:59,864
So even that now it looks
like a frozen planet,

540
00:29:59,897 --> 00:30:02,233
or a death planet,
some time in the past

541
00:30:02,266 --> 00:30:05,870
really it was a
very active planet.

542
00:30:05,903 --> 00:30:08,306
If you really zoom on the
things, this one is a test.

543
00:30:08,339 --> 00:30:11,175
I ask people to guess
which one is Death Valley

544
00:30:11,208 --> 00:30:12,877
and which one is Mars.

545
00:30:12,910 --> 00:30:15,112
I give that test all
the time to my students,

546
00:30:15,145 --> 00:30:17,148
so let me see how
many of you think

547
00:30:17,181 --> 00:30:19,884
the one to the right is Mars?

548
00:30:20,851 --> 00:30:22,820
Okay, that's a good number.

549
00:30:22,853 --> 00:30:26,157
How many of you think the
one to the left is Mars?

550
00:30:26,190 --> 00:30:27,225
That's a little bit more.

551
00:30:27,258 --> 00:30:28,860
Sorry, I forgot, I don't know

552
00:30:28,893 --> 00:30:30,061
which one is which.
(audience laughing)

553
00:30:30,094 --> 00:30:32,830
The two look so similar.

554
00:30:32,863 --> 00:30:36,133
Now, some of you might have
been a little bit perceptive.

555
00:30:36,166 --> 00:30:38,002
On the one to the
right at the beginning,

556
00:30:38,035 --> 00:30:41,239
there was a snake going through,
so that's how I remember

557
00:30:41,272 --> 00:30:44,141
that the one to the right,
I mean to your right,

558
00:30:44,174 --> 00:30:46,210
is actually the Earth,
because there was a snake

559
00:30:46,243 --> 00:30:47,979
which was going around it.

560
00:30:48,012 --> 00:30:50,948
But the point of this is
that the geologic activity

561
00:30:50,981 --> 00:30:53,150
which formed Mars are
the same as the geologic

562
00:30:53,183 --> 00:30:54,952
activity which formed Earth.

563
00:30:54,985 --> 00:30:59,190
So when human go and land on
it, an astronaut land on Mars,

564
00:30:59,223 --> 00:31:02,927
she will think that she's
in Death Valley doing that.

565
00:31:02,960 --> 00:31:05,930
So it's very similar
to our planet.

566
00:31:05,963 --> 00:31:07,832
And of course we
have now two rovers

567
00:31:07,865 --> 00:31:09,934
which have been
exploring that planet.

568

00:31:09,967 --> 00:31:12,203
The one to the left is
Opportunity has been there

569
00:31:12,236 --> 00:31:16,073
for 13 years, I kind
of lost track how long,

570
00:31:16,106 --> 00:31:18,910
it was supposed to work for
90 days, and then there was

571
00:31:18,943 --> 00:31:20,177
a whole bet going on.

572
00:31:20,210 --> 00:31:23,247
Some people said maybe one
year, and everybody thought

573
00:31:23,280 --> 00:31:26,150
they are crazy, they don't know
what they are talking about.

574
00:31:26,183 --> 00:31:28,185
Well 13 years later,
it's still exploring it,

575
00:31:28,218 --> 00:31:32,023
and the one to the
right is Curiosity.

576
00:31:32,056 --> 00:31:34,992
But the interesting thing
particularly about Curosity,

577
00:31:35,025 --> 00:31:37,828
it's basically like a
chemistry lab which was

578
00:31:37,861 --> 00:31:40,965

packaged inside a
car-sized rover,

579
00:31:40,998 --> 00:31:42,800
and it's now
exploring this planet.

580
00:31:42,833 --> 00:31:45,937
So it has in it most of
the things that you find

581
00:31:45,970 --> 00:31:48,072
in a first class chemistry lab,

582
00:31:48,105 --> 00:31:50,808
it has an oven that you
can put sample in it

583
00:31:50,841 --> 00:31:53,144
and heat it and note
what gas coming from it,

584
00:31:53,177 --> 00:31:57,048
it has an x-ray spectrometer,
which basically similar

585
00:31:57,081 --> 00:31:59,183
to what a dentist use
to look at your teeth,

586
00:31:59,216 --> 00:32:01,819
except a lot more expensive,

587
00:32:01,852 --> 00:32:04,055
we have a gamma
ray spectrometer,

588
00:32:04,088 --> 00:32:07,258
we have a laser beam which
actually zaps the rocks,

589
00:32:07,291 --> 00:32:09,260
see what's being
emitted from them,

590
00:32:09,293 --> 00:32:11,295
and actually make
an analysis for it.

591
00:32:11,328 --> 00:32:14,098
So it has a whole chemistry
lab in it, and it has

592
00:32:14,131 --> 00:32:16,133
a drill which actually
drills the rocks and takes

593
00:32:16,166 --> 00:32:20,271
samples and allow us to figure
out what's in that sample.

594
00:32:21,939 --> 00:32:24,041
And that's what the
surface kind of look like.

595
00:32:24,074 --> 00:32:26,877
For a geologist, this
gives a lot of feeling

596
00:32:26,910 --> 00:32:28,312
that these are dry lakes.

597
00:32:28,345 --> 00:32:30,881
It looks somewhat
similar to when you go

598
00:32:30,914 --> 00:32:33,150
in the Central Valley,
or around Owens Valley,

599
00:32:33,183 --> 00:32:35,186
and you see a lot
of those dry lakes.

600
00:32:35,219 --> 00:32:39,023
So it has a lot of the
similar features as dry lakes.

601
00:32:39,056 --> 00:32:42,026
And when you look at he
Orbiter data, it looks

602
00:32:42,059 --> 00:32:44,095
like there are streaks which
happen when the surface

603
00:32:44,128 --> 00:32:47,899
warms up, during the
summer or during noon,

604
00:32:48,999 --> 00:32:50,901
you see actually these
streaks coming down.

605
00:32:50,934 --> 00:32:53,904
To make a long story short,
the two major discoveries,

606
00:32:53,937 --> 00:32:56,907
that number one, we
believe that in a past time

607
00:32:56,940 --> 00:33:01,045
actually there was liquid water
H2O on Mars at the same time

608
00:33:01,078 --> 00:33:03,981
when Mars formed and Earth
formed, so we started

609
00:33:04,014 --> 00:33:07,084
very much alike, but
then Mars went one way

610
00:33:07,117 --> 00:33:10,087
where actually the water
went away, most likely

611
00:33:10,120 --> 00:33:13,290
it's frozen below the surface
and became much dryer,

612
00:33:13,323 --> 00:33:16,227
when Earth led to you
and I living here.

613
00:33:16,260 --> 00:33:20,064
So the key question is, during
those first few hundreds

614
00:33:20,097 --> 00:33:23,200
of millions of years, could
have life started on Mars?

615
00:33:23,233 --> 00:33:26,003
If it was very similar to
Earth, if it had H2O on it,

616
00:33:26,036 --> 00:33:29,173
it had volcanic activity,
it had thermal activity

617
00:33:29,206 --> 00:33:31,842
going on, could
have life started?

618
00:33:31,875 --> 00:33:34,045
And if it did, how
far did it evolve,

619
00:33:34,078 --> 00:33:36,113
and if it did, where is it?

620
00:33:36,146 --> 00:33:38,115
And if it did not, why not?

621
00:33:38,148 --> 00:33:41,052
Why did it happen here and
did not happen on Mars,

622
00:33:41,085 --> 00:33:43,754
so that's one of the key
objectives that the people

623
00:33:43,787 --> 00:33:47,858
on Curiosity are looking for,
and our future exploration.

624
00:33:47,891 --> 00:33:49,927
And you see sand dunes
similar to here again,

625
00:33:49,960 --> 00:33:52,763
I could have told you I just
was last week in Saudi Arabia,

626
00:33:52,796 --> 00:33:55,933
that kind of looks
like Saudi Arabia.

627
00:33:55,966 --> 00:33:57,835
And these are some of
the more recent images

628
00:33:57,868 --> 00:33:59,003
of these sand dunes.

629
00:33:59,036 --> 00:34:02,340
It looks very Earth-like

in arid regions.

630
00:34:04,041 --> 00:34:07,978
Now one thing to kind of maybe
impress you a little bit,

631
00:34:08,011 --> 00:34:09,847
to show you about the
challenge that the people

632
00:34:09,880 --> 00:34:12,850
who did this mission had to
face to actually accomplish.

633
00:34:12,883 --> 00:34:14,118
So I thought I'll
pick two example

634
00:34:14,151 --> 00:34:17,254
of the technical challenges
to do these missions.

635
00:34:17,287 --> 00:34:19,924
So in the case of
Curiosity, after we traveled

636
00:34:19,957 --> 00:34:23,261
225 million kilometers,
we landed in a area

637
00:34:25,229 --> 00:34:27,198
of about two kilometers.

638
00:34:27,231 --> 00:34:30,067
Now to give you an
idea of what that mean,

639
00:34:30,100 --> 00:34:32,269
that mean if I go outside
and hit a golf ball

640
00:34:32,302 --> 00:34:35,239
toward St. Andrews in
Scotland, the golf ball

641
00:34:35,272 --> 00:34:37,908
had to go straight in the cup.

642
00:34:37,941 --> 00:34:39,910
That's how accurate
it has to be.

643
00:34:39,943 --> 00:34:41,912
And to make it a little
bit more challenging

644
00:34:41,945 --> 00:34:44,081
for the good golfers,
the cup is moving,

645
00:34:44,114 --> 00:34:46,784
and you still have to get
it straight in the cup.

646
00:34:46,817 --> 00:34:50,921
So that's the kind of
accuracy that people had to do

647
00:34:50,954 --> 00:34:53,157
in the navigation and the
technology which had to be

648
00:34:53,190 --> 00:34:56,861
developed in the navigation
to make that happen.

649
00:34:56,894 --> 00:35:00,131
Another example of the
challenge is when we arrived

650
00:35:00,164 --> 00:35:04,068
at Mars, the energy in
the capsule, that mean

651
00:35:04,101 --> 00:35:08,139
for the technical people
here, the one half M V square,

652
00:35:08,172 --> 00:35:10,975
that amount of
energy is equivalent

653
00:35:11,008 --> 00:35:14,912
of 18,000 race cars
going at full speed.

654
00:35:14,945 --> 00:35:16,847
And we had seven
minutes to dissipate

655
00:35:16,880 --> 00:35:19,283
all that energy and land
softly on the surface.

656
00:35:19,316 --> 00:35:22,119
So we had to use, of course
we had to use heat shield,

657
00:35:22,152 --> 00:35:25,189
we had to use parachutes,
we had to use retro-rockets,

658
00:35:25,222 --> 00:35:28,292
and then finally we sky-craned
it, landed carefully,

659
00:35:28,325 --> 00:35:30,161
in the case of
Opportunity if you notice

660
00:35:30,194 --> 00:35:32,129
in the video it was airbags,

661
00:35:32,162 --> 00:35:35,166
and all of that had
to work perfectly.

662
00:35:35,199 --> 00:35:37,201
And you cannot joystick
it, because it takes

663
00:35:37,234 --> 00:35:39,837
about 10 to 15
minutes for the signal

664
00:35:39,870 --> 00:35:42,239
to go to Mars and
signal to come back.

665
00:35:42,272 --> 00:35:43,974
But you had only seven minutes,

666
00:35:44,007 --> 00:35:46,177
so you cannot sit down
and joystick all of this.

667
00:35:46,210 --> 00:35:47,912
So now I'm going to
show you a video,

668
00:35:47,945 --> 00:35:50,047
which I know many of
you probably have seen,

669
00:35:50,080 --> 00:35:53,217
I've seen like 300
times or 400 times.

