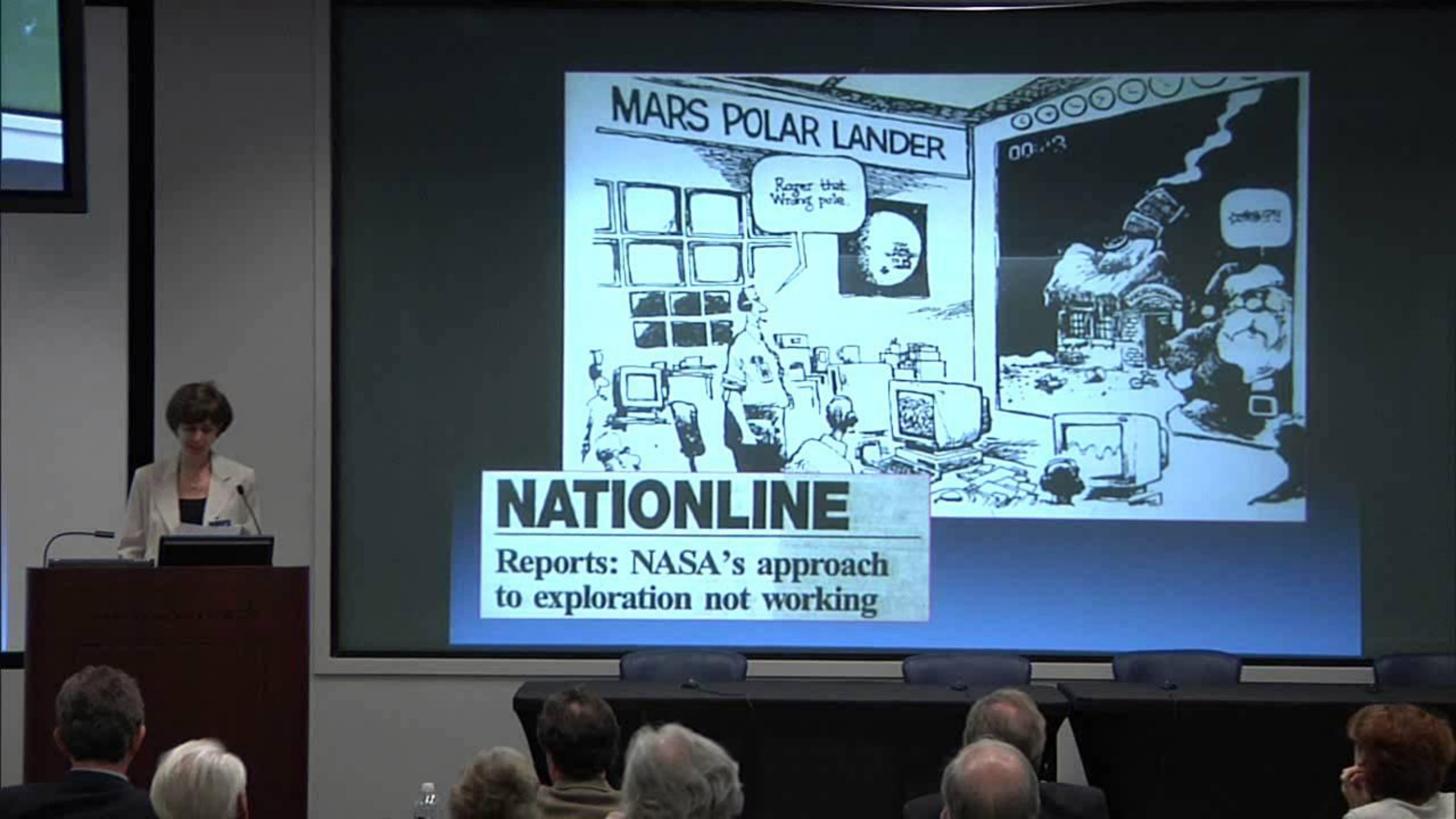
MARS POLAR LANDER
Roger that. Wrong pole.
NATIONLINE
Reports: NASA's approach to exploration not working

