
NASA
Dr. Robert Farquhar
Executive for Space Exploration, KinetX, Inc.

1
00:00:16,070 --> 00:00:14,470
well good morning my name is dwayne

2
00:00:18,390 --> 00:00:16,080
brown with nasa's office of

3
00:00:19,990 --> 00:00:18,400
communications at nasa headquarters in

4
00:00:21,750 --> 00:00:20,000
washington d.c

5
00:00:24,150 --> 00:00:21,760
it is my honor and pleasure to be your

6
00:00:25,589 --> 00:00:24,160
master of ceremonies for today's event

7
00:00:26,790 --> 00:00:25,599
here at the museum in the nation's

8
00:00:29,429 --> 00:00:26,800
capital

9
00:00:31,189 --> 00:00:29,439
it's all about comments today

10
00:00:33,830 --> 00:00:31,199
i want to welcome our studio audience

11
00:00:36,150 --> 00:00:33,840
here i also want to welcome our national

12
00:00:38,950 --> 00:00:36,160
audience viewing this program via nasa

13
00:00:41,510 --> 00:00:38,960

television and our worldwide audience

14
00:00:44,549 --> 00:00:41,520
viewing this via the agency's website at

15
00:00:47,910 --> 00:00:46,790
we have a lot to cover today about

16
00:00:49,830 --> 00:00:47,920
comments

17
00:00:52,310 --> 00:00:49,840
and before we officially

18
00:00:54,709 --> 00:00:52,320
declare a clash in session

19
00:00:56,709 --> 00:00:54,719
it is my pleasure to

20
00:00:58,549 --> 00:00:56,719
introduce to give brief remarks and

21
00:00:59,990 --> 00:00:58,559
acknowledgements

22
00:01:01,430 --> 00:01:00,000
joe urschel

23
00:01:03,670 --> 00:01:01,440
senior vice president sales and

24
00:01:09,510 --> 00:01:03,680
marketing for the museum

25
00:01:13,510 --> 00:01:11,590
well let me add my welcome to everyone

26
00:01:14,950 --> 00:01:13,520
to the knight studios here at the

27
00:01:16,230 --> 00:01:14,960
newseum

28
00:01:17,590 --> 00:01:16,240
if uh

29
00:01:19,350 --> 00:01:17,600
if a

30
00:01:21,670 --> 00:01:19,360
institution that's only been open two

31
00:01:24,310 --> 00:01:21,680
and a half years can have a long history

32
00:01:27,109 --> 00:01:24,320
with anyone uh we have indeed had a long

33
00:01:28,710 --> 00:01:27,119
history with nasa we've hosted many of

34
00:01:32,069 --> 00:01:28,720
your great events here

35
00:01:36,870 --> 00:01:32,079
and worked with your great staff on

36
00:01:41,749 --> 00:01:38,789
you no doubt are familiar with the

37
00:01:42,950 --> 00:01:41,759
expression it's not rocket science

38
00:01:44,870 --> 00:01:42,960

and

39
00:01:46,630 --> 00:01:44,880
i i confessed having used that

40
00:01:47,749 --> 00:01:46,640
expression several times myself over the

41
00:01:50,789 --> 00:01:47,759
course of

42
00:01:51,990 --> 00:01:50,799
building this museum

43
00:01:54,310 --> 00:01:52,000
but

44
00:01:55,670 --> 00:01:54,320
your work really is rocket science and

45
00:01:58,709 --> 00:01:55,680
uh we

46
00:02:01,190 --> 00:01:58,719
appreciate it so much and we are just

47
00:02:03,830 --> 00:02:01,200
awestruck by the things you've been able

48
00:02:06,230 --> 00:02:03,840
to accomplish over year long history

49
00:02:07,670 --> 00:02:06,240
and it is our great pleasure to

50
00:02:09,510 --> 00:02:07,680
help you celebrate them here at the

51
00:02:11,830 --> 00:02:09,520
museum

52
00:02:14,229 --> 00:02:11,840
uh the newseum is

53
00:02:15,350 --> 00:02:14,239
is not rocket science but our mission uh

54
00:02:16,390 --> 00:02:15,360
i think

55
00:02:18,470 --> 00:02:16,400
is uh

56
00:02:21,589 --> 00:02:18,480
similarly difficult if maybe not quite

57
00:02:24,630 --> 00:02:21,599
as complicated uh what we try to do is

58
00:02:27,190 --> 00:02:24,640
promote the idea of a free press being

59
00:02:28,630 --> 00:02:27,200
the cornerstone of democracy both here

60
00:02:30,070 --> 00:02:28,640
and worldwide

61
00:02:32,309 --> 00:02:30,080
and

62
00:02:35,030 --> 00:02:32,319
as you may have read you know the media

63
00:02:37,430 --> 00:02:35,040

is not the most popular institution in

64
00:02:41,030 --> 00:02:37,440
the united states nor in the world

65
00:02:43,670 --> 00:02:41,040
but we think the work that is done

66
00:02:45,589 --> 00:02:43,680
by members of a free press

67
00:02:47,830 --> 00:02:45,599
and oftentimes members of a repressed

68
00:02:50,390 --> 00:02:47,840
press is important

69
00:02:53,270 --> 00:02:50,400
to the development of the world both

70
00:02:56,229 --> 00:02:53,280
scientifically and socially

71
00:02:59,350 --> 00:02:56,239
and what we try to do with

72
00:03:01,350 --> 00:02:59,360
our museum here is tell

73
00:03:02,830 --> 00:03:01,360
the history of the world

74
00:03:05,350 --> 00:03:02,840
through recent news

75
00:03:09,110 --> 00:03:05,360
events and explain

76
00:03:11,830 --> 00:03:09,120
how the the role of the media

77
00:03:14,710 --> 00:03:11,840
played an important factor in bringing

78
00:03:18,470 --> 00:03:14,720
that news to people

79
00:03:20,149 --> 00:03:18,480
if people don't know what's gone on it's

80
00:03:22,229 --> 00:03:20,159
still news to them

81
00:03:24,309 --> 00:03:22,239
and if people don't know what's

82
00:03:26,949 --> 00:03:24,319
happening with their society

83
00:03:29,270 --> 00:03:26,959
be it scientific or political there's no

84
00:03:30,470 --> 00:03:29,280
way they can get involved in it

85
00:03:33,670 --> 00:03:30,480
and we

86
00:03:35,190 --> 00:03:33,680
really congratulate nasa for providing

87
00:03:36,869 --> 00:03:35,200
us with so many

88
00:03:39,030 --> 00:03:36,879

great news events

89
00:03:41,350 --> 00:03:39,040
of great uh human

90
00:03:44,710 --> 00:03:41,360
accomplishment that we can use here at

91
00:03:47,110 --> 00:03:44,720
the museum and celebrate uh in its role

92
00:03:49,830 --> 00:03:47,120
for the development of

93
00:03:52,390 --> 00:03:49,840
worldwide knowledge so

94
00:03:54,789 --> 00:03:52,400
with that i'd like to thank you for

95
00:03:56,869 --> 00:03:54,799
the work you've done and

96
00:03:58,630 --> 00:03:56,879
the work you continue to do and i'm sure

97
00:04:01,350 --> 00:03:58,640
there'll be some news

98
00:04:03,190 --> 00:04:01,360
from this event today that hopefully

99
00:04:05,030 --> 00:04:03,200
will end up someday

100
00:04:06,149 --> 00:04:05,040
on display at the museum along with all

101
00:04:08,309 --> 00:04:06,159
of our other

102
00:04:11,350 --> 00:04:08,319
great stories so thank you all for

103
00:04:12,789 --> 00:04:11,360
coming i hope your event goes well and

104
00:04:21,909 --> 00:04:12,799
we appreciate

105
00:04:26,550 --> 00:04:23,909
and thank you joe and of course we are

106
00:04:28,390 --> 00:04:26,560
always always uh honored to to be here

107
00:04:30,230 --> 00:04:28,400
in this incredible organization and

108
00:04:31,830 --> 00:04:30,240
facility okay so we're going to get

109
00:04:33,590 --> 00:04:31,840
started ladies and gentlemen

110
00:04:35,110 --> 00:04:33,600
today you're going to get

111
00:04:36,390 --> 00:04:35,120
first-hand insights about comet

112
00:04:38,070 --> 00:04:36,400
discoveries

113
00:04:41,189 --> 00:04:38,080

observations and encounters over the

114
00:04:44,230 --> 00:04:41,199
past 25 years and hear from the foremost

115
00:04:47,590 --> 00:04:45,830
for the next two

116
00:04:48,629 --> 00:04:47,600
common encounters occurring on november

117
00:04:49,909 --> 00:04:48,639
4th

118
00:04:52,629 --> 00:04:49,919
and another

119
00:04:54,710 --> 00:04:52,639
in february 14th of next year

120
00:04:56,790 --> 00:04:54,720
i'm going to give some brief backgrounds

121
00:04:59,350 --> 00:04:56,800
for today's presenters and if you want

122
00:05:03,310 --> 00:04:59,360
to get all of the details on these

123
00:05:06,230 --> 00:05:04,629
www.solarsystem.nasa.gov for their

124
00:05:09,029 --> 00:05:06,240
complete bios

125
00:05:11,270 --> 00:05:09,039
you can also read about the incredible

126
00:05:13,670 --> 00:05:11,280
activities that are coming up at nasa

127
00:05:15,350 --> 00:05:13,680
for the year of the solar system

128
00:05:16,469 --> 00:05:15,360
so let's get started it's all about

129
00:05:18,310 --> 00:05:16,479
comments

130
00:05:20,629 --> 00:05:18,320
first up will be

131
00:05:22,830 --> 00:05:20,639
dr james l green director of nasa's

132
00:05:25,110 --> 00:05:22,840
planetary science division and nasa

133
00:05:26,790 --> 00:05:25,120
headquarters dr green

134
00:05:28,710 --> 00:05:26,800
goes without saying is an extremely

135
00:05:31,029 --> 00:05:28,720
accomplished scientist

136
00:05:34,070 --> 00:05:31,039
and personally he is one of the coolest

137
00:05:38,390 --> 00:05:35,510
he received his degrees from the

138
00:05:40,310 --> 00:05:38,400

university of iowa and was personally

139
00:05:42,950 --> 00:05:40,320
mentored by the late

140
00:05:44,710 --> 00:05:42,960
dr james van allen

141
00:05:56,469 --> 00:05:44,720
ladies and gentlemen please give a warm

142
00:06:01,909 --> 00:05:58,390
well it's very exciting event we're here

143
00:06:04,950 --> 00:06:01,919
today to celebrate the 25th anniversary

144
00:06:07,430 --> 00:06:04,960
of our first common encounter

145
00:06:10,230 --> 00:06:07,440
and to do that we're going to look not

146
00:06:12,629 --> 00:06:10,240
only backwards but forwards

147
00:06:13,430 --> 00:06:12,639
we're going to take a little uh a tour

148
00:06:15,510 --> 00:06:13,440
of

149
00:06:18,150 --> 00:06:15,520
some ancient history

150
00:06:20,550 --> 00:06:18,160
try to put the context of what we now

151
00:06:21,749 --> 00:06:20,560
know about comets and how that's changed

152
00:06:24,629 --> 00:06:21,759
over time

153
00:06:27,029 --> 00:06:24,639
and in particular look forward

154
00:06:28,469 --> 00:06:27,039
to two upcoming encounters as dwane

155
00:06:31,749 --> 00:06:28,479
mentioned

156
00:06:35,189 --> 00:06:31,759
that will occur in the next six months

157
00:06:37,749 --> 00:06:35,199
so as dwayne says let's get started

158
00:06:40,550 --> 00:06:37,759
about five billion years ago

159
00:06:43,990 --> 00:06:40,560
as our solar nebula collapsed

160
00:06:45,830 --> 00:06:44,000
creating the sun the planets uh their

161
00:06:48,550 --> 00:06:45,840
satellites and and

162
00:06:49,589 --> 00:06:48,560
and uh asteroids but it also created

163
00:06:54,629 --> 00:06:49,599

comets

164
00:06:57,990 --> 00:06:54,639
regions of that nebula

165
00:06:59,510 --> 00:06:58,000
in the outer regions where icy gases

166
00:07:04,390 --> 00:06:59,520
along with

167
00:07:06,950 --> 00:07:04,400
rocks and dust coalesce to form a comet

168
00:07:09,589 --> 00:07:06,960
with the occasional tugs from the sun

169
00:07:10,710 --> 00:07:09,599
gravity to the point where they come

170
00:07:12,950 --> 00:07:10,720
inward

171
00:07:15,510 --> 00:07:12,960
they begin to show as they get close to

172
00:07:17,909 --> 00:07:15,520
the sun and sublimate their beautiful

173
00:07:20,550 --> 00:07:17,919
long tails

174
00:07:22,390 --> 00:07:20,560
now from early history

175
00:07:25,350 --> 00:07:22,400
as humans walked the earth they

176
00:07:27,749 --> 00:07:25,360
incorporated the sky into their culture

177
00:07:29,990 --> 00:07:27,759
and in their belief system

178
00:07:30,870 --> 00:07:30,000
well unfortunately comets got the bad

179
00:07:34,150 --> 00:07:30,880
rap

180
00:07:37,110 --> 00:07:34,160
nearly every culture in our history

181
00:07:39,189 --> 00:07:37,120
thought of comets as harbingers of gloom

182
00:07:42,070 --> 00:07:39,199
and doom and let me just give you a

183
00:07:43,430 --> 00:07:42,080
couple examples of that

184
00:07:44,390 --> 00:07:43,440
here are some

185
00:07:48,150 --> 00:07:44,400
ancient

186
00:07:51,110 --> 00:07:48,160
uh images uh in chinese text

187
00:07:53,589 --> 00:07:51,120
from well over uh 300 bc

188
00:07:54,629 --> 00:07:53,599

displaying comments displaying their

189
00:07:56,869 --> 00:07:54,639
tales

190
00:07:58,950 --> 00:07:56,879
and the text tells us of the disasters

191
00:08:01,110 --> 00:07:58,960
that occurred that year

192
00:08:04,070 --> 00:08:01,120
and probably in hopes of determining if

193
00:08:05,990 --> 00:08:04,080
a certain comet tail structure tells us

194
00:08:08,469 --> 00:08:06,000
a little bit about the disaster that may

195
00:08:13,110 --> 00:08:10,390
if you were to be famous

196
00:08:15,510 --> 00:08:13,120
and really a well-known individual

197
00:08:18,309 --> 00:08:15,520
you were associated with your death with

198
00:08:21,749 --> 00:08:18,319
the coming of a comet here is uh caesar

199
00:08:23,670 --> 00:08:21,759
julius caesar who died in 44 bc a coin

200
00:08:25,670 --> 00:08:23,680
commemorates his death

201
00:08:27,749 --> 00:08:25,680
with a beautiful comet

202
00:08:30,070 --> 00:08:27,759
the comet's tail raiding and all

203
00:08:33,110 --> 00:08:30,080
radiating in all directions as it passes

204
00:08:34,550 --> 00:08:33,120
in and around the sun

205
00:08:37,269 --> 00:08:34,560
montezuma

206
00:08:39,990 --> 00:08:37,279
believed that the coming of a comet was

207
00:08:42,709 --> 00:08:40,000
one of the major signs one of eight

208
00:08:44,710 --> 00:08:42,719
actually that he should have recognized

209
00:08:47,110 --> 00:08:44,720
that as the spanish came and nearly

210
00:08:49,430 --> 00:08:47,120
destroyed the aztecs

211
00:08:51,269 --> 00:08:49,440
the once again comets bringing on that

212
00:08:53,430 --> 00:08:51,279
harbinger

213
00:08:56,470 --> 00:08:53,440

in addition to that early painters even

214
00:08:57,990 --> 00:08:56,480
associated comments with disasters

215
00:09:00,550 --> 00:08:58,000
of climate

216
00:09:02,630 --> 00:09:00,560
whether they're huge storms

217
00:09:04,550 --> 00:09:02,640
whether they're floods

218
00:09:06,949 --> 00:09:04,560
hurricanes etc

219
00:09:09,030 --> 00:09:06,959
but just complete chaos

220
00:09:12,470 --> 00:09:09,040
that was occurring and it was because

221
00:09:13,990 --> 00:09:12,480
the of the comet that was coming

222
00:09:17,030 --> 00:09:14,000
well fortunately

223
00:09:18,710 --> 00:09:17,040
uh some of this

224
00:09:21,350 --> 00:09:18,720
these things started to get straightened

225
00:09:22,870 --> 00:09:21,360
out when edmund haley began to look at

226
00:09:24,790 --> 00:09:22,880
comets

227
00:09:26,230 --> 00:09:24,800
trying to employ some of the isaac

228
00:09:27,110 --> 00:09:26,240
newton's

229
00:09:30,230 --> 00:09:27,120
now

230
00:09:32,710 --> 00:09:30,240
fundamental equations to their motion

231
00:09:34,710 --> 00:09:32,720
and he began to notice that there were

232
00:09:37,110 --> 00:09:34,720
at least one comment

233
00:09:39,990 --> 00:09:37,120
in his list that he collected that

234
00:09:42,470 --> 00:09:40,000
seemed to reappear periodically about

235
00:09:45,269 --> 00:09:42,480
every 76 years or so

236
00:09:47,430 --> 00:09:45,279
and in fact edmund predicted when that

237
00:09:48,389 --> 00:09:47,440
next apparition of that comet would come

238
00:09:49,910 --> 00:09:48,399

by

239
00:09:51,590 --> 00:09:49,920
and this was assuming that it had an

240
00:09:53,590 --> 00:09:51,600
elliptical orbit he did a lot of

241
00:09:56,230 --> 00:09:53,600
calculations and he even included the

242
00:09:57,990 --> 00:09:56,240
effect of gravity from jupiter

243
00:10:00,310 --> 00:09:58,000
well it turns out

244
00:10:02,870 --> 00:10:00,320
hayley didn't see that comet he died

245
00:10:05,269 --> 00:10:02,880
well before that appeared the comet did

246
00:10:07,030 --> 00:10:05,279
come within a day or so as he predicted

247
00:10:09,190 --> 00:10:07,040
and it's currently called halley's

248
00:10:11,590 --> 00:10:09,200
comment

249
00:10:12,710 --> 00:10:11,600
what happened also to halle

250
00:10:15,430 --> 00:10:12,720
is

251
00:10:17,430 --> 00:10:15,440
even in the newspapers in fact i'd be

252
00:10:19,750 --> 00:10:17,440
remiss if i didn't show some news

253
00:10:23,269 --> 00:10:19,760
articles here in the in the beautiful

254
00:10:25,269 --> 00:10:23,279
museum facility but in the 1910

255
00:10:27,910 --> 00:10:25,279
apparation of haley

256
00:10:29,990 --> 00:10:27,920
we see these fabulous articles the earth

257
00:10:31,269 --> 00:10:30,000
was to actually cut through the tail of

258
00:10:34,150 --> 00:10:31,279
the comet

259
00:10:37,750 --> 00:10:34,160
so poisonous gases of course would would

260
00:10:39,269 --> 00:10:37,760
would be uh impinging on our atmosphere

261
00:10:41,910 --> 00:10:39,279
scientists had to come out in these

262
00:10:44,470 --> 00:10:41,920
articles and explain that wasn't true

263
00:10:47,509 --> 00:10:44,480

even a earthquake which killed many in

264
00:10:49,190 --> 00:10:47,519
costa rica scientists had to say no that

265
00:10:51,110 --> 00:10:49,200
comet that's coming

266
00:10:53,269 --> 00:10:51,120
had nothing to do with that

267
00:10:55,990 --> 00:10:53,279
and so indeed it was still in our

268
00:10:58,949 --> 00:10:56,000
culture even as recently as the last

269
00:11:01,110 --> 00:10:58,959
hundred or so years

270
00:11:02,870 --> 00:11:01,120
but comets today the ones that are

271
00:11:05,509 --> 00:11:02,880
really beautiful

272
00:11:08,310 --> 00:11:05,519
we observe these long tails

273
00:11:10,069 --> 00:11:08,320
only a few per decade

274
00:11:11,670 --> 00:11:10,079
and in fact

275
00:11:14,069 --> 00:11:11,680
now our modern

276
00:11:15,910 --> 00:11:14,079
set of observations are really changing

277
00:11:18,310 --> 00:11:15,920
this perspective

278
00:11:19,910 --> 00:11:18,320
and what we're finding out if we show

279
00:11:22,470 --> 00:11:19,920
the movie

280
00:11:24,790 --> 00:11:22,480
even from our solar observing uh

281
00:11:26,790 --> 00:11:24,800
spacecraft such as

282
00:11:29,030 --> 00:11:26,800
soho and stereo

283
00:11:31,670 --> 00:11:29,040
in fact this particular image which will

284
00:11:34,230 --> 00:11:31,680
cycle shows a comet coming in

285
00:11:36,550 --> 00:11:34,240
but not coming out as it crosses in and

286
00:11:38,150 --> 00:11:36,560
around the sun the sun's

287
00:11:40,230 --> 00:11:38,160
tremendous

288
00:11:42,790 --> 00:11:40,240

heat and light actually

289
00:11:44,870 --> 00:11:42,800
sublimates the comet away and and

290
00:11:47,509 --> 00:11:44,880
destroys it completely

291
00:11:49,190 --> 00:11:47,519
now over the last 10 years alone by

292
00:11:51,110 --> 00:11:49,200
staring at the sun and seeing these

293
00:11:53,430 --> 00:11:51,120
comets come in

294
00:11:54,829 --> 00:11:53,440
well over a thousand comments have gone

295
00:11:58,069 --> 00:11:54,839
through this process and have

296
00:12:00,470 --> 00:11:58,079
disappeared this changes our view

297
00:12:02,150 --> 00:12:00,480
completely of how ubiquitous these

298
00:12:04,870 --> 00:12:02,160
systems are

299
00:12:07,509 --> 00:12:04,880
and now with new spacecraft

300
00:12:09,590 --> 00:12:07,519
starting from the international

301
00:12:12,310 --> 00:12:09,600
commentary explorer ice

302
00:12:13,750 --> 00:12:12,320
25 years ago which will be discussed by

303
00:12:15,750 --> 00:12:13,760
bob farquhar

304
00:12:18,069 --> 00:12:15,760
we're going to hear now much more about

305
00:12:20,150 --> 00:12:18,079
that science what do we really know

306
00:12:21,269 --> 00:12:20,160
about comets and how important they

307
00:12:23,670 --> 00:12:21,279
really are

308
00:12:25,670 --> 00:12:23,680
in the origin and evolution of our solar

309
00:12:26,870 --> 00:12:25,680
system and perhaps even life here on

310
00:12:28,550 --> 00:12:26,880
earth

311
00:12:30,710 --> 00:12:28,560
and so with that

312
00:12:42,310 --> 00:12:30,720
let me turn it back over to dwayne to

313
00:12:46,150 --> 00:12:44,230

thank you jim

314
00:12:48,470 --> 00:12:46,160
next we have dr

315
00:12:50,629 --> 00:12:48,480
anita cochran

316
00:12:52,389 --> 00:12:50,639
his assistant director of the mcdonald

317
00:12:53,829 --> 00:12:52,399
observatory at the university of texas

318
00:12:55,590 --> 00:12:53,839
in austin

319
00:12:57,509 --> 00:12:55,600
she received her phd

320
00:13:00,389 --> 00:12:57,519
from the university of texas and her

321
00:13:01,430 --> 00:13:00,399
undergraduate degree in physics from

322
00:13:02,949 --> 00:13:01,440
cornell

323
00:13:04,790 --> 00:13:02,959
and i have to tell you while we were

324
00:13:06,790 --> 00:13:04,800
rehearsing i told her she has this

325
00:13:09,350 --> 00:13:06,800
incredible smile that just makes you

326
00:13:11,430 --> 00:13:09,360
want to feel good so you'll see that

327
00:13:18,829 --> 00:13:11,440
ladies and gentlemen please welcome dr

328
00:13:24,069 --> 00:13:22,310
cochrane good morning

329
00:13:25,350 --> 00:13:24,079
well

330
00:13:28,310 --> 00:13:25,360
comets are probably some of the most

331
00:13:29,990 --> 00:13:28,320
beautiful things in this in the universe

332
00:13:31,110 --> 00:13:30,000
i'll go past the solar system into the

333
00:13:32,629 --> 00:13:31,120
universe

334
00:13:34,629 --> 00:13:32,639
and

335
00:13:37,350 --> 00:13:34,639
they've been because they show up

336
00:13:40,069 --> 00:13:37,360
suddenly and

337
00:13:42,310 --> 00:13:40,079
are so prominent they have been we have

338
00:13:44,069 --> 00:13:42,320

records of them going back

339
00:13:45,509 --> 00:13:44,079
many thousands of years as jim talked

340
00:13:47,750 --> 00:13:45,519
about

341
00:13:50,069 --> 00:13:47,760
and this is an example of of one of the

342
00:13:52,150 --> 00:13:50,079
best comets in in the last several

343
00:13:53,829 --> 00:13:52,160
decades and that's comet hail bop the

344
00:13:56,470 --> 00:13:53,839
domes are mcdonald observatory i have to

345
00:13:58,389 --> 00:13:56,480
put in a plug for my own institution

346
00:14:00,389 --> 00:13:58,399
um

347
00:14:02,790 --> 00:14:00,399
and

348
00:14:04,629 --> 00:14:02,800
we get about one per decade that looks

349
00:14:07,590 --> 00:14:04,639
really spectacular like this this is

350
00:14:09,670 --> 00:14:07,600
comet west from 1978.