670
00:35:53,250 --> 00:35:56,153

But it really reflects the
spirit of the people here

671
00:35:56,186 --> 00:35:58,055
who do that, so I
thought you would enjoy,

672
00:35:58,088 --> 00:36:01,759
because even after 300 times
or 400, I still enjoy it.

673
00:36:01,792 --> 00:36:03,160
Matter fact, my
heartbeat goes up

674
00:36:03,193 --> 00:36:05,930
every time I watch that video.

675
00:36:07,197 --> 00:36:10,034
So that shows you what
actually was happening in the

676
00:36:10,067 --> 00:36:12,870
Mission Operation Room when
we actually landed Curiosity.

677
00:36:12,903 --> 00:36:16,874
- [Man] Coming upon entry.
(dramatic music)

678
00:36:16,907 --> 00:36:19,243
The (mumbling) entry interface.

679
00:36:19,276 --> 00:36:21,245
At this time, we'll begin
pressurizing the propulsion

680
00:36:21,278 --> 00:36:24,048
system to increase the
thrust of the system.

681
00:36:24,081 --> 00:36:25,182
We'll use that for
all the maneuvering

682
00:36:25,215 --> 00:36:28,219
in the atmosphere
we're about to do.

683
00:36:29,319 --> 00:36:30,888
Vehicle has just
reported via tones

684
00:36:30,921 --> 00:36:33,291
that it has started
guided entry.

685
00:36:35,125 --> 00:36:36,894
We have seen peak acceleration.

686
00:36:36,927 --> 00:36:39,930
(dramatic music)

687
00:36:39,963 --> 00:36:43,968
We should have parachute
deploy around mach 1.7.

688
00:36:46,837 --> 00:36:48,105
The parachute has deployed.

689
00:36:48,138 --> 00:36:49,974
We are decelerating.

690
00:36:50,907 --> 00:36:54,011
(speakers talking at once)

691
00:36:54,044 --> 00:36:55,145
We're down to 90
meters per second,

692
00:36:55,178 --> 00:36:59,016
at an altitude of 6.5
kilometers, descending.

693
00:37:00,150 --> 00:37:03,153
Standing by for
(mumbling) separation.

694
00:37:03,186 --> 00:37:06,924
(engines roaring)

695
00:37:06,957 --> 00:37:09,193
We are in powered flight.
(enthusiastic cheering)

696
00:37:09,226 --> 00:37:12,096
(all applauding)

697
00:37:13,997 --> 00:37:17,968
We're at an altitude of
one kilometer descending.

698
00:37:18,001 --> 00:37:20,004
Standing by for sky crane.

699
00:37:20,037 --> 00:37:21,939
Sky crane is starting.

700
00:37:24,274 --> 00:37:28,346
- [Man] (mumbling),
you remain strong.

701
00:37:34,985 --> 00:37:36,053
- [Man] Touchdown confirmed.

702
00:37:36,086 --> 00:37:40,057
We are safe on mars.
(enthusiastic cheering)

703
00:37:46,797 --> 00:37:50,268
Now let's see where our
curiosity will take us.

704
00:38:13,323 --> 00:38:16,126
- Isn't it pretty
cool, this movie?

705
00:38:16,159 --> 00:38:20,231
My wife keep complaining.
(audience applauding)

706
00:38:22,199 --> 00:38:23,934
She keep telling me, "But
Charles, you have showed

707
00:38:23,967 --> 00:38:26,170
"this movie 300 times, why
are you still showing it?"

708
00:38:26,203 --> 00:38:28,238
But people love it!

709
00:38:28,271 --> 00:38:31,175
And in a sense, it give an
example, all these people there,

710
00:38:31,208 --> 00:38:33,077
Adam Steltzner and
all the other people,

711
00:38:33,110 --> 00:38:35,145
these are the perfect
example of that employee

712
00:38:35,178 --> 00:38:36,880
I showed you earlier,

713

00:38:36,913 --> 00:38:38,182
who are, nothing stopped them.

714
00:38:38,215 --> 00:38:41,752
They look in a different
direction what everybody looks.

715
00:38:41,785 --> 00:38:44,054
I can tell you, when we
first took the concept

716
00:38:44,087 --> 00:38:47,157
of a sky crane to NASA
headquarter, we told them

717
00:38:47,190 --> 00:38:49,760
that's how we are
planning to land on land,

718
00:38:49,793 --> 00:38:51,128
people shook their
head and said,

719
00:38:51,161 --> 00:38:52,863
"You guys in California
must be smoking

720
00:38:52,896 --> 00:38:55,099
"something that is illegal.

721
00:38:55,132 --> 00:38:57,868
"Are you kidding us, is that
how you are going to do it?"

722
00:38:57,901 --> 00:39:01,238
But people explained it
to them, Adam and a number

723
00:39:01,271 --> 00:39:03,874
of his colleagues explained

to them, and fortunately

724
00:39:03,907 --> 00:39:06,076
at NASA there were a
number of smart engineers

725
00:39:06,109 --> 00:39:08,312
that said, "Yeah, that makes
sense, let's go and try it."

726
00:39:08,345 --> 00:39:11,915
And that's how this
all came about.

727
00:39:11,948 --> 00:39:13,884
Now of course the first
thing we did when we landed,

728
00:39:13,917 --> 00:39:18,155
or shortly after we landed,
we did like all of you do.

729
00:39:18,188 --> 00:39:20,023
You get your cell phone,
your mom gives you

730
00:39:20,056 --> 00:39:22,826
a new cell phone at
Christmas or at the holidays,

731
00:39:22,859 --> 00:39:24,194
and you go and take a
picture of yourself,

732
00:39:24,227 --> 00:39:27,297
send it to your mom, say,
"Mom, look how good I look!"

733
00:39:27,330 --> 00:39:29,066
You know, so that's

actually what this was,

734
00:39:29,099 --> 00:39:32,903
it's a, "Hey mom, I
landed safely on Mars!"

735
00:39:33,970 --> 00:39:35,873
Now what are we doing
next on that one?

736
00:39:35,906 --> 00:39:37,808
So the next
major step is

737
00:39:37,841 --> 00:39:40,077
basically we're
planning a mission

738
00:39:40,110 --> 00:39:44,148
which is very similar to
Mars 2020 to certain level,

739
00:39:44,181 --> 00:39:46,016
sorry it was then Curiosity,

740
00:39:46,049 --> 00:39:48,285
so it's a similar rover,
except the payload

741
00:39:48,318 --> 00:39:50,120
will be completely different.

742
00:39:50,153 --> 00:39:51,822
And what this
mission will be doing

743
00:39:51,855 --> 00:39:53,257
is actually to drive around,

744

00:39:53,290 --> 00:39:56,960
it has more sophisticated
instrument, look at samples

745
00:39:56,993 --> 00:40:00,164
which potentially could have
organic material in them.

746
00:40:00,197 --> 00:40:04,067
Collect those samples, about
30 or 40 or 50 of them,

747
00:40:04,100 --> 00:40:06,870
and put them in the location
where then after we can

748
00:40:06,903 --> 00:40:10,274
go land, grab those samples,
put them on a small rocket,

749
00:40:10,307 --> 00:40:12,309
launch them in orbit,
send another spacecraft,

750
00:40:12,342 --> 00:40:15,946
rendezvous with them and
bring those samples back.

751
00:40:15,979 --> 00:40:17,181
Piece of cake.
(audience chuckling)

752
00:40:17,214 --> 00:40:19,983
So that's the challenge for
the next generation to do that.

753
00:40:20,016 --> 00:40:22,019
Now, to make it a little
bit more exciting,

754

00:40:22,052 --> 00:40:23,554
we are looking at
actually adding

755
00:40:23,654 --> 00:40:25,189
a little
helicopter on it,

756
00:40:25,222 --> 00:40:27,958
so we probably will have
a drone which will fly

757
00:40:27,991 --> 00:40:30,227
in front of the rover,
and actually survey

758
00:40:30,260 --> 00:40:32,896
the area in front of it.

759
00:40:32,929 --> 00:40:35,299
And that has both aspects,
one it will start opening

760
00:40:35,332 --> 00:40:38,836
the frontier of actually
doing airplanes and mobility

761
00:40:38,869 --> 00:40:41,972
in the air, where you can
go a much broader range,

762
00:40:42,005 --> 00:40:44,842
but the other benefit is
now one of the limitation

763
00:40:44,875 --> 00:40:48,145
on how far we drive is
every day we can only see

764
00:40:48,178 --> 00:40:50,214

from the camera of the
rover, so you can only see

765
00:40:50,247 --> 00:40:52,149
about hundred
meter ahead of you.

766
00:40:52,182 --> 00:40:55,018
So you can only plan
about hundred meter drive.

767
00:40:55,051 --> 00:40:57,154
If you have the helicopter
it can go in front of you

768
00:40:57,187 --> 00:41:00,858
and survey many kilometers
and actually based

769
00:41:00,891 --> 00:41:03,060
on that survey, it could show,
"Well it's more interesting

770
00:41:03,093 --> 00:41:05,996
"to go here instead of
going in that direction."

771
00:41:06,029 --> 00:41:10,100
So it will help actually
planning the rover activity.

772
00:41:11,301 --> 00:41:13,837
And the other neat thing
twhich have evolved because

773
00:41:13,870 --> 00:41:17,274
of the technology now, is now
we have literally hundreds

774
00:41:17,307 --> 00:41:20,110

of scientists around the world
that get on their computer

775
00:41:20,143 --> 00:41:22,212
and on the phone
and try to debate

776
00:41:22,245 --> 00:41:24,147
what they should be doing next.

777
00:41:24,180 --> 00:41:26,917
By that time you'll be able
to put basically glasses

778
00:41:26,950 --> 00:41:31,255
which will actually transpose
you as if you are on Mars.

779
00:41:31,288 --> 00:41:34,124
So you can walk next to the
Rover and actually explore,

780
00:41:34,157 --> 00:41:36,793
so you'll have hundreds
of scientists around

781
00:41:36,826 --> 00:41:39,963
the world actually with those
glasses, actually debating

782
00:41:39,996 --> 00:41:42,966
and discussing and deciding
what should they do.

783
00:41:42,999 --> 00:41:45,769
So I can kind of imagine how
funny it will be if you see

784
00:41:45,802 --> 00:41:49,806
somebody at an airport in

Frankfurt with those glasses,

785
00:41:49,839 --> 00:41:52,042
talking about rocks on Mars,
I wonder what the other people

786
00:41:52,075 --> 00:41:54,978
around him or her will
actually be saying.

787
00:41:55,011 --> 00:41:56,980
But that's going to
evolve completely

788
00:41:57,013 --> 00:41:59,817
how we actually do exploration.

789
00:42:00,951 --> 00:42:03,086
Now let me go to the
third topic which has been

790
00:42:03,119 --> 00:42:06,156
a major advance as, not
only we are exploring

791
00:42:06,189 --> 00:42:09,259
our solar system, but we
are starting to actually

792
00:42:09,292 --> 00:42:13,931
explore other planetary
systems around other stars.

793
00:42:13,964 --> 00:42:16,066
20 years ago, if
people would have said,

794
00:42:16,099 --> 00:42:19,002
"Look there are planets
all over the place,"

795
00:42:19,035 --> 00:42:21,071
people would have
not believed you.

796
00:42:21,104 --> 00:42:23,140
Matter fact, I
forgot now his name,

797
00:42:23,173 --> 00:42:27,278
but there was a monk which
I think in the 1600 or 1700,

798
00:42:29,879 --> 00:42:31,315
wrote an article
about other worlds

799
00:42:31,348 --> 00:42:33,884
and other planets
similar to ours.