1
00:00:08,360 --> 00:00:07,039
if everybody take a seat I'd like before

2
00:00:11,749 --> 00:00:08,370
we start our last panel actually we have

3
00:00:16,990 --> 00:00:11,759
a one more special thing to do and I'd

4
00:00:23,120 --> 00:00:20,990
okay great thank you very much bill well

5
00:00:26,599 --> 00:00:23,130
you know it's um my really great

6
00:00:29,689 --> 00:00:26,609
pleasure to present our last Planetary

7
00:00:32,359 --> 00:00:29,699
Science Division award and this is an

8
00:00:37,000 --> 00:00:32,369
incredibly important individual in the

9
00:00:42,430 --> 00:00:37,010
history of planetary science from 1971

10
00:00:45,319 --> 00:00:42,440
to 1978 he basically had my position and

11
00:00:48,229 --> 00:00:45,329
i have to tell you his career is really

12
00:00:49,729 --> 00:00:48,239
enviable I know what he went through

13
00:00:52,310 --> 00:00:49,739

he's written a fabulous book which is

14
00:00:55,459 --> 00:00:52,320
back on the display please leave through

15
00:00:57,470 --> 00:00:55,469
that in fact when I six years ago to had

16
00:01:00,139 --> 00:00:57,480
the opportunity to be the planetary

17
00:01:01,490 --> 00:01:00,149
science division director I found out

18
00:01:05,149 --> 00:01:01,500
about the book and I read it thoroughly

19
00:01:09,590 --> 00:01:05,159
and in fact what's really great about

20
00:01:11,719 --> 00:01:09,600
that is how the rivalries between the

21
00:01:14,359 --> 00:01:11,729
scientists how he's worked with the

22
00:01:16,820 --> 00:01:14,369
projects with the federal budgets how we

23
00:01:18,620 --> 00:01:16,830
help to reshape the missions and how he

24
00:01:20,960 --> 00:01:18,630
met the challenging priorities and

25
00:01:23,510 --> 00:01:20,970
schedules and vehicle configurations and

26
00:01:25,190 --> 00:01:23,520
I know what that's all about and a

27
00:01:28,999 --> 00:01:25,200
number of people in the audience do too

28
00:01:33,380 --> 00:01:29,009
but let me tell you his record 1971

29
00:01:38,350 --> 00:01:33,390
Mariner 9 was launched 1972 piner 10 was

30
00:01:44,179 --> 00:01:38,360
launched 1973 mariner 10 was launched

31
00:01:49,399 --> 00:01:44,189
1975 viking 1 and 2 1976 helios to was

32
00:01:53,300 --> 00:01:49,409
launched 1977 Voyager 1 into 1978

33
00:01:56,209 --> 00:01:53,310
painter Venus 1 n 2 now if that's not a

34
00:01:59,120 --> 00:01:56,219
golden age of planetary science I don't

35
00:02:01,819 --> 00:01:59,130
know what is and so it's my very great

36
00:02:18,070 --> 00:02:01,829
pleasure that give a planetary science

37
00:02:53,760 --> 00:02:22,400
hahaha well come on up here but let me

38
00:02:53,770 --> 00:03:05,920

I really

39
00:03:05,930 --> 00:03:10,390
I know what you

40
00:03:10,400 --> 00:03:18,750
and now on to our last panel did it

41
00:03:26,709 --> 00:03:23,289
okay thank you Bill and let me I know

42
00:03:30,490 --> 00:03:26,719
this is not near the end yet we will be

43
00:03:34,209 --> 00:03:30,500
there but I want to say before I forget

44
00:03:35,770 --> 00:03:34,219
to to thank bill and Roger and everybody

45
00:03:39,009 --> 00:03:35,780
who put this conference together it's

46
00:03:45,160 --> 00:03:39,019
been terrific I just want to say glad

47
00:03:47,020 --> 00:03:45,170
you did it we're going to do still is a

48
00:03:50,410 --> 00:03:47,030
little differently on this panel then

49
00:03:56,289 --> 00:03:50,420
we've done up to now partly to keep you

50
00:03:58,659 --> 00:03:56,299
guys awake probably to keep us awake but

51
00:04:00,879 --> 00:03:58,669
what we'd like to do is we're going to

52
00:04:03,459 --> 00:04:00,889
have presentations that'll be a little

53
00:04:05,800 --> 00:04:03,469
briefer each panelist is going to talk

54
00:04:08,860 --> 00:04:05,810
for ten minutes or so and then we're

55
00:04:10,929 --> 00:04:08,870
going to sit down and have a little bit

56
00:04:14,220 --> 00:04:10,939
of a roundtable discussion and I think

57
00:04:16,930 --> 00:04:14,230
we had a really nice transition to this

58
00:04:19,870 --> 00:04:16,940
in the questions that followed the

59
00:04:23,159 --> 00:04:19,880
previous panel where people were asking

60
00:04:25,930 --> 00:04:23,169
about you know what have we learned from

61
00:04:28,570 --> 00:04:25,940
all that we've been through and and how

62
00:04:31,779 --> 00:04:28,580
can we use it to improve our chances of

63
00:04:33,219 --> 00:04:31,789

succeeding now and in the future so

64
00:04:36,240 --> 00:04:33,229
we're going to be looking back but we're

65
00:04:40,210 --> 00:04:36,250
also going to be looking ahead and

66
00:04:44,730 --> 00:04:40,220
before we get into the the discussions

67
00:04:48,120 --> 00:04:44,740
of the presentations I just want to

68
00:04:51,640 --> 00:04:48,130
mention something that David Grinspoon

69
00:04:53,499 --> 00:04:51,650
alerted me to several months ago when we

70
00:04:57,370 --> 00:04:53,509
were talking about this upcoming

71
00:04:59,409 --> 00:04:57,380
anniversary you know December marks the

72
00:05:03,100 --> 00:04:59,419
50th anniversary of the very first

73
00:05:06,670 --> 00:05:03,110
planetary encounter by mariner 2 and on

74
00:05:08,830 --> 00:05:06,680
december 14th merited to flew past Venus

75
00:05:12,580 --> 00:05:08,840
at a distance of about 20-something

76
00:05:15,159 --> 00:05:12,590
thousand miles and you know there had

77
00:05:16,990 --> 00:05:15,169
been a lot of speculation about what

78
00:05:20,170 --> 00:05:17,000
Venus might be like of course it was

79
00:05:22,810 --> 00:05:20,180
hidden and is hidden by dense opaque

80
00:05:25,839 --> 00:05:22,820
clouds and so nobody really knew we had

81
00:05:29,190 --> 00:05:25,849
clues to what Venus was likely worth for

82
00:05:31,320 --> 00:05:29,200
example a very strong microwave

83
00:05:34,380 --> 00:05:31,330
that had been detected from earth-based

84
00:05:36,030 --> 00:05:34,390
observations and people speculated that

85
00:05:39,000 --> 00:05:36,040
maybe this was due to the fact that

86
00:05:41,900 --> 00:05:39,010
Venus was a surrounded by a very warm

87
00:05:45,690 --> 00:05:41,910
and wet atmosphere in fact I remember

88
00:05:48,630 --> 00:05:45,700

when I was 56 years old right at the

89
00:05:51,840 --> 00:05:48,640
time of Mara to in my astronomy picture

90
00:05:53,610 --> 00:05:51,850
books there were some paintings that

91
00:05:57,060 --> 00:05:53,620
artists had done that showed Venus as a

92
00:05:59,940 --> 00:05:57,070
kind of a Jurassic swamp with the

93
00:06:04,670 --> 00:05:59,950
Venusian dinosaurs and that looked

94
00:06:06,990 --> 00:06:04,680
pretty cool to me but Mara to made one

95
00:06:12,030 --> 00:06:07,000
observation and it's so elegant it

96
00:06:15,120 --> 00:06:12,040
really is a beautiful example of of what

97
00:06:18,210 --> 00:06:15,130
can be done with a very little amount of

98
00:06:21,140 --> 00:06:18,220
data it's scanned across the disk of

99
00:06:24,540 --> 00:06:21,150
Venus where the microwave radiometer and

100
00:06:27,690 --> 00:06:24,550
it looked at how that intensity of

101
00:06:32,010 --> 00:06:27,700
microwave emission varied across the

102
00:06:33,900 --> 00:06:32,020
disk of the planet and if the they knew

103
00:06:36,630 --> 00:06:33,910
that if there if there was an increase

104
00:06:39,930 --> 00:06:36,640
in the in the intensity towards the

105
00:06:42,990 --> 00:06:39,940
center of the of the disk then the heat

106
00:06:46,320 --> 00:06:43,000
was coming from the surface whereas if

107
00:06:48,720 --> 00:06:46,330
the initial was most intense at the

108
00:06:51,360 --> 00:06:48,730
edges where you're looking through the

109
00:06:53,220 --> 00:06:51,370
most atmosphere then that would point to

110
00:06:55,500 --> 00:06:53,230
a very hot atmosphere well guess what

111
00:06:58,310 --> 00:06:55,510
the intensity was greatest in the middle

112
00:07:01,350 --> 00:06:58,320
and that's how we got our first

113
00:07:05,370 --> 00:07:01,360

awareness that Venus is in fact a

114
00:07:09,150 --> 00:07:05,380
hellishly hot surface underneath an

115
00:07:12,930 --> 00:07:09,160
atmosphere that's much less hot and that

116
00:07:16,620 --> 00:07:12,940
simple measurement began the the age of

117
00:07:21,000 --> 00:07:16,630
Institute planetary exploration well our

118
00:07:24,950 --> 00:07:21,010
first speaker is going to talk a little

119
00:07:27,450 --> 00:07:24,960
bit about the precursor missions that

120
00:07:29,960 --> 00:07:27,460
were so prominent in the early history

121
00:07:31,800 --> 00:07:29,970
of the space program glen boo gross is

122
00:07:34,440 --> 00:07:31,810
historian at the NASA Ames Research

123
00:07:35,730 --> 00:07:34,450
Center and in fact he's written a

124
00:07:38,900 --> 00:07:35,740
history of the senator cold atmosphere

125
00:07:40,890 --> 00:07:38,910
freedom which is commanding two editions

126
00:07:44,700 --> 00:07:40,900
and he's

127
00:07:46,860 --> 00:07:44,710
many articles on various topics in to do

128
00:07:49,260 --> 00:07:46,870
with the history of Ames he also has an

129
00:07:52,350 --> 00:07:49,270
interesting business history and has

130
00:07:57,990 --> 00:07:52,360
been a corporate history consult so

131
00:08:00,240 --> 00:07:58,000
Glenn have at it but 10 minutes thanks

132
00:08:02,999 --> 00:08:00,250
so I am a historian and one issue that

133
00:08:04,499 --> 00:08:03,009
confronted me when I joined ness about a

134
00:08:06,960 --> 00:08:04,509
decade ago is how to make sense of

135
00:08:09,029 --> 00:08:06,970
laddie laddie started as a robotic

136
00:08:11,490 --> 00:08:09,039
precursor first as a lander for an

137
00:08:14,100 --> 00:08:11,500
environmental survey network then one

138
00:08:16,020 --> 00:08:14,110

quick spacecraft to baseline left at

139
00:08:19,020 --> 00:08:16,030
dusk before the rush of expected human

140
00:08:20,430 --> 00:08:19,030
exploration on the moon now laddie is

141
00:08:23,070 --> 00:08:20,440
seen primarily as a science mission

142
00:08:25,320 --> 00:08:23,080
gathering data about the exosphere while

143
00:08:27,180 --> 00:08:25,330
the modular boss is a key part of a

144
00:08:29,850 --> 00:08:27,190
private effort to build an internetwork

145
00:08:33,060 --> 00:08:29,860
none of this yet has launched the

146
00:08:34,320 --> 00:08:33,070
technology has changed modestly how it's

147
00:08:36,600 --> 00:08:34,330
been viewed over time has changed

148
00:08:38,159 --> 00:08:36,610
dramatically that's why I first started

149
00:08:39,990 --> 00:08:38,169
to look at what it means to be a

150
00:08:41,670 --> 00:08:40,000
precursor in my research is focused

151
00:08:44,219 --> 00:08:41,680
largely on the robotic precursors to

152
00:08:45,630 --> 00:08:44,229
Apollo now I think it's great that so

153
00:08:48,930 --> 00:08:45,640
many to people at this conference come

154
00:08:51,090 --> 00:08:48,940
from JPL I think if the papers reflected

155
00:08:53,040 --> 00:08:51,100
the totality of our agency solar system

156
00:08:54,750 --> 00:08:53,050
exploration there might be a little bit

157
00:08:57,329 --> 00:08:54,760
less about how resolution photographs

158
00:08:59,670 --> 00:08:57,339
and more about data archives less about

159
00:09:01,350 --> 00:08:59,680
rocks and more about atmospheres less

160
00:09:03,840 --> 00:09:01,360
about geomorphology and more about

161
00:09:05,190 --> 00:09:03,850
astrobiology and astrochemistry less

162
00:09:07,710 --> 00:09:05,200
about flagships and more about

163
00:09:11,190 --> 00:09:07,720

instruments less about planetary science

164
00:09:12,810 --> 00:09:11,200
and more about precursors precursors

165
00:09:15,180 --> 00:09:12,820
it's such a hopeful word when applied to

166
00:09:16,949 --> 00:09:15,190
a science to to a space mission that

167
00:09:18,920 --> 00:09:16,959
suggests that any mission is a

168
00:09:22,460 --> 00:09:18,930
forerunner of a logical course of

169
00:09:25,650 --> 00:09:22,470
missions to come finding logic anywhere

170
00:09:27,720 --> 00:09:25,660
makes us hopeful today the route precose

171
00:09:29,699 --> 00:09:27,730
precursor most often means robotic

172
00:09:32,699 --> 00:09:29,709
missions to pave the way for human

173
00:09:34,890 --> 00:09:32,709
travel by reducing uncertainty the talk

174
00:09:37,170 --> 00:09:34,900
of precursors is to talk hopefully a

175
00:09:40,170 --> 00:09:37,180
planetary exploration as if space

176
00:09:41,970 --> 00:09:40,180
settlement was to come precursors can

177
00:09:43,800 --> 00:09:41,980
help here hopefully at this conference

178
00:09:45,420 --> 00:09:43,810
where historians and science and

179
00:09:47,850 --> 00:09:45,430
engineers are coming together to find

180
00:09:49,980 --> 00:09:47,860
some common dialog I find even that when

181
00:09:51,930 --> 00:09:49,990