351
00:14:11,030 --> 00:14:09,680
uh this is not my observatory this is

352
00:14:13,430 --> 00:14:11,040
this is the

353
00:14:16,629 --> 00:14:13,440
uh very large telescope down in paranal

354
00:14:18,790 --> 00:14:16,639
chile this is comet mcnaught and we see

355
00:14:20,629 --> 00:14:18,800
all these different behaviors of course

356
00:14:22,310 --> 00:14:20,639
most of the comets that we fly missions

357
00:14:23,590 --> 00:14:22,320
to unfortunately are not these

358
00:14:26,230 --> 00:14:23,600
magnificent

359
00:14:29,110 --> 00:14:26,240
big comets but we still learn incredible

360
00:14:30,629 --> 00:14:29,120
things about comets by looking at these

361
00:14:32,389 --> 00:14:30,639
they're not only very beautiful but

362
00:14:33,269 --> 00:14:32,399
there's a reason why we want to study

363
00:14:35,509 --> 00:14:33,279

them

364
00:14:37,030 --> 00:14:35,519
and that is because as jim talked about

365
00:14:39,670 --> 00:14:37,040
they were formed four and a half billion

366
00:14:40,790 --> 00:14:39,680
years ago at the start of the the solar

367
00:14:42,470 --> 00:14:40,800
system

368
00:14:44,710 --> 00:14:42,480
but they weren't

369
00:14:46,790 --> 00:14:44,720
built as part just

370
00:14:48,150 --> 00:14:46,800
at the same time as planets instead

371
00:14:50,470 --> 00:14:48,160
they're the building blocks of the

372
00:14:52,069 --> 00:14:50,480
planets of the outer solar system

373
00:14:54,310 --> 00:14:52,079
so

374
00:14:57,110 --> 00:14:54,320
planets like jupiter saturn uranus and

375
00:14:59,030 --> 00:14:57,120
neptune they were built out of started

376
00:15:00,550 --> 00:14:59,040
to be built out of comets or

377
00:15:03,750 --> 00:15:00,560
planetesimals

378
00:15:05,670 --> 00:15:03,760
small icy bodies that are now the ones

379
00:15:07,670 --> 00:15:05,680
that we see today are the leftovers from

380
00:15:09,670 --> 00:15:07,680
the formation of the solar system

381
00:15:11,590 --> 00:15:09,680
so the reason why we care to study

382
00:15:14,389 --> 00:15:11,600
comets is because they tell us about the

383
00:15:15,670 --> 00:15:14,399
conditions in the early solar nebula

384
00:15:17,509 --> 00:15:15,680
and

385
00:15:19,990 --> 00:15:17,519
unlike the planets which have undergone

386
00:15:22,470 --> 00:15:20,000
lots of change as the solar system has

387
00:15:24,389 --> 00:15:22,480
evolved the comets have not undergone a

388
00:15:25,829 --> 00:15:24,399

lot of change they're small they spend

389
00:15:28,069 --> 00:15:25,839
most of their time out in the outer

390
00:15:30,389 --> 00:15:28,079
regions of the solar system so they stay

391
00:15:32,310 --> 00:15:30,399
icy and therefore the comets that we see

392
00:15:34,069 --> 00:15:32,320
today coming into the inner solar system

393
00:15:35,269 --> 00:15:34,079
are very little change from when they

394
00:15:37,910 --> 00:15:35,279
formed

395
00:15:40,230 --> 00:15:37,920
and by studying them we learn all about

396
00:15:42,790 --> 00:15:40,240
the origins of our solar system so

397
00:15:45,269 --> 00:15:42,800
though most of us will tell you we

398
00:15:47,430 --> 00:15:45,279
look at debris leftovers it's very

399
00:15:49,189 --> 00:15:47,440
fundamental leftovers to understand

400
00:15:50,870 --> 00:15:49,199
where did we come from and that answer

401
00:15:52,870 --> 00:15:50,880
is one of the big questions that nasa's

402
00:15:54,389 --> 00:15:52,880
always been interested in where did we

403
00:15:56,069 --> 00:15:54,399
come from

404
00:15:57,269 --> 00:15:56,079
so that's why we want to study comets

405
00:16:00,629 --> 00:15:57,279
today

406
00:16:02,550 --> 00:16:00,639
and the modern era jim talked about the

407
00:16:04,949 --> 00:16:02,560
history but the modern era of comets

408
00:16:07,269 --> 00:16:04,959
really started in 1950

409
00:16:08,870 --> 00:16:07,279
and it started with several important

410
00:16:11,030 --> 00:16:08,880
people

411
00:16:14,470 --> 00:16:11,040
the person who's shown on this picture

412
00:16:15,749 --> 00:16:14,480
is fred whipple and fred whipple is

413
00:16:17,590 --> 00:16:15,759

basically

414
00:16:20,230 --> 00:16:17,600
the person who came up with our concept

415
00:16:22,150 --> 00:16:20,240
of what is a comet and as he's

416
00:16:24,949 --> 00:16:22,160
demonstrating with this picture it's an

417
00:16:27,189 --> 00:16:24,959
icy snowball or dirty snowball

418
00:16:31,030 --> 00:16:27,199
um that's probably a little small for a

419
00:16:32,470 --> 00:16:31,040
comet today not we wouldn't see that one

420
00:16:34,629 --> 00:16:32,480
although i don't know where fred got

421
00:16:35,749 --> 00:16:34,639
that large chunk of ice

422
00:16:37,910 --> 00:16:35,759
but

423
00:16:39,990 --> 00:16:37,920
he claims he was riding his bicycle home

424
00:16:43,030 --> 00:16:40,000
one day at harvard and he was thinking

425
00:16:45,590 --> 00:16:43,040
about comets and realized that they have

426
00:16:46,949 --> 00:16:45,600
to be made up of a combination of ice

427
00:16:47,990 --> 00:16:46,959
and dirt

428
00:16:50,069 --> 00:16:48,000
and

429
00:16:52,629 --> 00:16:50,079
that ice as the comet approaches the

430
00:16:55,590 --> 00:16:52,639
inner solar system gets heated

431
00:16:57,350 --> 00:16:55,600
and it's sublime so it if you took ice

432
00:16:59,590 --> 00:16:57,360
and put it on a table here you turn it

433
00:17:01,590 --> 00:16:59,600
into liquid but in space because you

434
00:17:03,590 --> 00:17:01,600
don't have the the gravity and you don't

435
00:17:05,750 --> 00:17:03,600
have the pressures

436
00:17:07,590 --> 00:17:05,760
you go straight into and it's very cold

437
00:17:09,590 --> 00:17:07,600
of course you go straight into the gas

438
00:17:11,429 --> 00:17:09,600

phase so you go from the ice phase

439
00:17:13,590 --> 00:17:11,439
straight into the gas phase and that gas

440
00:17:15,110 --> 00:17:13,600
will then take with it as it flows away

441
00:17:18,069 --> 00:17:15,120
from the the comet which doesn't have a

442
00:17:20,630 --> 00:17:18,079
lot of gravity it will take with it the

443
00:17:23,590 --> 00:17:20,640
dust and dirt that exists in the comet

444
00:17:26,309 --> 00:17:23,600
and form the tails that we see

445
00:17:28,069 --> 00:17:26,319
and also the atmosphere that's an

446
00:17:29,510 --> 00:17:28,079
unbound atmosphere around the comet

447
00:17:30,310 --> 00:17:29,520
called the coma

448
00:17:31,990 --> 00:17:30,320
so

449
00:17:34,230 --> 00:17:32,000
fred was really the father of our

450
00:17:36,310 --> 00:17:34,240
current com concept that comets were

451
00:17:38,549 --> 00:17:36,320
dirty snowballs

452
00:17:40,470 --> 00:17:38,559
um

453
00:17:41,590 --> 00:17:40,480
going back again to a picture of comet

454
00:17:43,110 --> 00:17:41,600
hale bop

455
00:17:45,990 --> 00:17:43,120
you see that

456
00:17:47,909 --> 00:17:46,000
in this spectacular example you have the

457
00:17:50,230 --> 00:17:47,919
coma which is the the

458
00:17:52,630 --> 00:17:50,240
atmosphere around the nucleus is never

459
00:17:54,870 --> 00:17:52,640
seen from the ground it's way too small

460
00:17:57,909 --> 00:17:54,880
nuclei of comets are sort of a few

461
00:17:59,110 --> 00:17:57,919
kilometers across so the size of a small

462
00:18:01,590 --> 00:17:59,120
city

463
00:18:03,590 --> 00:18:01,600

a big comet like hail bop is probably 30

464
00:18:06,150 --> 00:18:03,600
kilometers across so the size of a city

465
00:18:08,630 --> 00:18:06,160
like washington dc

466
00:18:11,270 --> 00:18:08,640
but as that material sublimes and takes

467
00:18:13,430 --> 00:18:11,280
with the dust you get you can you can

468
00:18:16,150 --> 00:18:13,440
form but you don't always form two

469
00:18:18,950 --> 00:18:16,160
different tails the dust tail the white

470
00:18:21,430 --> 00:18:18,960
tail on that picture is flowing is does

471
00:18:24,310 --> 00:18:21,440
flowing behind the comet in its orbit

472
00:18:26,390 --> 00:18:24,320
uh and the ion tail is gas that's been

473
00:18:27,430 --> 00:18:26,400
ionized by the solar wind

474
00:18:30,470 --> 00:18:27,440
and

475
00:18:32,310 --> 00:18:30,480
in entrained in the solar wind it's been

476
00:18:35,350 --> 00:18:32,320
ionized coming off

477
00:18:37,110 --> 00:18:35,360
and follows be follows directly outward

478
00:18:40,870 --> 00:18:37,120
from the sun so that's what a

479
00:18:44,710 --> 00:18:42,950
but where did they come from and what is

480
00:18:48,150 --> 00:18:44,720
the structure of the outer solar system

481
00:18:50,070 --> 00:18:48,160
now well in 1950 it was also figured out

482
00:18:51,830 --> 00:18:50,080
where

483
00:18:53,270 --> 00:18:51,840
some of the comets came from and that

484
00:18:55,669 --> 00:18:53,280
was done by a remarkable gentleman

485
00:18:57,909 --> 00:18:55,679
called yanort who worked on all branches

486
00:18:59,430 --> 00:18:57,919
of astronomy but was very important for

487
00:19:00,630 --> 00:18:59,440
understanding

488
00:19:08,310 --> 00:19:00,640

the

489
00:19:10,230 --> 00:19:08,320
and

490
00:19:11,669 --> 00:19:10,240
some of them are in the same plane as

491
00:19:13,590 --> 00:19:11,679
the planets going around the sun that's

492
00:19:15,750 --> 00:19:13,600
called the plane of the ecliptic but

493
00:19:17,430 --> 00:19:15,760
some of them come from random directions

494
00:19:19,029 --> 00:19:17,440
comet halley actually goes in the

495
00:19:21,350 --> 00:19:19,039
reverse direction around the sun than

496
00:19:23,110 --> 00:19:21,360
the earth does comet hail bop was 90

497
00:19:25,270 --> 00:19:23,120
degrees from the orbit of the earth

498
00:19:27,350 --> 00:19:25,280
around the sun and with all these

499
00:19:28,870 --> 00:19:27,360
seemingly random directions

500
00:19:30,390 --> 00:19:28,880
it was

501
00:19:32,789 --> 00:19:30,400
a difficult thing to understand where

502
00:19:35,510 --> 00:19:32,799
they come from well jan or looking at

503
00:19:37,669 --> 00:19:35,520
the orbits of 19 comets and only 19

504
00:19:40,870 --> 00:19:37,679
comets figured out that there's probably

505
00:19:43,190 --> 00:19:40,880
a reservoir of comets out way past the

506
00:19:45,110 --> 00:19:43,200
sun now he didn't get exactly the right

507
00:19:47,830 --> 00:19:45,120
distance but that's the limitations of

508
00:19:49,830 --> 00:19:47,840
the calculations of the time

509
00:19:52,390 --> 00:19:49,840
uh we now know that the what we call the

510
00:19:54,710 --> 00:19:52,400
oort cloud named in honor of janord is a

511
00:19:57,430 --> 00:19:54,720
reservoir of comets a spherical halo of

512
00:19:59,990 --> 00:19:57,440
comets at about a hundred thousand times

513
00:20:02,149 --> 00:20:00,000

further from the sun than the earth

514
00:20:04,390 --> 00:20:02,159
he also didn't realize at the time that

515
00:20:05,590 --> 00:20:04,400
the comets probably didn't actually form

516
00:20:07,190 --> 00:20:05,600
out that far

517
00:20:09,190 --> 00:20:07,200
we now know that they actually formed in

518
00:20:11,350 --> 00:20:09,200
the region of the giant planets and

519
00:20:13,750 --> 00:20:11,360
because of the poles and pushes of

520
00:20:15,669 --> 00:20:13,760
gravity they were thrown out to the oort

521
00:20:17,669 --> 00:20:15,679
cloud about 90 percent of them were lost

522
00:20:19,830 --> 00:20:17,679
from the solar system and about 10 still

523
00:20:22,149 --> 00:20:19,840
live out there that still leaves a lot

524
00:20:24,470 --> 00:20:22,159
of comments that's that's of order

525
00:20:25,669 --> 00:20:24,480
billions and billions as carl sagan

526
00:20:27,270 --> 00:20:25,679
would have said

527
00:20:29,110 --> 00:20:27,280
um

528
00:20:30,230 --> 00:20:29,120
so he figured out that there was this

529
00:20:32,390 --> 00:20:30,240
spherical

530
00:20:34,149 --> 00:20:32,400
halo of comets and that explains their

531
00:20:36,390 --> 00:20:34,159
orbits

532
00:20:38,310 --> 00:20:36,400
about the same time gerard kuiper who

533
00:20:41,190 --> 00:20:38,320
actually wasn't a director of mcdonald

534
00:20:43,350 --> 00:20:41,200
observatory at one point uh

535
00:20:45,430 --> 00:20:43,360
didn't figure out what we now call the

536
00:20:47,510 --> 00:20:45,440
kuiper belt but he said you know it

537
00:20:50,070 --> 00:20:47,520
makes no sense to have all these big

538
00:20:53,430 --> 00:20:50,080

planets and then nothing past the orbit

539
00:20:56,070 --> 00:20:53,440
of neptune well pluto but pluto's tiny

540
00:20:58,390 --> 00:20:56,080
there's got to be more material there

541
00:21:00,830 --> 00:20:58,400
he didn't he wasn't able to follow up on

542
00:21:03,909 --> 00:21:00,840
that but in late

543
00:21:06,710 --> 00:21:03,919
80s people had been worrying about

544
00:21:08,230 --> 00:21:06,720
not only what must be out there but also

545
00:21:10,710 --> 00:21:08,240
that there was a group of comets that

546
00:21:11,990 --> 00:21:10,720
didn't come from random directions but

547
00:21:14,470 --> 00:21:12,000
instead were in the plane of the

548
00:21:16,310 --> 00:21:14,480
ecliptic the same plane as the planets

549
00:21:18,070 --> 00:21:16,320
and so they realized that there must be

550
00:21:21,110 --> 00:21:18,080
another reservoir

551
00:21:23,270 --> 00:21:21,120
starting from neptune going outward

552
00:21:25,990 --> 00:21:23,280
that was in the plane it was a disk of

553
00:21:27,909 --> 00:21:26,000
material and that those were the things

554
00:21:29,430 --> 00:21:27,919
that fed what we call the jupiter family

555
00:21:30,549 --> 00:21:29,440
comets the ones that are in the plane of

556
00:21:32,789 --> 00:21:30,559
the ecliptic

557
00:21:35,029 --> 00:21:32,799
and uh duncan quinn and tremaine who

558
00:21:36,870 --> 00:21:35,039
wrote the seminal paper in 1988

559
00:21:38,630 --> 00:21:36,880
explaining all of that

560
00:21:41,190 --> 00:21:38,640
gave the name of to this to the as the

561
00:21:43,270 --> 00:21:41,200
kuiper belt because it was named after

562
00:21:46,310 --> 00:21:43,280
gerard kuiper who had posited that there

563
00:21:47,350 --> 00:21:46,320

must be material out there

564
00:21:48,950 --> 00:21:47,360
well

565
00:21:51,110 --> 00:21:48,960
what is a comet i've said it's a dirty

566
00:21:54,230 --> 00:21:51,120
snowball but what does that really mean

567
00:21:56,070 --> 00:21:54,240
it means that about 50 percent of the

568
00:21:59,510 --> 00:21:56,080
material in the cometary nuclei is

569
00:22:01,270 --> 00:21:59,520
probably ice and about 50 is is dirt

570
00:22:03,029 --> 00:22:01,280
what do we mean by dirt well same thing

571
00:22:05,510 --> 00:22:03,039
as we mean by dirt on the earth

572
00:22:07,669 --> 00:22:05,520
silicates and and olivines and all these

573
00:22:09,430 --> 00:22:07,679
kinds of things some of them crystalline

574
00:22:10,789 --> 00:22:09,440
some of them amorphous no crystalline

575
00:22:12,870 --> 00:22:10,799
structure

576
00:22:15,430 --> 00:22:12,880
but it's the the ice that

577
00:22:17,669 --> 00:22:15,440
sublimes and carries away this material

578
00:22:20,230 --> 00:22:17,679
and is of interest to us

579
00:22:23,430 --> 00:22:20,240
well when astronomers talk about ice

580
00:22:24,870 --> 00:22:23,440
they don't necessarily mean water ice

581
00:22:26,630 --> 00:22:24,880
some of the ice is water ice and

582
00:22:29,029 --> 00:22:26,640
probably about 80 percent of the ice is

583
00:22:30,789 --> 00:22:29,039
water ice and about 20 percent of the

584
00:22:33,669 --> 00:22:30,799
ice is other things carbon monoxide

585
00:22:34,630 --> 00:22:33,679
carbon dioxide formaldehyde all sorts of

586
00:22:36,549 --> 00:22:34,640
things

587
00:22:37,750 --> 00:22:36,559
uh and it was not the water of course

588
00:22:39,669 --> 00:22:37,760

that the tail of

589
00:22:42,230 --> 00:22:39,679
comet halley was going to bring to the

590
00:22:44,470 --> 00:22:42,240
earth but it was the hydrogen cyanogen

591
00:22:46,870 --> 00:22:44,480
that cyanide that they were really

592
00:22:48,630 --> 00:22:46,880
worried about

593
00:22:50,230 --> 00:22:48,640
so

594
00:22:52,830 --> 00:22:50,240
these are the building blocks of the

595
00:22:55,750 --> 00:22:52,840
outer solar system

596
00:22:59,430 --> 00:22:55,760
and one of the things that we started

597
00:23:01,029 --> 00:22:59,440
realizing as we studied comets was that

598
00:23:03,270 --> 00:23:01,039
the spectra of comets the things that

599
00:23:04,870 --> 00:23:03,280
tell us about the composition were all

600
00:23:06,630 --> 00:23:04,880
relatively similar there was different

601
00:23:09,830 --> 00:23:06,640
amounts of dust but we saw sort of the

602
00:23:12,310 --> 00:23:09,840
same species from one and the other so

603
00:23:13,909 --> 00:23:12,320
back in the 70s several of us started

604
00:23:16,310 --> 00:23:13,919
looking at

605
00:23:18,470 --> 00:23:16,320
what was the detailed composition were

606
00:23:20,710 --> 00:23:18,480
all of them the same or were there some

607
00:23:23,909 --> 00:23:20,720
differences and michael hearn who will

608
00:23:25,750 --> 00:23:23,919
speak later and myself and and um

609
00:23:29,110 --> 00:23:25,760
hi spinrad at

610
00:23:30,950 --> 00:23:29,120
uh lick and uh ray newbern at jpl all

611
00:23:32,950 --> 00:23:30,960
started looking at this and we realized

612
00:23:34,870 --> 00:23:32,960
there were really two groups of comets

613
00:23:37,110 --> 00:23:34,880

they were what we call normal comets

614
00:23:38,070 --> 00:23:37,120
we're very creative with our names

615
00:23:39,909 --> 00:23:38,080
um

616
00:23:41,510 --> 00:23:39,919
and that represents about 70 percent of

617
00:23:43,269 --> 00:23:41,520
the comets and then there were 30

618
00:23:45,430 --> 00:23:43,279
percent of the comets that looked subtly

619
00:23:48,310 --> 00:23:45,440
different they seem to be depleted in

620
00:23:50,950 --> 00:23:48,320
long carbon chain molecules

621
00:23:52,310 --> 00:23:50,960
now what is this telling us about the

622
00:23:53,830 --> 00:23:52,320
differences well we have these two

623
00:23:55,990 --> 00:23:53,840
different reservoirs we have the kuiper

624
00:23:57,190 --> 00:23:56,000
belt and the oort cloud were those

625
00:23:59,190 --> 00:23:57,200
some of them from the kuiper belt and

626
00:24:01,190 --> 00:23:59,200
some from the orc cloud unfortunately

627
00:24:04,470 --> 00:24:01,200
science is never simple

628
00:24:06,870 --> 00:24:04,480
most of the depleted comets are from the

629
00:24:08,390 --> 00:24:06,880
kuiper belt but not all of them and not

630
00:24:10,230 --> 00:24:08,400
all the comets from the kuiper belt are

631
00:24:12,470 --> 00:24:10,240
depleted so that's still one of the

632
00:24:13,909 --> 00:24:12,480
questions that we really have and one of

633
00:24:15,909 --> 00:24:13,919
the reasons we want to understand the

634
00:24:17,350 --> 00:24:15,919
chemistry of comets because

635
00:24:18,870 --> 00:24:17,360
if they were formed in different regions

636
00:24:20,390 --> 00:24:18,880
of the solar system and if we have

637
00:24:22,070 --> 00:24:20,400
different chemistries those are

638
00:24:25,110 --> 00:24:22,080

important clues to the conditions of the

639
00:24:27,430 --> 00:24:25,120
early solar nebula

640
00:24:29,430 --> 00:24:27,440
well the first mission to a comet was

641
00:24:31,750 --> 00:24:29,440
the ice

642
00:24:33,430 --> 00:24:31,760
uh spacecraft that was actually a

643
00:24:35,110 --> 00:24:33,440
spacecraft doing something else and bob

644
00:24:37,110 --> 00:24:35,120
farquhar who will talk after me will

645
00:24:38,870 --> 00:24:37,120
tell you how he thought about

646
00:24:41,750 --> 00:24:38,880
redirecting the spacecraft so we could

647
00:24:43,990 --> 00:24:41,760
go to comet jack of any center

648
00:24:45,590 --> 00:24:44,000
um

649
00:24:46,789 --> 00:24:45,600
so i'm not going to talk much about that

650
00:24:49,269 --> 00:24:46,799
one

651
00:24:52,870 --> 00:24:51,590
oh left out a slide

652
00:24:54,470 --> 00:24:52,880
this shows you the structure of the

653
00:24:57,990 --> 00:24:54,480
outer solar system

654
00:25:00,149 --> 00:24:58,000
um the plane of the ecliptic is