800
00:42:33,917 --> 00:42:36,286
Guess what happened to him,
he was burnt on a stake

801
00:42:36,319 --> 00:42:40,791
because people thought that
he's kind of lost his mind,

802
00:42:40,824 --> 00:42:43,060
when we are finding today
that almost every star

803
00:42:43,093 --> 00:42:45,829
has planets around it.

804
00:42:45,862 --> 00:42:48,065
And one of the most recent
discovery, which was done

805
00:42:48,098 --> 00:42:50,133
with the Spitzer Telescope,
which is an infrared

806
00:42:50,166 --> 00:42:54,238
telescope (mumbling), is
what's called TRAPPIST

807
00:42:55,839 --> 00:42:58,075
around a star, which
we'll call TRAPPIST-1.

808
00:42:58,108 --> 00:42:59,209
Now I remind people, TRAPPIST,

809
00:42:59,242 --> 00:43:00,877
that's not the beer in Belgium,

810
00:43:00,910 --> 00:43:04,214
that's actually a
star which is in our,

811
00:43:04,247 --> 00:43:07,818
kind of our neighborhood, and
it has about seven planets

812
00:43:07,851 --> 00:43:10,854
about the size of Earth,
and a number of them

813
00:43:10,887 --> 00:43:14,825
in what we call the region
where the temperature is right,

814
00:43:14,858 --> 00:43:16,193
that water could be liquid.

815
00:43:16,226 --> 00:43:19,863
So we haven't detected life,

but they are in an environment

816
00:43:19,896 --> 00:43:22,132
that's very similar to
our planet, the same size

817
00:43:22,165 --> 00:43:23,867
and you have what seem to be

818
00:43:23,900 --> 00:43:26,236
similar temperature environment.

819
00:43:27,971 --> 00:43:30,307
And basically that kind
of compare it, relative

820
00:43:30,340 --> 00:43:33,176
to the Earth star, it
compares relative to our star,

821
00:43:33,209 --> 00:43:35,278
so you can see most
of those planets

822
00:43:35,311 --> 00:43:39,049
are about in our neighborhood,
or similar neighborhood,

823
00:43:39,082 --> 00:43:40,851
and these are to scale.

824
00:43:40,884 --> 00:43:43,954
So they are roughly about
the same size as our planet.

825
00:43:43,987 --> 00:43:46,857
So that's going to be a very
exciting thing that we need

826

00:43:46,890 --> 00:43:49,793
to do next, is explore
those solar system,

827
00:43:49,826 --> 00:43:51,094
or planetary system.

828
00:43:51,127 --> 00:43:53,130
And the way we do it, you say,
"Well how did you do that?"

829
00:43:53,163 --> 00:43:55,899
Now we didn't have
pictures, those was artist.

830
00:43:55,932 --> 00:43:59,803
Basically what we do, we look
at the star and measure its,

831
00:43:59,836 --> 00:44:01,905
in this case, the heat
emission coming from it,

832
00:44:01,938 --> 00:44:03,273
or the infrared signal,

833
00:44:03,306 --> 00:44:06,877
and if you see every once
in a while a dip and then

834
00:44:06,910 --> 00:44:10,113
that dip repeat again
in a periodic fashion,

835
00:44:10,146 --> 00:44:12,215
that mean this planet is
coming around it and blocking

836
00:44:12,248 --> 00:44:15,085
a little bit of that star,

and it goes around it.

837
00:44:15,118 --> 00:44:17,120
It's kind of simple to do that.

838
00:44:17,153 --> 00:44:20,090
So basically between
this mission, and Kepler,

839
00:44:20,123 --> 00:44:21,958
which I'll show you in a
second, basically what we do

840
00:44:21,991 --> 00:44:24,294
we look at the stars, we
measure their brightness

841
00:44:24,327 --> 00:44:27,831
very very accurately, like
in one part per million,

842
00:44:27,864 --> 00:44:30,200
and if we see a periodic
dip, that indicate

843
00:44:30,233 --> 00:44:33,103
there is a planet which
is going around it.

844
00:44:33,136 --> 00:44:36,139
And I think the next one
illustrate a little bit better,

845
00:44:36,172 --> 00:44:39,910
because you can see at the
top, when you see those dips,

846
00:44:39,943 --> 00:44:42,946
series of dips, and they
are exactly periodic,

847
00:44:42,979 --> 00:44:45,048
that tell you a planet
is around it, you measure

848
00:44:45,081 --> 00:44:49,019
the period between the two
dips, that tell you how long

849
00:44:49,052 --> 00:44:51,855
it takes the planet
to go around it's sun.

850
00:44:51,888 --> 00:44:54,224
You look at how deep is that
dip, that tell you how big

851
00:44:54,257 --> 00:44:56,960
the planet is, because a
bigger planet will block

852
00:44:56,993 --> 00:44:59,062
more of the light
than a small planet.

853
00:44:59,095 --> 00:45:01,898
So we can learn a lot by
just looking at the dips

854
00:45:01,931 --> 00:45:04,101
in the light of that star.

855
00:45:06,269 --> 00:45:10,140
And so far, I lost track
of the number, 3483,

856
00:45:12,108 --> 00:45:14,945
it changes every week,
it keep being updated

857
00:45:14,978 --> 00:45:17,280
probably by now it's
even more than that.

858
00:45:17,313 --> 00:45:20,984
And recently, not only we
were looking at those planets,

859
00:45:21,017 --> 00:45:22,986
but we have a group
of artists at JPL

860
00:45:23,019 --> 00:45:25,956
which develop poster and
said, "Well let's imagine

861
00:45:25,989 --> 00:45:29,826
"we are on one of those planets,
what would it look like?"

862
00:45:29,859 --> 00:45:32,996
Or you're advertising
travel to go to that planet.

863
00:45:33,029 --> 00:45:35,298
So they developed
a series of posters

864
00:45:35,331 --> 00:45:38,068
which are reasonably accurate.

865
00:45:38,101 --> 00:45:41,772
The one completely to the
right, that's a planet

866
00:45:41,805 --> 00:45:43,907
which is around a double star.

867
00:45:43,940 --> 00:45:46,176

So if you live on that
planet, you see two suns

868
00:45:46,209 --> 00:45:48,145
in the sky of
different temperatures,

869
00:45:48,178 --> 00:45:50,847
so one looks a little bit
redder than the other one.

870
00:45:50,880 --> 00:45:52,883
I like personally the one
completely to the left,

871
00:45:52,916 --> 00:45:56,186
that's a planet which around
a star which is colder

872
00:45:56,219 --> 00:45:58,155
than ours, that
mean it emits mostly

873
00:45:58,188 --> 00:46:00,190
in the red and infrared,

874
00:46:00,223 --> 00:46:03,193
so the theory is grass
on that planet would be

875
00:46:03,226 --> 00:46:04,961
more red colored.

876
00:46:04,994 --> 00:46:07,230
So here the astronauts are
saying, well, it's redder

877
00:46:07,263 --> 00:46:08,965
on the other side of the fence,

878
00:46:08,998 --> 00:46:10,100
instead of greener on the other

879
00:46:10,133 --> 00:46:13,036
side of the fence.
(audience laughing)

880
00:46:13,069 --> 00:46:15,906
And this is the TRAPPIST system.

881
00:46:17,006 --> 00:46:19,109
If you were living on
one of those planets,

882
00:46:19,142 --> 00:46:22,979
you actually would see six
other planets, which are

883
00:46:23,012 --> 00:46:25,182
around you, so that
must be an amazing sight

884
00:46:25,215 --> 00:46:27,251
if we live in that world.

885
00:46:29,953 --> 00:46:32,289
Now, the next big challenge,
what we want to do next,

886
00:46:32,322 --> 00:46:35,125
is not only to be detected
there are planets,

887
00:46:35,158 --> 00:46:38,028
but actually to start
taking images of them.

888
00:46:38,061 --> 00:46:39,796
Now you say, "How

would you do that?"

889
00:46:39,829 --> 00:46:42,833
The challenge is that
we look at the star,

890
00:46:42,866 --> 00:46:44,801
it's very very bright.

891
00:46:44,834 --> 00:46:46,169
Again, the same example
I told you earlier,

892
00:46:46,202 --> 00:46:48,905
it's like I'm looking
at some little object

893
00:46:48,938 --> 00:46:50,807
next to that light
and I cannot see it

894
00:46:50,840 --> 00:46:52,209
because it's shining in my face.

895
00:46:52,242 --> 00:46:54,911
So what we want to do
is to block that light

896
00:46:54,944 --> 00:46:57,914
so we can see that
planet around it.

897
00:46:57,947 --> 00:47:00,817
To give you an idea, that's
actually in that glare,

898
00:47:00,850 --> 00:47:03,920
it's like having a
firefly in the glare

899
00:47:03,953 --> 00:47:06,022
and we want to be
able to detect that.

900
00:47:06,055 --> 00:47:10,894
So that light is about 10
minus eight, or 10 minus nine,

901
00:47:10,927 --> 00:47:13,964
so that's less
than one billionth

902
00:47:13,997 --> 00:47:16,032
the brightness of the star.

903
00:47:16,065 --> 00:47:19,035
And the challenge is
to develop telescopes

904
00:47:19,068 --> 00:47:21,872
which are perfect, and then
be able to do what we call

905
00:47:21,905 --> 00:47:25,308
a coronograph, to be able to
block the light from the star

906
00:47:25,341 --> 00:47:28,111
so we can see the
planet next to that.

907
00:47:28,144 --> 00:47:30,313
And this show you an
example of a concept

908
00:47:30,346 --> 00:47:32,849
that's being developed
here, so you can have

909

00:47:32,882 --> 00:47:36,286
the telescope to your right,
and then a smaller spacecraft

910
00:47:36,319 --> 00:47:39,222
which at the beginning it's
smaller, separate from it,

911
00:47:39,255 --> 00:47:43,927
deploy a huge shade, and then
you look across that shade,

912
00:47:43,960 --> 00:47:46,796
and that shade will
block the star and then

913
00:47:46,829 --> 00:47:48,999
you will be able to see
what's around that star,

914
00:47:49,032 --> 00:47:51,935
those little planets
which are around it.

915
00:47:51,968 --> 00:47:55,005
And by detecting the light
from the planet directly,

916
00:47:55,038 --> 00:47:57,207
then you'll be able to do
spectroscopy and determine,

917
00:47:57,240 --> 00:48:00,076
does that planet has
H2O, that's interesting,

918
00:48:00,109 --> 00:48:02,078
does it have CH4, methane?

919
00:48:02,111 --> 00:48:04,014

That's getting
really interesting.

920
00:48:04,047 --> 00:48:06,082
Does it have hydrocarbon in it?

921
00:48:06,115 --> 00:48:07,951
That's getting
really interesting.

922
00:48:07,984 --> 00:48:09,886
That they have fluorocarbon,
you know those things

923
00:48:09,919 --> 00:48:12,889
you have in your refrigerator,
some of these things

924
00:48:12,922 --> 00:48:15,058
are basically done by
an industrial society,

925
00:48:15,091 --> 00:48:17,294
they don't exist in
nature, so that's getting

926
00:48:17,327 --> 00:48:19,095
really even more exciting.

927
00:48:19,128 --> 00:48:21,932
So that's the kind of thing
that people are working on,

928
00:48:21,965 --> 00:48:23,934
and these are a bunch of
students are looking at,

929
00:48:23,967 --> 00:48:24,968
I know there are a
couple of students

930
00:48:25,001 --> 00:48:26,002
here sitting in
the front,

931
00:48:26,035 --> 00:48:29,139
actually developing
some of that technology

932
00:48:29,172 --> 00:48:33,944
that actually will be flown
possibly in the next decade.

933
00:48:33,977 --> 00:48:36,046
Now I am going to
close to remind you

934
00:48:36,079 --> 00:48:38,048
that we live on a
beautiful planet.