talking to people in the hallways here

182
00:09:52,569 --> 00:09:51,940
that even how to frame the issue of

183
00:09:54,789 --> 00:09:52,579
science and

184
00:09:56,710 --> 00:09:54,799
and exploration together we all have

185
00:09:59,530 --> 00:09:56,720
dramatically different expectations of

186
00:10:01,809 --> 00:09:59,540
how to do that the word precursor

187
00:10:03,929 --> 00:10:01,819
illuminates contest conceptual contest

188
00:10:06,220 --> 00:10:03,939

between robotic and human exploration

189
00:10:08,199 --> 00:10:06,230
between practices of manufacturing

190
00:10:10,359 --> 00:10:08,209
certainty between ways of viewing

191
00:10:12,939 --> 00:10:10,369
historical progress by looking back to

192
00:10:14,769 --> 00:10:12,949
the past as historians do about looking

193
00:10:17,079 --> 00:10:14,779
forward to the future as base architects

194
00:10:19,569 --> 00:10:17,089
do between science and technology

195
00:10:21,819 --> 00:10:19,579
perhaps depending on how NASA precedes

196
00:10:24,939 --> 00:10:21,829
these next few years between public and

197
00:10:26,109 --> 00:10:24,949
private my point is I hope we all use

198
00:10:29,590 --> 00:10:26,119
this term with a little bit more

199
00:10:30,939 --> 00:10:29,600
sophistication today any power point of

200
00:10:33,460 --> 00:10:30,949
space architecture starts with the

201
00:10:35,309 --> 00:10:33,470
precursor small cheap robotic spacecraft

202
00:10:38,109 --> 00:10:35,319
usually in the lower left-hand corner

203
00:10:39,869 --> 00:10:38,119
stepping stones or check boxes to the

204
00:10:42,069 --> 00:10:39,879
ultimate destination in the upper right

205
00:10:44,049 --> 00:10:42,079
the file interested parties can agree

206
00:10:46,329 --> 00:10:44,059
that a precursor address is a specific

207
00:10:47,530 --> 00:10:46,339
knowledge gap in spacecraft technology

208
00:10:49,629 --> 00:10:47,540
or on what we will find at our

209
00:10:51,609 --> 00:10:49,639
destination then we all agreed that we

210
00:10:53,769 --> 00:10:51,619
can use it to declare success or failure

211
00:10:56,530 --> 00:10:53,779
well enough to move forward with a

212
00:10:58,509 --> 00:10:56,540
larger more expensive program that's one

213
00:11:01,210 --> 00:10:58,519

way that the word precursor invites

214
00:11:04,449 --> 00:11:01,220
contest in the negotiation over what

215
00:11:06,309 --> 00:11:04,459
data manufacture certainty another way

216
00:11:08,199 --> 00:11:06,319
the term precursor invites contest is in

217
00:11:10,720 --> 00:11:08,209
whether it is best used by historians or

218
00:11:12,999 --> 00:11:10,730
by planners the hubris of calling

219
00:11:14,650 --> 00:11:13,009
anything a precursor ahead of time the

220
00:11:15,999 --> 00:11:14,660
place that you can anticipate in the

221
00:11:18,819 --> 00:11:16,009
nearest future what missions will

222
00:11:20,530 --> 00:11:18,829
actually fly it is easier to define a

223
00:11:22,659 --> 00:11:20,540
mission as a precursor historically

224
00:11:25,210 --> 00:11:22,669
retro actively once we know how the

225
00:11:27,850 --> 00:11:25,220
future unfolds than it is to define one

226
00:11:29,319 --> 00:11:27,860
prescriptive Lee as part of a plan but

227
00:11:30,989 --> 00:11:29,329
just because historians can apply the

228
00:11:33,039 --> 00:11:30,999
word precursor with more satisfaction

229
00:11:35,999 --> 00:11:33,049
doesn't mean the planners can't use it

230
00:11:39,609 --> 00:11:36,009
for their own means the word precursor

231
00:11:41,049 --> 00:11:39,619
has recently undergone rapid change with

232
00:11:44,259 --> 00:11:41,059
the power of google books in the NASA

233
00:11:46,600 --> 00:11:44,269
SGI database in the decade of the 1960s

234
00:11:48,519 --> 00:11:46,610
I saw only one use of the word precursor

235
00:11:51,280 --> 00:11:48,529
applied to space with the Apollo

236
00:11:52,509 --> 00:11:51,290
missions notably was by a chemist and a

237
00:11:54,400 --> 00:11:52,519
discipline where the word has an

238
00:11:56,139 --> 00:11:54,410

established meaning as an ingredient

239
00:11:58,150 --> 00:11:56,149
that undergoes chemical reaction or

240
00:12:01,059 --> 00:11:58,160
metabolic pathway to become a more

241
00:12:04,650 --> 00:12:01,069
definitive or stable compound in the

242
00:12:07,319 --> 00:12:04,660
1970s and 1980s precursor

243
00:12:09,150 --> 00:12:07,329
was used in a dozen than 100 more

244
00:12:11,670 --> 00:12:09,160
different contexts The Situation's like

245
00:12:14,460 --> 00:12:11,680
pioneers 10 min 11 being precursors to

246
00:12:16,559 --> 00:12:14,470
the more complex Voyager missions then

247
00:12:19,410 --> 00:12:16,569
in the 1990s the term exploded into its

248
00:12:20,939 --> 00:12:19,420
common meaning in 1989 notably on the

249
00:12:23,150 --> 00:12:20,949
20th anniversary of the Apollo 11

250
00:12:25,259 --> 00:12:23,160
landing the first Bush administration

251
00:12:27,480 --> 00:12:25,269
announced the space exploration

252
00:12:29,100 --> 00:12:27,490
initiative building out station a

253
00:12:31,170 --> 00:12:29,110
permanent presence on the moon as a

254
00:12:33,929 --> 00:12:31,180
precursor to humans on Mars all

255
00:12:35,759 --> 00:12:33,939
proceeded by robotic missions this is

256
00:12:39,179 --> 00:12:35,769
when we came to know as the precursors

257
00:12:41,129 --> 00:12:39,189
to Apollo were the robotic precursors

258
00:12:44,009 --> 00:12:41,139
the Ranger impactors the lunar orbiters

259
00:12:45,509 --> 00:12:44,019
and the surveyor Landers the history of

260
00:12:47,249 --> 00:12:45,519
the early lunar robots is often

261
00:12:51,480 --> 00:12:47,259
misinterpreted because of the sheer mass

262
00:12:53,759 --> 00:12:51,490
of Apollo in the historiography of the

263
00:12:55,290 --> 00:12:53,769

exploration of the moon and the first

264
00:12:58,350 --> 00:12:55,300
years of the space race before Apollo

265
00:13:00,059 --> 00:12:58,360
was announced in 1961 d spacecraft were

266
00:13:01,499 --> 00:13:00,069
designed for lunar science and their

267
00:13:03,720 --> 00:13:01,509
experiment packages designed to help

268
00:13:05,879 --> 00:13:03,730
planetary scientists understand the

269
00:13:07,619 --> 00:13:05,889
geology of the moon there were 13

270
00:13:09,509 --> 00:13:07,629
successful American encounters with the

271
00:13:10,829 --> 00:13:09,519
moon prior to the Apollo landing the

272
00:13:13,439 --> 00:13:10,839
first of which happened less than five

273
00:13:15,329 --> 00:13:13,449
years before quickly and efficiently

274
00:13:17,160 --> 00:13:15,339
these robotic missions with an

275
00:13:19,470 --> 00:13:17,170
experimental foundation for the

276
00:13:21,329 --> 00:13:19,480
discipline of lunar science on the eve

277
00:13:23,040 --> 00:13:21,339
of Apollo 11 it was clear which

278
00:13:25,860 --> 00:13:23,050
questions remained that the sample

279
00:13:27,420 --> 00:13:25,870
return could possibly answer so these

280
00:13:29,699 --> 00:13:27,430
are science missions but they did in

281
00:13:31,439 --> 00:13:29,709
fact service precursors with the start

282
00:13:34,110 --> 00:13:31,449
of work in the Apollo lander the robots

283
00:13:36,300 --> 00:13:34,120
will repurpose to collect data useful to

284
00:13:38,939 --> 00:13:36,310
Apollo engineers the changes to the

285
00:13:40,439 --> 00:13:38,949
robots were generally slight removing

286
00:13:42,240 --> 00:13:40,449
the cameras on the Rangers was the

287
00:13:44,999 --> 00:13:42,250
biggest the other would be an equatorial

288
00:13:47,790 --> 00:13:45,009

focus with the maps and the strain gauge

289
00:13:50,100 --> 00:13:47,800
I'm added to the landing pads before

290
00:13:51,809 --> 00:13:50,110
these robots launched Apollo designers

291
00:13:53,850 --> 00:13:51,819
had declared a nominal definition of the

292
00:13:55,049 --> 00:13:53,860
surface of the Moon the bank strength of

293
00:13:57,210 --> 00:13:55,059
the regolith the protrusion of the

294
00:13:58,769 --> 00:13:57,220
boulders this definition was little

295
00:14:01,769 --> 00:13:58,779
revised with the data that the robots

296
00:14:03,929 --> 00:14:01,779
returned still the robots validated that

297
00:14:07,049 --> 00:14:03,939
NASA could get to the moon orbited and

298
00:14:08,790 --> 00:14:07,059
land on it at the time in the 1960s what

299
00:14:11,369 --> 00:14:08,800
was seen as the real precursors though

300
00:14:13,290 --> 00:14:11,379
not by that term where the human

301
00:14:14,960 --> 00:14:13,300
missions gemini in the early Apollo

302
00:14:17,269 --> 00:14:14,970
flights both mission

303
00:14:19,670 --> 00:14:17,279
didn't get the attention just because of

304
00:14:21,019 --> 00:14:19,680
the astronauts they were validating the

305
00:14:23,150 --> 00:14:21,029
technology that was really on the

306
00:14:26,389 --> 00:14:23,160
critical path to Apollo two-week trips

307
00:14:28,340 --> 00:14:26,399
Evie a stocking lunar rendezvous but he

308
00:14:29,480 --> 00:14:28,350
inferred in time from the 1960s those

309
00:14:31,490 --> 00:14:29,490
main missions were the ones that

310
00:14:34,189 --> 00:14:31,500
manufactured certainty about Apollo

311
00:14:35,629 --> 00:14:34,199
looking backwards from the early 1990s

312
00:14:37,879 --> 00:14:35,639
the robots bear the weight of Apollo

313
00:14:41,720 --> 00:14:37,889

history and are now usually cast as

314
00:14:43,220 --> 00:14:41,730
precursors still some precursors

315
00:14:45,470 --> 00:14:43,230
actually follow a recognizable

316
00:14:47,179 --> 00:14:45,480
trajectory that makes sensible narrative

317
00:14:49,850 --> 00:14:47,189
of space exploration whether you look

318
00:14:51,889 --> 00:14:49,860
backwards or forwards probes into Luna

319
00:14:53,780 --> 00:14:51,899
Terry atmospheres for examples were

320
00:14:55,910 --> 00:14:53,790
imagined in the 1960s as ways of

321
00:14:58,129 --> 00:14:55,920
learning about the structure of all the

322
00:14:59,509 --> 00:14:58,139
many atmospheres in our solar system the

323
00:15:01,100 --> 00:14:59,519
probes have scientific goals since

324
00:15:03,679 --> 00:15:01,110
atmospheres teach us much about the

325
00:15:05,179 --> 00:15:03,689
evolution of planets they also had

326
00:15:06,829 --> 00:15:05,189
engineering goals in that we can design

327
00:15:09,460 --> 00:15:06,839
better heat shields and forecast weather

328
00:15:12,050 --> 00:15:09,470
at landing sites there have been a dozen

329
00:15:14,749 --> 00:15:12,060
probe since the first probe the paet

330
00:15:16,100 --> 00:15:14,759
into the atmosphere of Earth in 1971 up

331
00:15:18,860 --> 00:15:16,110
through the Horgan's in the Middle East

332
00:15:19,850 --> 00:15:18,870
weed and the heat shield of MSL and the

333
00:15:23,179 --> 00:15:19,860
progression of evermore sophisticated

334
00:15:25,160 --> 00:15:23,189
probes returning other better data is

335
00:15:28,610 --> 00:15:25,170
what those in nineteen seventy one might

336
00:15:30,619 --> 00:15:28,620
expect to see in 2012 let's jump forward

337
00:15:32,660 --> 00:15:30,629
to the most recent era of precursors and

338
00:15:35,150 --> 00:15:32,670

a final way in which the word precursor

339
00:15:37,329 --> 00:15:35,160
looks contest between between science

340
00:15:40,129 --> 00:15:37,339
and technology between knowing and doing

341
00:15:42,379 --> 00:15:40,139
the 2005 exploration systems

342
00:15:44,990 --> 00:15:42,389
architecture study predicated on a big

343
00:15:46,790 --> 00:15:45,000
launcher constellation was what Harry

344
00:15:48,860 --> 00:15:46,800
lambright yesterday is likely called pre

345
00:15:50,600 --> 00:15:48,870
kersey constellation about the

346
00:15:53,090 --> 00:15:50,610
reconstruction both historical and a

347
00:15:55,040 --> 00:15:53,100
some ways technological of Apollo and of

348
00:15:57,139 --> 00:15:55,050
old path not taken after the Apollo

349
00:15:59,240 --> 00:15:57,149
missions but really it was fueled by two

350
00:16:01,309 --> 00:15:59,250
more recent precursors Clementine and a

351
00:16:04,400 --> 00:16:01,319
lunar prospector that showed the moon to

352
00:16:06,829 --> 00:16:04,410
be wet NASA's constellation office built

353
00:16:08,689 --> 00:16:06,839
a robust robotic precursor program with

354
00:16:11,629 --> 00:16:08,699
the dozen perspective missions poised to

355
00:16:14,030 --> 00:16:11,639
fill knowledge gaps about the moon this

356
00:16:16,309 --> 00:16:14,040
preacher program took flight much later

357
00:16:19,460 --> 00:16:16,319
with the Lunar Reconnaissance Orbiter

358
00:16:20,840 --> 00:16:19,470
and L cross nasa's lunar precursor

359
00:16:23,299 --> 00:16:20,850
program as i understand it is now

360
00:16:26,569 --> 00:16:23,309
largely in hiatus or at least construed