655
00:25:02,470 --> 00:25:00,159
that disc going across the center and

656
00:25:04,549 --> 00:25:02,480
you can see that we have the

657
00:25:06,870 --> 00:25:04,559
uh quiver belt in the middle and then

658
00:25:09,110 --> 00:25:06,880
the oort cloud is this is a halo of

659
00:25:10,310 --> 00:25:09,120
material going around it

660
00:25:12,470 --> 00:25:10,320
so

661
00:25:14,310 --> 00:25:12,480
getting back to missions the first

662
00:25:15,510 --> 00:25:14,320
mission that that brought back an image

663
00:25:17,510 --> 00:25:15,520

of a comet

664
00:25:20,630 --> 00:25:17,520
uh were there were five missions that

665
00:25:23,029 --> 00:25:20,640
went to comet halley in 1986

666
00:25:25,269 --> 00:25:23,039
they were jotto which was a european

667
00:25:26,470 --> 00:25:25,279
space agency mission two missions from

668
00:25:29,190 --> 00:25:26,480
the the

669
00:25:32,710 --> 00:25:29,200
uh soviet union vega one and vega two

670
00:25:34,149 --> 00:25:32,720
and two missions from japan uh susie and

671
00:25:37,269 --> 00:25:34,159
sagagaki

672
00:25:39,190 --> 00:25:37,279
uh the one that got the closest was the

673
00:25:42,070 --> 00:25:39,200
giada mission from from the european

674
00:25:44,470 --> 00:25:42,080
space agency now that comment was going

675
00:25:46,549 --> 00:25:44,480
about 70 kilometers a second past the

676
00:25:49,430 --> 00:25:46,559
comet because comet as i said was going

677
00:25:50,710 --> 00:25:49,440
in the reverse direction from the earth

678
00:25:53,350 --> 00:25:50,720
around the sun

679
00:25:55,909 --> 00:25:53,360
now if you're like me you don't exactly

680
00:25:57,990 --> 00:25:55,919
intuit how fast that is uh i live in

681
00:26:00,149 --> 00:25:58,000
texas and if i were to leave austin

682
00:26:03,110 --> 00:26:00,159
headed for dallas which is 180 miles

683
00:26:04,789 --> 00:26:03,120
away uh going 70 kilometers a second i'd

684
00:26:07,590 --> 00:26:04,799
be there in less than three seconds

685
00:26:09,590 --> 00:26:07,600
three and that's pretty fast

686
00:26:11,350 --> 00:26:09,600
now imagine getting hit by a grain of

687
00:26:13,990 --> 00:26:11,360
sand what that would do to your car

688
00:26:16,230 --> 00:26:14,000

windshield well that spacecraft was hit

689
00:26:17,350 --> 00:26:16,240
by a grain of sand after this picture

690
00:26:19,430 --> 00:26:17,360
was taken

691
00:26:20,470 --> 00:26:19,440
and it caused the spacecraft to start to

692
00:26:22,549 --> 00:26:20,480
tumble

693
00:26:26,230 --> 00:26:22,559
but not before we got these first images

694
00:26:28,230 --> 00:26:26,240
that turned out to be very very critical

695
00:26:29,990 --> 00:26:28,240
this is a nucleus that's about 16

696
00:26:31,430 --> 00:26:30,000
kilometers by eight kilometers by eight

697
00:26:33,110 --> 00:26:31,440
kilometers you can see it's very

698
00:26:34,789 --> 00:26:33,120
irregular in shape there's some

699
00:26:36,630 --> 00:26:34,799
structure to it there's this bright

700
00:26:38,470 --> 00:26:36,640
stuff coming off of it those are jets

701
00:26:43,510 --> 00:26:38,480
that's the beginning of the

702
00:26:47,510 --> 00:26:45,190
we thought that comets because they

703
00:26:49,909 --> 00:26:47,520
would ice would be bright but it turns

704
00:26:51,830 --> 00:26:49,919
out no they only reflect about four

705
00:26:53,430 --> 00:26:51,840
percent of the light that gets to them

706
00:26:55,190 --> 00:26:53,440
and that was a bit of a surprise that

707
00:26:56,549 --> 00:26:55,200
only a spacecraft mission would really

708
00:26:57,590 --> 00:26:56,559
tell us

709
00:26:59,510 --> 00:26:57,600
uh

710
00:27:01,510 --> 00:26:59,520
we act the the

711
00:27:02,789 --> 00:27:01,520
the spacecraft was actually targeted on

712
00:27:04,789 --> 00:27:02,799
the brightest

713
00:27:06,630 --> 00:27:04,799

object and and had it actually succeeded

714
00:27:08,070 --> 00:27:06,640
in getting too close to the approach it

715
00:27:09,350 --> 00:27:08,080
would have been imaging the jets and not

716
00:27:10,710 --> 00:27:09,360
the nucleus which would have been

717
00:27:12,549 --> 00:27:10,720
unfortunate

718
00:27:15,350 --> 00:27:12,559
uh we learned that the shape is

719
00:27:18,310 --> 00:27:15,360
extremely irregular we learned for the

720
00:27:20,470 --> 00:27:18,320
first time the size which

721
00:27:22,389 --> 00:27:20,480
they're much smaller than we thought

722
00:27:23,669 --> 00:27:22,399
they were uh but

723
00:27:26,710 --> 00:27:23,679
bigger than would have been if they'd

724
00:27:28,870 --> 00:27:26,720
been really bright uh we discovered for

725
00:27:31,029 --> 00:27:28,880
that fred whipple was actually correct

726
00:27:32,630 --> 00:27:31,039
they are dirty snowballs and it was the

727
00:27:34,549 --> 00:27:32,640
giato mission with its mass

728
00:27:36,310 --> 00:27:34,559
spectrometers that first measured the

729
00:27:37,590 --> 00:27:36,320
fact that about 80 percent of the isis

730
00:27:39,110 --> 00:27:37,600
was water

731
00:27:41,110 --> 00:27:39,120
now we thought that was the way it was

732
00:27:42,950 --> 00:27:41,120
going to be but

733
00:27:44,710 --> 00:27:42,960
that was the confirmation of what we had

734
00:27:46,630 --> 00:27:44,720
believed

735
00:27:49,269 --> 00:27:46,640
so this was a critical mission in our

736
00:27:51,669 --> 00:27:49,279
understanding of

737
00:27:53,750 --> 00:27:51,679
what comets look like

738
00:27:56,710 --> 00:27:53,760

but obviously these aren't the best

739
00:27:58,950 --> 00:27:56,720
images it was 1986 after all and

740
00:28:00,950 --> 00:27:58,960
comments and cameras on spacecraft

741
00:28:03,669 --> 00:28:00,960
weren't as sophisticated we were flying

742
00:28:06,710 --> 00:28:03,679
extremely quickly past it and

743
00:28:09,110 --> 00:28:06,720
didn't know what to expect

744
00:28:11,510 --> 00:28:09,120
so nasa had a mission called the deep

745
00:28:13,430 --> 00:28:11,520
space one mission which was actually a

746
00:28:14,470 --> 00:28:13,440
technology demonstration mission trying

747
00:28:16,950 --> 00:28:14,480
to

748
00:28:18,389 --> 00:28:16,960
demonstrate uh solar electric propulsion

749
00:28:19,750 --> 00:28:18,399
and it was going to go past a comet

750
00:28:22,389 --> 00:28:19,760
borreli

751
00:28:24,630 --> 00:28:22,399
and this is the image that they took

752
00:28:26,710 --> 00:28:24,640
and it looks very different

753
00:28:29,190 --> 00:28:26,720
you don't see obvious

754
00:28:30,710 --> 00:28:29,200
jets coming off of it it's very very

755
00:28:32,710 --> 00:28:30,720
elongated this is probably the most

756
00:28:34,870 --> 00:28:32,720
elongated object we know it's all

757
00:28:37,430 --> 00:28:34,880
alternately called the uh bowling ball

758
00:28:39,110 --> 00:28:37,440
bowling club or the foot

759
00:28:42,230 --> 00:28:39,120
um

760
00:28:46,230 --> 00:28:42,240
it rotates around the narrowest point

761
00:28:47,750 --> 00:28:46,240
which is not an impossible thing but not

762
00:28:49,909 --> 00:28:47,760
not necessarily what we would have

763
00:28:51,750 --> 00:28:49,919

thought of and it has a jet going right

764
00:28:54,310 --> 00:28:51,760
off the pole which

765
00:28:56,549 --> 00:28:54,320
was a little bit of a surprise

766
00:28:57,430 --> 00:28:56,559
only a very small part of the surface is

767
00:28:59,750 --> 00:28:57,440
active

768
00:29:02,230 --> 00:28:59,760
you can see that it varies in

769
00:29:04,070 --> 00:29:02,240
color and and shape

770
00:29:06,950 --> 00:29:04,080
uh color at various places and has

771
00:29:09,669 --> 00:29:06,960
smoother and and less smooth regions uh

772
00:29:12,070 --> 00:29:09,679
the variation in in the the darkness and

773
00:29:14,070 --> 00:29:12,080
lightness is actually exaggerated in

774
00:29:15,830 --> 00:29:14,080
this picture it's still the brightest

775
00:29:18,070 --> 00:29:15,840
part is only reflecting about five

776
00:29:19,110 --> 00:29:18,080
percent of the light that impinges upon

777
00:29:20,710 --> 00:29:19,120
it

778
00:29:23,110 --> 00:29:20,720
uh

779
00:29:25,430 --> 00:29:23,120
what we were also able to do with not so

780
00:29:27,190 --> 00:29:25,440
much the spacecraft images but because

781
00:29:29,909 --> 00:29:27,200
this comet has

782
00:29:31,669 --> 00:29:29,919
now a known pole orientation and we know

783
00:29:34,149 --> 00:29:31,679
there's a jet coming off this pole we

784
00:29:36,870 --> 00:29:34,159
were able to look at the jet forces on

785
00:29:38,149 --> 00:29:36,880
the orbit of the comet and derive a

786
00:29:40,950 --> 00:29:38,159
density

787
00:29:43,909 --> 00:29:40,960
and confirm that this comet is extremely

788
00:29:46,149 --> 00:29:43,919

low density if you had an ice cube solid

789
00:29:48,630 --> 00:29:46,159
ice cube from earth you'd have a density

790
00:29:51,029 --> 00:29:48,640
of one gram per centimeter cubed well

791
00:29:53,590 --> 00:29:51,039
this comet has a density that's probably

792
00:29:56,230 --> 00:29:53,600
half of that so that tells us if it's

793
00:29:58,630 --> 00:29:56,240
ice and dirt and dirt is actually more

794
00:30:01,269 --> 00:29:58,640
dense than water

795
00:30:04,630 --> 00:30:01,279
that there must be lots of open regions

796
00:30:07,669 --> 00:30:04,640
there must be lots of porous material

797
00:30:11,029 --> 00:30:07,679
we also see smooth features in this and

798
00:30:12,710 --> 00:30:11,039
those were a mystery what those could be

799
00:30:14,870 --> 00:30:12,720
probably ice flows but we didn't know a

800
00:30:17,110 --> 00:30:14,880
lot about it

801
00:30:19,110 --> 00:30:17,120
well meanwhile there was another mission

802
00:30:21,269 --> 00:30:19,120
going stardust

803
00:30:23,350 --> 00:30:21,279
and that was a mission to go past a

804
00:30:25,990 --> 00:30:23,360
comet build 2

805
00:30:27,590 --> 00:30:26,000
and bring back samples which were then

806
00:30:28,870 --> 00:30:27,600
landed in

807
00:30:30,789 --> 00:30:28,880
utah

808
00:30:32,630 --> 00:30:30,799
and brought into the lab at johnson

809
00:30:34,389 --> 00:30:32,640
space center and laboratories around the

810
00:30:36,950 --> 00:30:34,399
world have analyzed the dust brought

811
00:30:38,470 --> 00:30:36,960
back from it it's just dust collected

812
00:30:40,389 --> 00:30:38,480
now first of all they took pictures you

813
00:30:42,470 --> 00:30:40,399

always got to take pictures and looking

814
00:30:45,350 --> 00:30:42,480
at this it looks very different from

815
00:30:46,389 --> 00:30:45,360
comet borelli it's round or more or less

816
00:30:47,190 --> 00:30:46,399
round

817
00:30:49,750 --> 00:30:47,200
uh

818
00:30:53,430 --> 00:30:49,760
it also has these nice

819
00:30:57,430 --> 00:30:53,440
dimples in it soft craters um

820
00:30:59,430 --> 00:30:57,440
one of them was labeled right foot uh

821
00:31:01,509 --> 00:30:59,440
um

822
00:31:04,470 --> 00:31:01,519
and uh

823
00:31:07,909 --> 00:31:04,480
this was this was something that again

824
00:31:10,470 --> 00:31:07,919
didn't show lots of jet structure

825
00:31:12,870 --> 00:31:10,480
it was small it was even smaller than

826
00:31:13,669 --> 00:31:12,880
the previous ones we looked at

827
00:31:16,870 --> 00:31:13,679
but

828
00:31:18,870 --> 00:31:16,880
it we were able to collect bits of dust

829
00:31:20,710 --> 00:31:18,880
in a composition called aerogel a

830
00:31:21,590 --> 00:31:20,720
catcher called aerogel and bring those

831
00:31:24,630 --> 00:31:21,600
back

832
00:31:26,870 --> 00:31:24,640
landed them in utah in 2006 and those

833
00:31:28,310 --> 00:31:26,880
are being analyzed all at labs all over

834
00:31:31,830 --> 00:31:28,320
the world

835
00:31:33,750 --> 00:31:31,840
now this is a montage of images and if

836
00:31:35,509 --> 00:31:33,760
you stretch the images in other words

837
00:31:37,590 --> 00:31:35,519
increase the contrast you can see in

838
00:31:40,070 --> 00:31:37,600

that bottom middle picture that there

839
00:31:41,590 --> 00:31:40,080
really are jets but they are very very

840
00:31:42,870 --> 00:31:41,600
faint jets

841
00:31:44,470 --> 00:31:42,880
and that's one of the things we've

842
00:31:46,710 --> 00:31:44,480
learned with this mission not only do

843
00:31:48,950 --> 00:31:46,720
all comets look different but very

844
00:31:52,710 --> 00:31:48,960
little of the surface is active when we

845
00:31:54,070 --> 00:31:52,720
see a comment like comet hail bop or

846
00:31:55,830 --> 00:31:54,080
comet west

847
00:31:57,430 --> 00:31:55,840
we think that

848
00:31:59,269 --> 00:31:57,440
every bit of it must be putting out

849
00:32:01,110 --> 00:31:59,279
material but when we look at comets

850
00:32:03,350 --> 00:32:01,120
these little comets we find that very

851
00:32:04,549 --> 00:32:03,360
little of their surface is active

852
00:32:06,230 --> 00:32:04,559
and so

853
00:32:08,470 --> 00:32:06,240
something has sealed them over probably

854
00:32:09,669 --> 00:32:08,480
the dirt that has fallen back upon the

855
00:32:11,190 --> 00:32:09,679
surface

856
00:32:13,269 --> 00:32:11,200
now

857
00:32:15,990 --> 00:32:13,279
that in itself is an interesting

858
00:32:18,070 --> 00:32:16,000
question why are some comets very active

859
00:32:19,029 --> 00:32:18,080
and some comets left active

860
00:32:20,950 --> 00:32:19,039
and

861
00:32:22,950 --> 00:32:20,960
michael hernan will talk about the the

862
00:32:25,430 --> 00:32:22,960
epoxy mission coming up and it's going

863
00:32:27,509 --> 00:32:25,440

to a comet that's as small as field 2

864
00:32:29,430 --> 00:32:27,519
but is very very active or we think it

865
00:32:31,029 --> 00:32:29,440
is we'll find out

866
00:32:33,029 --> 00:32:31,039
um with

867
00:32:34,310 --> 00:32:33,039
bill 2 we find that the craters are very

868
00:32:36,710 --> 00:32:34,320
soft and

869
00:32:39,029 --> 00:32:36,720
weathered and that's kind of what we

870
00:32:41,430 --> 00:32:39,039
would expect out of craters that are

871
00:32:42,950 --> 00:32:41,440
caused by outflowing material and i'll

872
00:32:44,789 --> 00:32:42,960
get back to the point about craters

873
00:32:46,470 --> 00:32:44,799
being soft when i get to the next

874
00:32:48,149 --> 00:32:46,480
mission

875
00:32:50,230 --> 00:32:48,159
i mentioned that we have samples in the

876
00:32:52,870 --> 00:32:50,240
lab and those samples have been very

877
00:32:54,470 --> 00:32:52,880
important to understanding the materials

878
00:32:56,630 --> 00:32:54,480
we find that the materials are

879
00:32:58,470 --> 00:32:56,640
chemically heterogeneous

880
00:33:00,070 --> 00:32:58,480
so they're mixed up some of the

881
00:33:01,990 --> 00:33:00,080
particles show that they've been in very

882
00:33:03,909 --> 00:33:02,000
high temperatures i said comets formed

883
00:33:05,509 --> 00:33:03,919
in the outer solar system but some of

884
00:33:06,549 --> 00:33:05,519
the material must have formed close to

885
00:33:08,230 --> 00:33:06,559
the sun

886
00:33:09,909 --> 00:33:08,240
so there's been a lot of mixing in the

887
00:33:11,669 --> 00:33:09,919
solar system that we learn about by

888
00:33:13,110 --> 00:33:11,679

looking at comets

889
00:33:14,310 --> 00:33:13,120
different fragments show very different

890
00:33:16,549 --> 00:33:14,320
chemistries

891
00:33:19,110 --> 00:33:16,559
some of the material has been

892
00:33:21,830 --> 00:33:19,120
identified as being coming from prior to

893
00:33:23,430 --> 00:33:21,840
the solar nebula forming

894
00:33:26,389 --> 00:33:23,440
some of those grains are simple and

895
00:33:28,389 --> 00:33:26,399
single others are fluffy aggregates and

896
00:33:30,950 --> 00:33:28,399
some of them are missing any evidence of

897
00:33:32,710 --> 00:33:30,960
water so that's pretty interesting

898
00:33:37,669 --> 00:33:32,720
and as i mentioned there are crystalline

899
00:33:42,789 --> 00:33:39,830
okay so the next mission was deep impact

900
00:33:45,269 --> 00:33:42,799
july 4th 2005 we had fireworks this

901
00:33:46,789 --> 00:33:45,279
mission which mike will talk more about

902
00:33:48,549 --> 00:33:46,799
um

903
00:33:50,230 --> 00:33:48,559
two spacecraft one being carried by the

904
00:33:52,710 --> 00:33:50,240
other the little guy was put in the way

905
00:33:54,389 --> 00:33:52,720
of comet temple one and temple one ran

906
00:33:56,470 --> 00:33:54,399
into it

907
00:33:57,669 --> 00:33:56,480
the spacecraft didn't survive or well it

908
00:33:59,590 --> 00:33:57,679
might have it's

909
00:34:01,590 --> 00:33:59,600
embedded well in and the flyby

910
00:34:04,950 --> 00:34:01,600
spacecraft took images as it went past

911
00:34:06,549 --> 00:34:04,960
and this is an image of the comet and

912
00:34:08,550 --> 00:34:06,559
doesn't look like very much like a comet

913
00:34:10,710 --> 00:34:08,560

it looks like a rocky body

914
00:34:13,030 --> 00:34:10,720
uh you see there's an arrow coming from

915
00:34:14,790 --> 00:34:13,040
the left pointing to a smooth region

916
00:34:16,550 --> 00:34:14,800
everybody's first reaction was oh well

917
00:34:17,750 --> 00:34:16,560
that's a low spot and it filled in from

918
00:34:20,629 --> 00:34:17,760
icy

919
00:34:22,629 --> 00:34:20,639
slush and it's a flow no it's a high

920
00:34:23,829 --> 00:34:22,639
spot it's a scarp and that's pretty

921
00:34:25,430 --> 00:34:23,839
unusual

922
00:34:27,190 --> 00:34:25,440
right above the

923
00:34:28,869 --> 00:34:27,200
arrow on the bottom left which is where

924
00:34:32,149 --> 00:34:28,879
the impact crater would be if it could

925
00:34:33,589 --> 00:34:32,159
be seen um is a very sharp crater i

926
00:34:36,470 --> 00:34:33,599
remember i talked about in build two

927
00:34:37,750 --> 00:34:36,480
there was these round features well

928
00:34:39,990 --> 00:34:37,760
uh

929
00:34:41,589 --> 00:34:40,000
the craters on temple one some of them

930
00:34:43,750 --> 00:34:41,599
are extremely sharp we would have said

931
00:34:45,829 --> 00:34:43,760
those were impact craters but we know

932
00:34:48,230 --> 00:34:45,839
that as the comet sublimes it pulls off

933
00:34:49,750 --> 00:34:48,240
material and shouldn't leave behind

934
00:34:50,710 --> 00:34:49,760
sharp craters

935
00:34:52,629 --> 00:34:50,720
so

936
00:34:54,310 --> 00:34:52,639
we're eagerly waiting for stardust next

937
00:34:56,950 --> 00:34:54,320
to go by and tell us what the crater

938
00:35:01,510 --> 00:34:56,960

that deep impact made looks like

939
00:35:06,150 --> 00:35:03,829
in this image you see some colored

940
00:35:08,470 --> 00:35:06,160
regions these blue colored regions this

941
00:35:10,790 --> 00:35:08,480
was this was taken with an infrared

942
00:35:12,950 --> 00:35:10,800
spectrograph those are the regions that

943
00:35:14,950 --> 00:35:12,960
show ice on the surface so even though i

944
00:35:16,390 --> 00:35:14,960
told you the comet is a dirty snowball

945
00:35:19,670 --> 00:35:16,400
we see almost

946
00:35:21,910 --> 00:35:19,680
no regions that we can attribute to ice

947
00:35:26,870 --> 00:35:21,920
so only small regions of the surface are

948
00:35:30,630 --> 00:35:29,030
um

949
00:35:32,790 --> 00:35:30,640
so

950
00:35:33,829 --> 00:35:32,800
in the near future we have two missions

951
00:35:35,829 --> 00:35:33,839
coming up

952
00:35:38,470 --> 00:35:35,839
which which we talked about by both mike

953
00:35:41,589 --> 00:35:38,480
and joe uh my karen's going to tell you

954
00:35:42,950 --> 00:35:41,599
about epoxy which is the deep impact

955
00:35:44,950 --> 00:35:42,960
spacecraft

956
00:35:47,589 --> 00:35:44,960
which is being retargeted to comet

957
00:35:50,310 --> 00:35:47,599
hartley 2 and that will be in

958
00:35:51,589 --> 00:35:50,320
that flyby will be on on november 4th of

959
00:35:53,109 --> 00:35:51,599
this year

960
00:35:54,550 --> 00:35:53,119
uh

961
00:35:56,390 --> 00:35:54,560
then joe vaverka will talk about the

962
00:35:58,230 --> 00:35:56,400
stardust next

963
00:35:59,510 --> 00:35:58,240

spacecraft which is a return to temple

964
00:36:01,589 --> 00:35:59,520
one and one of the things they want to

965
00:36:04,069 --> 00:36:01,599
do is search for the crater