935
00:48:38,081 --> 00:48:40,216
People always ask me,
"Charles, would you like to

936
00:48:40,249 --> 00:48:41,918
"travel to Mars?"

937
00:48:41,951 --> 00:48:43,820
And everybody's
expecting for me to say,

938
00:48:43,853 --> 00:48:45,088
"Yeah, of course I would."

939
00:48:45,121 --> 00:48:46,823
And I keep tell them, "No,
I think I like it here,

940

00:48:46,856 --> 00:48:48,925
"it's very nice around here.

941
00:48:48,958 --> 00:48:51,027
I love the trees,
I love the flowers,

942
00:48:51,060 --> 00:48:52,162
I love all those things here.

943
00:48:52,195 --> 00:48:54,230
So let me tell you a
little bit in closing

944
00:48:54,263 --> 00:48:58,835
about what we are doing,
looking at our own planet.

945
00:48:58,868 --> 00:49:00,770
One of the thing we have
been doing for literally

946
00:49:00,803 --> 00:49:02,839
now more than two
decade, is monitoring

947
00:49:02,872 --> 00:49:04,307
the height of the ocean.

948
00:49:04,340 --> 00:49:07,277
We have been measuring
very very accurately

949
00:49:07,310 --> 00:49:10,046
the height of the ocean
relative to a frame,

950
00:49:10,079 --> 00:49:13,049
and we are seeing that the
ocean actually is rising,

951
00:49:13,082 --> 00:49:15,952
and you can see it in that
picture at the bottom right.

952
00:49:15,985 --> 00:49:18,121
And the reason the ocean
is rising, is that actually

953
00:49:18,154 --> 00:49:21,291
ice is melting in the polar
region, the temperature

954
00:49:21,324 --> 00:49:23,927
is going up, even
that some people

955
00:49:23,960 --> 00:49:26,129
don't think that
that's happening,

956
00:49:26,162 --> 00:49:28,932
and actually the ocean
is actually rising.

957
00:49:28,965 --> 00:49:31,101
And the people who
live along the coast,

958
00:49:31,134 --> 00:49:33,036
you know particularly
in Florida,

959
00:49:33,069 --> 00:49:35,972
20, 30 years from
now if this continue,

960
00:49:36,005 --> 00:49:38,074
their property is going
to be below water.

961
00:49:38,107 --> 00:49:40,276
Now you say, "How do I know
that the ice is melting?"

962
00:49:40,309 --> 00:49:42,178
Well, we actually measure it.

963
00:49:42,211 --> 00:49:45,015
We have another mission
which actually measure

964
00:49:45,048 --> 00:49:48,151
the gravity field, in
this case over Greenland.

965
00:49:48,184 --> 00:49:50,920
And by measuring the gravity
field, you can determine

966
00:49:50,953 --> 00:49:54,290
how much mass in that
ice actually exists.

967
00:49:54,323 --> 00:49:57,927
And as you can see in that
picture in the last decade,

968
00:49:57,960 --> 00:50:00,196
actually you see things going
down and up, down and up,

969
00:50:00,229 --> 00:50:03,133
because that's the season,
going through summer and winter.

970
00:50:03,166 --> 00:50:05,969
But on the average,
it's trending down.

971
00:50:06,002 --> 00:50:08,138
And if you calculate
how much of that ice

972
00:50:08,171 --> 00:50:10,040
actually has melted,

973
00:50:10,073 --> 00:50:12,108
and how much the
temperature has changed,

974
00:50:12,141 --> 00:50:15,311
which expand the water, when
you add those two components,

975
00:50:15,344 --> 00:50:19,949
it's exactly what we saw on
the previous chart of the ice.

976
00:50:19,982 --> 00:50:22,986
So, usually when I talk
with people in Washington

977
00:50:23,019 --> 00:50:26,056
who are kind of not sure or
skeptical, but just showing

978
00:50:26,089 --> 00:50:30,160
them those two slides, actually
people become believers.

979
00:50:30,193 --> 00:50:32,896
Tell them that actually it's
happening, I'm not making it

980
00:50:32,929 --> 00:50:35,865
up, it's actually measurement,
which is actually happening,

981

00:50:35,898 --> 00:50:37,801
and the only
explanation is actually

982
00:50:37,834 --> 00:50:40,970
that there is warming
which is occurring.

983
00:50:41,003 --> 00:50:43,173
Another key application
that we have developed

984
00:50:43,206 --> 00:50:46,976
to look at here, and I think
I saw Mark here earlier,

985
00:50:47,009 --> 00:50:48,845
I think he's sitting back there,

986
00:50:48,878 --> 00:50:51,047
one of my colleagues
down at Caltech,

987
00:50:51,080 --> 00:50:53,917
is actually to use
satellite images to look

988
00:50:53,950 --> 00:50:56,019
at slight motions
which are happening

989
00:50:56,052 --> 00:50:57,954
on the surface of our planet.

990
00:50:57,987 --> 00:51:00,857
So this is like you
take a picture today,

991
00:51:00,890 --> 00:51:03,159
and then you go home, and then

tomorrow you take a picture

992
00:51:03,192 --> 00:51:05,195
and in between an
earthquake happened,

993
00:51:05,228 --> 00:51:07,263
but don't worry it's not
going to happen tonight,

994
00:51:07,296 --> 00:51:10,100
but if something happened,
we can actually take

995
00:51:10,133 --> 00:51:13,002
those two images,
superimpose them, and measure

996
00:51:13,035 --> 00:51:16,172
displacement down
to centimeter scale.

997
00:51:16,205 --> 00:51:19,109
So in a sense we can get a
picture of the earthquake.

998
00:51:19,142 --> 00:51:22,178
What you see on the left here
is the Napa Valley earthquake,

999
00:51:22,211 --> 00:51:25,949
and it show you the actual
motion that have happened.

1000
00:51:25,982 --> 00:51:28,852
Now, clearly that have
scientific benefit,

1001
00:51:28,885 --> 00:51:31,821
but also it has a practical

benefit, because where you see

1002
00:51:31,854 --> 00:51:34,224
those fringes being very
close to each other,

1003
00:51:34,257 --> 00:51:36,893
that means there was a lot of
motion which have happened,

1004
00:51:36,926 --> 00:51:38,962
and then you can pass that
to the rescuers because

1005
00:51:38,995 --> 00:51:41,164
most likely that's where
there was most destruction,

1006
00:51:41,197 --> 00:51:42,966
which actually have happened.

1007
00:51:42,999 --> 00:51:47,036
And this have been used in
(mumbling) operational base,

1008
00:51:47,069 --> 00:51:49,205
you know like when there was
an earthquake which happened

1009
00:51:49,238 --> 00:51:51,908
in Nepal, we shared something,
were able to get the data

1010
00:51:51,941 --> 00:51:55,145
very quickly, and over
the next few years

1011
00:51:55,178 --> 00:51:57,881
there will be operational
system which will be doing this

1012
00:51:57,914 --> 00:52:00,750
on a global basis, so
we'll be able to monitor

1013
00:52:00,783 --> 00:52:03,820
every day continuously,
what is changing.

1014
00:52:03,853 --> 00:52:06,856
Now, there are additional
benefit people came up with,

1015
00:52:06,889 --> 00:52:08,858
they said, "Well you
know, if I'm pumping water

1016
00:52:08,891 --> 00:52:12,061
"from the Central Valley,
the surface actually subside

1017
00:52:12,094 --> 00:52:13,963
"a little bit," because
you are pulling water from

1018
00:52:13,996 --> 00:52:17,000
underground and actually you
see it in many of the farm.

1019
00:52:17,033 --> 00:52:19,202
This technique actually can
measure how much subsides

1020
00:52:19,235 --> 00:52:22,172
is occurring, so you can
determine how much water

1021
00:52:22,205 --> 00:52:25,041
is being pumped out, so
that's another example

1022
00:52:25,074 --> 00:52:27,177
of the practicality of it.

1023
00:52:28,911 --> 00:52:30,280
And this is show you that
one example, I think this

1024
00:52:30,313 --> 00:52:33,917
is a dynamic one, we're
actually monitoring the changes

1025
00:52:33,950 --> 00:52:37,053
which have been
occurring in Los Angeles.

1026
00:52:37,086 --> 00:52:39,889
Now they are amplified a
little bit, but actually

1027
00:52:39,922 --> 00:52:41,824
with this technique you
see actually Los Angeles

1028
00:52:41,857 --> 00:52:44,761
breathing up and down, and
you look at the scale up,

1029
00:52:44,794 --> 00:52:47,864
that's about five centimeters,
that's about that much

1030
00:52:47,897 --> 00:52:49,899
that actually we are
measuring the changes

1031
00:52:49,932 --> 00:52:52,835
which are occurring due to
pumping which is occurring

1032
00:52:52,868 --> 00:52:55,805
from the aquifer
below Los Angeles.

1033
00:52:56,906 --> 00:52:58,875
Now, let me close
by, particularly

1034
00:52:58,908 --> 00:53:01,177
for the younger people
here, to tell you,

1035
00:53:01,210 --> 00:53:04,847
I told you about how I
started at JPL, now I tell you

1036
00:53:04,880 --> 00:53:08,818
during the period I was
at JPL, it's great fun.

1037
00:53:08,851 --> 00:53:10,019
It's a great thing to work here.

1038
00:53:10,052 --> 00:53:12,255
People think, gee,
scientists and engineers,

1039
00:53:12,288 --> 00:53:15,124
they sit down in their lab
and that's all what they work,

1040
00:53:15,157 --> 00:53:17,994
but now if you are a
geologist or you are doing

1041
00:53:18,027 --> 00:53:21,030
Earth exploration you can
travel all around the world.

1042

00:53:21,063 --> 00:53:23,166
This shows some example,
up in the left I was in

1043
00:53:23,199 --> 00:53:26,302
the Sahara Desert in Egypt
actually doing some work

1044
00:53:26,335 --> 00:53:28,871
looking at some
surface drainage.

1045
00:53:28,904 --> 00:53:31,140
The one top to the right we
were looking for the City

1046
00:53:31,173 --> 00:53:35,011
of Ubar, so we were doing
a little bit of archeology.

1047
00:53:35,044 --> 00:53:37,247
The one bottom right we
were hosted by some of the

1048
00:53:37,280 --> 00:53:39,782
Bedouins who were living
in the middle of the desert

1049
00:53:39,815 --> 00:53:40,983
in the middle of nowhere,

1050
00:53:41,016 --> 00:53:44,988
and one to the left actually
there you have to have people

1051
00:53:45,021 --> 00:53:47,890
which go with you, it's not
like you go to the nearest

1052
00:53:47,923 --> 00:53:49,926

earths and you rent a
car and then you can go

1053
00:53:49,959 --> 00:53:51,094
in the middle of the desert.

1054
00:53:51,127 --> 00:53:53,863
So you have to do a lot
of preparation for it.

1055
00:53:53,896 --> 00:53:55,765
And here I want to
tell you a little joke

1056
00:53:55,798 --> 00:53:57,834
I always like to kind of tell.

1057
00:53:57,867 --> 00:54:01,204
We were doing an expedition in
Egypt a number of years ago,

1058
00:54:01,237 --> 00:54:05,942
so we had about 30 workers,
Egyptian workers who were hired

1059
00:54:05,975 --> 00:54:08,911
by the Egyptian Geologic
Survey who went with us

1060
00:54:08,944 --> 00:54:12,248
and we were about couple hundred
miles away form any town.

1061
00:54:12,281 --> 00:54:15,051
So to get fresh food, and
we were there for like three

1062
00:54:15,084 --> 00:54:17,153
four weeks, to get fresh food

1063
00:54:17,186 --> 00:54:19,889
they brought with
them live ducks,

1064
00:54:19,922 --> 00:54:22,892
and because it turned out that
ducks can support the heat

1065
00:54:22,925 --> 00:54:25,228
very well, I didn't know that
but I learned it from them.