361
00:16:27,920 --> 00:16:26,579
a science since 2010 nasa has embarked

362
00:16:29,600 --> 00:16:27,930
on a flexible path

363
00:16:31,280 --> 00:16:29,610

and we'll decide where astronauts will

364
00:16:34,639 --> 00:16:31,290
go once the launch vehicle is firmly in

365
00:16:37,040 --> 00:16:34,649
hand it could be the moon Mars a moon of

366
00:16:38,870 --> 00:16:37,050
Mars or near Earth object with no

367
00:16:40,400 --> 00:16:38,880
destination there's no immediate need

368
00:16:42,889 --> 00:16:40,410
for robots to pave a safe way for

369
00:16:45,050 --> 00:16:42,899
astronauts still our knowledge of the

370
00:16:46,790 --> 00:16:45,060
planets keeps growing over the past

371
00:16:49,610 --> 00:16:46,800
decade there have been 10 expeditions to

372
00:16:51,620 --> 00:16:49,620
the moon orbiters and Rovers on Mars and

373
00:16:53,920 --> 00:16:51,630
data useful to the taxonomy of any us

374
00:16:56,449 --> 00:16:53,930
there is much to make sense of

375
00:16:58,370 --> 00:16:56,459
historians have spoke much ink over the

376
00:17:01,490 --> 00:16:58,380
interplay between science and technology

377
00:17:04,189 --> 00:17:01,500
those of us in NASA rather than directly

378
00:17:06,230 --> 00:17:04,199
address that in a play we use a proxy if

379
00:17:07,910 --> 00:17:06,240
something is funded by the space mission

380
00:17:09,260 --> 00:17:07,920
director sorry something is funded by

381
00:17:11,179 --> 00:17:09,270
the science Mission Directorate than it

382
00:17:13,069 --> 00:17:11,189
is science if it is funded by the human

383
00:17:15,290 --> 00:17:13,079
exploration mission directorate and

384
00:17:17,199 --> 00:17:15,300
technology the NASA lunar Science

385
00:17:20,510 --> 00:17:17,209
Institute right now is funded by both

386
00:17:23,750 --> 00:17:20,520
let me conclude with it an lsi is a

387
00:17:25,460 --> 00:17:23,760
virtual Institute founded in 2008 its

388
00:17:27,260 --> 00:17:25,470

goal is to reinvigorate a discipline of

389
00:17:31,100 --> 00:17:27,270
planetary science started as we have

390
00:17:34,160 --> 00:17:31,110
heard yesterday about 1962 as NASA's

391
00:17:35,810 --> 00:17:34,170
institute an lsi teams crunch new

392
00:17:38,060 --> 00:17:35,820
planetary data to make it useful to

393
00:17:40,130 --> 00:17:38,070
those in NASA planning missions robotic

394
00:17:42,140 --> 00:17:40,140
or crowed the nasa astrobiology

395
00:17:44,840 --> 00:17:42,150
institute serve much the same role in

396
00:17:46,669 --> 00:17:44,850
the 1990s when Dan Goldin kept the lava

397
00:17:49,580 --> 00:17:46,679
Mars program with vague precursor

398
00:17:51,560 --> 00:17:49,590
ambitions the NAI teams help then

399
00:17:54,380 --> 00:17:51,570
operationalize the mantra of how exactly

400
00:17:56,060 --> 00:17:54,390
to follow the water the lunar Science

401
00:17:57,530 --> 00:17:56,070
Institute is now being rican sieved as

402
00:18:00,169 --> 00:17:57,540
an asset institute of science and

403
00:18:03,470 --> 00:18:00,179
exploration its purview brought into the

404
00:18:05,510 --> 00:18:03,480
moons of mars and asteroids someday

405
00:18:07,400 --> 00:18:05,520
national policy or private investment

406
00:18:09,470 --> 00:18:07,410
may again shift so that we can talk of

407
00:18:11,480 --> 00:18:09,480
precursors we will again use the word

408
00:18:14,840 --> 00:18:11,490
hopefully anticipating a future history

409
00:18:17,150 --> 00:18:14,850
in space as historians and scientists we

410
00:18:19,490 --> 00:18:17,160
may use the word precursor to bring

411
00:18:29,600 --> 00:18:19,500
focus to the contest about how this

412
00:18:38,060 --> 00:18:33,950
Thank You Glenn our next speaker is only

413
00:18:39,980 --> 00:18:38,070

page kaminski and she is senior policy

414
00:18:43,130 --> 00:18:39,990
adviser to the chief scientist at NASA

415
00:18:44,780 --> 00:18:43,140
headquarters and as a PhD candidate in

416
00:18:47,350 --> 00:18:44,790
science and technology studies at

417
00:18:50,090 --> 00:18:47,360
Virginia Tech now here's an interesting

418
00:18:52,910 --> 00:18:50,100
biographical note she has previously

419
00:18:56,270 --> 00:18:52,920
served as a NASA program examiner at the

420
00:18:58,760 --> 00:18:56,280
office of management and budget and I

421
00:19:01,610 --> 00:18:58,770
think we're going to be maybe revisiting

422
00:19:03,320 --> 00:19:01,620
that part of her career for her

423
00:19:06,799 --> 00:19:03,330
perspectives on what's going on right

424
00:19:09,200 --> 00:19:06,809
now she's also been an analyst in the

425
00:19:11,090 --> 00:19:09,210
Federal Aviation Administration's office

426
00:19:13,510 --> 00:19:11,100
of the associate administrator for

427
00:19:16,159 --> 00:19:13,520
commercial space transportation and

428
00:19:18,710 --> 00:19:16,169
policy and outreach administrator at the

429
00:19:21,650 --> 00:19:18,720
National Space Society former editor of

430
00:19:25,549 --> 00:19:21,660
the American Astronomical Society space

431
00:19:28,280 --> 00:19:25,559
times magazine where of the 2012

432
00:19:30,260 --> 00:19:28,290
sakharov prize for space history she has

433
00:19:33,380 --> 00:19:30,270
a master's in science technology and

434
00:19:35,180 --> 00:19:33,390
public policy from gwu and a bachelors

435
00:19:37,789 --> 00:19:35,190
from Cornell in earth and planetary

436
00:19:40,870 --> 00:19:37,799
scientists sciences and she is going to

437
00:19:54,510 --> 00:19:40,880
talk about the faster better cheaper

438
00:20:00,210 --> 00:19:57,470

mr. remote is

439
00:20:03,060 --> 00:20:00,220
great all right we'll see if I solve

440
00:20:05,130 --> 00:20:03,070
anything left to talk about now okay

441
00:20:06,510 --> 00:20:05,140
well a role of the historian or

442
00:20:09,360 --> 00:20:06,520
sociologists of science and technology

443
00:20:11,340 --> 00:20:09,370
is to make sense of why and how

444
00:20:13,500 --> 00:20:11,350
throughout time certain paths in

445
00:20:16,230 --> 00:20:13,510
technical fields like solar system

446
00:20:19,200 --> 00:20:16,240
exploration are pursued by organizations

447
00:20:22,650 --> 00:20:19,210
nations and societies while others are

448
00:20:24,750 --> 00:20:22,660
not most such social scientists will say

449
00:20:27,110 --> 00:20:24,760
the resulting choices can't be seen as

450
00:20:30,150 --> 00:20:27,120
based solely on rational decision-making

451
00:20:32,250 --> 00:20:30,160
the state of science and technology or

452
00:20:35,280 --> 00:20:32,260
the idea that these enterprises proceed

453
00:20:37,110 --> 00:20:35,290
along a linear path of progress rather

454
00:20:39,120 --> 00:20:37,120
they will say decisions in science and

455
00:20:42,000 --> 00:20:39,130
technology and what's perceived as a

456
00:20:43,650 --> 00:20:42,010
success or a failure also have social

457
00:20:45,630 --> 00:20:43,660
and political determinants and we've

458
00:20:48,510 --> 00:20:45,640
already heard a lot about that in this

459
00:20:50,630 --> 00:20:48,520
conference as I see it determining how

460
00:20:53,730 --> 00:20:50,640
and why solar system exploration

461
00:20:56,640 --> 00:20:53,740
programs embrace particular form scales

462
00:20:59,900 --> 00:20:56,650
and destinations requires accounting for

463
00:21:03,390 --> 00:20:59,910

both the technical and the social and

464
00:21:09,610 --> 00:21:03,400
and conceiving of solar system

465
00:21:15,820 --> 00:21:13,210
or network comprised of many interacting

466
00:21:19,060 --> 00:21:15,830
actors as applied to solar system

467
00:21:22,200 --> 00:21:19,070
exploration activities performed by NASA

468
00:21:24,520 --> 00:21:22,210
these actors include NASA leadership

469
00:21:27,910 --> 00:21:24,530
planetary scientists and would be

470
00:21:30,790 --> 00:21:27,920
mission developers in NASA JPL industry

471
00:21:34,060 --> 00:21:30,800
and other institutions US political

472
00:21:36,880 --> 00:21:34,070
leadership the mass media and sometimes

473
00:21:38,890 --> 00:21:36,890
others all of whom have goals values and

474
00:21:41,260 --> 00:21:38,900
priorities of their own as well as

475
00:21:43,180 --> 00:21:41,270
particular interests in and definitions

476
00:21:45,640 --> 00:21:43,190
of success and failure for space and

477
00:21:48,040 --> 00:21:45,650
solar system exploration it also

478
00:21:50,380 --> 00:21:48,050
encompasses and I want to stress it

479
00:21:52,780 --> 00:21:50,390
encompasses non-human elements

480
00:21:55,419 --> 00:21:52,790
particularly spacecraft as the

481
00:21:58,000 --> 00:21:55,429
technological centerpieces of solar

482
00:22:00,280 --> 00:21:58,010
system exploration conditions such as

483
00:22:03,130 --> 00:22:00,290
the state of the economy scientific

484
00:22:06,040 --> 00:22:03,140
knowledge other NASA programs national

485
00:22:09,520 --> 00:22:06,050
policies International Space programs as

486
00:22:12,760 --> 00:22:09,530
well as cultural preferences can serve

487
00:22:15,490 --> 00:22:12,770
as influences on if not arguably part of

488
00:22:17,260 --> 00:22:15,500

the elements of the network NASA's

489
00:22:19,600 --> 00:22:17,270
approach to robotics solar system

490
00:22:22,120 --> 00:22:19,610
exploration can best be seen as the

491
00:22:24,280 --> 00:22:22,130
product of how the agency attempts to

492
00:22:26,320 --> 00:22:24,290
integrate resolve differences and

493
00:22:29,049 --> 00:22:26,330
harmonize this network of disparate

494
00:22:31,360 --> 00:22:29,059
actors and elements conversely we can

495
00:22:33,280 --> 00:22:31,370
think of it being the conflict the

496
00:22:35,020 --> 00:22:33,290
cohesion and the feedback among these

497
00:22:38,020 --> 00:22:35,030
elements that shape solar system

498
00:22:40,180 --> 00:22:38,030
exploration and by viewing solar system

499
00:22:42,940 --> 00:22:40,190
exploration in this way and by seeing

500
00:22:44,260 --> 00:22:42,950
strategies in the making so to speak we

501
00:22:46,090 --> 00:22:44,270
can account more broadly for their

502
00:22:48,970 --> 00:22:46,100
emergence and in turn see the social

503
00:22:51,340 --> 00:22:48,980
preferences expectations of success and

504
00:22:59,790 --> 00:22:51,350
value propositions that have existed for

505
00:23:04,020 --> 00:23:02,180
this idea that solar system exploration

506
00:23:05,910 --> 00:23:04,030
strategies are the product of a

507
00:23:08,400 --> 00:23:05,920
continuous struggle to stabilize a

508
00:23:11,640 --> 00:23:08,410
network of elements is quite evident in

509
00:23:13,170 --> 00:23:11,650
its just one example NASA's move to and

510
00:23:14,850 --> 00:23:13,180
then away from the faster better cheaper

511
00:23:17,730 --> 00:23:14,860
approach to solar system exploration

512
00:23:20,160 --> 00:23:17,740
within several years time beginning in

513
00:23:22,830 --> 00:23:20,170

the 1990s the science engineering and

514
00:23:25,620 --> 00:23:22,840
management strategy entailed the pursuit

515
00:23:27,600 --> 00:23:25,630
of low-cost missions up to a couple

516
00:23:29,760 --> 00:23:27,610
hundred million dollars with limited

517
00:23:31,850 --> 00:23:29,770
scientific objectives and that could be

518
00:23:34,140 --> 00:23:31,860
flown frequently and visit a variety of

519
00:23:36,660 --> 00:23:34,150
destinations as part of a broad

520
00:23:38,820 --> 00:23:36,670
portfolio of solar system investigations

521
00:23:41,340 --> 00:23:38,830
such that a single lost mission would

522
00:23:44,670 --> 00:23:41,350
not signal disaster for the entire

523
00:23:47,040 --> 00:23:44,680
program as espoused by the NASA

524
00:23:50,190 --> 00:23:47,050
Administrator golden these missions and

525
00:23:52,080 --> 00:23:50,200
were encouraged to take certain risks

526
00:23:54,270 --> 00:23:52,090
embracing new technologies and new

527
00:23:57,450 --> 00:23:54,280
management techniques to reduce the

528
00:24:00,960 --> 00:23:57,460
costs and advanced solar solar system

529
00:24:02,580 --> 00:24:00,970
exploration in the long run so how did

530
00:24:05,550 --> 00:24:02,590
the faster better cheaper idea come

531
00:24:08,010 --> 00:24:05,560
about when it did Dan Goldin is often

532
00:24:11,250 --> 00:24:08,020
seen as the catalyst for this initiative

533
00:24:13,140 --> 00:24:11,260
but in short I would say that the

534
00:24:14,820 --> 00:24:13,150
incompatibility of various actors

535
00:24:17,040 --> 00:24:14,830
interests with the mission strategy of

536
00:24:19,170 --> 00:24:17,050
the previous decade prompted them to

537
00:24:21,660 --> 00:24:19,180
adopt a discourse if you will that

538
00:24:23,370 --> 00:24:21,670

smaller lower-court lower-cost missions

539
00:24:25,260 --> 00:24:23,380
were possible and necessary for the

540
00:24:28,050 --> 00:24:25,270