966
00:36:05,990 --> 00:36:04,079
all these things tell us about

967
00:36:08,310 --> 00:36:06,000
the pieces of the comet

968
00:36:09,910 --> 00:36:08,320
are they agglomerations of big blocks

969
00:36:11,510 --> 00:36:09,920
that we can identify

970
00:36:13,349 --> 00:36:11,520
how much structure do we have the

971
00:36:15,589 --> 00:36:13,359
material that came off when the impact

972
00:36:17,829 --> 00:36:15,599
occurred was extremely low density it

973
00:36:19,430 --> 00:36:17,839
was very very fine like talcum powder

974
00:36:20,390 --> 00:36:19,440
although it was ice

975
00:36:22,230 --> 00:36:20,400
um

976
00:36:23,750 --> 00:36:22,240
the chemistry looked the same all the

977
00:36:25,589 --> 00:36:23,760
way through

978
00:36:28,470 --> 00:36:25,599
what is this telling us about the

979
00:36:29,990 --> 00:36:28,480
origins of our solar system

980
00:36:31,750 --> 00:36:30,000
and then there's another mission on its

981
00:36:33,430 --> 00:36:31,760
way which will get which is already on

982
00:36:35,270 --> 00:36:33,440
its way and we'll get there in 2014 and

983
00:36:37,270 --> 00:36:35,280
that's a european space agency mission

984
00:36:39,030 --> 00:36:37,280
called rosetta which will have a little

985
00:36:43,030 --> 00:36:39,040
lander that's the guy in the top called

986
00:36:44,710 --> 00:36:43,040
filet and it has a full instrument suite

987
00:36:46,470 --> 00:36:44,720
and it will the next mission will tell

988
00:36:48,390 --> 00:36:46,480

us about the chemistry because it has a

989
00:36:50,069 --> 00:36:48,400
mass spectrometer board

990
00:36:52,550 --> 00:36:50,079
so what do we still need to know what

991
00:36:54,310 --> 00:36:52,560
are we trying to understand because if

992
00:36:56,310 --> 00:36:54,320
we want to understand the origins of our

993
00:36:58,630 --> 00:36:56,320
solar system we need to know more about

994
00:37:00,310 --> 00:36:58,640
comets we still need to know their mass

995
00:37:03,190 --> 00:37:00,320
nobody has measured the mass yet of a

996
00:37:04,710 --> 00:37:03,200
comet because on these fast flybys

997
00:37:06,870 --> 00:37:04,720
you just don't get enough gravitational

998
00:37:08,630 --> 00:37:06,880
influence these are little guys

999
00:37:11,510 --> 00:37:08,640
we haven't really pinned down the

1000
00:37:14,150 --> 00:37:11,520
density we have factors of many be

1001
00:37:16,230 --> 00:37:14,160
in our understanding we want to know are

1002
00:37:19,349 --> 00:37:16,240
comets rubble piles or are they

1003
00:37:21,030 --> 00:37:19,359
assemblages of bigger building blocks

1004
00:37:23,670 --> 00:37:21,040
we want to understand the detailed

1005
00:37:26,230 --> 00:37:23,680
chemistry the comparison of the

1006
00:37:28,069 --> 00:37:26,240
typical comets and the depleted comets

1007
00:37:29,829 --> 00:37:28,079
and find out are those

1008
00:37:32,390 --> 00:37:29,839
chemically very similar or they're

1009
00:37:33,829 --> 00:37:32,400
really structural differences

1010
00:37:35,670 --> 00:37:33,839
we would like to be able to measure

1011
00:37:38,390 --> 00:37:35,680
species that you can't measure with

1012
00:37:39,190 --> 00:37:38,400
ground-based observations

1013
00:37:41,430 --> 00:37:39,200

uh

1014
00:37:43,750 --> 00:37:41,440
we want to change look at how the

1015
00:37:46,069 --> 00:37:43,760
morphology of the comet changes during

1016
00:37:49,670 --> 00:37:46,079
an orbital passage so stardust next

1017
00:37:50,790 --> 00:37:49,680
we'll go past comet temple one one orbit

1018
00:37:52,950 --> 00:37:50,800
after it

1019
00:37:56,710 --> 00:37:52,960
the impact and we will be able to tell

1020
00:37:58,870 --> 00:37:56,720
not only is there a crater we can find

1021
00:38:01,030 --> 00:37:58,880
but what else has changed in the comet

1022
00:38:01,990 --> 00:38:01,040
is that crater that was so sharp still

1023
00:38:04,870 --> 00:38:02,000
there

1024
00:38:07,910 --> 00:38:04,880
uh is that scarp that we see changed at

1025
00:38:09,589 --> 00:38:07,920
all how do things change with time

1026
00:38:12,390 --> 00:38:09,599
uh

1027
00:38:13,589 --> 00:38:12,400
we want to know why some comets are so

1028
00:38:15,829 --> 00:38:13,599
are active over so little of their

1029
00:38:18,630 --> 00:38:15,839
surface and others over most of their

1030
00:38:19,990 --> 00:38:18,640
surface so going to hartley 2 what's it

1031
00:38:21,510 --> 00:38:20,000
going to look like is it going to be

1032
00:38:23,750 --> 00:38:21,520
dramatically different is it going to

1033
00:38:25,670 --> 00:38:23,760
have stuff coming out all over or is it

1034
00:38:26,710 --> 00:38:25,680
going to be the same

1035
00:38:28,950 --> 00:38:26,720
and

1036
00:38:31,430 --> 00:38:28,960
what drives the activity what causes

1037
00:38:32,790 --> 00:38:31,440
those jets to come off do they come off

1038
00:38:38,550 --> 00:38:32,800

out of

1039
00:38:40,630 --> 00:38:38,560
soft air

1040
00:38:42,870 --> 00:38:40,640
cones of mater soft

1041
00:38:44,710 --> 00:38:42,880
regions of material so all of those

1042
00:38:47,430 --> 00:38:44,720
things are things that we will answer in

1043
00:38:49,349 --> 00:38:47,440
the next four or five years and with

1044
00:38:50,950 --> 00:38:49,359
many missions hopefully in the past in

1045
00:38:53,910 --> 00:38:50,960
the future

1046
00:38:55,829 --> 00:38:53,920
we hope sometime in nasa's future we

1047
00:38:59,109 --> 00:38:55,839
will actually even bring back samples

1048
00:39:01,670 --> 00:38:59,119
the icy portions as ice to tell us about

1049
00:39:03,430 --> 00:39:01,680
the structure of the comet nucleus

1050
00:39:12,230 --> 00:39:03,440
and i think that's about it so any

1051
00:39:12,240 --> 00:39:18,150
okay

1052
00:39:18,160 --> 00:39:29,349
regenerate in what sense build up

1053
00:39:34,630 --> 00:39:30,470
no

1054
00:39:36,790 --> 00:39:34,640
have the leftover debris that would

1055
00:39:38,470 --> 00:39:36,800
allow them to add material now some of

1056
00:39:40,390 --> 00:39:38,480
the material that hasn't succeeded in

1057
00:39:42,069 --> 00:39:40,400
fully getting away

1058
00:39:44,390 --> 00:39:42,079
will fall back on the surface mostly

1059
00:39:46,390 --> 00:39:44,400
that's the dirt part and that dirt part

1060
00:39:47,910 --> 00:39:46,400
will actually end up sealing up some of

1061
00:39:53,270 --> 00:39:47,920
it and that's part of the explanation of

1062
00:39:59,349 --> 00:39:56,550
oh does anyone have any idea as to what

1063
00:40:01,030 --> 00:39:59,359

the original population of comets might

1064
00:40:03,349 --> 00:40:01,040
have been at the beginning of the solar

1065
00:40:04,790 --> 00:40:03,359
system if they're disappearing

1066
00:40:06,150 --> 00:40:04,800
at the ones that we've seen about a

1067
00:40:07,270 --> 00:40:06,160
thousand a year

1068
00:40:08,950 --> 00:40:07,280
right

1069
00:40:11,510 --> 00:40:08,960
do we have any idea what the original

1070
00:40:13,910 --> 00:40:11,520
population might have been well we

1071
00:40:17,030 --> 00:40:13,920
believe that what what is left of the

1072
00:40:22,829 --> 00:40:17,040
population is a 10 of the original and

1073
00:40:26,870 --> 00:40:25,750
uh a hundred thousand million billion

1074
00:40:28,150 --> 00:40:26,880
right now

1075
00:40:29,829 --> 00:40:28,160
so

1076
00:40:31,510 --> 00:40:29,839
a hundred times that

1077
00:40:33,750 --> 00:40:31,520
it's a lot

1078
00:40:34,950 --> 00:40:33,760
but that's the ones that were not

1079
00:40:36,950 --> 00:40:34,960
already

1080
00:40:38,390 --> 00:40:36,960
incorporated into the planets now a

1081
00:40:40,309 --> 00:40:38,400
large fraction of them had to have been

1082
00:40:41,190 --> 00:40:40,319
incorporated into the planets

1083
00:40:51,190 --> 00:40:41,200
so

1084
00:40:53,990 --> 00:40:52,550
is there any material

1085
00:40:56,309 --> 00:40:54,000
on why there's so much water

1086
00:40:57,829 --> 00:40:56,319
concentration in the commons

1087
00:40:58,870 --> 00:40:57,839
water tends to be a pretty rare and

1088
00:41:00,630 --> 00:40:58,880

precious

1089
00:41:04,150 --> 00:41:00,640
element

1090
00:41:08,710 --> 00:41:06,790
yeah well the most dominant material in

1091
00:41:11,030 --> 00:41:08,720
the universe is hydrogen

1092
00:41:13,750 --> 00:41:11,040
and hydrogen will bond to lots of things

1093
00:41:15,910 --> 00:41:13,760
oxygen is also pretty common

1094
00:41:17,750 --> 00:41:15,920
so when you're at the right temperature

1095
00:41:20,790 --> 00:41:17,760
you get water out of it it's it's a

1096
00:41:23,750 --> 00:41:20,800
pretty common thing to to hydrogenate

1097
00:41:25,750 --> 00:41:23,760
any material and so you get water out of

1098
00:41:28,950 --> 00:41:25,760
it now it turns out that the point in

1099
00:41:31,670 --> 00:41:28,960
the solar system where water ice can be

1100
00:41:34,230 --> 00:41:31,680
stable is out past jupiter's orbit

1101
00:41:38,550 --> 00:41:34,240
and we call that the snow line basically

1102
00:41:40,069 --> 00:41:38,560
and so as the the sun uh formed uh and

1103
00:41:41,270 --> 00:41:40,079
the material in the solar nebula started

1104
00:41:42,870 --> 00:41:41,280
to cool

1105
00:41:45,030 --> 00:41:42,880
it was natural that the outer part of

1106
00:41:46,950 --> 00:41:45,040
the solar system the the

1107
00:41:48,710 --> 00:41:46,960
planetesimals that were left over were

1108
00:41:49,910 --> 00:41:48,720
the comets and in the inner part it was

1109
00:41:56,950 --> 00:41:49,920
the rocky bodies and it was the

1110
00:42:11,270 --> 00:42:05,670
thank you

1111
00:42:14,470 --> 00:42:11,280
now ladies and gentlemen we're going to

1112
00:42:18,309 --> 00:42:14,480
change the format here

1113
00:42:22,230 --> 00:42:18,319

first we're going to have dr green

1114
00:42:26,309 --> 00:42:24,150
and it's important that we do it this

1115
00:42:27,589 --> 00:42:26,319
way because the next individual is

1116
00:42:30,710 --> 00:42:27,599
coming up

1117
00:42:33,109 --> 00:42:30,720
to really put things in context with his

1118
00:42:35,589 --> 00:42:33,119
incredible history and accomplishments

1119
00:42:38,309 --> 00:42:35,599
we have to do it in a talk show setting

1120
00:42:40,950 --> 00:42:38,319
because the personal stories

1121
00:42:43,829 --> 00:42:40,960
make even the history come out

1122
00:42:45,670 --> 00:42:43,839
life in live and living color and this

1123
00:42:47,910 --> 00:42:45,680
individual that will be joining jim is

1124
00:42:49,829 --> 00:42:47,920
dr robert farquhar

1125
00:42:52,150 --> 00:42:49,839
he's executive

1126
00:42:55,109 --> 00:42:52,160
for space exploration kinetics

1127
00:42:57,030 --> 00:42:55,119
incorporated in tempe arizona his phds

1128
00:42:59,430 --> 00:42:57,040
from stanford

1129
00:43:01,829 --> 00:42:59,440
masters from engineering and at ucla

1130
00:43:03,510 --> 00:43:01,839
from ucla and his bs from

1131
00:43:05,349 --> 00:43:03,520
university of illinois he has an

1132
00:43:08,069 --> 00:43:05,359
incredible history

1133
00:43:10,630 --> 00:43:08,079
of comets spanning the 25 years that

1134
00:43:13,510 --> 00:43:10,640
we've been talking about here

1135
00:43:14,390 --> 00:43:13,520
so we're going to set the stage they're

1136
00:43:17,829 --> 00:43:14,400
going to

1137
00:43:19,910 --> 00:43:17,839
join here up on the uh coffee table and

1138
00:43:22,870 --> 00:43:19,920

uh this is live television so i have to

1139
00:43:25,510 --> 00:43:22,880
warn you guys about dr farquhar he's a

1140
00:43:28,630 --> 00:43:26,710
so

1141
00:43:30,230 --> 00:43:28,640
he he was entertaining us all all

1142
00:43:33,349 --> 00:43:30,240
morning so

1143
00:43:35,030 --> 00:43:33,359
bob you know keep it clean

1144
00:43:37,349 --> 00:43:35,040
live television

1145
00:43:39,670 --> 00:43:37,359
but ladies and gentlemen uh it is an

1146
00:43:41,349 --> 00:43:39,680
honor that i talking with him and just

1147
00:43:43,510 --> 00:43:41,359
listen to his stories

1148
00:43:50,950 --> 00:43:43,520
and please welcome dr jim green and dr

1149
00:43:55,829 --> 00:43:53,030
all right sit down here

1150
00:43:57,589 --> 00:43:55,839
all right well thank you very much

1151
00:43:59,750 --> 00:43:57,599
thank you duane

1152
00:44:02,550 --> 00:43:59,760
uh we'll see if i can come up with any

1153
00:44:04,950 --> 00:44:02,560
good jokes i'm not sure about that

1154
00:44:06,230 --> 00:44:04,960
it's the stories we want oh okay we want

1155
00:44:08,150 --> 00:44:06,240
stories

1156
00:44:10,630 --> 00:44:08,160
are you gonna wait we haven't really

1157
00:44:12,950 --> 00:44:10,640
rehearsed this very well so this is kind

1158
00:44:14,230 --> 00:44:12,960
of ad-libbed but you'll get the general

1159
00:44:16,790 --> 00:44:14,240
idea

1160
00:44:19,190 --> 00:44:16,800
i have a nice presentation that i was

1161
00:44:20,950 --> 00:44:19,200
having for a seminar setting but that's

1162
00:44:23,270 --> 00:44:20,960
not what we have here

1163
00:44:24,150 --> 00:44:23,280

so we'll have to wing it a little bit

1164
00:44:25,990 --> 00:44:24,160
and

1165
00:44:27,510 --> 00:44:26,000
figure it out so let's start at the

1166
00:44:29,109 --> 00:44:27,520
beginning

1167
00:44:31,030 --> 00:44:29,119
in the sense that

1168
00:44:32,710 --> 00:44:31,040
you'd been

1169
00:44:34,710 --> 00:44:32,720
at ucla

1170
00:44:36,470 --> 00:44:34,720
you'd been studying

1171
00:44:38,230 --> 00:44:36,480
orbit dynamics

1172
00:44:40,470 --> 00:44:38,240
and uh you'd written an interesting

1173
00:44:42,870 --> 00:44:40,480
thesis that's uh that's really set the

1174
00:44:44,309 --> 00:44:42,880
stage for your life and a lot of our

1175
00:44:45,829 --> 00:44:44,319
future missions why don't you tell us a

1176
00:44:48,309 --> 00:44:45,839
little bit about that bob well that was

1177
00:44:50,390 --> 00:44:48,319
a terrible thesis actually i'm not proud

1178
00:44:52,470 --> 00:44:50,400
of it at all

1179
00:44:54,950 --> 00:44:52,480
but it did give me my master's degree

1180
00:44:56,950 --> 00:44:54,960
from ucla

1181
00:44:59,750 --> 00:44:56,960
that was about

1182
00:45:02,470 --> 00:44:59,760
preliminary considerations for placing a

1183
00:45:04,790 --> 00:45:02,480
spacecraft at a libration point

1184
00:45:06,710 --> 00:45:04,800
okay then uh but what's the liberation

1185
00:45:09,109 --> 00:45:06,720
point well i'm not going to talk about

1186
00:45:11,430 --> 00:45:09,119
that yet we're not there yet

1187
00:45:13,190 --> 00:45:11,440
you're getting way ahead of my story

1188
00:45:15,270 --> 00:45:13,200

uh but uh

1189
00:45:17,109 --> 00:45:15,280
let's see i was working on that thesis

1190
00:45:19,270 --> 00:45:17,119
while i was at marshall space flight

1191
00:45:20,950 --> 00:45:19,280
center in 1960

1192
00:45:22,309 --> 00:45:20,960
i was supposed to be working on the

1193
00:45:24,950 --> 00:45:22,319
first stage

1194
00:45:26,710 --> 00:45:24,960
of the saturn v rocket

1195
00:45:28,150 --> 00:45:26,720
and i worked for a couple days on that

1196
00:45:30,069 --> 00:45:28,160
but most of the time i worked on my

1197
00:45:32,150 --> 00:45:30,079
thesis and i did get it done so that was

1198
00:45:34,309 --> 00:45:32,160
a good thing that was my start in

1199
00:45:35,910 --> 00:45:34,319
libration points and later on i went to

1200
00:45:38,550 --> 00:45:35,920
stanford

1201
00:45:40,710 --> 00:45:38,560
and i did a phd thesis on the control

1202
00:45:42,470 --> 00:45:40,720
and use of libration point satellites so

1203
00:45:44,390 --> 00:45:42,480
my big goal in life

1204
00:45:47,190 --> 00:45:44,400
was to do the first mission to a

1205
00:45:49,109 --> 00:45:47,200
libration point so that that's the thing

1206
00:45:51,910 --> 00:45:49,119
i was really motivated by trying to do

1207
00:45:52,710 --> 00:45:51,920
that before anybody else

1208
00:45:56,069 --> 00:45:52,720
and

1209
00:45:58,309 --> 00:45:56,079
around 1970 i was transferred to goddard

1210
00:46:00,069 --> 00:45:58,319
space flight center

1211
00:46:01,670 --> 00:46:00,079
and uh

1212
00:46:04,230 --> 00:46:01,680
i was only there for about a month and

1213
00:46:05,030 --> 00:46:04,240

they said bob we need you to go to this

1214
00:46:10,550 --> 00:46:05,040
uh

1215
00:46:12,230 --> 00:46:10,560
the explorer project

1216
00:46:14,470 --> 00:46:12,240
and i didn't really want to go there but

1217
00:46:16,390 --> 00:46:14,480
i had to sometimes i have to do what the

1218
00:46:18,390 --> 00:46:16,400
management tells me

1219
00:46:19,190 --> 00:46:18,400
so but that's been rare in your history

1220
00:46:20,870 --> 00:46:19,200
i know

1221
00:46:22,870 --> 00:46:20,880
you're right yes

1222
00:46:24,230 --> 00:46:22,880
anyway i went to the i went to the

1223
00:46:25,829 --> 00:46:24,240
meeting and

1224
00:46:27,750 --> 00:46:25,839
they were talking about some three

1225
00:46:29,190 --> 00:46:27,760
spacecraft program they were going to do

1226
00:46:31,109 --> 00:46:29,200
in the future

1227
00:46:33,829 --> 00:46:31,119
two of the spacecraft are going to be in

1228
00:46:36,870 --> 00:46:33,839
the magnetosphere of the earth

1229
00:46:38,790 --> 00:46:36,880
making fine scale measurements of the

1230
00:46:41,270 --> 00:46:38,800
interaction with the solar wind and then

1231
00:46:43,430 --> 00:46:41,280
there was a third spacecraft

1232
00:46:45,990 --> 00:46:43,440
an interplanetary spacecraft that was

1233
00:46:47,270 --> 00:46:46,000
going to be measuring the ambient solar

1234
00:46:48,950 --> 00:46:47,280
wind

1235
00:46:51,349 --> 00:46:48,960
and i sat there for a little bit and

1236
00:46:53,270 --> 00:46:51,359
they they said that well this will be

1237
00:46:54,630 --> 00:46:53,280
either leading or lagging the earth in

1238
00:46:56,309 --> 00:46:54,640

its orbit

1239
00:46:57,750 --> 00:46:56,319
and i said wait a minute this isn't

1240
00:47:00,069 --> 00:46:57,760
going to work

1241
00:47:01,829 --> 00:47:00,079
what you've got here it's impossible to

1242
00:47:03,430 --> 00:47:01,839
put this thing at the edge of the sphere

1243
00:47:05,510 --> 00:47:03,440
of influence it's going to cost too much

1244
00:47:07,190 --> 00:47:05,520
fuel and they looked around who is this

1245
00:47:09,190 --> 00:47:07,200
guy where where did he come from out of

1246
00:47:11,430 --> 00:47:09,200
left field you know he's telling us what

1247
00:47:13,510 --> 00:47:11,440
to do not only that then i said but i've

1248
00:47:15,750 --> 00:47:13,520
got a better place to put it

1249
00:47:17,750 --> 00:47:15,760
you can put it at a libration point in

1250
00:47:20,069 --> 00:47:17,760
front of the earth where you measure the

1251
00:47:21,829 --> 00:47:20,079
input of the solar wind before it hits

1252
00:47:23,589 --> 00:47:21,839
the magnetosphere

1253
00:47:26,150 --> 00:47:23,599
and well of course they were getting

1254
00:47:28,150 --> 00:47:26,160
pretty irritated with me at that point

1255
00:47:30,549 --> 00:47:28,160
but i showed them this diagram which we

1256
00:47:32,950 --> 00:47:30,559
have up on the screen i believe

1257
00:47:38,390 --> 00:47:35,990
what the libration points for every

1258
00:47:40,630 --> 00:47:38,400
isolated two-body system in the solar

1259
00:47:42,630 --> 00:47:40,640
system such as the earth and the moon

1260
00:47:45,190 --> 00:47:42,640
there are five of these equilibrium

1261
00:47:47,109 --> 00:47:45,200
points that i call libration points and

1262
00:47:49,030 --> 00:47:47,119
if you put a spacecraft there with just

1263
00:47:51,030 --> 00:47:49,040

the right velocity

1264
00:47:53,109 --> 00:47:51,040
it will stay in the constant

1265
00:47:54,950 --> 00:47:53,119
configuration with the two main bodies

1266
00:47:56,549 --> 00:47:54,960
that are orbiting each other such as the

1267
00:47:57,670 --> 00:47:56,559
earth and moon that are shown in this

1268
00:47:59,990 --> 00:47:57,680
diagram

1269
00:48:02,150 --> 00:48:00,000
there are three collinear points

1270
00:48:04,150 --> 00:48:02,160
and all of these points are unstable so

1271
00:48:05,910 --> 00:48:04,160
if you put a spacecraft there exactly at

1272
00:48:08,069 --> 00:48:05,920
the right place it'll stay there for a