1066
00:54:25,261 --> 00:54:27,130
So one evening we were
sitting and all the ducks

1067
00:54:27,163 --> 00:54:30,833
were in the cook tent,
so we told the cook,

1068
00:54:30,866 --> 00:54:32,135
"How do you sleep at
night, these ducks

1069
00:54:32,168 --> 00:54:33,903
"are so noisy, you know.

1070
00:54:33,936 --> 00:54:35,872
"They are staying in the
same place you are sleeping."

1071
00:54:35,905 --> 00:54:37,073
He said, "Oh no,
it's no problem,

1072
00:54:37,106 --> 00:54:38,875
"whichever is the noisiest
duck, that's what you

1073

00:54:38,908 --> 00:54:41,077
"get for dinner that night."
(audience laughing)

1074
00:54:41,110 --> 00:54:43,112
And he said, "You'd be amazed,
after a couple of nights

1075
00:54:43,145 --> 00:54:45,282
"the ducks get very quiet."

1076
00:54:48,818 --> 00:54:50,987
And the other thing, let's
see I think I'm pushing

1077
00:54:51,020 --> 00:54:54,190
the right button, I
think maybe John you can,

1078
00:54:54,223 --> 00:54:57,994
and you meet a lot of great
people, that's Cousteau

1079
00:54:58,027 --> 00:55:01,164
who has came here a long time
ago and (mumbling) with us.

1080
00:55:01,197 --> 00:55:05,034
You see Prince Andrew, Al
Gore, so it is a great place

1081
00:55:05,067 --> 00:55:07,303
to work and a great
career to do that.

1082
00:55:07,336 --> 00:55:11,140
And famous movie stars, one
thing I tell people stories,

1083
00:55:11,173 --> 00:55:13,242

the reason I came to Caltech
I didn't know anything about

1084
00:55:13,275 --> 00:55:17,013
Caltech other than my professor
said it's a good school,

1085
00:55:17,046 --> 00:55:19,849
but I looked at the map
and I saw gee, it's close

1086
00:55:19,882 --> 00:55:21,951
to Hollywood, if I go there
I might meet movie stars,

1087
00:55:21,984 --> 00:55:23,953
I was very much in
the movie business.

1088
00:55:23,986 --> 00:55:27,256
But I didn't meet any movie
stars until I came to JPL,

1089
00:55:27,289 --> 00:55:29,192
and then I became the
director so we had

1090
00:55:29,225 --> 00:55:31,060
a lot of these movie stars.

1091
00:55:31,093 --> 00:55:33,930
But at the end, the most
important people around you

1092
00:55:33,963 --> 00:55:36,933
are your family, so I
always like to end my talk

1093
00:55:36,966 --> 00:55:39,068
by tell you I get great

support from my family,

1094
00:55:39,101 --> 00:55:42,004
these are two daughters
and my son-in-law,

1095
00:55:42,037 --> 00:55:44,240
and my wife and her parents.

1096
00:55:44,273 --> 00:55:47,910
So I love every evening going
home and telling my wife

1097
00:55:47,943 --> 00:55:50,880
and daughter, "Guess what,
we just landed a spacecraft

1098
00:55:50,913 --> 00:55:54,150
"on Mars today, we just
brought a sample from a comet."

1099
00:55:54,183 --> 00:55:55,818
So again, thank you very much,

1100
00:55:55,851 --> 00:55:59,956
and this is (mumbling).
(audience applauding)

1101
00:56:10,166 --> 00:56:14,237
So I guess we have a little
time for easy questions.

1102
00:56:15,971 --> 00:56:18,241
So I think if anybody, you
can either have to shout,

1103
00:56:18,274 --> 00:56:22,112
or there's a microphone
in the middle there.

1104
00:56:31,287 --> 00:56:34,290
Go ahead, don't pay attention
to the people who are leaving.

1105
00:56:34,323 --> 00:56:39,162
- You have a remarkable
historical perspective over JPL

1106
00:56:39,195 --> 00:56:40,897
and all the work of
the last few decades.

1107
00:56:40,930 --> 00:56:43,132
When you first arrived
here, what would you say

1108
00:56:43,165 --> 00:56:45,968
was the spirit of JPL in
terms of the engineering

1109
00:56:46,001 --> 00:56:48,137
and science that was happening,
and how has it changed

1110
00:56:48,170 --> 00:56:49,238
over the years?

1111
00:56:49,271 --> 00:56:51,774
How has JPL changed
versus when you started,

1112
00:56:51,807 --> 00:56:53,843
and as you leave today?

1113
00:56:53,876 --> 00:56:56,946
- That's a very
interesting question.

1114
00:56:56,979 --> 00:56:58,781

I would say the
spirit hasn't changed,

1115
00:56:58,814 --> 00:57:00,883
but the technology
have changed a lot.

1116
00:57:00,916 --> 00:57:03,019
And the spirit, I mean
you saw that picture

1117
00:57:03,052 --> 00:57:05,054
I showed you earlier
about the guy looking,

1118
00:57:05,087 --> 00:57:07,290
I mean that was taken
in the '50's I think.

1119
00:57:07,323 --> 00:57:12,094
And really the spirit here
is, we are here to explore.

1120
00:57:12,127 --> 00:57:14,297
We look at what's almost
impossible and then

1121
00:57:14,330 --> 00:57:16,032
we go and do it.

1122
00:57:16,065 --> 00:57:18,234
However, the technology
have changed tremendously,

1123
00:57:18,267 --> 00:57:20,837
and I'm sure you know that,
I mean you look at your cell,

1124
00:57:20,870 --> 00:57:23,139
probably your cellphone

has a hell lot more power

1125
00:57:23,172 --> 00:57:26,175
than this whole spacecraft,
the Voyageur here.

1126
00:57:26,208 --> 00:57:30,112
I remember I was giving
some kids a tour here

1127
00:57:30,145 --> 00:57:32,281
a few years ago, and
one of the kids he said,

1128
00:57:32,314 --> 00:57:36,018
"Oh what kind of, how do you
record the data on that?"

1129
00:57:36,051 --> 00:57:38,821
"Well we have a tape,"
and I got this blank look,

1130
00:57:38,854 --> 00:57:40,022
"What's a tape?"

1131
00:57:40,055 --> 00:57:41,924
(audience laughing)
Now you put it on a chip.

1132
00:57:41,957 --> 00:57:44,760
So really the technology
has changed in amazing ways,

1133
00:57:44,793 --> 00:57:47,096
and I think it's going
to continue to change,

1134
00:57:47,129 --> 00:57:48,931
the technology for instrument,

1135
00:57:48,964 --> 00:57:50,233
the technology of communication.

1136
00:57:50,266 --> 00:57:53,002
One example on future
mission, we are looking

1137
00:57:53,035 --> 00:57:56,105
at having laser communication
instead of these big

1138
00:57:56,138 --> 00:57:58,808
antennas that you see here,
you basically will have

1139
00:57:58,841 --> 00:58:01,110
a lens which has a laser,
and that will allow you

1140
00:58:01,143 --> 00:58:05,181
to get a lot more
data than we do today.

1141
00:58:05,214 --> 00:58:07,216
I started in the
radar field myself,

1142
00:58:07,249 --> 00:58:09,051
that's my technical background.

1143
00:58:09,084 --> 00:58:12,121
I would have never thought
we can do what Mark

1144
00:58:12,154 --> 00:58:15,124
is doing now with this
interferometry kind of thing.

1145
00:58:15,157 --> 00:58:18,227

So it's always, exploration,
that's what exploration's

1146
00:58:18,260 --> 00:58:22,064
about, is you do things that
have not been done before,

1147
00:58:22,097 --> 00:58:26,202
and what it requires, it
requires people to be curious,

1148
00:58:26,235 --> 00:58:29,906
not to be afraid of doing
something for the first time,

1149
00:58:29,939 --> 00:58:34,844
not to hesitate if even if you
fail, not to be discouraged

1150
00:58:34,877 --> 00:58:37,847
from doing that, that's how
you learn by some failure,

1151
00:58:37,880 --> 00:58:41,150
and on purpose I think you saw
in that video that I showed,

1152
00:58:41,183 --> 00:58:45,187
there was one capsule which
crashed on the surface,

1153
00:58:45,220 --> 00:58:47,123
and I do on purpose
show it because

1154
00:58:47,156 --> 00:58:49,091
not everything works perfect.

1155
00:58:49,124 --> 00:58:50,826
Matter fact, if

everything worked perfect,

1156
00:58:50,859 --> 00:58:52,795
maybe you're not
trying hard enough.

1157
00:58:52,828 --> 00:58:55,998
So, that's how you learn,
and we have learned

1158
00:58:56,031 --> 00:58:58,834
a lot if you go through
the history of JPL

1159
00:58:58,867 --> 00:59:02,038
in the early days, I think
when we landed on the moon

1160
00:59:02,071 --> 00:59:05,207
we had six failure before
we had one success.

1161
00:59:05,240 --> 00:59:09,912
And average people would have
given up after six failures.

1162
00:59:09,945 --> 00:59:13,215
But we didn't give up, or our
predecessors didn't give up,

1163
00:59:13,248 --> 00:59:15,851
and you see what
we are doing today,

1164
00:59:15,884 --> 00:59:17,820
so really the work
has changed a lot,

1165
00:59:17,853 --> 00:59:19,255
and I'd love to come

50 years from now

1166
00:59:19,288 --> 00:59:23,125
and see what people
here will be doing.

1167
00:59:23,158 --> 00:59:25,061
- Do you think that has,

1168
00:59:25,094 --> 00:59:27,163
back then it seemed like there
was a real national purpose,

1169
00:59:27,196 --> 00:59:29,198
there was such a priority
placed on the space program,

1170
00:59:29,231 --> 00:59:32,101
especially with regard to
competing with the Soviet Union,

1171
00:59:32,134 --> 00:59:33,836
we don't really have
that much today,

1172
00:59:33,869 --> 00:59:35,137
how do you maintain that
sense of national purpose

1173
00:59:35,170 --> 00:59:38,007
when there's not so much
a sense of competition

1174
00:59:38,040 --> 00:59:40,309
between nations, but--
- Sense of what?

1175
00:59:40,342 --> 00:59:42,211
- Oh, a competition, we don't
have the same competition

1176
00:59:42,244 --> 00:59:44,914
as much between nations as
we did during the Cold War.

1177
00:59:44,947 --> 00:59:48,017
How do you sustain the
investment required for

1178
00:59:48,050 --> 00:59:49,852
missions going forward.
- Well I mean,

1179
00:59:49,885 --> 00:59:53,856
in a sense scientists
tend to collaborate a lot,

1180
00:59:53,889 --> 00:59:55,992
even that there is competition,
but competition is done

1181
00:59:56,025 --> 00:59:58,160
in a constructive way,
because at the end

1182
00:59:58,193 --> 01:00:00,262
there are smart
people everywhere.

1183
01:00:00,295 --> 01:00:03,833
You learn from each other,
you learn from competition

1184
01:00:03,866 --> 01:00:06,068
and doing that, but being
competition nationally

1185
01:00:06,101 --> 01:00:09,905
or internationally, and you
learn from collaboration.

1186
01:00:09,938 --> 01:00:13,009
I come up with an idea, and
if I talk with you about it,

1187
01:00:13,042 --> 01:00:15,277
you come up with a little bit
better idea, you talk with me

1188
01:00:15,310 --> 01:00:18,114
I come up, somebody else
comes with a better idea.

1189
01:00:18,147 --> 01:00:21,117
So the whole area in the
scientific world you find

1190
01:00:21,150 --> 01:00:24,186
that it's not like in the
industrial world where I want

1191
01:00:24,219 --> 01:00:26,822
to beat the other
person, it's really

1192
01:00:26,855 --> 01:00:28,190
building together in the world.