vitality of robotics solar system

541
00:24:30,240 --> 00:24:28,060
exploration planetary scientists had

542
00:24:33,120 --> 00:24:30,250
discussed the idea of solar system or

543
00:24:35,340 --> 00:24:33,130
sorry small missions in the past but

544
00:24:37,290 --> 00:24:35,350
these hadn't materialized as mission

545
00:24:40,280 --> 00:24:37,300
opportunities were budget constrained as

546
00:24:42,930 --> 00:24:40,290
we've heard in the late 1970s and 1980s

547
00:24:45,030 --> 00:24:42,940
planetary scientists tried to maximize

548
00:24:49,290 --> 00:24:45,040
scientific objectives on what few

549
00:24:50,880 --> 00:24:49,300
missions they could secure and this and

550
00:24:52,950 --> 00:24:50,890
the missions dependence on the shuttle

551
00:24:55,980 --> 00:24:52,960
led to very costly missions and only two

552
00:24:57,750 --> 00:24:55,990
being launched in the 1980s this

553
00:24:59,460 --> 00:24:57,760
experience made the community reflect

554
00:25:02,580 --> 00:24:59,470
more carefully on the value of small

555
00:25:05,220 --> 00:25:02,590
missions meanwhile staff in the George

556
00:25:07,530 --> 00:25:05,230
HW Bush White House's National Space

557
00:25:09,480 --> 00:25:07,540
Council were frustrated with NASA's

558
00:25:11,880 --> 00:25:09,490
penchant for expensive space systems

559
00:25:13,040 --> 00:25:11,890
they had seen the Strategic Defense

560
00:25:15,840 --> 00:25:13,050
Initiative

561
00:25:18,900 --> 00:25:15,850
organization for example deploy a

562
00:25:22,890 --> 00:25:18,910
space-based ballistic missile system for

563
00:25:24,720 --> 00:25:22,900

relatively inexpensive cost and a short

564
00:25:27,960 --> 00:25:24,730
schedule and thought that NASA would

565
00:25:30,510 --> 00:25:27,970
need to act similarly to and commit to

566
00:25:33,930 --> 00:25:30,520
lower-cost systems to afford the bush

567
00:25:36,420 --> 00:25:33,940
space exploration initiative to shore up

568
00:25:37,590 --> 00:25:36,430
NASA program costs agency-wide they

569
00:25:40,520 --> 00:25:37,600
brought in the new NASA Administrator

570
00:25:43,500 --> 00:25:40,530
Dan Goldin who was an advocate of

571
00:25:45,990 --> 00:25:43,510
mitigating cost growth by shrinking the

572
00:25:48,960 --> 00:25:46,000
sizes of missions also in the early

573
00:25:50,970 --> 00:25:48,970
1990s multiple congresses and the

574
00:25:52,470 --> 00:25:50,980
Clinton administration committed to

575
00:25:55,920 --> 00:25:52,480
reining in federal discretionary

576
00:25:57,360 --> 00:25:55,930
spending including at NASA where the

577
00:25:59,220 --> 00:25:57,370
agency was concerned the Clinton

578
00:26:01,500 --> 00:25:59,230
administration who retained gold in as

579
00:26:03,120 --> 00:26:01,510
administrator prioritized securing

580
00:26:06,830 --> 00:26:03,130
funding from the International Space

581
00:26:09,300 --> 00:26:06,840
Station but along with golden and then

582
00:26:11,460 --> 00:26:09,310
head of space science West Huntress

583
00:26:13,800 --> 00:26:11,470
wanted to see a vibrant program for

584
00:26:16,260 --> 00:26:13,810
space science finally of course we've

585
00:26:19,710 --> 00:26:16,270
heard already much about this but the

586
00:26:22,050 --> 00:26:19,720
1993 failure of the billion-dollar Mars

587
00:26:24,210 --> 00:26:22,060
Observer and the ensuing media criticism

588
00:26:26,400 --> 00:26:24,220

only affirmed for NASA the science

589
00:26:28,380 --> 00:26:26,410
community and political leadership the

590
00:26:31,110 --> 00:26:28,390
prudence of a program of small missions

591
00:26:33,540 --> 00:26:31,120
that distributed benefits and risks so

592
00:26:36,090 --> 00:26:33,550
in short no single mission or no single

593
00:26:38,040 --> 00:26:36,100
element promoted the move to faster

594
00:26:40,560 --> 00:26:38,050
better cheaper it was a convergence of

595
00:26:42,600 --> 00:26:40,570
these conditions that spawn NASA not to

596
00:26:44,340 --> 00:26:42,610
push through more flagship missions nor

597
00:26:46,530 --> 00:26:44,350
to eliminate robotics solar system

598
00:26:48,870 --> 00:26:46,540
exploration as the Reagan administration

599
00:26:50,430 --> 00:26:48,880
had contemplated but to focus on small

600
00:26:56,870 --> 00:26:50,440
missions as a solution that would

601
00:27:02,010 --> 00:26:59,760
NASA's earliest experiences with its to

602
00:27:04,680 --> 00:27:02,020
low-cost mission programs discovery and

603
00:27:07,410 --> 00:27:04,690
Mars surveyor suggested that perhaps the

604
00:27:09,720 --> 00:27:07,420
agency had found a found in faster

605
00:27:11,520 --> 00:27:09,730
better cheaper a strategy to synchronize

606
00:27:14,040 --> 00:27:11,530
and stabilize the solar system

607
00:27:17,370 --> 00:27:14,050
exploration network under the new regime

608
00:27:19,380 --> 00:27:17,380
13 new mission starts were obtained to a

609
00:27:21,990 --> 00:27:19,390
diverse range of solar system targets

610
00:27:24,120 --> 00:27:22,000
some of these missions achieved low cost

611
00:27:25,890 --> 00:27:24,130
using off-the-shelf hardware but many

612
00:27:28,260 --> 00:27:25,900
did so using new technologies and

613
00:27:31,680 --> 00:27:28,270

management techniques as golden had

614
00:27:34,320 --> 00:27:31,690
advocated planetary scientists enjoyed

615
00:27:36,150 --> 00:27:34,330
newfound creative license and autonomy

616
00:27:39,300 --> 00:27:36,160
under the approach for example with the

617
00:27:41,850 --> 00:27:39,310
discovery mission being able to propose

618
00:27:44,250 --> 00:27:41,860
and manage entire missions as principal

619
00:27:46,560 --> 00:27:44,260
investigators and mission performance

620
00:27:48,960 --> 00:27:46,570
led to a steady stream of science data

621
00:27:51,990 --> 00:27:48,970
and results that were published in major

622
00:27:54,270 --> 00:27:52,000
scientific journals the arrival of Mars

623
00:27:56,430 --> 00:27:54,280
Pathfinder thrilled the media and

624
00:27:59,490 --> 00:27:56,440
political leadership and captured the

625
00:28:02,790 --> 00:27:59,500
public imagination as the first

626
00:28:10,290 --> 00:28:02,800
successful spacecraft on Mars launched

627
00:28:11,960 --> 00:28:10,300
in nearly 20 years then in 1999 several

628
00:28:15,420 --> 00:28:11,970
faster better cheaper missions failed

629
00:28:18,750 --> 00:28:15,430
one an astrophysics mission wire in

630
00:28:22,670 --> 00:28:18,760
March than in September the Mars climate

631
00:28:26,670 --> 00:28:22,680
observer fall a Mars climate orbiter

632
00:28:29,060 --> 00:28:26,680
thank you thank you acronyms and and

633
00:28:32,220 --> 00:28:29,070
then in December the mars polar lander

634
00:28:34,890 --> 00:28:32,230
with the to deep space to technology

635
00:28:36,600 --> 00:28:34,900
programs it carried independent reviews

636
00:28:38,340 --> 00:28:36,610
following the mars failures found that

637
00:28:40,200 --> 00:28:38,350
NASA had cut mission costs too much

638
00:28:42,390 --> 00:28:40,210

trying to achieve the two missions for

639
00:28:44,400 --> 00:28:42,400
the price of one and as a result making

640
00:28:46,860 --> 00:28:44,410
mistakes that the agency might well have

641
00:28:48,300 --> 00:28:46,870
caught with more reviews and tests but

642
00:28:50,340 --> 00:28:48,310
still the reviewers thought that with

643
00:28:53,010 --> 00:28:50,350
adjustments NASA could and should

644
00:28:55,140 --> 00:28:53,020
continue to use faster better cheaper as

645
00:28:58,410 --> 00:28:55,150
a guiding program management technique

646
00:29:00,390 --> 00:28:58,420
but NASA and Dan Goldin backed away from

647
00:29:02,870 --> 00:29:00,400
faster better cheaper in favor of what I

648
00:29:05,760 --> 00:29:02,880
would call a cost-conscious conservatism

649
00:29:08,630 --> 00:29:05,770
mission side mission costs and sizes did

650
00:29:10,940 --> 00:29:08,640
not return to the levels of the 1980s

651
00:29:13,220 --> 00:29:10,950
NASA began to put more money into each

652
00:29:15,740 --> 00:29:13,230
mission and with each admission costing

653
00:29:17,990 --> 00:29:15,750
more reliability became paramount and

654
00:29:20,480 --> 00:29:18,000
every mission became strategic and value

655
00:29:22,880 --> 00:29:20,490
failure was no longer an option and NASA

656
00:29:25,910 --> 00:29:22,890
became quite conservative about how it

657
00:29:27,920 --> 00:29:25,920
designed and managed missions I think

658
00:29:29,840 --> 00:29:27,930
it's easy to say that NASA abandoned

659
00:29:31,700 --> 00:29:29,850
faster better cheaper because reliable

660
00:29:33,680 --> 00:29:31,710
building reliable low-cost spacecraft

661
00:29:35,750 --> 00:29:33,690
proved too difficult but this would

662
00:29:38,360 --> 00:29:35,760
simply be a technical explanation and

663
00:29:40,430 --> 00:29:38,370

not a socio-technical one NASA might

664
00:29:42,860 --> 00:29:40,440
have continued only with small solar

665
00:29:44,840 --> 00:29:42,870
system missions with modifications as

666
00:29:47,510 --> 00:29:44,850
the independent reviewers had suggested

667
00:29:49,700 --> 00:29:47,520
or invested in a few flagships or

668
00:29:52,700 --> 00:29:49,710
perhaps invested heavily in technologies

669
00:29:55,010 --> 00:29:52,710
for long-run advancement or perhaps put

670
00:29:58,370 --> 00:29:55,020
the extra funds into other programs in

671
00:30:00,770 --> 00:29:58,380
NASA altogether but instead NASA went in

672
00:30:03,530 --> 00:30:00,780
the direction it did because of how the

673
00:30:06,560 --> 00:30:03,540
spacecraft failures perturb the network

674
00:30:09,770 --> 00:30:06,570
as it of actors as it threatened the

675
00:30:14,540 --> 00:30:09,780
goals and expectations of them the

676
00:30:16,670 --> 00:30:14,550
planetary community as far back as 1994

677
00:30:19,070 --> 00:30:16,680
had and prior to that I would say but

678
00:30:21,770 --> 00:30:19,080
during the era of faster better cheaper

679
00:30:26,150 --> 00:30:21,780
had opined that a mix of mission sizes

680
00:30:27,800 --> 00:30:26,160
was optimal to serve science and in 2000

681
00:30:30,590 --> 00:30:27,810
they released a report through the

682
00:30:34,970 --> 00:30:30,600
National Research Council stating that

683
00:30:36,800 --> 00:30:34,980
the faster better cheaper zapana and its

684
00:30:38,780 --> 00:30:36,810
restrictions on larger missions had

685
00:30:41,120 --> 00:30:38,790
compromised scientific objectives and

686
00:30:43,100 --> 00:30:41,130
outcomes the news media meanwhile

687
00:30:45,470 --> 00:30:43,110
published stories suggesting NASA had

688
00:30:47,660 --> 00:30:45,480

acted incompetently if not with

689
00:30:50,240 --> 00:30:47,670
negligence on the to Mars missions in

690
00:30:52,040 --> 00:30:50,250
hearings members of Congress blasted

691
00:30:54,890 --> 00:30:52,050
NASA for the failures calling them

692
00:30:56,810 --> 00:30:54,900
national embarrassments and saying that

693
00:31:00,350 --> 00:30:56,820
US taxpayer is expected and deserved

694
00:31:02,000 --> 00:31:00,360
better although each of these sets of

695
00:31:04,780 --> 00:31:02,010
actors had disparate interests in

696
00:31:07,160 --> 00:31:04,790
spacecraft seeing them respectively as

697
00:31:08,870 --> 00:31:07,170
necessities for their profession in

698
00:31:11,450 --> 00:31:08,880
their livelihood and the pursuit of

699
00:31:13,490 --> 00:31:11,460
scientific knowledge as symbols of

700
00:31:16,520 --> 00:31:13,500
technological achievement and national

701
00:31:19,160 --> 00:31:16,530
pride and as major taxpayer investments

702
00:31:20,509 --> 00:31:19,170
necessitating public accountability the

703
00:31:22,629 --> 00:31:20,519
1999 mission

704
00:31:25,669 --> 00:31:22,639
failures were natha mud to them all

705
00:31:27,709 --> 00:31:25,679
success in solar system exploration for

706
00:31:29,539 --> 00:31:27,719
all of these actors meant the delivery

707
00:31:32,060 --> 00:31:29,549
of near-term results by individual

708
00:31:33,619 --> 00:31:32,070
missions not the promise or prospect of

709
00:31:36,349 --> 00:31:33,629
advancements in solar system exploration

710
00:31:38,199 --> 00:31:36,359
over the long term by learning from

711
00:31:41,060 --> 00:31:38,209
failure as golden had envisioned

712
00:31:42,949 --> 00:31:41,070
discourse about failure this came to

713
00:31:45,320 --> 00:31:42,959

prevail over talked about the need for

714
00:31:48,049 --> 00:31:45,330
cost-cutting among the the network

715
00:31:50,119 --> 00:31:48,059
actors NASA stakeholders and this

716
00:31:52,609 --> 00:31:50,129
criticism along with criticism during

717
00:31:56,389 --> 00:31:52,619
the time about Space Shuttle security

718
00:31:58,639 --> 00:31:56,399
sorry safety issues by NASA's advisory

719
00:32:01,729 --> 00:31:58,649