1273
00:48:11,109 --> 00:48:08,079
little while but if you deviate the very

1274
00:48:13,430 --> 00:48:11,119
slightest it'll it'll leave the that

1275
00:48:15,829 --> 00:48:13,440
area but if the equilateral triangle

1276
00:48:17,990 --> 00:48:15,839
points the l4 and l5

1277
00:48:20,950 --> 00:48:18,000
it will stay there most of the time

1278
00:48:23,589 --> 00:48:20,960
it'll oscillate around well the thing i

1279
00:48:25,589 --> 00:48:23,599
was interested in was the uh

1280
00:48:27,190 --> 00:48:25,599
the co-linear points of the sun earth

1281
00:48:28,309 --> 00:48:27,200
system and they're also close to the

1282
00:48:30,069 --> 00:48:28,319
earth

1283
00:48:32,150 --> 00:48:30,079
about a million and a half kilometers

1284
00:48:34,630 --> 00:48:32,160
away from the earth now this shows where

1285
00:48:36,870 --> 00:48:34,640
they are they're on the sun earth line

1286
00:48:39,750 --> 00:48:36,880
and i wanted to put this interplanetary

1287
00:48:40,630 --> 00:48:39,760
spacecraft at the sun earth l1 point

1288
00:48:42,630 --> 00:48:40,640

where

1289
00:48:44,790 --> 00:48:42,640
it would be able to measure the solar

1290
00:48:45,910 --> 00:48:44,800
wind about 40 minutes before it got to

1291
00:48:48,069 --> 00:48:45,920
the earth

1292
00:48:50,710 --> 00:48:48,079
so then we could measure the solar wind

1293
00:48:52,470 --> 00:48:50,720
input and then see what the reaction was

1294
00:48:55,030 --> 00:48:52,480
with the other two spacecraft that were

1295
00:48:57,430 --> 00:48:55,040
in the magnetosphere so that seemed like

1296
00:48:59,190 --> 00:48:57,440
a good idea but then someone said they

1297
00:49:01,270 --> 00:48:59,200
were already irritated with me because i

1298
00:49:02,710 --> 00:49:01,280
interrupted their whole study and

1299
00:49:04,230 --> 00:49:02,720
telling them that there's a better way

1300
00:49:05,589 --> 00:49:04,240
to do things and they didn't even know

1301
00:49:06,950 --> 00:49:05,599
who i was

1302
00:49:09,030 --> 00:49:06,960
they said well wait a minute you can't

1303
00:49:10,470 --> 00:49:09,040
put something right at the sun earth l1

1304
00:49:12,630 --> 00:49:10,480
point because then you're going to be

1305
00:49:13,829 --> 00:49:12,640
looking right into the sun

1306
00:49:15,589 --> 00:49:13,839
and how are we going to get any

1307
00:49:17,510 --> 00:49:15,599
information back from the spacecraft

1308
00:49:20,630 --> 00:49:17,520
because there's a lot of noise there it

1309
00:49:22,870 --> 00:49:20,640
will swap the signal yes and uh

1310
00:49:26,309 --> 00:49:22,880
i says well that i can take care of that

1311
00:49:28,870 --> 00:49:26,319
because if you oscillate back and forth

1312
00:49:31,510 --> 00:49:28,880
normal to the or perpendicular to the

1313
00:49:33,430 --> 00:49:31,520

sun earth line

1314
00:49:34,630 --> 00:49:33,440
it'll only pass in front of the sun once

1315
00:49:35,910 --> 00:49:34,640
in a while

1316
00:49:37,670 --> 00:49:35,920
yes but

1317
00:49:39,990 --> 00:49:37,680
we have a spacecraft that doesn't have

1318
00:49:41,910 --> 00:49:40,000
any data storage on it

1319
00:49:44,390 --> 00:49:41,920
so that's no good you have to you you

1320
00:49:46,710 --> 00:49:44,400
can't go across the sun at all so you

1321
00:49:48,630 --> 00:49:46,720
can also oscillate out of the plane

1322
00:49:51,109 --> 00:49:48,640
and you can get into what i called a

1323
00:49:54,549 --> 00:49:51,119
halo orbit which i'd worked on in my

1324
00:49:56,309 --> 00:49:54,559
thesis and let's show the next slide

1325
00:49:57,349 --> 00:49:56,319
and you can see what this orbit looks

1326
00:49:59,190 --> 00:49:57,359
like

1327
00:50:00,069 --> 00:49:59,200
this is to scale the figure in the

1328
00:50:01,670 --> 00:50:00,079
bottom

1329
00:50:03,750 --> 00:50:01,680
and then the figure in the upper left

1330
00:50:05,270 --> 00:50:03,760
hand corner is the view

1331
00:50:07,750 --> 00:50:05,280
from the earth

1332
00:50:10,069 --> 00:50:07,760
there's a in the center there there's a

1333
00:50:12,790 --> 00:50:10,079
zone of solar interference

1334
00:50:14,230 --> 00:50:12,800
and much larger than the diameter of the

1335
00:50:15,990 --> 00:50:14,240
sun

1336
00:50:18,630 --> 00:50:16,000
as seen from the earth that only

1337
00:50:20,549 --> 00:50:18,640
subtends an angle of about half a degree

1338
00:50:22,790 --> 00:50:20,559

whereas this is about six degrees so

1339
00:50:25,030 --> 00:50:22,800
it's pretty large

1340
00:50:27,109 --> 00:50:25,040
but if you have something in this orbit

1341
00:50:29,030 --> 00:50:27,119
it takes six months to go around this

1342
00:50:31,109 --> 00:50:29,040
orbit it isn't really in orbit it's

1343
00:50:32,710 --> 00:50:31,119
really oscillating around the libration

1344
00:50:34,549 --> 00:50:32,720
point

1345
00:50:35,589 --> 00:50:34,559
oscillating in the plane and out of the

1346
00:50:38,710 --> 00:50:35,599
plane

1347
00:50:40,790 --> 00:50:38,720
so that viewing it from the earth

1348
00:50:42,230 --> 00:50:40,800
the spacecraft never gets in the line

1349
00:50:44,069 --> 00:50:42,240
with the sun and you're able to

1350
00:50:45,750 --> 00:50:44,079
communicate with it or get all the data

1351
00:50:47,109 --> 00:50:45,760
back from it

1352
00:50:49,109 --> 00:50:47,119
but you still have some problems with

1353
00:50:50,710 --> 00:50:49,119
that in the sense that it needed to be

1354
00:50:51,910 --> 00:50:50,720
sold to the scientist

1355
00:50:55,109 --> 00:50:51,920
oh yeah

1356
00:50:56,470 --> 00:50:55,119
well they didn't like this at all

1357
00:50:58,710 --> 00:50:56,480
as a matter of fact people said yeah

1358
00:50:59,750 --> 00:50:58,720
well this is a nice theory

1359
00:51:02,630 --> 00:50:59,760
but

1360
00:51:03,510 --> 00:51:02,640
we're talking about a real mission here

1361
00:51:05,030 --> 00:51:03,520
and

1362
00:51:07,109 --> 00:51:05,040
how are you going to keep something this

1363
00:51:08,549 --> 00:51:07,119

orbit is not stable

1364
00:51:10,549 --> 00:51:08,559
and so

1365
00:51:12,549 --> 00:51:10,559
if your orbit determination isn't very

1366
00:51:14,470 --> 00:51:12,559
good where does the spacecraft go well

1367
00:51:16,390 --> 00:51:14,480
it goes either in orbit around the sun

1368
00:51:18,549 --> 00:51:16,400
or it comes back to the earth

1369
00:51:21,109 --> 00:51:18,559
now they didn't like that very much and

1370
00:51:22,630 --> 00:51:21,119
so i kept trying to sell the idea to the

1371
00:51:27,589 --> 00:51:22,640
project

1372
00:51:29,990 --> 00:51:27,599
i dare to mention his name i hope he's

1373
00:51:31,270 --> 00:51:30,000
not watching

1374
00:51:33,990 --> 00:51:31,280
he probably is

1375
00:51:36,390 --> 00:51:34,000
keith ogilvy at goddard space flight

1376
00:51:38,390 --> 00:51:36,400
center said no no i don't want the i

1377
00:51:39,750 --> 00:51:38,400
don't want the interplanetary spacecraft

1378
00:51:42,150 --> 00:51:39,760
to go there and he's the project

1379
00:51:43,829 --> 00:51:42,160
scientist how can i argue with him you

1380
00:51:46,309 --> 00:51:43,839
know and he's just wasn't going to do it

1381
00:51:48,790 --> 00:51:46,319
i tried for over a year to convince him

1382
00:51:50,069 --> 00:51:48,800
but i was getting nowhere

1383
00:51:52,230 --> 00:51:50,079
so in the meantime the mission's

1384
00:51:54,309 --> 00:51:52,240
proceeding uh well it's now called it

1385
00:51:56,549 --> 00:51:54,319
was called the international sun earth

1386
00:52:00,950 --> 00:51:56,559
explorer and they named the satellites

1387
00:52:03,430 --> 00:52:00,960
ic1 ic2 and ic3 right so ic3 where were

1388
00:52:04,950 --> 00:52:03,440

you going to put it well i wanted to put

1389
00:52:06,309 --> 00:52:04,960
it in the halo orbit

1390
00:52:08,150 --> 00:52:06,319
but people said well that's a nice

1391
00:52:10,230 --> 00:52:08,160
theoretical concept but how do we know

1392
00:52:12,710 --> 00:52:10,240
that's going to work and keith ogilvy

1393
00:52:14,470 --> 00:52:12,720
didn't want it there in any case

1394
00:52:17,270 --> 00:52:14,480
and so i thought well how am i going to

1395
00:52:21,349 --> 00:52:17,280
beat this situation so i went i resorted

1396
00:52:22,630 --> 00:52:21,359
to my usual tactic which is an end run

1397
00:52:25,109 --> 00:52:22,640
and so

1398
00:52:26,470 --> 00:52:25,119
i went to keith ogilvy's boss

1399
00:52:28,069 --> 00:52:26,480
norman ness

1400
00:52:31,109 --> 00:52:28,079
who's the head of the

1401
00:52:33,750 --> 00:52:31,119
laboratory for extraterrestrial physics

1402
00:52:35,910 --> 00:52:33,760
and i explained the thing to him and he

1403
00:52:37,910 --> 00:52:35,920
listened very patiently to me and he

1404
00:52:40,069 --> 00:52:37,920
agreed from a scientific point of view

1405
00:52:42,950 --> 00:52:40,079
you would rather have it out

1406
00:52:44,630 --> 00:52:42,960
be between the sun and the earth so that

1407
00:52:47,750 --> 00:52:44,640
you measure the input function of the

1408
00:52:50,870 --> 00:52:47,760
solar wind very close to the uh the

1409
00:52:53,030 --> 00:52:50,880
the uh magnetosphere of the earth

1410
00:52:54,950 --> 00:52:53,040
so that all made sense to him and then

1411
00:52:57,990 --> 00:52:54,960
but i had to convince him also that this

1412
00:52:59,990 --> 00:52:58,000
thing was a practical concept and i

1413
00:53:01,510 --> 00:53:00,000

talked to him for a while and he somehow

1414
00:53:04,069 --> 00:53:01,520
he figured that i knew what i was

1415
00:53:05,589 --> 00:53:04,079
talking about i don't know how

1416
00:53:07,910 --> 00:53:05,599
but

1417
00:53:09,030 --> 00:53:07,920
he overruled keith ogilvy pretty well

1418
00:53:11,589 --> 00:53:09,040
and then

1419
00:53:13,030 --> 00:53:11,599
the the thing was pretty much on target

1420
00:53:14,510 --> 00:53:13,040
and we were going to launch the

1421
00:53:17,990 --> 00:53:14,520
spacecraft in

1422
00:53:20,309 --> 00:53:18,000
1978 and fulfill my lifelong ambition to

1423
00:53:22,230 --> 00:53:20,319
do the first liberation point satellite

1424
00:53:24,230 --> 00:53:22,240
i remember calling home and telling my

1425
00:53:26,069 --> 00:53:24,240
wife at the time that oh and finally i

1426
00:53:28,150 --> 00:53:26,079
finally sold the halo satellite we're

1427
00:53:31,030 --> 00:53:28,160
going to do it i didn't just write a

1428
00:53:33,270 --> 00:53:31,040
thesis but we're really going to do this

1429
00:53:35,510 --> 00:53:33,280
but then

1430
00:53:37,510 --> 00:53:35,520
norman ness came up with another idea he

1431
00:53:40,309 --> 00:53:37,520
had an idea to do a

1432
00:53:41,670 --> 00:53:40,319
low-cost explorer spacecraft going to a

1433
00:53:46,309 --> 00:53:41,680
comet

1434
00:53:47,910 --> 00:53:46,319
wanted me to come in there and do some

1435
00:53:50,870 --> 00:53:47,920
of the mission design for it and i

1436
00:53:53,910 --> 00:53:50,880
thought oh i don't want to do this now

1437
00:53:55,589 --> 00:53:53,920
i don't know anything about comets and i

1438
00:53:58,630 --> 00:53:55,599

want to do the first libration point

1439
00:53:59,670 --> 00:53:58,640
spacecraft now this is a distraction

1440
00:54:01,589 --> 00:53:59,680
i mean

1441
00:54:03,510 --> 00:54:01,599
so i went to the first meeting i really

1442
00:54:05,829 --> 00:54:03,520
didn't want to go at all

1443
00:54:08,150 --> 00:54:05,839
and but after the first meeting i found

1444
00:54:10,710 --> 00:54:08,160
out a lot about comets i thought

1445
00:54:13,109 --> 00:54:10,720
these things are really cool

1446
00:54:14,790 --> 00:54:13,119
now i wanted to do the first comet

1447
00:54:16,790 --> 00:54:14,800
mission as much as i wanted to do the

1448
00:54:18,470 --> 00:54:16,800
first libration point mission so that

1449
00:54:20,470 --> 00:54:18,480
that was a good thing

1450
00:54:24,470 --> 00:54:20,480
next slide please

1451
00:54:27,750 --> 00:54:24,480
here we see uh norma and i working on on

1452
00:54:30,710 --> 00:54:27,760
these uh on the comet missions in 1972

1453
00:54:32,950 --> 00:54:30,720
we actually wrote a paper that year

1454
00:54:34,710 --> 00:54:32,960
on a low-cost mission to a comet a

1455
00:54:38,470 --> 00:54:34,720
couple of them

1456
00:54:40,549 --> 00:54:38,480
this is norman and i in in earlier days

1457
00:54:42,230 --> 00:54:40,559
now norman is in the audience right out

1458
00:54:43,510 --> 00:54:42,240
there raise your hand norman then we'll

1459
00:54:45,430 --> 00:54:43,520
put you on the

1460
00:54:48,390 --> 00:54:45,440
camera

1461
00:54:51,190 --> 00:54:48,400
he looks a little bit like this guy here

1462
00:54:54,069 --> 00:54:51,200
oh he had darker glasses in those days

1463
00:54:56,069 --> 00:54:54,079

well of course norm had a tremendous uh

1464
00:54:58,230 --> 00:54:56,079
scientific body of work that he'd

1465
00:55:00,789 --> 00:54:58,240
accomplished during that time planetary

1466
00:55:03,030 --> 00:55:00,799
magnetospheres made measurements

1467
00:55:05,030 --> 00:55:03,040
at mercury and many of the other planets

1468
00:55:07,910 --> 00:55:05,040
and and done some really groundbreaking

1469
00:55:09,430 --> 00:55:07,920
work uh in the earth's magnetosphere on

1470
00:55:11,270 --> 00:55:09,440
top of that

1471
00:55:13,270 --> 00:55:11,280
so you had a really solid scientist

1472
00:55:15,030 --> 00:55:13,280
helping you in that and that was a that

1473
00:55:16,950 --> 00:55:15,040
made a big difference oh that made a

1474
00:55:19,349 --> 00:55:16,960
huge difference and he introduced me to

1475
00:55:21,510 --> 00:55:19,359
comets if if he hadn't had me come to

1476
00:55:23,510 --> 00:55:21,520
that meeting that study team meeting i

1477
00:55:25,430 --> 00:55:23,520
never would have really thought about

1478
00:55:27,430 --> 00:55:25,440
doing missions to comets so that that

1479
00:55:30,150 --> 00:55:27,440
was a big help

1480
00:55:35,430 --> 00:55:30,160
let's see next view graph i'm not sure

1481
00:55:38,150 --> 00:55:35,440
oh i see this is the ic3 spacecraft and

1482
00:55:40,710 --> 00:55:38,160
it's it's not a very big spacecraft uh

1483
00:55:42,390 --> 00:55:40,720
about one and three quarters meters in

1484
00:55:46,390 --> 00:55:42,400
in diameter

1485
00:55:48,630 --> 00:55:46,400
and about 1.6 meters high but actually

1486
00:55:51,109 --> 00:55:48,640
that's a little deceiving because it's a

1487
00:55:52,549 --> 00:55:51,119
lot bigger than that we have wires going

1488
00:55:53,829 --> 00:55:52,559

out of it it's spin stabilized

1489
00:55:56,470 --> 00:55:53,839
spacecraft

1490
00:55:59,109 --> 00:55:56,480
and as it's spinning around the wires

1491
00:56:00,870 --> 00:55:59,119
are going out 92 meters tip to tip so

1492
00:56:02,950 --> 00:56:00,880
it's actually pretty big if you look at

1493
00:56:05,270 --> 00:56:02,960
it from that point of view

1494
00:56:07,910 --> 00:56:05,280
had a lot of instruments on 13

1495
00:56:08,950 --> 00:56:07,920
experiments

1496
00:56:10,870 --> 00:56:08,960
mostly

1497
00:56:13,109 --> 00:56:10,880
plasma physics

1498
00:56:15,109 --> 00:56:13,119
high and high energy particles and

1499
00:56:16,710 --> 00:56:15,119
fields

1500
00:56:18,630 --> 00:56:16,720
and two

1501
00:56:20,150 --> 00:56:18,640
there was a magnetometer which you see

1502
00:56:21,990 --> 00:56:20,160
on the one boom

1503
00:56:24,870 --> 00:56:22,000
uh that was from one of my favorite

1504
00:56:27,109 --> 00:56:24,880
scientists on here ed smith at jpl he's

1505
00:56:30,230 --> 00:56:27,119
still working at jpl

1506
00:56:31,910 --> 00:56:30,240
and uh then on the other end of the

1507
00:56:33,750 --> 00:56:31,920
opposite to the magnetometer on the

1508
00:56:35,430 --> 00:56:33,760
other boom was the plasma wave

1509
00:56:37,910 --> 00:56:35,440
experiment

1510
00:56:40,390 --> 00:56:37,920
from fred scarf

1511
00:56:42,710 --> 00:56:40,400
and so

1512
00:56:45,589 --> 00:56:42,720
there was also a lot of hydrazine fuel

1513
00:56:47,910 --> 00:56:45,599

on here much more fuel than we really

1514
00:56:49,510 --> 00:56:47,920
needed to do the basic mission because i

1515
00:56:51,109 --> 00:56:49,520
thought well if i put a lot of fuel on

1516
00:56:53,589 --> 00:56:51,119
there i might think of some other things

1517
00:56:56,150 --> 00:56:53,599
that we can do with the spacecraft

1518
00:56:59,670 --> 00:56:56,160
now and ever since this time people know

1519
00:57:01,589 --> 00:56:59,680
now that i hog a lot of extra fuel and

1520
00:57:05,670 --> 00:57:01,599
and it has a lot of extra delta v

1521
00:57:07,430 --> 00:57:05,680
capability so i'm known as a delta v hog

1522
00:57:09,670 --> 00:57:07,440
ever since then i can't shake this

1523
00:57:11,349 --> 00:57:09,680
reputation so people never believe any

1524
00:57:11,829 --> 00:57:11,359
of

1525
00:57:14,069 --> 00:57:11,839
fuel my

1526
00:57:15,030 --> 00:57:14,079
has served you well it's worked out so

1527
00:57:17,030 --> 00:57:15,040
far

1528
00:57:18,789 --> 00:57:17,040
now ic3 didn't have an imager on it

1529
00:57:21,510 --> 00:57:18,799
indeed it was uh

1530
00:57:23,990 --> 00:57:21,520
right plasma plasma wave

1531
00:57:25,910 --> 00:57:24,000
measurements looking at the solar wind

1532
00:57:28,230 --> 00:57:25,920
so what about the launch what happens

1533
00:57:30,470 --> 00:57:28,240
next okay let me see what the next slide

1534
00:57:32,230 --> 00:57:30,480
is here oh well here's a picture of the

1535
00:57:33,510 --> 00:57:32,240
spacecraft now you get a better idea of

1536
00:57:36,789 --> 00:57:33,520
the size

1537
00:57:39,270 --> 00:57:36,799
this is my late wife bonnie on the right

1538
00:57:41,990 --> 00:57:39,280

and my and our daughter patty in the

1539
00:57:46,150 --> 00:57:42,000
middle and i'm on the left and this is

1540
00:57:49,270 --> 00:57:46,160
uh when the spacecraft was having its uh

1541
00:57:51,109 --> 00:57:49,280
in the magnetic test facility at goddard

1542
00:57:53,589 --> 00:57:51,119
space flight center so we got her

1543
00:57:54,710 --> 00:57:53,599
picture taken in front of it

1544
00:57:56,150 --> 00:57:54,720
and

1545
00:57:59,030 --> 00:57:56,160
then we were getting ready for the

1546
00:58:01,589 --> 00:57:59,040
launch this was 1978 and on the next

1547
00:58:03,750 --> 00:58:01,599
slide i think they showed the launch yes

1548
00:58:07,990 --> 00:58:03,760
here it is

1549
00:58:10,150 --> 00:58:08,000
this is on delta 144 on august the 12th

1550
00:58:11,750 --> 00:58:10,160
1978

1551
00:58:14,630 --> 00:58:11,760
and

1552
00:58:17,510 --> 00:58:14,640
i wanted to have my thesis advisor at

1553
00:58:19,750 --> 00:58:17,520
the launch and the project manager says

1554
00:58:21,109 --> 00:58:19,760
yes absolutely we'd like to have him at

1555
00:58:23,270 --> 00:58:21,119
the launch because there was still a lot

1556
00:58:25,270 --> 00:58:23,280
of skepticism as to whether this was

1557
00:58:27,589 --> 00:58:25,280
really going to work

1558
00:58:30,470 --> 00:58:27,599
and so they wanted him to be at the

1559
00:58:31,910 --> 00:58:30,480
launch and to bring a copy of my thesis

1560
00:58:34,870 --> 00:58:31,920
with him

1561
00:58:37,190 --> 00:58:34,880
and if it didn't work properly the way i

1562
00:58:43,109 --> 00:58:37,200
said it was then they were going to have

1563
00:58:47,109 --> 00:58:45,109

fortunately it worked and he didn't have

1564
00:58:49,750 --> 00:58:47,119
to do that

1565
00:58:51,910 --> 00:58:49,760
next slide please

1566
00:58:54,789 --> 00:58:51,920
okay this is just a picture of the

1567
00:58:56,950 --> 00:58:54,799
transfer from uh from the earth orbit

1568
00:58:57,829 --> 00:58:56,960
out to the halo orbit

1569
00:58:59,990 --> 00:58:57,839
and

1570
00:59:02,789 --> 00:59:00,000
it took about a hundred days to get out

1571
00:59:05,589 --> 00:59:02,799
there and we inserted into the orbit on

1572
00:59:07,589 --> 00:59:05,599
november 20th 1978

1573
00:59:09,349 --> 00:59:07,599
and takes six months to make every one

1574
00:59:11,190 --> 00:59:09,359
of these circuits of the halo orbit

1575
00:59:12,150 --> 00:59:11,200
everything worked quite well for a long

1576
00:59:14,230 --> 00:59:12,160