1193
01:00:28,223 --> 01:00:29,191
Now, every once
in a while

1194
01:00:29,224 --> 01:00:31,861
politics intervenes
a little bit,

1195
01:00:31,894 --> 01:00:33,195
but that's the
world we live in.

1196
01:00:33,228 --> 01:00:36,832
But, almost every mission
you saw here we had

1197
01:00:36,865 --> 01:00:40,102
international collaboration,
and vice versa.

1198
01:00:40,135 --> 01:00:42,938
There are also we fly on
other, we put instrument

1199
01:00:42,971 --> 01:00:46,008
on other people, spacecraft.

1200
01:00:46,041 --> 01:00:48,811
- [Woman] Thank you very much.

1201
01:00:50,012 --> 01:00:52,882
- Some of the folks who
didn't give up when Ranger

1202
01:00:52,915 --> 01:00:54,850
didn't work still come
around occasionally,

1203
01:00:54,883 --> 01:00:56,752
I'm thinkin' of John
Cassani in particular,

1204
01:00:56,785 --> 01:01:01,190
he still visits us, he's one
of the Ranger senior engineers.

1205
01:01:01,223 --> 01:01:03,926
I'd like to reinforce what you
said, I've been coming here

1206
01:01:03,959 --> 01:01:05,961

for even longer than
you've been coming here,

1207
01:01:05,994 --> 01:01:07,096
and I come and sit down

1208
01:01:07,129 --> 01:01:08,230
at my desk every day--
- You are older than me?

1209
01:01:08,263 --> 01:01:11,067
- Yeah, I've been,
on Bastille Day

1210
01:01:11,100 --> 01:01:13,903
is my 50th service anniversary.

1211
01:01:15,037 --> 01:01:16,972
I go to my desk
every day and I say,

1212
01:01:17,005 --> 01:01:19,208
"They're payin' me to do this?"

1213
01:01:19,241 --> 01:01:21,143
I'm not an employee!

1214
01:01:21,176 --> 01:01:25,081
But now I have a kind of
a narrow arcane question.

1215
01:01:25,114 --> 01:01:29,185
The crane for Curiosity
flew away and crash landed

1216
01:01:30,119 --> 01:01:32,888
far enough away for safety.

1217
01:01:32,921 --> 01:01:35,891

If the crane for the
next lander is actually

1218
01:01:35,924 --> 01:01:38,094
landed carefully, with
some instruments on it,

1219
01:01:38,127 --> 01:01:42,231
we can brag that we have
put two different instrument

1220
01:01:42,264 --> 01:01:46,168
platforms on a planet
with one launch.

1221
01:01:46,201 --> 01:01:48,971
- Bob, that's an interesting
idea what you are saying,

1222
01:01:49,004 --> 01:01:51,807
we need people to come
up with idea like this,

1223
01:01:51,840 --> 01:01:53,809
so in a sense here, if
you know on the next one,

1224
01:01:53,842 --> 01:01:56,178
it has the helicopter, so
in a sense you are putting

1225
01:01:56,211 --> 01:02:00,983
a solid surface platform
and a flying platform on it,

1226
01:02:01,016 --> 01:02:02,752
and you can put a third one.

1227
01:02:02,785 --> 01:02:04,220
I'm not anymore the

director, you might want to

1228
01:02:04,253 --> 01:02:07,156
go talk with Mike
Watkins about doing that,

1229
01:02:07,189 --> 01:02:11,260
but on a more serious note
based on what you say,

1230
01:02:11,293 --> 01:02:12,995
that's how people
come up with it,

1231
01:02:13,028 --> 01:02:14,997
we need people to come
always with what seem

1232
01:02:15,030 --> 01:02:16,298
to be crazy idea.

1233
01:02:16,331 --> 01:02:19,001
I mean, my philosophy
was when somebody tell me

1234
01:02:19,034 --> 01:02:21,103
this is a crazy idea,
say, "Wow, that's cool,

1235
01:02:21,136 --> 01:02:23,172
"let's go and figure
out how do we do it."

1236
01:02:23,205 --> 01:02:26,108
Because that's how you
explore, and it's not unique

1237
01:02:26,141 --> 01:02:29,979
only about JPL, all
explorers in history,

1238
01:02:30,012 --> 01:02:33,849
that's how they explore is
by really pushing the limit,

1239
01:02:33,882 --> 01:02:36,886
trying new ideas, trying
new ways of doing things.

1240
01:02:36,919 --> 01:02:39,155
Failing every once in a
while, learning from it,

1241
01:02:39,188 --> 01:02:41,124
and then trying again.

1242
01:02:42,257 --> 01:02:46,128
So keep on coming
with the new ideas.

1243
01:02:46,161 --> 01:02:48,197
- Thank you very much for
the interesting presentation.

1244
01:02:48,230 --> 01:02:50,900
My question, are
two questions okay?

1245
01:02:50,933 --> 01:02:53,102
- [Charles] That's fine,
say them at the same time,

1246
01:02:53,135 --> 01:02:54,904
then I think it's only one.

1247
01:02:54,937 --> 01:02:57,940
- One question is what are
your thoughts on planetary

1248

01:02:57,973 --> 01:03:00,910
protection, is it something
helpful, to what extreme

1249
01:03:00,943 --> 01:03:03,779
is it helpful and when
does it become not helpful,

1250
01:03:03,812 --> 01:03:06,849
and how would that
interact with the future

1251
01:03:06,882 --> 01:03:09,084
of human exploration
of Mars for example.

1252
01:03:09,117 --> 01:03:10,820
- You know, I think that's
a very good question.

1253
01:03:10,853 --> 01:03:13,055
That's a debate we
have done many times.

1254
01:03:13,088 --> 01:03:16,158
Clearly if you are going
to search for life,

1255
01:03:16,191 --> 01:03:19,929
you want to make sure you
are not taking life with you.

1256
01:03:19,962 --> 01:03:23,833
And also, depending what life
you find, you want to make

1257
01:03:23,866 --> 01:03:27,069
sure you don't bring something
you don't like back to Earth.

1258

01:03:27,102 --> 01:03:30,005
So there are all kinds of
protocols about cleaning

1259
01:03:30,038 --> 01:03:34,276
spacecraft, particularly when
you have organic (mumbling).

1260
01:03:34,309 --> 01:03:38,214
On Mars 2020, there's a
major effort of how to clean

1261
01:03:38,247 --> 01:03:41,817
the spacecraft, and we have
done that on previous missions,

1262
01:03:41,850 --> 01:03:46,755
and that's exactly why on
Cassini we are going to crash it

1263
01:03:46,788 --> 01:03:48,224
in the atmosphere
and actually burn it,

1264
01:03:48,257 --> 01:03:51,060
I shouldn't say crash it,
burn it in the atmosphere

1265
01:03:51,093 --> 01:03:54,063
because we did not clean it,
we were not planning for it

1266
01:03:54,096 --> 01:03:57,032
to survive for so
long on the way back.

1267
01:03:57,065 --> 01:03:58,467
So we talked to
planetary protection,

1268

01:03:58,500 --> 01:04:00,169
now having said that,

1269
01:04:00,202 --> 01:04:02,104
there is a big dilemma of
what we are going to do

1270
01:04:02,137 --> 01:04:05,207
when we send a human because
you cannot take the human

1271
01:04:05,240 --> 01:04:07,243
and put them in an
oven and heat them

1272
01:04:07,276 --> 01:04:09,311
to a thousand
degrees to do that,

1273
01:04:09,344 --> 01:04:11,914
or use chemical to clean them.

1274
01:04:11,947 --> 01:04:13,916
So it is a dilemma
on doing that,

1275
01:04:13,949 --> 01:04:16,252
so sooner or later
we have to accept

1276
01:04:16,285 --> 01:04:20,189
that we might take some
of our life with us

1277
01:04:20,222 --> 01:04:24,827
to other planets, so
that is a very legitimate

1278
01:04:24,860 --> 01:04:27,096
debate to talk about.

1279
01:04:27,129 --> 01:04:28,964
- And the other question is--
- Oh I thought these were

1280
01:04:28,997 --> 01:04:32,201
your two questions.
(audience laughing)

1281
01:04:32,234 --> 01:04:34,203
- And the other question
is what are your thoughts

1282
01:04:34,236 --> 01:04:35,871
on new space
companies

1283
01:04:35,904 --> 01:04:38,941
participating in
future exploration?

1284
01:04:38,974 --> 01:04:40,175
So--
- You mean like

1285
01:04:40,208 --> 01:04:42,044
commercial companies--
- Exactly, so like SpaceX

1286
01:04:42,077 --> 01:04:44,113
talking about
colonization of Mars,

1287
01:04:44,146 --> 01:04:46,782
Blue Origin
participating in that.

1288
01:04:46,815 --> 01:04:48,150
- No I think also that's
a very good question,

1289
01:04:48,183 --> 01:04:50,152
and it's very important topic.

1290
01:04:50,185 --> 01:04:53,956
Basically at NASA, the role
of NASA is to basically

1291
01:04:53,989 --> 01:04:56,125
push the frontier and do
things for the first time,

1292
01:04:56,158 --> 01:04:58,093
and that's what JPL
does, and that's

1293
01:04:58,126 --> 01:05:00,062
what the government
should be doing.

1294
01:05:00,095 --> 01:05:02,131
Once you develop that
technology and you develop

1295
01:05:02,164 --> 01:05:04,967
that capability, then I
think it's the right thing

1296
01:05:05,000 --> 01:05:07,303
to turn it over to the
commercial sector and have

1297
01:05:07,336 --> 01:05:10,839
the commercial sector
make a business out of it.

1298
01:05:10,872 --> 01:05:13,075
So, many of the
commercial company now

1299
01:05:13,108 --> 01:05:16,145
who are building rocket,
basically they are capitalizing

1300
01:05:16,178 --> 01:05:19,214
on the technology and the
investment that NASA has done

1301
01:05:19,247 --> 01:05:21,216
over the last 50 years.

1302
01:05:21,249 --> 01:05:23,953
You know we are called
the Jet Propulsion Lab,

1303
01:05:23,986 --> 01:05:25,254
we don't do any propulsion.

1304
01:05:25,287 --> 01:05:28,924
We did that in the '50's and
the '60's, and developed that

1305
01:05:28,957 --> 01:05:31,160
capability and then turned
it over to industry.

1306
01:05:31,193 --> 01:05:33,963
Now we are getting
companies want to go

1307
01:05:33,996 --> 01:05:36,832
and do tourism around
Earth, that's great.

1308
01:05:36,865 --> 01:05:38,033
The technology have
been developed,

1309
01:05:38,066 --> 01:05:40,002

the capability have
been developed.

1310
01:05:40,035 --> 01:05:42,237
Some day in the future,
the capability of having

1311
01:05:42,270 --> 01:05:46,141
commercial companies send humans
to Mars, but I think still,

1312
01:05:46,174 --> 01:05:49,111
the government has a role to
do things for the first time,

1313
01:05:49,144 --> 01:05:52,948
because you require a major
amount of investment to do that,

1314
01:05:52,981 --> 01:05:55,184
that normal companies
will not do.

1315
01:05:55,217 --> 01:05:58,120
You know, you have stocks,
I'm not sure you have stocks,

1316
01:05:58,153 --> 01:06:01,190
I'm sure your parents have
stocks in a number of companies,

1317
01:06:01,223 --> 01:06:04,259
and they want to make sure
they make a profit for them

1318
01:06:04,292 --> 01:06:06,028
that's what our system is here,

1319
01:06:06,061 --> 01:06:07,930
so that's where the

government could invest

1320
01:06:07,963 --> 01:06:11,133
and take the high risk activity
and develop the technology,

1321
01:06:11,166 --> 01:06:13,869
then turn it to the
commercial sector.