committees the media and the Congress

720
00:32:04,609 --> 00:32:01,739
provided the impetus for golden and NASA

721
00:32:07,129 --> 00:32:04,619
via golden to back away from faster

722
00:32:08,899 --> 00:32:07,139
better cheaper with federal budgets just

723
00:32:11,599 --> 00:32:08,909
having moved into an era of surpluses

724
00:32:13,999 --> 00:32:11,609
the White House not wanting the solar

725
00:32:16,549 --> 00:32:14,009
system program to fail worked with NASA

726
00:32:18,399 --> 00:32:16,559
to increase space science budgets fund

727
00:32:20,569 --> 00:32:18,409
the discovery missions at higher levels

728
00:32:23,509 --> 00:32:20,579
introduce the new frontiers line of

729
00:32:29,779 --> 00:32:23,519
moderate missions and redesign the

730
00:32:32,839 --> 00:32:29,789
agency's more strategy this so in

731
00:32:34,579 --> 00:32:32,849
conclusion in conclusion this socio

732
00:32:36,919 --> 00:32:34,589
technical analysis of faster better

733
00:32:39,049 --> 00:32:36,929
cheaper an examining history in the

734
00:32:41,719 --> 00:32:39,059
making more generally tells us about the

735
00:32:44,419 --> 00:32:41,729
complexity and contingency that governs

736
00:32:46,999 --> 00:32:44,429
decisions in solar system exploration it

737
00:32:50,119 --> 00:32:47,009
provides an explanatory context for the

738
00:32:52,399 --> 00:32:50,129

forms goals and destinations of the

739
00:32:54,859 --> 00:32:52,409
solar system exploration program showing

740
00:32:57,169 --> 00:32:54,869
just how instrumental each element of

741
00:32:59,239 --> 00:32:57,179
the network is or can be in sculpting

742
00:33:01,639 --> 00:32:59,249
the programs that materialize at any

743
00:33:03,409 --> 00:33:01,649
given time it also illustrates the

744
00:33:04,869 --> 00:33:03,419
challenges of trying to predict and

745
00:33:07,879 --> 00:33:04,879
control the solar system exploration

746
00:33:10,699 --> 00:33:07,889
enterprises future but even as it shows

747
00:33:13,399 --> 00:33:10,709
the difficulty of predicting precisely

748
00:33:15,440 --> 00:33:13,409
what will work or be in the future this

749
00:33:18,319 --> 00:33:15,450
analytical approach provides insights

750
00:33:20,180 --> 00:33:18,329
into social expectations preferences and

751
00:33:22,579 --> 00:33:20,190
interests shaping solar system

752
00:33:25,459 --> 00:33:22,589
exploration NASA and the u.s. space

753
00:33:27,409 --> 00:33:25,469
program the socio-technical examination

754
00:33:29,749 --> 00:33:27,419
of faster better cheaper zimmern sand

755
00:33:31,459 --> 00:33:29,759
decline in particular shows that we have

756
00:33:33,829 --> 00:33:31,469
become quite a demanding bunch

757
00:33:34,649 --> 00:33:33,839
collectively speaking and the quest for

758
00:33:37,710 --> 00:33:34,659
perfection

759
00:33:40,200 --> 00:33:37,720
high expectations held for NASA and

760
00:33:42,810 --> 00:33:40,210
spacecraft success means the agency's

761
00:33:48,450 --> 00:33:42,820
reputation constantly hangs in the

762
00:33:50,430 --> 00:33:48,460
balance think of what this cartoon would

763
00:33:52,219 --> 00:33:50,440

have looked like if curiosity hadn't

764
00:33:54,479 --> 00:33:52,229
survived the seven minutes of Terror

765
00:33:56,849 --> 00:33:54,489
perhaps NASA's attempts to communicate

766
00:33:59,279 --> 00:33:56,859
ahead of time just how difficult the

767
00:34:01,139 --> 00:33:59,289
feat was would have staved off critical

768
00:34:04,200 --> 00:34:01,149
news stories and congressional hearings

769
00:34:05,669 --> 00:34:04,210
but maybe not as long as our standards

770
00:34:07,289 --> 00:34:05,679
remain high while the technical

771
00:34:09,899 --> 00:34:07,299
challenges and costs of spaceflight

772
00:34:11,639 --> 00:34:09,909
remain formidable debates and policy

773
00:34:13,500 --> 00:34:11,649
shifts will almost certainly continue

774
00:34:24,190 --> 00:34:13,510
concerning how best to explore the solar

775
00:34:30,619 --> 00:34:28,010
okay thank you Amy next we have scott

776
00:34:32,690 --> 00:34:30,629
hubbard professor in the Department of

777
00:34:34,820 --> 00:34:32,700
aeronautics and astronautics at Stanford

778
00:34:37,220 --> 00:34:34,830
and the director of the Stanford center

779
00:34:39,590 --> 00:34:37,230
of excellence for commercial space

780
00:34:43,460 --> 00:34:39,600
transportation he is the former director

781
00:34:46,520 --> 00:34:43,470
of NASA Ames and he's written a book

782
00:34:49,490 --> 00:34:46,530
called exploring Mars chronicles from a

783
00:34:52,520 --> 00:34:49,500
decade of discovery which tells in

784
00:34:54,800 --> 00:34:52,530
longer form the story that he's about to

785
00:34:57,920 --> 00:34:54,810
tell about reinventing the Mars program

786
00:35:04,130 --> 00:34:57,930
in the wake of the failures that Amy

787
00:35:06,320 --> 00:35:04,140
just talked about Scott thank you very

788
00:35:09,260 --> 00:35:06,330

much Andy let me just start by saying

789
00:35:13,010 --> 00:35:09,270
this is a truly excellent conference I'd

790
00:35:16,010 --> 00:35:13,020
like to thank bill bay our sponsor here

791
00:35:18,170 --> 00:35:16,020
Jim Green and everyone when you have an

792
00:35:20,480 --> 00:35:18,180
interdisciplinary gathering that brings

793
00:35:23,030 --> 00:35:20,490
together such disparate knowledge as

794
00:35:27,950 --> 00:35:23,040
historians sociologists scientists

795
00:35:31,430 --> 00:35:27,960
engineers recovering executives you have

796
00:35:35,150 --> 00:35:31,440
a whole new way of looking at things and

797
00:35:38,320 --> 00:35:35,160
so I'm just delighted to to be here i

798
00:35:40,790 --> 00:35:38,330
modified the title just a little bit

799
00:35:43,250 --> 00:35:40,800
exploring Mars following the water a

800
00:35:46,400 --> 00:35:43,260
talk out given many times but I've added

801
00:35:48,109 --> 00:35:46,410
in the next decade sitting next to my

802
00:35:49,910 --> 00:35:48,119
longtime friend and colleague West

803
00:35:55,910 --> 00:35:49,920
Huntress i discovered that we've become

804
00:35:58,849 --> 00:35:55,920
part of history Oh Chuck but I'm not a

805
00:36:01,730 --> 00:35:58,859
historian yes Esther living history

806
00:36:04,040 --> 00:36:01,740
living history but I'm not a historian

807
00:36:06,770 --> 00:36:04,050
and so I'm going to give a little bit of

808
00:36:09,700 --> 00:36:06,780
a look ahead as well of where I think

809
00:36:15,290 --> 00:36:09,710
that Mars exploration in particular

810
00:36:17,510 --> 00:36:15,300
really ought to be headed as Andy said

811
00:36:19,930 --> 00:36:17,520
much of what I'm going to talk about is

812
00:36:24,410 --> 00:36:19,940
drawn from particularly chapter 12 of

813
00:36:26,720 --> 00:36:24,420

the book that I just published I have

814
00:36:29,870 --> 00:36:26,730
been complimented several times during

815
00:36:33,319 --> 00:36:29,880
this conference for being the first Mars

816
00:36:36,440 --> 00:36:33,329
are and putting the program

817
00:36:40,099 --> 00:36:36,450
back on track after the twin failures in

818
00:36:42,769 --> 00:36:40,109
1999 but of course it wasn't just me the

819
00:36:45,849 --> 00:36:42,779
large cast of players including then

820
00:36:48,859 --> 00:36:45,859
golden and Steve aisaka wits at OMB had

821
00:36:53,569 --> 00:36:48,869
whiler farrugia there a Jim Garvin and a

822
00:36:56,120 --> 00:36:53,579
cast of many many others what we had the

823
00:36:58,069 --> 00:36:56,130
extraordinary opportunity to do was to

824
00:37:01,219 --> 00:36:58,079
take nearly a clean sheet of paper and

825
00:37:05,029 --> 00:37:01,229
completely restructure a decade of

826
00:37:07,009 --> 00:37:05,039
missions and we started off with the

827
00:37:10,640 --> 00:37:07,019
science requirements what we're trying

828
00:37:14,059 --> 00:37:10,650
to do there and understanding Mars as a

829
00:37:16,219 --> 00:37:14,069
system not a single measurement that

830
00:37:18,920 --> 00:37:16,229
hope to find life but rather understand

831
00:37:20,839 --> 00:37:18,930
the past and present climate understand

832
00:37:23,920 --> 00:37:20,849
the water cycles on Mars and

833
00:37:26,690 --> 00:37:23,930
particularly its biological potential so

834
00:37:30,469 --> 00:37:26,700
my all the questions that we asked the

835
00:37:33,620 --> 00:37:30,479
first among equals was is life there in

836
00:37:36,289 --> 00:37:33,630
the past could it even be there today

837
00:37:38,660 --> 00:37:36,299
with the conditions of habitability of

838
00:37:42,199 --> 00:37:38,670

Mars were paramount than our thinking

839
00:37:44,029 --> 00:37:42,209
and we adopted this phrase to explain

840
00:37:46,400 --> 00:37:44,039
what we were doing not only to our

841
00:37:48,829 --> 00:37:46,410
colleagues but particularly to the

842
00:37:52,519 --> 00:37:48,839
taxpayers and their representatives and

843
00:37:56,180 --> 00:37:52,529
I found many many times in that trip

844
00:37:57,769 --> 00:37:56,190
between the first floor and the third

845
00:38:00,529 --> 00:37:57,779
floor fifth floor of NASA headquarters

846
00:38:02,900 --> 00:38:00,539
having somebody step in it was a staffer

847
00:38:05,390 --> 00:38:02,910
and say so so what is this Mars thing

848
00:38:07,279 --> 00:38:05,400
and you'd say well it's about follow the

849
00:38:09,229 --> 00:38:07,289
water and it's understanding the past

850
00:38:12,140 --> 00:38:09,239
present life on Mars how that sort of

851
00:38:13,370 --> 00:38:12,150
sounds pretty good so these kinds of

852
00:38:16,039 --> 00:38:13,380
things although they're sometimes

853
00:38:19,160 --> 00:38:16,049
derided as sound bites give you a way of

854
00:38:22,670 --> 00:38:19,170
communication to people who are not

855
00:38:24,559 --> 00:38:22,680
insiders that tell them succinctly what

856
00:38:28,039 --> 00:38:24,569
you're all about and I think there's a

857
00:38:31,189 --> 00:38:28,049
value great value in that now I have

858
00:38:33,529 --> 00:38:31,199
added with emphasis at the bottom that

859
00:38:36,880 --> 00:38:33,539
this decade of Mars missions was not

860
00:38:39,410 --> 00:38:36,890
only intended and in fact i think has

861
00:38:43,160 --> 00:38:39,420
given us an understanding of mars as a

862
00:38:45,140 --> 00:38:43,170
system it also was fully intended to

863
00:38:48,109 --> 00:38:45,150

prepare for the next decade

864
00:38:50,180 --> 00:38:48,119
of sample return and I'm going to just

865
00:38:53,299 --> 00:38:50,190
give you in the interest of time only

866
00:38:56,690 --> 00:38:53,309
one example and that is the improvement

867
00:38:58,630 --> 00:38:56,700
in landing accuracy you see up here what

868
00:39:02,029 --> 00:38:58,640
we were capable of with Viking

869
00:39:04,490 --> 00:39:02,039
Pathfinder and then when we got into the

870
00:39:08,690 --> 00:39:04,500
current decade Spirit and Opportunity

871
00:39:11,510 --> 00:39:08,700
we've gone from Viking 174 miles by 62

872
00:39:13,849 --> 00:39:11,520
miles as the footprint the error ellipse

873
00:39:17,359 --> 00:39:13,859
that you had to deal with down in the

874
00:39:20,120 --> 00:39:17,369
case of spirit and opportunity to better

875
00:39:25,370 --> 00:39:20,130
than half that 93 miles by 12 miles

876
00:39:29,930 --> 00:39:25,380
Phoenix 62 by 12 curiosity down to 12

877
00:39:33,769 --> 00:39:29,940
miles by four miles we would not have

878
00:39:35,690 --> 00:39:33,779
even been able to consider at all going

879
00:39:38,720 --> 00:39:35,700
to the foot of Mount sharp and Gale

880
00:39:40,940 --> 00:39:38,730
Crater had this deliberate improvement

881
00:39:43,579 --> 00:39:40,950
of landing accuracy the deliberate

882
00:39:46,010 --> 00:39:43,589
increase and Rover capability been built

883
00:39:48,260 --> 00:39:46,020
into the program and that was not only

884
00:39:51,440 --> 00:39:48,270
to be able to sample the diversity of

885
00:39:54,920 --> 00:39:51,450
Mars but to prepare for the next decade

886
00:39:59,029 --> 00:39:54,930
of Mars sample return so where are we

887
00:40:02,299 --> 00:39:59,039
today with respect to Mars this I think

888
00:40:05,990 --> 00:40:02,309

is essentially the consensus of groups

889
00:40:09,650 --> 00:40:06,000
like the Mars analysis program group me

890
00:40:12,319 --> 00:40:09,660
peg we have lots of evidence of ancient

891
00:40:14,180 --> 00:40:12,329
liquid water surface and ground past

892
00:40:17,660 --> 00:40:14,190
geological environments that have

893
00:40:20,059 --> 00:40:17,670
preserved this knowledge understanding

894
00:40:22,670 --> 00:40:20,069
much greater detail variations and

895
00:40:25,400 --> 00:40:22,680
habitability and so in summary i think

896
00:40:28,490 --> 00:40:25,410
we now have the means to prioritize the

897
00:40:32,059 --> 00:40:28,500