time

1577
00:59:16,309 --> 00:59:14,240
and we were in this orbit for a couple

1578
00:59:18,230 --> 00:59:16,319
years and i was getting bored with all

1579
00:59:19,750 --> 00:59:18,240
the operations that's four of these

1580
00:59:22,309 --> 00:59:19,760
orbits

1581
00:59:23,109 --> 00:59:22,319
around the libration point

1582
00:59:25,270 --> 00:59:23,119
and

1583
00:59:27,589 --> 00:59:25,280
even prior to the launch i talked to

1584
00:59:28,870 --> 00:59:27,599
fred scarf about trying to do something

1585
00:59:30,870 --> 00:59:28,880
else

1586
00:59:33,030 --> 00:59:30,880
couldn't we send this out into the tail

1587
00:59:35,190 --> 00:59:33,040
of the earth beyond the moon and no one

1588
00:59:37,030 --> 00:59:35,200

has made any measurements out there this

1589
00:59:39,589 --> 00:59:37,040
is the earth's plasma table to the other

1590
00:59:41,589 --> 00:59:39,599
libration point uh yeah but i didn't

1591
00:59:44,309 --> 00:59:41,599
care about the vibration point

1592
00:59:46,150 --> 00:59:44,319
i wanted to go into the geotail area and

1593
00:59:48,230 --> 00:59:46,160
you know all about that you're a plasma

1594
00:59:50,069 --> 00:59:48,240
physicist right right and why is that

1595
00:59:52,230 --> 00:59:50,079
important the solar wind interaction

1596
00:59:54,630 --> 00:59:52,240
with the ah well uh that's where they

1597
00:59:56,630 --> 00:59:54,640
believe the aurora really starts from a

1598
00:59:57,910 --> 00:59:56,640
reconnection that occurs in the tail

1599
01:00:00,470 --> 00:59:57,920
field lines

1600
01:00:02,870 --> 01:00:00,480
uh from the north to the south and come

1601
01:00:04,630 --> 01:00:02,880
together particles are accelerated to

1602
01:00:06,950 --> 01:00:04,640
the earth and then rains on our upper

1603
01:00:10,470 --> 01:00:06,960
atmosphere creating the aurora and of

1604
01:00:13,190 --> 01:00:10,480
course the icy mission the two inside

1605
01:00:15,030 --> 01:00:13,200
were making fabulous discoveries

1606
01:00:17,190 --> 01:00:15,040
because they could make that measurement

1607
01:00:20,309 --> 01:00:17,200
in the solar wind and see the effect in

1608
01:00:22,789 --> 01:00:20,319
the magnetosphere so the set of three

1609
01:00:24,950 --> 01:00:22,799
was doing a fabulous job and so the

1610
01:00:27,109 --> 01:00:24,960
scientists were i'm sure

1611
01:00:29,109 --> 01:00:27,119
very delighted your idea worked out well

1612
01:00:30,789 --> 01:00:29,119
they were very happy to have it in the

1613
01:00:33,430 --> 01:00:30,799

halo orbit but they didn't want to move

1614
01:00:35,190 --> 01:00:33,440
it back into the tail because of all the

1615
01:00:37,030 --> 01:00:35,200
discoveries that they were being that

1616
01:00:39,190 --> 01:00:37,040
were coming out from that relationship

1617
01:00:41,190 --> 01:00:39,200
but fred scarf wanted to the the

1618
01:00:43,430 --> 01:00:41,200
spacecraft to go back out into the tail

1619
01:00:44,710 --> 01:00:43,440
he wanted to do something different

1620
01:00:45,510 --> 01:00:44,720
and so

1621
01:00:55,270 --> 01:00:45,520
he

1622
01:00:57,589 --> 01:00:55,280
not

1623
01:00:59,910 --> 01:00:57,599
finally we convinced them to let it go

1624
01:01:01,589 --> 01:00:59,920
back okay you can have one pass in the

1625
01:01:03,829 --> 01:01:01,599
tail but then we want to put back into

1626
01:01:06,710 --> 01:01:03,839
the halo orbit get back to work and we

1627
01:01:07,589 --> 01:01:06,720
want to keep doing that and stuff

1628
01:01:09,270 --> 01:01:07,599
and

1629
01:01:11,510 --> 01:01:09,280
this wasn't going to happen for a couple

1630
01:01:13,430 --> 01:01:11,520
more years yet anyway so they thought

1631
01:01:15,430 --> 01:01:13,440
well they'll get four years in the halo

1632
01:01:18,069 --> 01:01:15,440
orbit before we have to

1633
01:01:20,230 --> 01:01:18,079
divert the spacecraft in any way

1634
01:01:23,510 --> 01:01:20,240
but then other things were going on at

1635
01:01:25,430 --> 01:01:23,520
the same time in 1981

1636
01:01:27,670 --> 01:01:25,440
there were a lot of spacecraft going out

1637
01:01:29,910 --> 01:01:27,680
to halley's comet and everybody was very

1638
01:01:31,430 --> 01:01:29,920

interested in this and the united states

1639
01:01:33,430 --> 01:01:31,440
was interested in doing a mission to

1640
01:01:36,710 --> 01:01:33,440
halley's comet also

1641
01:01:38,549 --> 01:01:36,720
and i was even sent down to headquarters

1642
01:01:41,270 --> 01:01:38,559
to be the program manager for the

1643
01:01:43,430 --> 01:01:41,280
halley's comet mission

1644
01:01:45,349 --> 01:01:43,440
and jpl was going to do it but they had

1645
01:01:47,109 --> 01:01:45,359
something that was going to cost a

1646
01:01:49,270 --> 01:01:47,119
little too much and

1647
01:01:51,589 --> 01:01:49,280
we ended up not doing anything but the

1648
01:01:53,829 --> 01:01:51,599
japanese and the russians

1649
01:01:55,430 --> 01:01:53,839
and the europeans all sent spacecraft to

1650
01:01:58,470 --> 01:01:55,440
helly's comet

1651
01:02:00,789 --> 01:01:58,480
so one day in late 1981 fred scarf

1652
01:02:03,270 --> 01:02:00,799
called me up he said bob you said that

1653
01:02:04,789 --> 01:02:03,280
we might be able to send ic3 out to

1654
01:02:07,910 --> 01:02:04,799
halley's comet

1655
01:02:10,549 --> 01:02:07,920
by using the gravity field of the moon

1656
01:02:14,309 --> 01:02:10,559
and slinging it out there

1657
01:02:16,549 --> 01:02:14,319
i i said yeah i think we can do that but

1658
01:02:18,470 --> 01:02:16,559
halley's comets

1659
01:02:20,150 --> 01:02:18,480
with any encounter with that would be

1660
01:02:22,549 --> 01:02:20,160
too far from the earth and we really

1661
01:02:23,910 --> 01:02:22,559
can't get very much data back almost

1662
01:02:25,750 --> 01:02:23,920
nothing

1663
01:02:27,910 --> 01:02:25,760

but there's other comets that are a lot

1664
01:02:30,630 --> 01:02:27,920
closer maybe we could try to do that

1665
01:02:32,390 --> 01:02:30,640
well fred scarf was all for that

1666
01:02:35,829 --> 01:02:32,400
and we brought that up with the with the

1667
01:02:37,349 --> 01:02:35,839
ic science team oh no way

1668
01:02:38,789 --> 01:02:37,359
yeah right no way you know how you're

1669
01:02:40,950 --> 01:02:38,799
not going to take you're not going to

1670
01:02:42,710 --> 01:02:40,960
steal our spacecraft from the halo orbit

1671
01:02:44,390 --> 01:02:42,720
we want to keep it there we'll let you

1672
01:02:45,990 --> 01:02:44,400
go back in the tail

1673
01:02:49,430 --> 01:02:46,000
come back out to the halo orbit and

1674
01:02:51,270 --> 01:02:49,440
that's going to be it uh well well no we

1675
01:02:53,349 --> 01:02:51,280
want to send it we want the united

1676
01:02:54,789 --> 01:02:53,359
states to have a comet mission too and

1677
01:02:56,710 --> 01:02:54,799
besides

1678
01:02:58,549 --> 01:02:56,720
i was motivated by the fact that we'd

1679
01:03:00,630 --> 01:02:58,559
get to this other comet

1680
01:03:02,470 --> 01:03:00,640
about six months before everybody else

1681
01:03:04,630 --> 01:03:02,480
got to helly's comet so this would be

1682
01:03:06,549 --> 01:03:04,640
the the first comet mission we didn't

1683
01:03:07,910 --> 01:03:06,559
have a camera but we could do a lot of

1684
01:03:10,069 --> 01:03:07,920
good things with the solar wind

1685
01:03:10,789 --> 01:03:10,079
interaction

1686
01:03:12,870 --> 01:03:10,799
so

1687
01:03:14,309 --> 01:03:12,880
the science team would not budge they

1688
01:03:16,549 --> 01:03:14,319

were not going to do it they voted

1689
01:03:18,150 --> 01:03:16,559
against it and there's no way you can

1690
01:03:19,990 --> 01:03:18,160
ever change something like that what are

1691
01:03:21,670 --> 01:03:20,000
you going to do about that bob well then

1692
01:03:23,430 --> 01:03:21,680
what we're going to do is make another

1693
01:03:24,309 --> 01:03:23,440
end run that's right

1694
01:03:31,190 --> 01:03:24,319
and

1695
01:03:33,910 --> 01:03:31,200
the principal investigator for the

1696
01:03:35,270 --> 01:03:33,920
magnetometer instrument ed smith from

1697
01:03:37,750 --> 01:03:35,280
jpl

1698
01:03:39,829 --> 01:03:37,760
the two of them were my champions and we

1699
01:03:42,150 --> 01:03:39,839
set up a meeting with the national

1700
01:03:43,829 --> 01:03:42,160
academy of sciences

1701
01:03:47,109 --> 01:03:43,839
and

1702
01:03:49,190 --> 01:03:47,119
we managed to get them to agree that

1703
01:03:50,630 --> 01:03:49,200
this this was a better idea than putting

1704
01:03:53,270 --> 01:03:50,640
it back in the halo of course the

1705
01:03:55,190 --> 01:03:53,280
scientists weren't happy about that

1706
01:03:56,950 --> 01:03:55,200
now there was that there was one other

1707
01:03:59,029 --> 01:03:56,960
problem we had though even though we

1708
01:04:00,710 --> 01:03:59,039
were getting some player with the with

1709
01:04:02,630 --> 01:04:00,720
the national academy of sciences we

1710
01:04:05,510 --> 01:04:02,640
still had to get nasa headquarters to

1711
01:04:08,069 --> 01:04:05,520
okay the whole thing

1712
01:04:10,630 --> 01:04:08,079
and we had a more serious problem

1713
01:04:12,710 --> 01:04:10,640

and that is uh i hadn't really worked

1714
01:04:15,589 --> 01:04:12,720
out all the details of how i was going

1715
01:04:17,589 --> 01:04:15,599
to transfer the spacecraft from the halo

1716
01:04:19,990 --> 01:04:17,599
orbit back in the tail and then out to

1717
01:04:22,870 --> 01:04:20,000
the out to the comet and the comet we

1718
01:04:25,190 --> 01:04:22,880
were going to go to was something called

1719
01:04:27,270 --> 01:04:25,200
jacubini zinner and i think a picture

1720
01:04:28,390 --> 01:04:27,280
that is on the next no no this is fred

1721
01:04:32,470 --> 01:04:28,400
scarf

1722
01:04:35,990 --> 01:04:32,480
me

1723
01:04:38,069 --> 01:04:36,000
make this end run also another fabulous

1724
01:04:39,270 --> 01:04:38,079
planetary scientist and been on a number

1725
01:04:41,670 --> 01:04:39,280
of missions

1726
01:04:43,270 --> 01:04:41,680
in plasma waves and uh was a real

1727
01:04:45,829 --> 01:04:43,280
pioneer

1728
01:04:47,990 --> 01:04:45,839
yeah i really miss fred yeah uh but

1729
01:04:50,870 --> 01:04:48,000
fortunately he lived to see the actual

1730
01:04:52,870 --> 01:04:50,880
common encounter and uh several years

1731
01:04:55,510 --> 01:04:52,880
afterwards published all kinds of papers

1732
01:04:58,069 --> 01:04:55,520
on it so that that was all good

1733
01:05:00,309 --> 01:04:58,079
uh but as i was saying that we we still

1734
01:05:02,150 --> 01:05:00,319
didn't know how to get there

1735
01:05:03,670 --> 01:05:02,160
but but in theory you figured it would

1736
01:05:06,069 --> 01:05:03,680
it would work right just like your

1737
01:05:08,069 --> 01:05:06,079
thesis and i knew that we could use a

1738
01:05:10,390 --> 01:05:08,079

lunar swing by that would give us enough

1739
01:05:12,950 --> 01:05:10,400
energy to get out there but we had to

1740
01:05:15,190 --> 01:05:12,960
get there at exactly the right time

1741
01:05:16,549 --> 01:05:15,200
the right angle and everything had to be

1742
01:05:19,510 --> 01:05:16,559
just perfect

1743
01:05:21,430 --> 01:05:19,520
and we were already in an orbit

1744
01:05:23,829 --> 01:05:21,440
around the earth and out in the halo

1745
01:05:25,829 --> 01:05:23,839
orbit as well and how are we going to do

1746
01:05:26,710 --> 01:05:25,839
that and we had to do it in a very short

1747
01:05:28,549 --> 01:05:26,720
time

1748
01:05:31,029 --> 01:05:28,559
next slide plays

1749
01:05:33,589 --> 01:05:31,039
oh this is a picture of jacobini's inner

1750
01:05:36,309 --> 01:05:33,599
and you see it has a nice ion tail going

1751
01:05:38,230 --> 01:05:36,319
out right which is unusual for the

1752
01:05:40,069 --> 01:05:38,240
shorter period comets

1753
01:05:42,470 --> 01:05:40,079
and this helped to sell the thing a

1754
01:05:44,710 --> 01:05:42,480
little bit because uh it did have this

1755
01:05:47,750 --> 01:05:44,720
nice tail it didn't look like a blob but

1756
01:05:49,670 --> 01:05:47,760
the idea because it was a uh

1757
01:05:51,750 --> 01:05:49,680
didn't have an image or that then it

1758
01:05:53,910 --> 01:05:51,760
made measurements of the solar wind and

1759
01:05:55,349 --> 01:05:53,920
the plasma interactions that indeed from

1760
01:05:58,549 --> 01:05:55,359
the very beginning you had planned to go

1761
01:06:00,150 --> 01:05:58,559
through the tail yes oh yeah definitely

1762
01:06:00,870 --> 01:06:00,160
yeah that was the only way we could do

1763
01:06:01,910 --> 01:06:00,880

it

1764
01:06:03,589 --> 01:06:01,920
uh

1765
01:06:05,670 --> 01:06:03,599
and we were going to get there at the

1766
01:06:08,230 --> 01:06:05,680
time it crossed the

1767
01:06:11,910 --> 01:06:08,240
ecliptic plane because that was the

1768
01:06:14,069 --> 01:06:11,920
lowest energy way to intercept the comet

1769
01:06:16,069 --> 01:06:14,079
and i wanted to get there on my birthday

1770
01:06:18,789 --> 01:06:16,079
which was september the 12th but

1771
01:06:20,630 --> 01:06:18,799
september 11th was the optimal time so i

1772
01:06:23,510 --> 01:06:20,640
couldn't change it you did make a

1773
01:06:26,230 --> 01:06:23,520
compromise i tried to come yeah i don't

1774
01:06:28,630 --> 01:06:26,240
always do this you don't yes you know

1775
01:06:31,190 --> 01:06:28,640
okay next slide please now now this show

1776
01:06:33,190 --> 01:06:31,200
this is too complicated but but the idea

1777
01:06:35,349 --> 01:06:33,200
is that

1778
01:06:37,510 --> 01:06:35,359
we we knew uh

1779
01:06:39,750 --> 01:06:37,520
pretty much when we had to hit the comet

1780
01:06:41,829 --> 01:06:39,760
so working with my colleague

1781
01:06:44,789 --> 01:06:41,839
david dunham who's in the audience out

1782
01:06:46,710 --> 01:06:44,799
there there he is hi dave

1783
01:06:49,910 --> 01:06:46,720
we worked on this thing for many many

1784
01:06:51,829 --> 01:06:49,920
months and what we had to do

1785
01:06:54,390 --> 01:06:51,839
was take the orbit that we were in and

1786
01:06:56,309 --> 01:06:54,400
we knew we had to use the moon to shape

1787
01:06:58,789 --> 01:06:56,319
things just right

1788
01:07:00,950 --> 01:06:58,799

so we had to use passes of the moon use

1789
01:07:02,230 --> 01:07:00,960
its gravity to shape the

1790
01:07:04,630 --> 01:07:02,240
flight path

1791
01:07:06,549 --> 01:07:04,640
so we would get to the moon at the on

1792
01:07:08,150 --> 01:07:06,559
the final time we wanted to launch out

1793
01:07:09,349 --> 01:07:08,160
to the comet at the right time and

1794
01:07:11,510 --> 01:07:09,359
everything

1795
01:07:13,750 --> 01:07:11,520
and we thought this well it's going to

1796
01:07:15,829 --> 01:07:13,760
take a little work but

1797
01:07:18,390 --> 01:07:15,839
we knew the beginning of the of the

1798
01:07:21,190 --> 01:07:18,400
flight path in the end but it's like

1799
01:07:23,109 --> 01:07:21,200
digging a tunnel through a mountain

1800
01:07:25,270 --> 01:07:23,119
from both sides and hoping you're going

1801
01:07:27,589 --> 01:07:25,280
to meet in the middle and you're not

1802
01:07:29,430 --> 01:07:27,599
sure and we kept going this way as we

1803
01:07:30,950 --> 01:07:29,440
calculated things and then no this

1804
01:07:32,470 --> 01:07:30,960
wasn't going to work we worked out for

1805
01:07:34,789 --> 01:07:32,480
about three months

1806
01:07:36,230 --> 01:07:34,799
trying to shotgun the thing

1807
01:07:39,270 --> 01:07:36,240
but then you had this meeting at nasa

1808
01:07:41,349 --> 01:07:39,280
headquarters and it had to be right

1809
01:07:43,109 --> 01:07:41,359
we had to find it in time for that

1810
01:07:44,710 --> 01:07:43,119
meeting but we figured we had about

1811
01:07:46,309 --> 01:07:44,720
eight or nine months and it shouldn't

1812
01:07:47,990 --> 01:07:46,319
take it shouldn't be any big problem but

1813
01:07:50,470 --> 01:07:48,000

we worked out for about three months and

1814
01:07:51,910 --> 01:07:50,480
dave really worked hard trying all kinds

1815
01:07:53,750 --> 01:07:51,920
of different things

1816
01:07:56,309 --> 01:07:53,760
but there's an infinite number of ways

1817
01:07:57,190 --> 01:07:56,319
that you can do this and we only did

1818
01:07:59,510 --> 01:07:57,200
maybe

1819
01:08:01,430 --> 01:07:59,520
a few thousand tried a few thousand

1820
01:08:03,829 --> 01:08:01,440
cases and nothing worked

1821
01:08:05,910 --> 01:08:03,839
well i wasn't too concerned then then

1822
01:08:07,510 --> 01:08:05,920
then we came up with a more systematic

1823
01:08:09,750 --> 01:08:07,520
way and we narrowed it down to about a

1824
01:08:11,510 --> 01:08:09,760
hundred possibilities

1825
01:08:12,549 --> 01:08:11,520
and i was pretty sure we would get the

1826
01:08:13,670 --> 01:08:12,559
answer

1827
01:08:18,550 --> 01:08:13,680
and

1828
01:08:20,309 --> 01:08:18,560
that i was positive this was going to

1829
01:08:22,470 --> 01:08:20,319
work i said dave here

1830
01:08:24,550 --> 01:08:22,480
try this this and this and so dave went

1831
01:08:26,229 --> 01:08:24,560
away he worked on the thing came into my

1832
01:08:29,189 --> 01:08:26,239
office one day

1833
01:08:31,189 --> 01:08:29,199
and had about 10 of the cases there and

1834
01:08:32,870 --> 01:08:31,199
and and we had to move the flight path

1835
01:08:34,789 --> 01:08:32,880
through a certain angle

1836
01:08:36,630 --> 01:08:34,799
but none of the cases moved through that

1837
01:08:38,390 --> 01:08:36,640
angle i thought wait a minute this thing

1838
01:08:40,309 --> 01:08:38,400

is not going to work what am i going to

1839
01:08:42,309 --> 01:08:40,319
do it we've already talked to the

1840
01:08:43,910 --> 01:08:42,319
national academy of sciences they said

1841
01:08:45,829 --> 01:08:43,920
go ahead and do this thing and now we

1842
01:08:47,189 --> 01:08:45,839
don't know how to do it yeah and you're

1843
01:08:48,709 --> 01:08:47,199
going to ask what are my headquarters

1844
01:08:50,709 --> 01:08:48,719
yeah what are the money to pull it off

1845
01:08:53,829 --> 01:08:50,719
what am i going to tell people

1846
01:08:55,590 --> 01:08:53,839
so i drove home that evening i said oh

1847
01:08:57,829 --> 01:08:55,600
no now i've done it

1848
01:09:00,149 --> 01:08:57,839
but then i got home and dave called me

1849
01:09:02,229 --> 01:09:00,159
there was another case and we had

1850
01:09:04,309 --> 01:09:02,239
overshot the area that we were trying to

1851
01:09:07,110 --> 01:09:04,319
get to so now we had it bracketed so i

1852
01:09:10,309 --> 01:09:07,120
figured in in the end we would find the

1853
01:09:11,349 --> 01:09:10,319
the final solution and we did

1854
01:09:12,229 --> 01:09:11,359
barely

1855
01:09:18,470 --> 01:09:12,239
we

1856
01:09:20,309 --> 01:09:18,480
12 or 15 people

1857
01:09:22,390 --> 01:09:20,319
and they were integrating the flight

1858
01:09:24,550 --> 01:09:22,400
path out and it took them about two

1859
01:09:26,709 --> 01:09:24,560
weeks to go through each case

1860
01:09:28,070 --> 01:09:26,719
this is a very complicated thing because

1861
01:09:30,630 --> 01:09:28,080
we're operating at the edge of the

1862
01:09:33,030 --> 01:09:30,640
sphere of influence of the earth so

1863
01:09:34,470 --> 01:09:33,040

we're in the the whole flight path is

1864
01:09:36,390 --> 01:09:34,480
very chaotic

1865
01:09:37,590 --> 01:09:36,400
so it's difficult to calculate these

1866
01:09:40,309 --> 01:09:37,600
things

1867
01:09:43,030 --> 01:09:40,319
can't use two body formulas

1868
01:09:45,030 --> 01:09:43,040
but we did eventually find it and this

1869
01:09:47,430 --> 01:09:45,040
is the mission that we flew

1870
01:09:50,789 --> 01:09:47,440
and we did the first ever

1871
01:09:53,590 --> 01:09:50,799
lunar gravity as cis and we flew by the

1872
01:09:56,709 --> 01:09:53,600
moon five times to get to the comet

1873
01:10:00,229 --> 01:09:56,719
well for the first four times

1874
01:10:02,149 --> 01:10:00,239
we flew by the moon and we flew quite

1875
01:10:04,149 --> 01:10:02,159
far from the moon about 20 000