1322
01:06:13,902 --> 01:06:15,838
So I think you're going
to see the future within

1323
01:06:15,871 --> 01:06:19,274
the next decade, more and
more commercial companies,

1324
01:06:19,307 --> 01:06:22,311
actually not only launching
but actually possibly

1325
01:06:22,344 --> 01:06:27,049
conducting business if
you want, or doing mining,

1326
01:06:27,082 --> 01:06:30,019
or doing monitoring in
space, and that's great,

1327
01:06:30,052 --> 01:06:31,954
that's what we should be doing.

1328
01:06:31,987 --> 01:06:34,256
- Thank you very much.
- Sure.

1329
01:06:36,825 --> 01:06:39,128
- Hi, very nice presentation.

1330
01:06:39,161 --> 01:06:43,165
In regard to the
Stardust NExT mission,

1331
01:06:43,198 --> 01:06:46,969
is it possible to
decontaminate an isotope?

1332
01:06:48,170 --> 01:06:52,074
- To decontaminate what?
- Decontaminate an isotope.

1333
01:06:53,241 --> 01:06:54,810
- What do you mean, I'm
not sure what you mean

1334
01:06:54,843 --> 01:06:57,013
by decontaminate an isotope?

1335
01:06:58,046 --> 01:07:01,750
- Okay, let me
explain a bit further.

1336
01:07:01,783 --> 01:07:05,087
There was a Stardust
NExT mission--

1337
01:07:05,120 --> 01:07:07,156
- Oh I see.
- To a comet,

1338
01:07:07,189 --> 01:07:10,226
and we tapped the
nucleus of a comet,

1339
01:07:11,927 --> 01:07:15,197
whereby we got some amino
acids that were taken

1340

01:07:17,866 --> 01:07:21,971
and tested in a laboratory,
brought down as organic matter,

1341
01:07:23,338 --> 01:07:26,976
and it turned out
that it was carbon-1,

1342
01:07:28,143 --> 01:07:32,281
carbon-1 being six
protons and six neutrons,

1343
01:07:32,314 --> 01:07:36,218
and Earthly bound, maybe
we got it off of the grid,

1344
01:07:36,251 --> 01:07:40,256
maybe it was from some other
source, but there was also

1345
01:07:42,124 --> 01:07:46,195
a compound that was six
protons and seven neutrons

1346
01:07:49,030 --> 01:07:53,135
that was very heavy that
couldn't be terrestrial.

1347
01:07:53,168 --> 01:07:55,871
- I don't think I know how
to answer your question,

1348
01:07:55,904 --> 01:07:58,040
even that I was the
director of JPL,

1349
01:07:58,073 --> 01:07:59,208
I don't know everything.

1350
01:07:59,241 --> 01:08:02,010

So, I really don't know.

1351
01:08:02,043 --> 01:08:03,212
I mean I have to
be candid with you,

1352
01:08:03,245 --> 01:08:05,280
I really don't know how
to answer your question.

1353
01:08:05,313 --> 01:08:07,116
- Okay.
- Sorry about that.

1354
01:08:07,149 --> 01:08:09,151
- But, thank you any way.
- I know I'm almost perfect,

1355
01:08:09,184 --> 01:08:13,255
but not completely perfect.
(audience laughing)

1356
01:08:15,957 --> 01:08:18,827
- I understand that if you
wanna see the corona of the sun,

1357
01:08:18,860 --> 01:08:22,097
you use a coronograph, which
is simply a disc that appears

1358
01:08:22,130 --> 01:08:26,101
to block the image of the
sun from your perspective,

1359
01:08:26,134 --> 01:08:30,272
but with the star shield, all
the stars other than the sun

1360
01:08:30,305 --> 01:08:33,008
are far enough away that

they're simply a point source,

1361
01:08:33,041 --> 01:08:36,912
there's no discernible disc
because they're so far away,

1362
01:08:36,945 --> 01:08:39,982
so how do you decide on the
size of the star shield,

1363
01:08:40,015 --> 01:08:41,984
and how far away
you view from it,

1364
01:08:42,017 --> 01:08:43,952
and why the pointy leaflets?

1365
01:08:43,985 --> 01:08:46,188
- Yeah, I think
people can figure out

1366
01:08:46,221 --> 01:08:50,058
there is a relationship between
the size of the star shade,

1367
01:08:50,091 --> 01:08:54,129
and the distance from
your telescope to do that,

1368
01:08:54,162 --> 01:08:55,764
and there are two techniques.

1369
01:08:55,797 --> 01:08:59,001
I mean one technique
is, inside the telescope

1370
01:08:59,034 --> 01:09:01,136
to put the coronograph,
that mean you put the camera

1371
01:09:01,169 --> 01:09:04,873
and put a little dot in it
which will block the light

1372
01:09:04,906 --> 01:09:08,911
of the star, but it turn
out by putting a star shade

1373
01:09:08,944 --> 01:09:12,247
a significant distance away
from you, you will be able

1374
01:09:12,280 --> 01:09:16,285
to see even closer to the star,
so you can do the geometry

1375
01:09:16,318 --> 01:09:20,255
between them, so this star
shade, from memory now

1376
01:09:20,288 --> 01:09:24,259
I can tell you, is many
hundreds of meters in size,

1377
01:09:24,292 --> 01:09:26,228
the one I showed you in here,

1378
01:09:26,261 --> 01:09:29,064
and it will be many tens
of thousands of kilometers

1379
01:09:29,097 --> 01:09:31,967
away from the telescope,

1380
01:09:32,000 --> 01:09:33,902
and the challenge as you
could imagine, I'm sure

1381
01:09:33,935 --> 01:09:37,206

you can quickly think about
it, is how do you line them up.

1382
01:09:37,239 --> 01:09:41,043
So your telescope
cannot jitter very much,

1383
01:09:41,076 --> 01:09:45,247
and then your star shade has
to be lined up very accurately.

1384
01:09:45,280 --> 01:09:47,216
But we think we can
develop that technology,

1385
01:09:47,249 --> 01:09:49,918
I think with that, it
is within our capability

1386
01:09:49,951 --> 01:09:51,086
of actually doing that.

1387
01:09:51,119 --> 01:09:53,155
And then when you move
the telescope to look

1388
01:09:53,188 --> 01:09:56,191
at another star, the
star shade has to move

1389
01:09:56,224 --> 01:10:00,128
and then line up
relative to that star.

1390
01:10:00,161 --> 01:10:01,230
So that's how these things work.

1391
01:10:01,263 --> 01:10:03,165
- Why the pointy
ends to the leaflets

1392
01:10:03,198 --> 01:10:06,068
that we saw in the
design that was showing?

1393
01:10:06,101 --> 01:10:08,070
- So the pointed what?
- Well, the star shade

1394
01:10:08,103 --> 01:10:12,007
you showed, it looked
like it had pointy ends.

1395
01:10:12,040 --> 01:10:14,276
It wasn't circular, it was--
- Oh I see,

1396
01:10:14,309 --> 01:10:16,144
that is was not a circle?
- It was circle, but then

1397
01:10:16,177 --> 01:10:19,047
it had pointy ends.
- Well it turn out,

1398
01:10:19,080 --> 01:10:22,818
if you really do
the math and so on,

1399
01:10:22,851 --> 01:10:26,154
that pattern is a perfect
pattern to counterbalance

1400
01:10:26,187 --> 01:10:28,890
the diffraction that you
will get in the telescope.

1401
01:10:28,923 --> 01:10:30,993
I asked the same question
when I first saw it, I said,

1402
01:10:31,026 --> 01:10:34,029
"Gee that looks bizarre, why
isn't it a perfect circle?"

1403
01:10:34,062 --> 01:10:36,798
It turn out that when
you do the calculation,

1404
01:10:36,831 --> 01:10:39,101
and I don't have the time
to go through it here,

1405
01:10:39,134 --> 01:10:41,870
and I don't think you'd
be interested, it turn out

1406
01:10:41,903 --> 01:10:45,073
that this pattern is the best
pattern to actually block

1407
01:10:45,106 --> 01:10:47,075
the light from the
star and see very faint

1408
01:10:47,108 --> 01:10:49,011
object next to it.

1409
01:10:49,044 --> 01:10:51,179
- Okay, thank you.
- Okay.

1410
01:10:51,212 --> 01:10:54,082
Oh see, I think there are other,
because this thing is being

1411
01:10:54,115 --> 01:10:58,220
I guess transmitted and there
are a couple of questions.

1412
01:11:01,189 --> 01:11:03,992
Okay one question is
from Crystal Ball,

1413
01:11:04,025 --> 01:11:07,963
which is what is your vision
of the space industry future,

1414
01:11:07,996 --> 01:11:11,199
and that's kind of the same
question that somebody ask here,

1415
01:11:11,232 --> 01:11:13,235
and again I think there
will be great opportunity

1416
01:11:13,268 --> 01:11:15,304
in the space business.

1417
01:11:15,337 --> 01:11:19,308
Now, people tend to
underestimate the complexity

1418
01:11:19,341 --> 01:11:21,076
when people say, "Oh
we are going to send

1419
01:11:21,109 --> 01:11:25,147
"a thousand inhabitant to
Mars in the next 10 years."

1420
01:11:25,180 --> 01:11:28,050
I think is going to take us a
little bit longer than that.

1421
01:11:28,083 --> 01:11:31,186
But I personally do believe
that within the next 10,

1422

01:11:31,219 --> 01:11:33,955
15 years, maybe 15 years,
we actually will be sending

1423
01:11:33,988 --> 01:11:37,092
humans to Mars, and that
will open the frontier

1424
01:11:37,125 --> 01:11:39,895
for possible
industrial activity.

1425
01:11:39,928 --> 01:11:43,198
I could imagine doing
mining of asteroids.

1426
01:11:43,231 --> 01:11:45,867
So I think there is an
opportunity, but it's not

1427
01:11:45,900 --> 01:11:50,772
a short term, it's not something
which will happen tomorrow.

1428
01:11:50,805 --> 01:11:53,775
However, what will happen and
what is happening now is all

1429
01:11:53,808 --> 01:11:57,112
the telecommunication industry,
all the monitoring industry,

1430
01:11:57,145 --> 01:12:00,849
I'm sure all of you use Google,
people don't think about it

1431
01:12:00,882 --> 01:12:03,085
twice that actually those
pictures have actually go

1432

01:12:03,118 --> 01:12:05,220
from a map to a picture,
actually that was

1433
01:12:05,253 --> 01:12:07,856
taken from orbiting satellite.

1434
01:12:07,889 --> 01:12:10,892
Many of you when you watch
the news you see 3D images

1435
01:12:10,925 --> 01:12:13,962
of Los Angeles, and you
see clouds coming over it,

1436
01:12:13,995 --> 01:12:16,865
people don't remember that
that was taken from space,

1437
01:12:16,898 --> 01:12:19,167
it was one of the missions
that Joby was involved in,

1438
01:12:19,200 --> 01:12:21,903
and a number of us who
were involved in it.

1439
01:12:21,936 --> 01:12:24,973
You use your GPS, every
time I look at my iPhone

1440
01:12:25,006 --> 01:12:27,275
and I'm lost, I try
to find where I am.

1441
01:12:27,308 --> 01:12:29,911
People don't remember that
that's coming from satellite.

1442
01:12:29,944 --> 01:12:33,115

So already, the space
industry is in many areas,

1443
01:12:33,148 --> 01:12:36,852
we have a major space
industry going on.