sites to go and get samples and bring

898
00:40:35,210 --> 00:40:32,069
them back modern life don't know we're

899
00:40:37,400 --> 00:40:35,220
waiting on the methane results with

900
00:40:41,740 --> 00:40:37,410
bated breath which i think will be

901
00:40:44,240 --> 00:40:41,750
coming shortly so the next decade is

902
00:40:46,279 --> 00:40:44,250
shifting from follow the water which has

903
00:40:47,839 --> 00:40:46,289
been extraordinarily successful to

904
00:40:50,690 --> 00:40:47,849
looking I would argue for the

905
00:40:53,059 --> 00:40:50,700
fingerprints of life and the way to do

906
00:40:55,579 --> 00:40:53,069
that as recommended by the national

907
00:40:56,180 --> 00:40:55,589
academy of sciences and the decadal

908
00:40:59,240 --> 00:40:56,190
survey

909
00:41:02,990 --> 00:40:59,250
that we have talked about many times is

910
00:41:07,690 --> 00:41:03,000
with a Mars sample return a campaign of

911
00:41:10,790 --> 00:41:07,700
three missions to land get the samples

912
00:41:13,490 --> 00:41:10,800
launch those samples to orbit return

913
00:41:16,190 --> 00:41:13,500

them to earth and now why is this the

914
00:41:18,589 --> 00:41:16,200
next logical step because looking across

915
00:41:22,220 --> 00:41:18,599
the full range of things you might do it

916
00:41:24,440 --> 00:41:22,230
Mars this has been recently rhian dorst

917
00:41:27,910 --> 00:41:24,450
by Orlando Figaro as Mars program

918
00:41:31,910 --> 00:41:27,920
planning group it gives the greatest

919
00:41:34,849 --> 00:41:31,920
increase in knowledge that we can have

920
00:41:37,250 --> 00:41:34,859
it is not only an incremental increase

921
00:41:39,980 --> 00:41:37,260
it is rather a giant step function in

922
00:41:43,760 --> 00:41:39,990
knowledge because samples can now be

923
00:41:46,490 --> 00:41:43,770
analyzed by not just a few investigators

924
00:41:49,040 --> 00:41:46,500
but hundreds of investigators not only

925
00:41:51,740 --> 00:41:49,050
by one mobile laboratory but dozens of

926
00:41:54,140 --> 00:41:51,750
laboratories and using equipment that

927
00:41:56,510 --> 00:41:54,150
could not possibly be shrunk in any

928
00:42:00,530 --> 00:41:56,520
current environment to the size of a

929
00:42:03,829 --> 00:42:00,540
shoebox to put on board a rover on Mars

930
00:42:06,470 --> 00:42:03,839
you can follow the pathways of discovery

931
00:42:09,050 --> 00:42:06,480
the samples here on earth something that

932
00:42:10,790 --> 00:42:09,060
in situ is very difficult to do so i'll

933
00:42:14,059 --> 00:42:10,800
make one reference to the Mars program

934
00:42:15,859 --> 00:42:14,069
planning group the can the study that

935
00:42:19,819 --> 00:42:15,869
was just concluded and they addressed

936
00:42:22,750 --> 00:42:19,829
the question of as was called for in the

937
00:42:26,359 --> 00:42:22,760
decadal survey can you d scope

938
00:42:28,460 --> 00:42:26,369

significantly the Mars rover that was

939
00:42:32,180 --> 00:42:28,470
supposed to cost two and a half billion

940
00:42:34,640 --> 00:42:32,190
dollars and begin this process of

941
00:42:36,589 --> 00:42:34,650
caching samples can you d scope that and

942
00:42:39,069 --> 00:42:36,599
still recover the fundamental science

943
00:42:42,890 --> 00:42:39,079
their answer as independently validated

944
00:42:46,849 --> 00:42:42,900
was definitely yes a bottom line here of

945
00:42:51,140 --> 00:42:46,859
about half of what the proposed amount

946
00:42:53,569 --> 00:42:51,150
was for the decadence survey it does

947
00:42:55,670 --> 00:42:53,579
this by reusing material from the Mars

948
00:42:57,710 --> 00:42:55,680
Science Laboratory and other details

949
00:43:01,819 --> 00:42:57,720
here that I won't go into in the

950
00:43:04,240 --> 00:43:01,829
interest of time so where are we then on

951
00:43:07,040 --> 00:43:04,250
the challenges for Mars sample return

952
00:43:08,720 --> 00:43:07,050
the reason I cancelled the bars sample

953
00:43:11,480 --> 00:43:08,730
return that was on the book

954
00:43:14,540 --> 00:43:11,490
in the year 2000 because we didn't know

955
00:43:16,700 --> 00:43:14,550
where to go that made it worth that

956
00:43:19,970 --> 00:43:16,710
large expenditure of time and effort

957
00:43:23,510 --> 00:43:19,980
today after this deliberate decade of

958
00:43:26,750 --> 00:43:23,520
understanding we are very well prepared

959
00:43:30,140 --> 00:43:26,760
to pick the site to get those high-value

960
00:43:34,040 --> 00:43:30,150
samples we have the capabilities to

961
00:43:37,010 --> 00:43:34,050
drive to them to land accurately the

962
00:43:39,730 --> 00:43:37,020
orbital rendezvous and docking has been

963
00:43:43,010 --> 00:43:39,740

largely demonstrated by orbital Express

964
00:43:45,800 --> 00:43:43,020
planetary protection and the saving of

965
00:43:49,580 --> 00:43:45,810
these samples has been studied the

966
00:43:51,560 --> 00:43:49,590
sample return vehicle the one that we

967
00:43:53,870 --> 00:43:51,570
would bring back these samples to earth

968
00:43:56,660 --> 00:43:53,880
with was demonstrated through Stardust

969
00:43:58,490 --> 00:43:56,670
and Genesis the main remaining

970
00:44:01,610 --> 00:43:58,500
technological challenges with the

971
00:44:03,470 --> 00:44:01,620
so-called mars ascent vehicle that needs

972
00:44:05,600 --> 00:44:03,480
some development but it's basically a

973
00:44:08,090 --> 00:44:05,610
sounding rocket only it has to land on

974
00:44:10,580 --> 00:44:08,100
Mars and sit there for a year and then

975
00:44:13,190 --> 00:44:10,590
work with two nines reliability but I

976
00:44:15,500 --> 00:44:13,200
think it can be done so the study by

977
00:44:18,080 --> 00:44:15,510
Orlando Figueroa demonstrates that a

978
00:44:21,530 --> 00:44:18,090
caching Rover to begin the sample return

979
00:44:24,740 --> 00:44:21,540
campaign can be developed for far less

980
00:44:27,530 --> 00:44:24,750
than the cost of a flagship in twenty

981
00:44:29,780 --> 00:44:27,540
fifteen dollars perhaps one half of that

982
00:44:32,450 --> 00:44:29,790
and I think that given the appropriate

983
00:44:36,050 --> 00:44:32,460
technology and instrument development

984
00:44:47,530 --> 00:44:36,060
that a credible Mars sample return

985
00:44:54,630 --> 00:44:50,230
was Great Scott and you also came in

986
00:44:58,510 --> 00:44:54,640
under time which is amazing finally

987
00:45:01,120 --> 00:44:58,520
Chazz Chazz bikeman is the executive

988
00:45:03,910 --> 00:45:01,130

director of NASA's exoplanet Science

989
00:45:06,400 --> 00:45:03,920
Institute at JPL and Caltech starting in

990
00:45:09,040 --> 00:45:06,410
the mid 90s he helped to develop NASA's

991
00:45:10,780 --> 00:45:09,050
exoplanet program including ambitious

992
00:45:13,150 --> 00:45:10,790
missions like the terrestrial planet

993
00:45:15,840 --> 00:45:13,160
finder his research includes the study

994
00:45:18,040 --> 00:45:15,850
of debris disks or add nearby stars

995
00:45:20,620 --> 00:45:18,050
which are possible remnants of the

996
00:45:24,070 --> 00:45:20,630
planetary formation process and the

997
00:45:27,250 --> 00:45:24,080
identification of free-floating a few

998
00:45:29,620 --> 00:45:27,260
jupiter-mass brown dwarfs using the wise

999
00:45:33,370 --> 00:45:29,630
Spitzer and keck telescopes as a member

1000
00:45:35,710 --> 00:45:33,380
of the near cam instrument team of JWST

1001
00:45:41,130 --> 00:45:35,720
he is planning imaging and spectroscopic

1002
00:45:47,740 --> 00:45:41,140
observations of nearby exoplanets yes

1003
00:45:51,400 --> 00:45:47,750
yeah yep okay so it's really an honor to

1004
00:45:53,620 --> 00:45:51,410
be here at the 50th anniversary of the

1005
00:45:55,900 --> 00:45:53,630
exploration of our own solar system and

1006
00:45:58,420 --> 00:45:55,910
I'm going to speak today briefly from

1007
00:46:01,420 --> 00:45:58,430
the perspective of a historian which I

1008
00:46:04,420 --> 00:46:01,430
am NOT of the 50th anniversary of the

1009
00:46:06,640 --> 00:46:04,430
exploration of exoplanets and the data

1010
00:46:10,360 --> 00:46:06,650
on my chart is up to over twenty six

1011
00:46:13,720 --> 00:46:10,370
twenty 45 so everything i'm going to say

1012
00:46:16,600 --> 00:46:13,730
now is my version of history as seen

1013
00:46:20,740 --> 00:46:16,610

from the 50th anniversary of the

1014
00:46:24,340 --> 00:46:20,750
discovery of the first exoplanet so in

1015
00:46:27,490 --> 00:46:24,350
the 1940s through the 1980s really we

1016
00:46:30,120 --> 00:46:27,500
had the first glimmers of exoplanets

1017
00:46:33,730 --> 00:46:30,130
that kept coming and going astrometry

1018
00:46:37,420 --> 00:46:33,740
was finding in the 40s 210 jupiter-mass

1019
00:46:39,460 --> 00:46:37,430
planets orbiting nearby stars barnard

1020
00:46:43,480 --> 00:46:39,470
star and other ones they kept coming and

1021
00:46:46,150 --> 00:46:43,490
going eventually they just went in 1952

1022
00:46:49,930 --> 00:46:46,160
the year of my birth autos trouver and

1023
00:46:51,690 --> 00:46:49,940
astronomer laid out the idea that one of

1024
00:46:54,610 --> 00:46:51,700
the most burning questions in astronomy

1025
00:46:56,410 --> 00:46:54,620
was the frequency of planet like bodies

1026
00:46:58,840 --> 00:46:56,420
in the galaxy which belonged to stars

1027
00:47:00,200 --> 00:46:58,850
other than our Sun and how shall we

1028
00:47:02,030 --> 00:47:00,210
proceed to find them

1029
00:47:05,000 --> 00:47:02,040
and he laid out the techniques that were

1030
00:47:07,390 --> 00:47:05,010
using to this day imaging he regarded as

1031
00:47:10,609 --> 00:47:07,400
quite limited in scope giving the very

1032
00:47:14,060 --> 00:47:10,619
great contrast ratio between a planet

1033
00:47:16,130 --> 00:47:14,070
and its nearby star radial velocities he

1034
00:47:18,200 --> 00:47:16,140
said that it's not unreasonable that a

1035
00:47:20,900 --> 00:47:18,210
planet might exist at a distance of a

1036
00:47:23,480 --> 00:47:20,910
fiftieth of an au causing a radial

1037
00:47:25,640 --> 00:47:23,490
velocity variation of a fraction of a

1038
00:47:30,440 --> 00:47:25,650

kilometer per second could be just

1039
00:47:33,680 --> 00:47:30,450
detectable transits he said would be

1040
00:47:35,990 --> 00:47:33,690
quite observable about to hundreds of a

1041
00:47:38,630 --> 00:47:36,000
magnitude and this should be ascertained

1042
00:47:40,579 --> 00:47:38,640
by modern photoelectric techniques he

1043
00:47:42,980 --> 00:47:40,589
basically laid out the entire program

1044
00:47:45,320 --> 00:47:42,990
that would come to pass some 50 years

1045
00:47:47,870 --> 00:47:45,330
later Bruce Campbell and Gordon Walker

1046
00:47:50,230 --> 00:47:47,880
at the canada france hawaii telescope

1047
00:47:52,700 --> 00:47:50,240
pioneered the radial velocity technique

1048
00:47:54,010 --> 00:47:52,710
claiming to have found seven stars it

1049
00:47:57,349 --> 00:47:54,020
shows small but statistically

1050
00:48:00,530 --> 00:47:57,359
significant long-term trends companions

1051
00:48:04,070 --> 00:48:00,540
of 129 Jupiter masses are inferred none

1052
00:48:07,099 --> 00:48:04,080
of those actually survived contact with

1053
00:48:10,070 --> 00:48:07,109
reality but they invented the technique

1054
00:48:12,620 --> 00:48:10,080
that is being used today Dave Latham &

1055
00:48:14,839 --> 00:48:12,630
Company actually found what we now would

1056
00:48:16,520 --> 00:48:14,849
regard as the first planet it was

1057
00:48:20,240 --> 00:48:16,530
actually they called it at that point

1058
00:48:24,380 --> 00:48:20,250
very modestly a probable brown dwarf so

1059
00:48:27,620 --> 00:48:24,390
that was the 40s into the 80s by 1995

1060
00:48:32,380 --> 00:48:27,630
the floods gates began to open and so I

1061
00:48:34,310 --> 00:48:32,390
mark as 1995 really the beginning of

1062
00:48:37,099 --> 00:48:34,320
exoplanet research which were

1063
00:48:38,780 --> 00:48:37,109

celebrating the 50th anniversary of here

1064
00:48:41,300 --> 00:48:38,790
today or at least for the duration of my

1065
00:48:45,579 --> 00:48:41,310
talk but I call that the annus mirabilis

1066
00:48:48,980 --> 00:48:45,589
the half jupiter-mass can pan into a

1067
00:48:51,220 --> 00:48:48,990
nearby star 51 peg that led to the

1068
00:48:53,900 --> 00:48:51,230
beginning of the origins program that

1069
00:48:56,329 --> 00:48:53,910
Wes and others helped to bring to pass

1070
00:48:58,849 --> 00:48:56,339
and it led to the first call by a

1071
00:49:02,560 --> 00:48:58,859
president of the United States for an

1072
00:49:05,210 --> 00:49:02,570
advanced telescope on the first call for

1073
00:49:06,890 --> 00:49:05,220
telescope by president since John Adams

1074
00:49:09,950 --> 00:49:06,900
called for the founding of the u.s.