1876
01:10:06,229 --> 01:10:04,159
kilometers each time

1877
01:10:08,950 --> 01:10:06,239
there so management wasn't too worried

1878
01:10:11,910 --> 01:10:08,960
about us there were no reviews dave and

1879
01:10:13,510 --> 01:10:11,920
i were just two guys working on our own

1880
01:10:15,669 --> 01:10:13,520
and i said dave what do you think we

1881
01:10:17,510 --> 01:10:15,679
should go this way oh no let's just move

1882
01:10:19,590 --> 01:10:17,520
it a little bit this way okay that's

1883
01:10:21,750 --> 01:10:19,600
fine there's no reviews nothing it's not

1884
01:10:23,270 --> 01:10:21,760
like things are done nowadays yeah gone

1885
01:10:24,790 --> 01:10:23,280
are those days i can tell you that how

1886
01:10:26,390 --> 01:10:24,800
are they done nowadays oh you'd have

1887
01:10:28,470 --> 01:10:26,400
been reviewed to death you wouldn't have

1888
01:10:31,110 --> 01:10:28,480

time to do it

1889
01:10:32,950 --> 01:10:31,120
well but then we get we get we we got to

1890
01:10:35,270 --> 01:10:32,960
the final lunar swing by and all of a

1891
01:10:36,870 --> 01:10:35,280
sudden the the management realized that

1892
01:10:38,550 --> 01:10:36,880
these were going to be this one was

1893
01:10:40,870 --> 01:10:38,560
going to be a lot closer than all the

1894
01:10:43,030 --> 01:10:40,880
others this is going to be 120

1895
01:10:45,590 --> 01:10:43,040
kilometers above the surface of the moon

1896
01:10:47,510 --> 01:10:45,600
what they found out about wait wait a

1897
01:10:49,669 --> 01:10:47,520
minute this is very close

1898
01:10:52,310 --> 01:10:49,679
what if something goes wrong

1899
01:10:54,229 --> 01:10:52,320
next slide please

1900
01:10:56,390 --> 01:10:54,239
and this shows just how close it did

1901
01:10:57,189 --> 01:10:56,400
come to the lunar surface

1902
01:10:59,110 --> 01:10:57,199
and

1903
01:11:01,830 --> 01:10:59,120
about a month before

1904
01:11:03,990 --> 01:11:01,840
uh someone doing the orbit determination

1905
01:11:05,430 --> 01:11:04,000
wrote in the goddard weekly

1906
01:11:07,669 --> 01:11:05,440
they said well our latest orbit

1907
01:11:09,030 --> 01:11:07,679
determination shows

1908
01:11:11,030 --> 01:11:09,040
that the

1909
01:11:13,510 --> 01:11:11,040
flight path is going about 200

1910
01:11:15,990 --> 01:11:13,520
kilometers under the surface of the moon

1911
01:11:18,229 --> 01:11:16,000
and then and then they also wrote down

1912
01:11:20,390 --> 01:11:18,239
in this is in the in the goddard weekly

1913
01:11:23,030 --> 01:11:20,400

that went to the director and so forth

1914
01:11:25,510 --> 01:11:23,040
it says well we can't be perfect all the

1915
01:11:28,870 --> 01:11:27,430
then everybody made fun of the fact that

1916
01:11:30,950 --> 01:11:28,880
there was going to be a new feature on

1917
01:11:33,110 --> 01:11:30,960
the moon and they called it farquar's

1918
01:11:34,470 --> 01:11:33,120
furrow

1919
01:11:35,830 --> 01:11:34,480
you were going to dig a trench that's

1920
01:11:37,750 --> 01:11:35,840
right yeah

1921
01:11:39,510 --> 01:11:37,760
but humans of course is that raises it

1922
01:11:41,270 --> 01:11:39,520
to what we always call the level of

1923
01:11:43,270 --> 01:11:41,280
deadly visibility

1924
01:11:46,149 --> 01:11:43,280
now you've got reviews but you'd already

1925
01:11:47,669 --> 01:11:46,159
solved that problem yeah yeah i wasn't

1926
01:11:49,430 --> 01:11:47,679
really worried because i we we had

1927
01:11:52,310 --> 01:11:49,440
another correction to make and only took

1928
01:11:55,510 --> 01:11:52,320
a very small correction and we flew by

1929
01:11:56,950 --> 01:11:55,520
perfectly at 120 kilometers so it wasn't

1930
01:11:58,790 --> 01:11:56,960
a big deal yeah

1931
01:12:00,390 --> 01:11:58,800
then there were many other adventures on

1932
01:12:02,790 --> 01:12:00,400
the way out to the comet but we don't

1933
01:12:05,990 --> 01:12:02,800
have time to talk about all that and we

1934
01:12:08,790 --> 01:12:06,000
eventually got to comet jacobini center

1935
01:12:11,110 --> 01:12:08,800
and six months before everybody else

1936
01:12:13,350 --> 01:12:11,120
and time magazine talked about us

1937
01:12:15,430 --> 01:12:13,360
upstaging all the other people

1938
01:12:17,350 --> 01:12:15,440

and of course i ate that up that's what

1939
01:12:19,430 --> 01:12:17,360
i'd like to do

1940
01:12:21,510 --> 01:12:19,440
and so we were able to do the first

1941
01:12:24,229 --> 01:12:21,520
libration point mission and the first

1942
01:12:26,470 --> 01:12:24,239
comet mission and the next slide

1943
01:12:28,550 --> 01:12:26,480
uh oh that this is still showing us

1944
01:12:30,390 --> 01:12:28,560
flying by the moon and this is what it

1945
01:12:31,669 --> 01:12:30,400
looked like uh

1946
01:12:33,270 --> 01:12:31,679
if you were sitting behind the

1947
01:12:35,430 --> 01:12:33,280
spacecraft and the earth is in the

1948
01:12:38,550 --> 01:12:35,440
background looking like a crescent moon

1949
01:12:41,350 --> 01:12:38,560
here but the moon is in the foreground

1950
01:12:43,430 --> 01:12:41,360
and in the next slide

1951
01:12:46,390 --> 01:12:43,440
here we are coming to the comet this is

1952
01:12:48,550 --> 01:12:46,400
a picture that we gave to science news

1953
01:12:51,030 --> 01:12:48,560
i just got permission from science news

1954
01:12:53,110 --> 01:12:51,040
i can reproduce this picture now

1955
01:12:56,149 --> 01:12:53,120
okay so it's good that i did this before

1956
01:12:57,030 --> 01:12:56,159
this this meeting

1957
01:12:59,270 --> 01:12:57,040
and

1958
01:13:01,669 --> 01:12:59,280
the the next slide shows some of the

1959
01:13:04,630 --> 01:13:01,679
details of the traverse through the tail

1960
01:13:05,990 --> 01:13:04,640
and this also shows the magnetic field

1961
01:13:08,709 --> 01:13:06,000
measurements

1962
01:13:10,550 --> 01:13:08,719
uh superimposed on this false color

1963
01:13:12,550 --> 01:13:10,560

image of the comet

1964
01:13:15,590 --> 01:13:12,560
and you see we did a nice cross section

1965
01:13:17,110 --> 01:13:15,600
of the tail and

1966
01:13:18,709 --> 01:13:17,120
you can see the magnetic field

1967
01:13:20,229 --> 01:13:18,719
measurements and there

1968
01:13:22,390 --> 01:13:20,239
the

1969
01:13:24,550 --> 01:13:22,400
direction is changing as we fly through

1970
01:13:26,390 --> 01:13:24,560
the tail and since you're a scientist

1971
01:13:28,550 --> 01:13:26,400
that knows about this you go you know

1972
01:13:29,510 --> 01:13:28,560
comets don't have an intrinsic magnetic

1973
01:13:30,870 --> 01:13:29,520
field

1974
01:13:33,030 --> 01:13:30,880
but

1975
01:13:34,709 --> 01:13:33,040
they're much different than a

1976
01:13:36,470 --> 01:13:34,719
terrestrial planet with an atmosphere

1977
01:13:38,310 --> 01:13:36,480
it's sort of like a sort of like a

1978
01:13:40,149 --> 01:13:38,320
reverse you know instead of a big planet

1979
01:13:43,270 --> 01:13:40,159
with a small atmosphere a comet is a

1980
01:13:44,470 --> 01:13:43,280
small object with a large

1981
01:13:48,630 --> 01:13:44,480
neutral

1982
01:13:50,630 --> 01:13:48,640
then

1983
01:13:51,830 --> 01:13:50,640
a variety of plasma wave turbulence

1984
01:13:54,390 --> 01:13:51,840
takes over

1985
01:13:57,350 --> 01:13:54,400
uh the material interacts with the solar

1986
01:14:00,070 --> 01:13:57,360
wind and an induced magnetic field

1987
01:14:01,910 --> 01:14:00,080
arises from that and and this trajectory

1988
01:14:04,390 --> 01:14:01,920

that you had created

1989
01:14:07,030 --> 01:14:04,400
goes right through the tail

1990
01:14:09,350 --> 01:14:07,040
and uh this is um uh now

1991
01:14:11,910 --> 01:14:09,360
a fabulous set of observations are first

1992
01:14:14,630 --> 01:14:11,920
we can see as we go through the tail

1993
01:14:15,990 --> 01:14:14,640
the the the magnetic field directions

1994
01:14:17,990 --> 01:14:16,000
reverse from the southern and the

1995
01:14:20,229 --> 01:14:18,000
northern lobes and we go through the

1996
01:14:22,550 --> 01:14:20,239
center part called the plasma sheet

1997
01:14:24,070 --> 01:14:22,560
where the where the iron tail actually

1998
01:14:26,709 --> 01:14:24,080
is being formed

1999
01:14:28,310 --> 01:14:26,719
and so being uh

2000
01:14:29,350 --> 01:14:28,320
you know seeing it from earth and then

2001
01:14:31,110 --> 01:14:29,360
actually going through it and

2002
01:14:33,430 --> 01:14:31,120
understanding the physics of it uh of

2003
01:14:36,790 --> 01:14:33,440
course has really got the magnetospheric

2004
01:14:39,350 --> 01:14:36,800
uh community and and and uh plasma wave

2005
01:14:41,430 --> 01:14:39,360
and solar wind community very excited

2006
01:14:43,510 --> 01:14:41,440
and of course we've never done this

2007
01:14:45,510 --> 01:14:43,520
again all the other spacecraft or

2008
01:14:47,270 --> 01:14:45,520
imagers and have other types of

2009
01:14:48,709 --> 01:14:47,280
instrumentation on it and always went in

2010
01:14:51,030 --> 01:14:48,719
the front side where they could actually

2011
01:14:52,229 --> 01:14:51,040
see the comet itself going through the

2012
01:14:53,750 --> 01:14:52,239
tail you don't you don't have that

2013
01:14:56,310 --> 01:14:53,760

illumination we'll have to do another

2014
01:14:58,149 --> 01:14:56,320
one yeah we'll have to bob i'm sure

2015
01:14:59,270 --> 01:14:58,159
that's it works i'm going to get to this

2016
01:15:01,990 --> 01:14:59,280
in a second

2017
01:15:06,630 --> 01:15:04,470
yes discovery proposals are due today by

2018
01:15:07,910 --> 01:15:06,640
the way that's right

2019
01:15:14,390 --> 01:15:07,920
and

2020
01:15:20,950 --> 01:15:17,350
it's called prime i don't want it

2021
01:15:23,350 --> 01:15:20,960
bob okay i'm sorry i'm sorry okay um i'm

2022
01:15:25,189 --> 01:15:23,360
not supposed to do this uh let's see the

2023
01:15:28,950 --> 01:15:25,199
the next slide

2024
01:15:31,990 --> 01:15:28,960
um okay notable accomplishments yes uh

2025
01:15:34,149 --> 01:15:32,000
first spacecraft uh is stationed at a

2026
01:15:36,790 --> 01:15:34,159
libration point and

2027
01:15:38,709 --> 01:15:36,800
this has paved the way for a lot of

2028
01:15:41,270 --> 01:15:38,719
missions that have gone to libration

2029
01:15:43,350 --> 01:15:41,280
points yes like uh there's a spacecraft

2030
01:15:45,830 --> 01:15:43,360
called soho that's looking at the sun

2031
01:15:48,390 --> 01:15:45,840
from the european space agency

2032
01:15:51,590 --> 01:15:48,400
and um ace is there yeah

2033
01:15:52,470 --> 01:15:51,600
linda's there yeah and and genesis was

2034
01:15:53,590 --> 01:15:52,480
their

2035
01:15:55,149 --> 01:15:53,600
map

2036
01:15:58,390 --> 01:15:55,159
and uh in

2037
01:15:59,189 --> 01:15:58,400
2014 or so there's going to be

2038
01:16:01,590 --> 01:15:59,199

the

2039
01:16:03,830 --> 01:16:01,600
james webb space telescope is going to

2040
01:16:06,149 --> 01:16:03,840
the center of the l2 point

2041
01:16:08,790 --> 01:16:06,159
so now people don't don't feel like this

2042
01:16:11,590 --> 01:16:08,800
is just some theoretical thing now and

2043
01:16:13,350 --> 01:16:11,600
and and the ic3 mission really showed

2044
01:16:15,510 --> 01:16:13,360
them that this could be done was

2045
01:16:16,709 --> 01:16:15,520
practical and we could be done for very

2046
01:16:19,910 --> 01:16:16,719
little fuel

2047
01:16:22,070 --> 01:16:19,920
and it wasn't all that hard to do it and

2048
01:16:24,070 --> 01:16:22,080
we also did the first exploration of the

2049
01:16:25,990 --> 01:16:24,080
distant geotale

2050
01:16:27,990 --> 01:16:26,000
in the first common encounter so i liked

2051
01:16:29,669 --> 01:16:28,000
all these things

2052
01:16:31,750 --> 01:16:29,679
we did three missions with one

2053
01:16:33,750 --> 01:16:31,760
spacecraft this is probably the most

2054
01:16:35,990 --> 01:16:33,760
cost effective mission that nasa has

2055
01:16:39,510 --> 01:16:36,000
ever had at least i say so

2056
01:16:43,110 --> 01:16:39,520
uh and uh we did the extra two missions

2057
01:16:45,350 --> 01:16:43,120
uh and the the the surcharge

2058
01:16:47,510 --> 01:16:45,360
to do the extra two missions was like

2059
01:16:49,910 --> 01:16:47,520
two million dollars

2060
01:16:51,270 --> 01:16:49,920
very cheap yeah

2061
01:16:52,550 --> 01:16:51,280
well of course we're taking the page

2062
01:16:54,070 --> 01:16:52,560
from that book

2063
01:16:55,990 --> 01:16:54,080

uh both

2064
01:16:58,149 --> 01:16:56,000
the next two speakers are going to talk

2065
01:17:00,390 --> 01:16:58,159
about uh epoxy

2066
01:17:02,149 --> 01:17:00,400
and start us next and both of those

2067
01:17:03,590 --> 01:17:02,159
spacecraft have already completed their

2068
01:17:05,590 --> 01:17:03,600
prime missions but have enough fuel to

2069
01:17:07,910 --> 01:17:05,600
go on and do some other special

2070
01:17:09,990 --> 01:17:07,920
activities with comets it's good to have

2071
01:17:12,310 --> 01:17:10,000
do more than one thing and have extended

2072
01:17:14,470 --> 01:17:12,320
missions yes it is but as i say on the

2073
01:17:16,870 --> 01:17:14,480
last bullet here what's next

2074
01:17:18,950 --> 01:17:16,880
what's next for the ic3 spacecraft yeah

2075
01:17:21,830 --> 01:17:18,960
the story's not over okay let's see the

2076
01:17:24,149 --> 01:17:21,840
next slide well this shows the

2077
01:17:26,550 --> 01:17:24,159
path of the spacecraft around the sun

2078
01:17:28,830 --> 01:17:26,560
relative to a fixed sun earth line so

2079
01:17:31,430 --> 01:17:28,840
the earth and the sun are fixed in this

2080
01:17:32,950 --> 01:17:31,440
diagram and we have this looping motion

2081
01:17:34,709 --> 01:17:32,960
because when it goes inside of the

2082
01:17:36,229 --> 01:17:34,719
earth's orbit it's moving faster than

2083
01:17:39,750 --> 01:17:36,239
the earth

2084
01:17:42,149 --> 01:17:39,760
orbit you get this little loop it's

2085
01:17:45,189 --> 01:17:42,159
moving slower so relative to the earth

2086
01:17:47,590 --> 01:17:45,199
it seems to take this looping motion

2087
01:17:49,910 --> 01:17:47,600
and shortly after we

2088
01:17:53,110 --> 01:17:49,920

flew by jacobini's inner

2089
01:17:55,669 --> 01:17:53,120
i retargeted the spacecraft so that when

2090
01:17:58,790 --> 01:17:55,679
it it would come back to the earth in

2091
01:18:01,110 --> 01:17:58,800
august the 10th of 2014

2092
01:18:05,350 --> 01:18:01,120
and it would come by close to the moon

2093
01:18:07,430 --> 01:18:05,360
so we could recapture in an earth orbit

2094
01:18:10,870 --> 01:18:07,440
well

2095
01:18:14,310 --> 01:18:10,880
nasa decided that

2096
01:18:16,470 --> 01:18:14,320
it had done enough operations in 1997

2097
01:18:18,310 --> 01:18:16,480
and they terminated the operations on

2098
01:18:20,070 --> 01:18:18,320
the spacecraft well i didn't like that

2099
01:18:21,189 --> 01:18:20,080
but i couldn't say too much about it at

2100
01:18:23,510 --> 01:18:21,199
the time

2101
01:18:25,510 --> 01:18:23,520
but then we tried again to contact it in

2102
01:18:28,709 --> 01:18:25,520
2008

2103
01:18:30,790 --> 01:18:28,719
and i talked some people in the dsn to

2104
01:18:33,750 --> 01:18:30,800
look for it and sure enough we found it

2105
01:18:35,910 --> 01:18:33,760
was still working in 2008 and it's on

2106
01:18:38,310 --> 01:18:35,920
its way back to the earth

2107
01:18:41,590 --> 01:18:38,320
uh the next slide plays

2108
01:18:44,950 --> 01:18:41,600
we had thought about this uh one year

2109
01:18:46,630 --> 01:18:44,960
after the encounter with the comet

2110
01:18:48,790 --> 01:18:46,640
we thought well if the spacecraft can

2111
01:18:51,510 --> 01:18:48,800
come back to the earth sometime maybe we

2112
01:18:54,310 --> 01:18:51,520
can recapture it in earth orbit

2113
01:18:55,990 --> 01:18:54,320

bring it and use aerobraking to bring it

2114
01:18:58,630 --> 01:18:56,000
down to a lower earth orbit and then

2115
01:19:00,709 --> 01:18:58,640
pick it up with the space shuttle

2116
01:19:02,470 --> 01:19:00,719
so we had a little ceremony at the air

2117
01:19:04,470 --> 01:19:02,480
and space museum

2118
01:19:07,030 --> 01:19:04,480
and in this photograph

2119
01:19:09,350 --> 01:19:07,040
the second from the left there is

2120
01:19:12,550 --> 01:19:09,360
the nasa administrator at the time jim

2121
01:19:15,830 --> 01:19:12,560
fletcher and he signed a notice of

2122
01:19:17,990 --> 01:19:15,840
intent with the air and space museum

2123
01:19:20,470 --> 01:19:18,000
to bring the spacecraft back to the air

2124
01:19:23,189 --> 01:19:20,480
and space museum if we recapture it with

2125
01:19:25,750 --> 01:19:23,199
the space shuttle so i'm still hoping

2126
01:19:29,350 --> 01:19:25,760
that we can do something like that

2127
01:19:31,590 --> 01:19:29,360
and the final slide the next one

2128
01:19:34,149 --> 01:19:31,600
shows us coming back and here it is

2129
01:19:37,270 --> 01:19:34,159
coming back to the moon in

2130
01:19:38,630 --> 01:19:37,280
august 10 2014 doing a swing by of the

2131
01:19:41,110 --> 01:19:38,640
moon

2132
01:19:43,430 --> 01:19:41,120
uh coming back and then bringing it back

2133
01:19:44,870 --> 01:19:43,440
into the halo orbit

2134
01:19:47,669 --> 01:19:44,880
because i have to put it in the halo

2135
01:19:51,030 --> 01:19:47,679
orbit for a while because uh most of the

2136
01:19:53,189 --> 01:19:51,040
scientists on the ic3 mission felt that

2137
01:19:55,350 --> 01:19:53,199
we stole the spacecraft from him but we

2138
01:19:56,630 --> 01:19:55,360

really didn't steal it we just borrowed

2139
01:19:59,430 --> 01:19:56,640
it for a while

2140
01:20:01,270 --> 01:19:59,440
keith will be happy for the 30 yes he's

2141
01:20:02,870 --> 01:20:01,280
still working out at goddard and now

2142
01:20:05,750 --> 01:20:02,880
he'll be happy

2143
01:20:07,669 --> 01:20:05,760
he can do his thing again

2144
01:20:10,390 --> 01:20:07,679
but i'm planning to send it to another

2145
01:20:12,310 --> 01:20:10,400
comet in 2018 and we'll have to use some

2146
01:20:14,470 --> 01:20:12,320
more lunar swing buys but it's rather

2147
01:20:16,229 --> 01:20:14,480
it's kind of easy to do so that's what

2148
01:20:18,950 --> 01:20:16,239
i'm working on right now hopefully we

2149
01:20:20,310 --> 01:20:18,960
can do this all right well bob it's just

2150
01:20:22,550 --> 01:20:20,320
been delightful

2151
01:20:24,790 --> 01:20:22,560
talking to you this morning and we need

2152
01:20:26,229 --> 01:20:24,800
we need to have uh some questions from

2153
01:20:38,709 --> 01:20:26,239
the audience

2154
01:20:41,350 --> 01:20:39,510
okay

2155
01:20:43,990 --> 01:20:41,360
oh before you do that there's one story

2156
01:20:47,110 --> 01:20:44,000
that you didn't tell that i dearly love

2157
01:20:48,870 --> 01:20:47,120
and that is uh okay it might not be a

2158
01:20:50,709 --> 01:20:48,880
dearly love story but but you had a

2159
01:20:52,870 --> 01:20:50,719
heart attack

2160
01:20:54,550 --> 01:20:52,880
and you ended up in the hospital yeah

2161
01:20:56,550 --> 01:20:54,560
okay i can tell this story all right

2162
01:20:58,229 --> 01:20:56,560
yeah okay yeah uh

2163
01:21:00,310 --> 01:20:58,239

well dave and i were

2164
01:21:02,310 --> 01:21:00,320
i said we were working trying to find

2165
01:21:04,390 --> 01:21:02,320
the solution how were we going to use

2166
01:21:06,629 --> 01:21:04,400
the swing bias of the moon

2167
01:21:09,189 --> 01:21:06,639
to get out to the comet and there was no

2168
01:21:11,189 --> 01:21:09,199
and no solution was coming up

2169
01:21:12,870 --> 01:21:11,199
so

2170
01:21:14,950 --> 01:21:12,880
having nothing to do with that i was

2171
01:21:17,350 --> 01:21:14,960
playing basketball with my daughter and

2172
01:21:20,229 --> 01:21:17,360
then around thanksgiving time it was

2173
01:21:21,910 --> 01:21:20,239
cold outside and i didn't feel right and

2174
01:21:23,910 --> 01:21:21,920
i found out i was getting a heart attack

2175
01:21:24,870 --> 01:21:23,920
so i had to go to the intensive care

2176
01:21:27,030 --> 01:21:24,880
unit

2177
01:21:29,430 --> 01:21:27,040