1444
01:12:36,885 --> 01:12:39,221
And then June ask, what are
your thoughts of the amateur

1445
01:12:39,254 --> 01:12:42,924
astronomer contribution to the
Juno mission, are there plans

1446
01:12:42,957 --> 01:12:45,394
for continuing
community involvement

1447
01:12:45,427 --> 01:12:46,995
with future missions?

1448
01:12:47,028 --> 01:12:50,899
Yes, I think amateur astronomers
could play a major role

1449
01:12:50,932 --> 01:12:53,168
in all the mission, because
we get tremendous amount

1450
01:12:53,201 --> 01:12:56,071
of data, and as I showed
you the picture earlier,

1451
01:12:56,104 --> 01:12:59,775
you have millions of stars
in the sky, and even if you

1452
01:12:59,808 --> 01:13:02,010
get the smartest and

the best scientist,

1453
01:13:02,043 --> 01:13:04,946
there is not enough of them
to actually be able to look

1454
01:13:04,979 --> 01:13:08,049
at all the data, to actually
examine all the phenomena.

1455
01:13:08,082 --> 01:13:11,086
So I think having amateur
astronomer is a great thing

1456
01:13:11,119 --> 01:13:13,822
to continue, and I hope
JPL, I mean I'm not

1457
01:13:13,855 --> 01:13:16,057
controlling it anymore,
but I hope that that will

1458
01:13:16,090 --> 01:13:18,994
continue in our future mission.

1459
01:13:19,027 --> 01:13:23,098
And the last one from Param,
what opportunities does JPL

1460
01:13:24,999 --> 01:13:28,170
have for quantum physicists
and astrophysicists?

1461
01:13:28,203 --> 01:13:32,174
Clearly we have a lot of
opportunity for astrophysicist,

1462
01:13:32,207 --> 01:13:34,242
Quantum physicist too,
because people ask me,

1463
01:13:34,275 --> 01:13:37,212
"What should I study to
be able to work at JPL?"

1464
01:13:37,245 --> 01:13:40,182
And I tell them, "We hire
people from every background."

1465
01:13:40,215 --> 01:13:44,052
Every technical discipline,
every scientific discipline,

1466
01:13:44,085 --> 01:13:47,989
as I told you earlier, we have
six artist who work at JPL.

1467
01:13:48,022 --> 01:13:51,827
People from business background,
outreach, communication,

1468
01:13:51,860 --> 01:13:55,096
education, from all the
disciplines that you need that,

1469
01:13:55,129 --> 01:13:57,833
because you can never tell
where the next discovery

1470
01:13:57,866 --> 01:14:01,002
will happen, so it could be
somebody a quantum physicist

1471
01:14:01,035 --> 01:14:02,938
and they come and
they come with idea

1472
01:14:02,971 --> 01:14:04,940
about quantum computing,

1473
01:14:04,973 --> 01:14:08,210
putting a new version of
computers in our spacecraft

1474
01:14:08,243 --> 01:14:10,946
versus the computers
we use today.

1475
01:14:10,979 --> 01:14:13,915
So clearly I usually tell
people, don't try to be

1476
01:14:13,948 --> 01:14:17,853
too specific on what you
study, as long as you are in

1477
01:14:17,886 --> 01:14:21,189
a technical discipline, almost
any technical discipline,

1478
01:14:21,222 --> 01:14:24,893
you will have opportunity
to work at place like JPL.

1479
01:14:24,926 --> 01:14:27,262
So I see we have two more, so
I'll take two more questions,

1480
01:14:27,295 --> 01:14:30,198
and I let people go and
I'll stick around in case

1481
01:14:30,231 --> 01:14:33,301
people want to ask
more questions.

1482
01:14:33,334 --> 01:14:36,204
- Well it's been an
honor to hear you talk.

1483
01:14:36,237 --> 01:14:38,840
I have a question about
kind of the development

1484
01:14:38,873 --> 01:14:42,978
of the space industry, in
sort of like a holistic way,

1485
01:14:43,011 --> 01:14:47,048
so with technology,
you know, it tends to,

1486
01:14:47,081 --> 01:14:49,217
development of technology
tends to grow exponentially,

1487
01:14:49,250 --> 01:14:52,120
like it grows on itself
with stuff like Moore's Law,

1488
01:14:52,153 --> 01:14:55,891
especially in computing,
whereas the space industry

1489
01:14:55,924 --> 01:14:57,993
isn't just a technological
beast, it's political

1490
01:14:58,026 --> 01:15:02,063
and it's tied to money,
so when you were director,

1491
01:15:02,096 --> 01:15:06,167
did you see a pattern of
things tending to speed up

1492
01:15:06,200 --> 01:15:08,904
exponentially, or does it
kind of like bounce around,

1493
01:15:08,937 --> 01:15:11,873
depending on the political
climate, or some mixture?

1494
01:15:11,906 --> 01:15:13,141
- Now when you say there
is not enough money,

1495
01:15:13,174 --> 01:15:15,877
I mean what do you mean,
what did you mean by that?

1496
01:15:15,910 --> 01:15:19,982
You mean the funding to play
things like what we do here?

1497
01:15:21,849 --> 01:15:24,152
Well I'm not sure I can
answer your question exactly,

1498
01:15:24,185 --> 01:15:26,855
but let me give you
perspective from my experience

1499
01:15:26,888 --> 01:15:29,090
as the director here.

1500
01:15:29,123 --> 01:15:32,227
People are very fascinated
with exploration,

1501
01:15:32,260 --> 01:15:34,930
even in Washington,
might be hard to believe,

1502
01:15:34,963 --> 01:15:36,798
but that's true,

1503
01:15:36,831 --> 01:15:39,935

and I know it's being
recorded and transmitted.

1504
01:15:39,968 --> 01:15:43,138
But I found that in
general, people believe

1505
01:15:43,171 --> 01:15:47,008
that technology really is
a great investment for our

1506
01:15:47,041 --> 01:15:50,178
country, almost no matter
what technology you do.

1507
01:15:50,211 --> 01:15:52,948
Almost never did I get a
question when I used to go

1508
01:15:52,981 --> 01:15:55,216
and talk with congressmen and
senator, or people saying,

1509
01:15:55,249 --> 01:15:57,886
"Why should I give you the
money, what are you going

1510
01:15:57,919 --> 01:15:59,220
"to do for me tomorrow?"

1511
01:15:59,253 --> 01:16:01,990
They always think about
that in the long term,

1512
01:16:02,023 --> 01:16:04,125
by investing in
technology and education,

1513
01:16:04,158 --> 01:16:06,995
there will be a benefit from it.

1514
01:16:07,028 --> 01:16:09,097
And I always give them
one simple example,

1515
01:16:09,130 --> 01:16:10,932
I'm sure you all have an iPhone.

1516
01:16:10,965 --> 01:16:14,869
And you have a camera in your
iPhone, and I tell people,

1517
01:16:14,902 --> 01:16:16,972
"Do you realize that the
focal plane in that camera

1518
01:16:17,005 --> 01:16:20,208
"was developed at JPL
for our telescope?"

1519
01:16:20,241 --> 01:16:23,278
We had no idea that it
could be used in a iPhone,

1520
01:16:23,311 --> 01:16:25,914
but then entrepreneurs
took that technology

1521
01:16:25,947 --> 01:16:28,950
and developed it, and made
a whole business out of it.

1522
01:16:28,983 --> 01:16:31,252
So, basically there
is a strong belief,

1523
01:16:31,285 --> 01:16:33,288
and I think that's
great in our country,

1524
01:16:33,321 --> 01:16:37,125
there is a belief that by
investing in technology,

1525
01:16:37,158 --> 01:16:38,927
you will get benefit from it.

1526
01:16:38,960 --> 01:16:42,097
It might not be tomorrow,
it will be maybe 40 years

1527
01:16:42,130 --> 01:16:43,898
from now, five years from now.

1528
01:16:43,931 --> 01:16:46,768
When I was your age,
we used to send memos,

1529
01:16:46,801 --> 01:16:49,871
we had no idea about email
and all of this thing,

1530
01:16:49,904 --> 01:16:51,106
we didn't have
any of that stuff.

1531
01:16:51,139 --> 01:16:53,808
I still have, when I cleaned
my office, I still have

1532
01:16:53,841 --> 01:16:56,044
stacks of memos
that we used to send

1533
01:16:56,077 --> 01:16:57,879
around and communicate.

1534
01:16:57,912 --> 01:17:00,882
But somebody invested in that

technology and now you use

1535
01:17:00,915 --> 01:17:04,052
the internet, you can't
even think of sending

1536
01:17:04,085 --> 01:17:06,121
a memo these days.

1537
01:17:06,154 --> 01:17:08,123
So, I don't know if I
answered your question,

1538
01:17:08,156 --> 01:17:11,826
but I think from what I
grabbed from what you intended.

1539
01:17:11,859 --> 01:17:13,061
- Thanks so much.

1540
01:17:14,862 --> 01:17:17,298
- Okay we'll do
one more and then.

1541
01:17:17,331 --> 01:17:20,835
- Stephen Hawkings said that--
- Can you turn down the mike?

1542
01:17:20,868 --> 01:17:21,936
Yeah, sorry, yeah.

1543
01:17:21,969 --> 01:17:23,038
- Like this?

1544
01:17:23,071 --> 01:17:25,206
Okay, Stephen Hawkings
made some comment

1545
01:17:25,239 --> 01:17:29,344

about some prediction that
for humankind to survive,

1546
01:17:31,012 --> 01:17:33,982
we would need to
colonize somewhere.

1547
01:17:34,015 --> 01:17:36,151
I'd like your opinion
about that please.

1548
01:17:36,184 --> 01:17:37,819
- Okay, I think I'm
not going to debate

1549
01:17:37,852 --> 01:17:38,987
with Hawkings, I mean,

1550
01:17:39,020 --> 01:17:41,022
he's pretty smart guy.
(audience laughing)

1551
01:17:41,055 --> 01:17:44,225
But I think before we start
thinking about finding

1552
01:17:44,258 --> 01:17:47,128
another place to go,
we ought to be thinking

1553
01:17:47,161 --> 01:17:50,031
about how we protect our planet.

1554
01:17:50,064 --> 01:17:53,768
Because I think, I'm a
strong believer that we are

1555
01:17:53,801 --> 01:17:57,038
smart species, and sooner or
later we are going to realize

1556
01:17:57,071 --> 01:18:00,075
that we might be doing
damage to our planet,

1557
01:18:00,108 --> 01:18:02,811
and I'm optimistic that
actually we'll say look,

1558
01:18:02,844 --> 01:18:06,114
we really need to do a better
job at managing our planet

1559
01:18:06,147 --> 01:18:09,250
and have more
peaceful relationship,

1560
01:18:09,283 --> 01:18:11,019
care about our environment,

1561
01:18:11,052 --> 01:18:13,855
I mean it might sound strange
considering what happened

1562
01:18:13,888 --> 01:18:16,257
this morning, but I
think that at the end,

1563
01:18:16,290 --> 01:18:19,260
I have a strong confidence,
I'm an optimist,

1564
01:18:19,293 --> 01:18:22,263
so I have confidence that
our species will realize

1565
01:18:22,296 --> 01:18:25,200
that we better do better
job at protecting our planet

1566
01:18:25,233 --> 01:18:26,901
and keep it a good place.

1567
01:18:26,934 --> 01:18:29,137
Now, that doesn't mean
we shouldn't explore

1568
01:18:29,170 --> 01:18:32,907
and go to other places,
but it doesn't have to be

1569
01:18:32,940 --> 01:18:34,175
because we are worried
that we are going to

1570
01:18:34,208 --> 01:18:36,978
blow ourself up here,
or blow our planet.

1571
01:18:37,011 --> 01:18:41,083
So I think I put more priority
on protecting our own planet.

1572
01:18:42,150 --> 01:18:43,885
Okay, thank you very
much, and thank you