1075
00:49:12,020 --> 00:49:09,960
naval observatory so he called for a

1076
00:49:12,320 --> 00:49:12,030
telescope to look for earth-like planets

1077
00:49:13,910 --> 00:49:12,330
and

1078
00:49:17,980 --> 00:49:13,920
habitable environments around other

1079
00:49:21,200 --> 00:49:17,990
stars on that led to over many years

1080
00:49:24,110 --> 00:49:21,210
after that the radial velocity teams of

1081
00:49:26,900 --> 00:49:24,120
Marcy and Butler may or and Kalos found

1082
00:49:28,940 --> 00:49:26,910
more than 500 radial velocity plan us a

1083
00:49:31,520 --> 00:49:28,950
lot of them using the NASA Keck

1084
00:49:33,920 --> 00:49:31,530
telescopes and we went from the few

1085
00:49:38,240 --> 00:49:33,930
planets in our solar system with periods

1086
00:49:41,540 --> 00:49:38,250
shown there from a few days up to 30

1087
00:49:43,430 --> 00:49:41,550
years to what we have now is a huge

1088
00:49:45,980 --> 00:49:43,440

plethora of planets either just the

1089
00:49:48,710 --> 00:49:45,990
radial velocity systems in terms of

1090
00:49:51,050 --> 00:49:48,720
their period and orbital eccentricity a

1091
00:49:53,120 --> 00:49:51,060
remarkable diversity of systems that

1092
00:49:56,210 --> 00:49:53,130
just becomes more remarkable with every

1093
00:49:58,130 --> 00:49:56,220
passing day and this the hot breaking

1094
00:50:00,380 --> 00:49:58,140
news of course in the last week is that

1095
00:50:04,280 --> 00:50:00,390
we have a hot earth orbiting the nearby

1096
00:50:10,040 --> 00:50:04,290
star Alpha Centauri be many more to come

1097
00:50:12,080 --> 00:50:10,050
I'm sure so 2005 2 2015 is the the

1098
00:50:14,900 --> 00:50:12,090
decade really of transits the first

1099
00:50:17,540 --> 00:50:14,910
ground-based transits were found in 2004

1100
00:50:20,450 --> 00:50:17,550
and then the discovery program discussed

1101
00:50:24,350 --> 00:50:20,460
here earlier led to the selection of

1102
00:50:27,170 --> 00:50:24,360
Bill buc-ee's long ridiculed and now of

1103
00:50:29,570 --> 00:50:27,180
course widely acclaimed Kepler program

1104
00:50:33,080 --> 00:50:29,580
which has found more than 2,000

1105
00:50:35,390 --> 00:50:33,090
planetary candidates shown here is just

1106
00:50:38,780 --> 00:50:35,400
one version of those represented in the

1107
00:50:41,540 --> 00:50:38,790
in the image we have now the plot that

1108
00:50:44,630 --> 00:50:41,550
torrance alluded to where you have a

1109
00:50:48,050 --> 00:50:44,640
mass of the planet horizontal axis its

1110
00:50:50,300 --> 00:50:48,060
radius and you see Uranus and Neptune up

1111
00:50:53,720 --> 00:50:50,310
in the upper right sort of ice giants

1112
00:50:56,390 --> 00:50:53,730
all the systems here in kepler-11 six

1113
00:50:59,780 --> 00:50:56,400

systems orbiting inside the orbit of

1114
00:51:02,300 --> 00:50:59,790
mercury with the range of masses and

1115
00:51:06,950 --> 00:51:02,310
densities are the earth like water

1116
00:51:10,280 --> 00:51:06,960
planets gaseous systems with some

1117
00:51:12,740 --> 00:51:10,290
fraction of rock and hydrogen and helium

1118
00:51:16,220 --> 00:51:12,750
all the way down to earth like systems

1119
00:51:19,670 --> 00:51:16,230
kuro 7b Kepler 10 B we're really

1120
00:51:20,810 --> 00:51:19,680
starting to discover and do exoplanet

1121
00:51:23,480 --> 00:51:20,820
physics and plant

1122
00:51:26,270 --> 00:51:23,490
ecology with these systems and of course

1123
00:51:28,430 --> 00:51:26,280
we were able to discover Tatooine shown

1124
00:51:32,510 --> 00:51:28,440
here where we actually now have planets

1125
00:51:35,270 --> 00:51:32,520
orbiting binary stars and the progress

1126
00:51:38,210 --> 00:51:35,280
just continues I'll show here a quote

1127
00:51:39,830 --> 00:51:38,220
that proves once again you should never

1128
00:51:43,700 --> 00:51:39,840
say that science can never do anything

1129
00:51:45,470 --> 00:51:43,710
back in 1835 August comp a French

1130
00:51:47,930 --> 00:51:45,480
scientist said on the subject of stars

1131
00:51:51,050 --> 00:51:47,940
we shall never be able by any means to

1132
00:51:54,350 --> 00:51:51,060
study their chemical composition well a

1133
00:51:56,180 --> 00:51:54,360
hundred and some years later we are

1134
00:51:58,340 --> 00:51:56,190
actually using the Spitzer Hubble and

1135
00:52:00,560 --> 00:51:58,350
ground-based telescopes to probe the

1136
00:52:02,260 --> 00:52:00,570
atmospheric composition and vertical

1137
00:52:06,020 --> 00:52:02,270
structure and weather patterns on

1138
00:52:09,590 --> 00:52:06,030

planets not just stars we're finding two

1139
00:52:14,720 --> 00:52:09,600
evidence for water methane co2 and this

1140
00:52:17,630 --> 00:52:14,730
is just one of the the spectra of one of

1141
00:52:20,180 --> 00:52:17,640
the bright transiting systems so this is

1142
00:52:22,370 --> 00:52:20,190
really a remarkable step forward we're

1143
00:52:24,050 --> 00:52:22,380
actually really doing planetary

1144
00:52:27,410 --> 00:52:24,060
composition we're looking at weather

1145
00:52:30,620 --> 00:52:27,420
patterns on the planets themselves and I

1146
00:52:33,140 --> 00:52:30,630
was pleased that in the choice between

1147
00:52:35,930 --> 00:52:33,150
the two explorers now under

1148
00:52:37,450 --> 00:52:35,940
consideration that in fact history tells

1149
00:52:40,640 --> 00:52:37,460
us that the planetary astrophysics

1150
00:52:43,580 --> 00:52:40,650
divisions jointly SAT together and chose

1151
00:52:45,830 --> 00:52:43,590
both tests and finesse instead of having

1152
00:52:49,520 --> 00:52:45,840
to choose between them and so we're able

1153
00:52:52,610 --> 00:52:49,530
to make a find a mission that did

1154
00:52:54,470 --> 00:52:52,620
thousands of planetary transiting

1155
00:52:56,510 --> 00:52:54,480
systems discovered those as well as

1156
00:53:00,800 --> 00:52:56,520
making an atlas of hundreds of ice and

1157
00:53:04,160 --> 00:53:00,810
gas giant spectrum so I hope that has

1158
00:53:06,020 --> 00:53:04,170
indeed come to pass let's see what else

1159
00:53:08,570 --> 00:53:06,030
do we have that other thing has been

1160
00:53:11,210 --> 00:53:08,580
happening that happened in the 25 2015

1161
00:53:13,400 --> 00:53:11,220
arena was imaging a planet's young

1162
00:53:16,130 --> 00:53:13,410
Jupiter still contracting and giving off

1163
00:53:18,350 --> 00:53:16,140

energy from their gravitational slow

1164
00:53:20,960 --> 00:53:18,360
gravitational collapse we've been

1165
00:53:23,150 --> 00:53:20,970
finding planets using extreme adaptive

1166
00:53:25,970 --> 00:53:23,160
optics on large ground-based telescopes

1167
00:53:28,850 --> 00:53:25,980
presently five to ten meters eventually

1168
00:53:30,210 --> 00:53:28,860
thirty meter telescope also from space

1169
00:53:37,859 --> 00:53:30,220
we have

1170
00:53:39,690 --> 00:53:37,869
pick which first shows up on one side of

1171
00:53:41,820 --> 00:53:39,700
the star disappears for a couple of

1172
00:53:45,890 --> 00:53:41,830
years and then comes up around the other

1173
00:53:49,440 --> 00:53:45,900
side of the star a couple of years later

1174
00:53:55,410 --> 00:53:49,450
so 33 years ago from our perspective now

1175
00:53:58,980 --> 00:53:55,420
in 2045 we have 798 planets around 630

1176
00:54:01,080 --> 00:53:58,990
systems and in top of that another 2300

1177
00:54:03,450 --> 00:54:01,090
Kepler candidates and this just shows

1178
00:54:05,339 --> 00:54:03,460
the discovery year and the different

1179
00:54:08,190 --> 00:54:05,349
techniques that are being used radial

1180
00:54:12,180 --> 00:54:08,200
velocities transits microlensing imaging

1181
00:54:14,820 --> 00:54:12,190
pulse our timing and the were heads ill

1182
00:54:18,420 --> 00:54:14,830
planets before about 1989 and Dave

1183
00:54:20,760 --> 00:54:18,430
Latham's first discovery going back to

1184
00:54:22,530 --> 00:54:20,770
2,000 BC when people first started

1185
00:54:27,570 --> 00:54:22,540
speculating that there might be other

1186
00:54:30,839 --> 00:54:27,580
planets out there um after 20 15 to 20

1187
00:54:32,940 --> 00:54:30,849
25 we have more census taking we have

1188
00:54:34,829 --> 00:54:32,950

images and transits from space the

1189
00:54:37,410 --> 00:54:34,839
Europeans are very active in this field

1190
00:54:41,250 --> 00:54:37,420
the Gaia mission will go up and find

1191
00:54:43,020 --> 00:54:41,260
probably some 2,000 Jupiter's orbiting

1192
00:54:46,050 --> 00:54:43,030
stars within about two hundred parsecs

1193
00:54:48,390 --> 00:54:46,060
the new ISA small mission their version

1194
00:54:53,720 --> 00:54:48,400
of small faster better cheaper called

1195
00:54:56,730 --> 00:54:53,730
Cheops just selected a few weeks ago a

1196
00:54:58,829 --> 00:54:56,740
the ultimate and Dan Goldin faster

1197
00:55:02,640 --> 00:54:58,839
better cheaper mission called the James

1198
00:55:05,150 --> 00:55:02,650
Webb Space Telescope went up and found

1199
00:55:08,750 --> 00:55:05,160
water on super earth with spectroscopy

1200
00:55:11,400 --> 00:55:08,760
also is able to image young Saturn

1201
00:55:14,630 --> 00:55:11,410
planets such as those who were shown

1202
00:55:19,260 --> 00:55:14,640
here planted into an image of HR 8799

1203
00:55:23,760 --> 00:55:19,270
simulated with jwst so that was a very

1204
00:55:26,099 --> 00:55:23,770
active period beyond that 20 25 to 20 35

1205
00:55:28,290 --> 00:55:26,109
we completed the understanding of

1206
00:55:31,800 --> 00:55:28,300
planetary system architectures and

1207
00:55:34,770 --> 00:55:31,810
imaged the first nearby Earth's we used

1208
00:55:38,160 --> 00:55:34,780
the W first mission and micro lensing to

1209
00:55:41,380 --> 00:55:38,170
probe out beyond the snow line ESA's

1210
00:55:43,210 --> 00:55:41,390
plateau mission found hundreds of earth

1211
00:55:46,350 --> 00:55:43,220
for which we also were able to use astro

1212
00:55:49,720 --> 00:55:46,360
seismology to get accurate stellar ages

1213
00:55:51,940 --> 00:55:49,730

NASA then selected a modest-sized one

1214
00:55:55,080 --> 00:55:51,950
and a half meter chronographic telescope

1215
00:55:58,300 --> 00:55:55,090
and was able to image alphason be

1216
00:55:59,920 --> 00:55:58,310
planets C D and E which turned out to

1217
00:56:03,220 --> 00:55:59,930
exist including an earth in the

1218
00:56:06,070 --> 00:56:03,230
habitable zone and obtained spectra of

1219
00:56:08,740 --> 00:56:06,080
dozens of other gas giant planets and an

1220
00:56:10,630 --> 00:56:08,750
ISA Chinese mission did the estranha

1221
00:56:13,420 --> 00:56:10,640
tree goals originally set out for the

1222
00:56:15,960 --> 00:56:13,430
sim mission and identified ten habitable

1223
00:56:19,870 --> 00:56:15,970
zone Earth's among the nearby stars

1224
00:56:22,330 --> 00:56:19,880
finally in 20-40 the life finder mission

1225
00:56:25,810 --> 00:56:22,340
was actually launched it was a human

1226
00:56:28,450 --> 00:56:25,820
robotic tended facility at l2 enabled

1227
00:56:30,820 --> 00:56:28,460
giant telescopes to be built as visible

1228
00:56:33,550 --> 00:56:30,830
coronagraph and external of culture that

1229
00:56:36,460 --> 00:56:33,560
a Darwin class infrared interferometer

1230
00:56:39,400 --> 00:56:36,470
and announcing today at this meeting

1231
00:56:42,990 --> 00:56:39,410
breaking news three of the ten habitable

1232
00:56:45,940 --> 00:56:43,000
planets found by the ISA Chinese

1233
00:56:49,750 --> 00:56:45,950
astrometric mission proved to have signs

1234
00:56:51,370 --> 00:56:49,760
of photosynthetic life and now I want to

1235
00:56:58,090 --> 00:56:51,380
enter into a little bit of speculation

1236
00:57:01,360 --> 00:56:58,100
with my last slide so just announcing

1237
00:57:03,160 --> 00:57:01,370
here that complementary searches on our

1238
00:57:05,860 --> 00:57:03,170

own solar system and towards other

1239
00:57:07,930 --> 00:57:05,870
systems were able to find life in our

1240
00:57:11,170 --> 00:57:07,940
own and other solar systems so the Mars

1241
00:57:13,510 --> 00:57:11,180
colonists were able to find non DNA life

1242
00:57:17,830 --> 00:57:13,520
by drilling deeply down into a deep

1243
00:57:20,020 --> 00:57:17,840
aquifer on Mars and then finally Jill

1244
00:57:22,360 --> 00:57:20,030
Tartars granddaughter received the first