and everything and

2178
01:21:31,030 --> 01:21:29,440
i told my wife i said listen bring my

2179
01:21:32,950 --> 01:21:31,040
briefcase in here and everything because

2180
01:21:35,669 --> 01:21:32,960
i can't stop working on this thing dave

2181
01:21:37,830 --> 01:21:35,679
and i have got to solve this problem

2182
01:21:40,070 --> 01:21:37,840
so i brought that in there and i started

2183
01:21:41,910 --> 01:21:40,080
talking about how and and they tried to

2184
01:21:43,990 --> 01:21:41,920
stop me from doing this but the the

2185
01:21:45,830 --> 01:21:44,000
doctor said well i won't be as stressed

2186
01:21:48,149 --> 01:21:45,840
out if i bring all the work in with me

2187
01:21:50,709 --> 01:21:48,159
so they went along with that

2188
01:21:53,590 --> 01:21:50,719

but then a couple of days later they had

2189
01:21:54,310 --> 01:21:53,600
the psychologist at the hospital talk to

2190
01:21:56,470 --> 01:21:54,320
me

2191
01:21:58,470 --> 01:21:56,480
because who's this crazy guy he's

2192
01:22:00,950 --> 01:21:58,480
talking about sending a spacecraft out

2193
01:22:03,110 --> 01:22:00,960
to the moon flying by the moon and then

2194
01:22:05,990 --> 01:22:03,120
sending it out to a comet this guy is

2195
01:22:09,430 --> 01:22:07,669
but i wasn't really and they well

2196
01:22:21,830 --> 01:22:09,440
unfortunately they did let you do that

2197
01:22:26,070 --> 01:22:23,350
thank you all and bob thank you for

2198
01:22:28,310 --> 01:22:26,080
keeping it clean i appreciate that

2199
01:22:29,990 --> 01:22:28,320
and uh dr green i have to tell you uh

2200
01:22:32,229 --> 01:22:30,000
after you finish your incredible work in

2201
01:22:35,430 --> 01:22:32,239
science you make a pretty good

2202
01:22:39,830 --> 01:22:37,270
okay well i have to tell you

2203
01:22:42,270 --> 01:22:39,840
particularly to our folks watching nasa

2204
01:22:44,310 --> 01:22:42,280
television across the country and via

2205
01:22:45,430 --> 01:22:44,320
www.nasa.gov i'm hearing in my ear that

2206
01:22:47,430 --> 01:22:45,440
we have

2207
01:22:50,070 --> 01:22:47,440
numerous classrooms watching the show

2208
01:22:52,390 --> 01:22:50,080
and for me i want to be very clear that

2209
01:22:54,629 --> 01:22:52,400
scientists are certainly incredibly

2210
01:22:56,870 --> 01:22:54,639
smart and brilliant and do incredible

2211
01:22:59,030 --> 01:22:56,880
work but they are really a lot of fun to

2212
01:23:00,310 --> 01:22:59,040
be around and they're really cool

2213
01:23:02,790 --> 01:23:00,320

so

2214
01:23:04,390 --> 01:23:02,800
those classrooms your science teachers

2215
01:23:05,669 --> 01:23:04,400
are really cool okay

2216
01:23:08,629 --> 01:23:05,679
remember that

2217
01:23:11,430 --> 01:23:08,639
speaking of cool our next speaker

2218
01:23:13,510 --> 01:23:11,440
dr michael ahern principal investigator

2219
01:23:16,629 --> 01:23:13,520
for the upcoming comment encounter which

2220
01:23:18,950 --> 01:23:16,639
i mentioned coming up on november 4th

2221
01:23:21,030 --> 01:23:18,960
dr hearn received his phd in astronomy

2222
01:23:22,790 --> 01:23:21,040
from the university of wisconsin and is

2223
01:23:24,550 --> 01:23:22,800
currently a distinguished

2224
01:23:26,950 --> 01:23:24,560
university professor at the university

2225
01:23:28,790 --> 01:23:26,960
of maryland and you probably know his

2226
01:23:29,830 --> 01:23:28,800
name because he was

2227
01:23:32,229 --> 01:23:29,840
is

2228
01:23:33,750 --> 01:23:32,239
the principal investigator for the deep

2229
01:23:37,030 --> 01:23:33,760
impact mission which

2230
01:23:38,709 --> 01:23:37,040
incredible media coverage and just was

2231
01:23:40,950 --> 01:23:38,719
just an awesome mission so ladies and

2232
01:23:49,350 --> 01:23:40,960
gentlemen please welcome dr michael

2233
01:23:53,990 --> 01:23:51,510
thank you duane

2234
01:23:55,590 --> 01:23:54,000
uh so i'm going to talk to you uh

2235
01:23:57,350 --> 01:23:55,600
today a little bit

2236
01:24:00,229 --> 01:23:57,360
about the deep impact mission you

2237
01:24:04,470 --> 01:24:00,239
already heard some of it from anita

2238
01:24:08,149 --> 01:24:04,480

and how it turned into the epoxy mission

2239
01:24:13,430 --> 01:24:10,709
if i can make this work

2240
01:24:17,030 --> 01:24:13,440
the deep impact mission was actually

2241
01:24:19,430 --> 01:24:17,040
two spacecraft not one

2242
01:24:21,990 --> 01:24:19,440
and

2243
01:24:24,310 --> 01:24:22,000
you have to see a picture of it there

2244
01:24:26,310 --> 01:24:24,320
where it was being the two spacecraft

2245
01:24:29,189 --> 01:24:26,320
were being mated together in the clean

2246
01:24:32,550 --> 01:24:29,199
room at ball aerospace ball built the

2247
01:24:36,149 --> 01:24:32,560
entire spacecraft two of them

2248
01:24:38,709 --> 01:24:36,159
the lower one is the impactor

2249
01:24:42,709 --> 01:24:38,719
and that's the one that went into comet

2250
01:24:44,709 --> 01:24:42,719
tempel 1 on the 4th of july in 2005

2251
01:24:46,470 --> 01:24:44,719
and the larger upper one is being

2252
01:24:47,750 --> 01:24:46,480
lowered down

2253
01:24:51,030 --> 01:24:47,760
to uh

2254
01:24:53,750 --> 01:24:51,040
mate with the impactor uh nestled inside

2255
01:24:55,830 --> 01:24:53,760
one end of the flyby spacecraft

2256
01:24:57,590 --> 01:24:55,840
uh so the flyby spacecraft is a little

2257
01:25:01,030 --> 01:24:57,600
bit bigger than the people you see there

2258
01:25:06,310 --> 01:25:03,110
the

2259
01:25:08,550 --> 01:25:06,320
flyby spacecraft is still doing fine

2260
01:25:11,030 --> 01:25:08,560
the impactor spacecraft

2261
01:25:13,030 --> 01:25:11,040
isn't really there

2262
01:25:15,110 --> 01:25:13,040
i should say that

2263
01:25:18,310 --> 01:25:15,120

bob farquhar i told you a lot about the

2264
01:25:19,990 --> 01:25:18,320
ice mission the first mission to any

2265
01:25:21,110 --> 01:25:20,000
comet

2266
01:25:25,910 --> 01:25:21,120
uh

2267
01:25:28,790 --> 01:25:25,920
vaverka will be talking about shortly

2268
01:25:30,550 --> 01:25:28,800
were the first two missions selected by

2269
01:25:34,790 --> 01:25:30,560
nasa and flown

2270
01:25:43,030 --> 01:25:38,950
stardust was selected in 1996 and

2271
01:25:45,510 --> 01:25:43,040
deep impact was selected in 1998

2272
01:25:53,030 --> 01:25:48,390
deep impact was meant to be the first

2273
01:25:55,910 --> 01:25:53,040
planet scale experiment on a comet

2274
01:25:57,270 --> 01:25:55,920
the impact

2275
01:25:58,870 --> 01:25:57,280
had

2276
01:26:01,110 --> 01:25:58,880
several aspects

2277
01:26:03,030 --> 01:26:01,120
uh some people thought

2278
01:26:04,709 --> 01:26:03,040
before they saw what science came out

2279
01:26:05,830 --> 01:26:04,719
thought oh this is just a publicity

2280
01:26:07,510 --> 01:26:05,840
stunt

2281
01:26:08,629 --> 01:26:07,520
uh

2282
01:26:13,189 --> 01:26:08,639
the

2283
01:26:14,950 --> 01:26:13,199
asked me in an interview once how much

2284
01:26:17,590 --> 01:26:14,960
of this is little boys wanting to throw

2285
01:26:19,430 --> 01:26:17,600
things in a sandbox

2286
01:26:21,350 --> 01:26:19,440
and while there's a bit of that in it uh

2287
01:26:24,390 --> 01:26:21,360
we really were driven by the science and

2288
01:26:30,470 --> 01:26:26,310

but before i go on to talk a little bit

2289
01:26:32,310 --> 01:26:30,480
about deep impact i need to tell you

2290
01:26:35,030 --> 01:26:32,320
about the name evolution because a lot

2291
01:26:38,550 --> 01:26:35,040
of people get confused by it

2292
01:26:39,510 --> 01:26:38,560
after deep impact was all over

2293
01:26:41,990 --> 01:26:39,520
uh

2294
01:26:43,750 --> 01:26:42,000
drake deming of goddard space flight

2295
01:26:47,590 --> 01:26:43,760
center and i

2296
01:26:51,510 --> 01:26:47,600
wrote two entirely separate proposals to

2297
01:26:54,470 --> 01:26:51,520
reuse the deep impact flyby spacecraft

2298
01:26:56,709 --> 01:26:54,480
drake wanted to use it as an observatory

2299
01:26:59,430 --> 01:26:56,719
to study extrasolar planets

2300
01:27:02,830 --> 01:26:59,440
and i wanted to use it to

2301
01:27:07,990 --> 01:27:05,830
nasa selected both proposals

2302
01:27:11,030 --> 01:27:08,000
and said put them together

2303
01:27:13,430 --> 01:27:11,040
so the extrasolar planet observation and

2304
01:27:15,750 --> 01:27:13,440
characterization mission plus the deep

2305
01:27:18,070 --> 01:27:15,760
impact extended investigation became

2306
01:27:19,990 --> 01:27:18,080
epoxy

2307
01:27:21,350 --> 01:27:20,000
and i'm only going to talk about the

2308
01:27:23,910 --> 01:27:21,360
dixie part

2309
01:27:25,830 --> 01:27:23,920
the epic part is all finished and drake

2310
01:27:28,950 --> 01:27:25,840
deming's team is writing lots of papers

2311
01:27:31,030 --> 01:27:28,960
about the results from that

2312
01:27:32,709 --> 01:27:31,040
but i'll talk about the dixie part

2313
01:27:34,470 --> 01:27:32,719

that's going to comet hartley 2 on

2314
01:27:36,229 --> 01:27:34,480
november 4th

2315
01:27:37,510 --> 01:27:36,239
we have two

2316
01:27:39,510 --> 01:27:37,520
primary

2317
01:27:41,030 --> 01:27:39,520
scientific goals

2318
01:27:42,310 --> 01:27:41,040
of this mission

2319
01:27:45,270 --> 01:27:42,320
the first

2320
01:27:49,030 --> 01:27:45,280
is to try to understand

2321
01:27:51,590 --> 01:27:49,040
why comets are different by going to a

2322
01:27:53,750 --> 01:27:51,600
much smaller comet as anita said this is

2323
01:27:55,430 --> 01:27:53,760
a very small comet seems to be active

2324
01:27:57,590 --> 01:27:55,440
over all its surface

2325
01:27:59,510 --> 01:27:57,600
unlike the other comets we've been to

2326
01:28:01,750 --> 01:27:59,520
that are active only over a small part

2327
01:28:04,070 --> 01:28:01,760
of their surface

2328
01:28:05,910 --> 01:28:04,080
we also want to try to understand many

2329
01:28:07,910 --> 01:28:05,920
of the things we saw

2330
01:28:09,030 --> 01:28:07,920
at comet temple 1 during the prime

2331
01:28:10,310 --> 01:28:09,040
mission

2332
01:28:12,310 --> 01:28:10,320
and ask

2333
01:28:14,070 --> 01:28:12,320
which of these features really are

2334
01:28:16,149 --> 01:28:14,080
telling us about the origin of the solar

2335
01:28:17,990 --> 01:28:16,159
system and which of them are telling us

2336
01:28:20,149 --> 01:28:18,000
about more recent evolution of the

2337
01:28:24,229 --> 01:28:20,159
comets so those are the two goals of the

2338
01:28:29,110 --> 01:28:26,470

and

2339
01:28:30,870 --> 01:28:29,120
anita showed you some pictures from the

2340
01:28:32,870 --> 01:28:30,880
prime mission i'll show you a couple of

2341
01:28:34,709 --> 01:28:32,880
movies

2342
01:28:36,790 --> 01:28:34,719
think of yourself as running backwards

2343
01:28:39,430 --> 01:28:36,800
as fast as you can and the comet coming

2344
01:28:42,550 --> 01:28:39,440
down and hitting you on the head

2345
01:28:44,550 --> 01:28:42,560
that's roughly what's happening you have

2346
01:28:46,310 --> 01:28:44,560
to be running pretty fast

2347
01:28:49,430 --> 01:28:46,320
because the comet's coming at you at

2348
01:28:50,950 --> 01:28:49,440
about 10 kilometers per second

2349
01:28:53,990 --> 01:28:50,960
and you notice that the view from the

2350
01:28:55,990 --> 01:28:54,000
comet is bouncing around

2351
01:29:01,750 --> 01:28:56,000
these images are taken by the impactor

2352
01:29:07,430 --> 01:29:04,390
that image is bouncing around because

2353
01:29:10,070 --> 01:29:07,440
that third of a ton spacecraft

2354
01:29:14,470 --> 01:29:10,080
is being hit by dust particles that are

2355
01:29:16,070 --> 01:29:14,480
roughly 1 100 of an ounce

2356
01:29:17,110 --> 01:29:16,080
when you get to these high encounter

2357
01:29:20,470 --> 01:29:17,120
speeds

2358
01:29:21,830 --> 01:29:20,480
really tiny things can have a big effect

2359
01:29:24,149 --> 01:29:21,840
and you see we come down right in

2360
01:29:28,229 --> 01:29:24,159
between those two big craters that anita

2361
01:29:30,870 --> 01:29:29,030
so

2362
01:29:33,510 --> 01:29:30,880
uh

2363
01:29:36,149 --> 01:29:33,520

the impactor images stopped just before

2364
01:29:38,709 --> 01:29:36,159
we hit actually it kept on taking them

2365
01:29:40,070 --> 01:29:38,719
but last one we got back

2366
01:29:42,550 --> 01:29:40,080
here is the view from the flyby

2367
01:29:45,750 --> 01:29:42,560
spacecraft

2368
01:29:48,070 --> 01:29:45,760
and you need to notice two things

2369
01:29:50,390 --> 01:29:48,080
there's a time scale uh on the lower

2370
01:29:51,990 --> 01:29:50,400
left telling you the time frame impact

2371
01:29:54,229 --> 01:29:52,000
right at the time of impact there's a

2372
01:29:56,310 --> 01:29:54,239
really hot puff that goes really fast to

2373
01:29:58,870 --> 01:29:56,320
the lower right corner there it's gone

2374
01:30:03,510 --> 01:30:01,430
that hot puff that went by is about a

2375
01:30:06,709 --> 01:30:03,520
ton of material three times the amount

2376
01:30:10,390 --> 01:30:06,719
of material that went in moving at about

2377
01:30:13,990 --> 01:30:11,910
probably it contained part of the

2378
01:30:15,669 --> 01:30:14,000
impactor some parts of the impact are

2379
01:30:17,590 --> 01:30:15,679
evaporated

2380
01:30:21,189 --> 01:30:17,600
the rest of the impactor

2381
01:30:24,229 --> 01:30:21,199
is probably molten metal buried 20 20 to

2382
01:30:26,790 --> 01:30:24,239
30 meters deep on the cometary nucleus

2383
01:30:29,110 --> 01:30:26,800
probably most of it's still there

2384
01:30:30,870 --> 01:30:29,120
most of it wouldn't vaporize at least as

2385
01:30:34,629 --> 01:30:30,880
we understand from our analogies with

2386
01:30:38,709 --> 01:30:36,709
so anita told you some of the things we

2387
01:30:42,070 --> 01:30:38,719
found out

2388
01:30:48,550 --> 01:30:47,189

impact was the key goal of the mission

2389
01:30:51,270 --> 01:30:48,560
and

2390
01:30:53,510 --> 01:30:51,280
from that we found out for example by a

2391
01:30:55,750 --> 01:30:53,520
completely independent method

2392
01:30:57,350 --> 01:30:55,760
watching the debris fall back on the

2393
01:30:58,229 --> 01:30:57,360
surface

2394
01:31:00,390 --> 01:30:58,239
that

2395
01:31:02,470 --> 01:31:00,400
the gravity is very low

2396
01:31:05,990 --> 01:31:02,480
and most of the inside of the comet has

2397
01:31:11,030 --> 01:31:08,870
and as anita told you we found out

2398
01:31:13,110 --> 01:31:11,040
that the material we dug up

2399
01:31:15,270 --> 01:31:13,120
down going down 20 meters had the same

2400
01:31:17,110 --> 01:31:15,280
composition as what normally comes out

2401
01:31:18,790 --> 01:31:17,120
right at the surface

2402
01:31:20,390 --> 01:31:18,800
that contradicts a lot of the

2403
01:31:22,149 --> 01:31:20,400
theoretical models of what should be

2404
01:31:23,110 --> 01:31:22,159
happening

2405
01:31:27,030 --> 01:31:23,120
and

2406
01:31:29,590 --> 01:31:28,390
although

2407
01:31:30,790 --> 01:31:29,600
we predict

2408
01:31:32,790 --> 01:31:30,800
that

2409
01:31:34,550 --> 01:31:32,800
the dry ice the car frozen carbon

2410
01:31:36,070 --> 01:31:34,560
dioxide and the water ice should

2411
01:31:37,110 --> 01:31:36,080
separate

2412
01:31:38,870 --> 01:31:37,120
the

2413
01:31:41,110 --> 01:31:38,880

surface erodes

2414
01:31:43,750 --> 01:31:41,120
fast enough all the dust getting lifted

2415
01:31:45,830 --> 01:31:43,760
up by the gas it erodes fast enough so

2416
01:31:47,590 --> 01:31:45,840
that the ices down below don't have time

2417
01:31:49,510 --> 01:31:47,600
to separate now that's not what most of

2418
01:31:50,470 --> 01:31:49,520
the models predicted

2419
01:31:52,709 --> 01:31:50,480
so

2420
01:31:56,830 --> 01:31:52,719
we found many results that

2421
01:31:59,590 --> 01:31:56,840
uh contradict previous predictions

2422
01:32:03,350 --> 01:31:59,600
the very low density is a problem for

2423
01:32:06,950 --> 01:32:04,950
you know out in the kuiper belt that

2424
01:32:08,790 --> 01:32:06,960
anita talked about we think things

2425
01:32:10,709 --> 01:32:08,800
should come together at one or two

2426
01:32:12,390 --> 01:32:10,719
kilometers per second

2427
01:32:14,950 --> 01:32:12,400
how do you bring things together at one

2428
01:32:16,950 --> 01:32:14,960
or two kilometers per second

2429
01:32:20,229 --> 01:32:16,960
have them stick together

2430
01:32:22,310 --> 01:32:20,239
and still maintain that porosity

2431
01:32:25,430 --> 01:32:22,320
that's a challenge for the physicists

2432
01:32:31,590 --> 01:32:26,870
so

2433
01:32:37,030 --> 01:32:33,910
saw

2434
01:32:40,629 --> 01:32:38,950
i want to say that

2435
01:32:43,669 --> 01:32:40,639
here are the pictures of the four comets

2436
01:32:49,750 --> 01:32:46,390
the three pictures on the right

2437
01:32:52,390 --> 01:32:49,760
are all printed at the same scale

2438
01:32:54,790 --> 01:32:52,400

so those three cometary nuclei are

2439
01:32:58,149 --> 01:32:54,800
roughly all the same size comet halley

2440
01:33:00,390 --> 01:32:58,159
is a factor of a few bigger

2441
01:33:03,750 --> 01:33:00,400
the comet we are going to comet hartley

2442
01:33:05,669 --> 01:33:03,760
2 is 5 times smaller

2443
01:33:07,990 --> 01:33:05,679
and we think it's active over all its

2444
01:33:10,709 --> 01:33:08,000
surface

2445
01:33:13,350 --> 01:33:10,719
so by going to a much smaller comet and

2446
01:33:15,910 --> 01:33:13,360
one that's much more active

2447
01:33:18,550 --> 01:33:15,920
uh in terms of how much surface is

2448
01:33:25,030 --> 01:33:18,560
active we hope to understand why some of

2449
01:33:28,629 --> 01:33:25,990
now

2450
01:33:31,510 --> 01:33:28,639
one of the important things i like to

2451
01:33:35,189 --> 01:33:31,520
point out about deep impact is

2452
01:33:37,830 --> 01:33:35,199
that although we proposed a mission

2453
01:33:39,350 --> 01:33:37,840
to do an impact and see what happens

2454
01:33:43,110 --> 01:33:39,360
and measure the physical properties and

2455
01:33:47,030 --> 01:33:44,870
only about half of the results from the

2456
01:33:48,950 --> 01:33:47,040
mission came from the impact

2457
01:33:50,390 --> 01:33:48,960
the other half came from what i call the

2458
01:33:51,990 --> 01:33:50,400
harwitt principle

2459
01:33:55,189 --> 01:33:52,000
martin harwitt was a professor at

2460
01:33:56,709 --> 01:33:55,199
cornell a director of the national air

2461
01:33:58,870 --> 01:33:56,719
and space museum

2462
01:33:59,990 --> 01:33:58,880
wrote a book pointing out

2463
01:34:01,990 --> 01:34:00,000

that

2464
01:34:03,669 --> 01:34:02,000
you write a lot of science justification

2465
01:34:05,510 --> 01:34:03,679
every time you want to do a big project

2466
01:34:07,350 --> 01:34:05,520
in astronomy

2467
01:34:09,189 --> 01:34:07,360
and you look back 10 years after you did

2468
01:34:11,510 --> 01:34:09,199
the project and what do you remember it

2469
01:34:12,870 --> 01:34:11,520
for not what you proposed it for but

2470
01:34:14,310 --> 01:34:12,880
because of all the unexpected

2471
01:34:16,310 --> 01:34:14,320
discoveries

2472
01:34:18,149 --> 01:34:16,320
because you went to a new place with a

2473
01:34:19,590 --> 01:34:18,159
new technique did a new kind of

2474
01:34:23,510 --> 01:34:19,600
experiment

2475
01:34:26,149 --> 01:34:23,520
had much better spatial resolution

2476
01:34:27,669 --> 01:34:26,159
or you did some something else unique

2477
01:34:30,390 --> 01:34:27,679
and you've made

2478
01:34:32,149 --> 01:34:30,400
unexpected discoveries

2479
01:34:34,149 --> 01:34:32,159
so that's an important principle and at

2480
01:34:36,790 --> 01:34:34,159
least half the results from deep impact

2481
01:34:39,189 --> 01:34:36,800
came from that

2482
01:34:41,830 --> 01:34:39,199
so here are a few pictures from deep

2483
01:34:46,390 --> 01:34:44,390
the picture on the lower left

2484
01:34:48,470 --> 01:34:46,400
points out the smooth areas that anita

2485
01:34:50,070 --> 01:34:48,480
talked about and joe vaverka will talk

2486
01:34:52,310 --> 01:34:50,080
more about that when he talks about

2487
01:34:54,870 --> 01:34:52,320
stardust next going back to comet temple

2488
01:34:59,590 --> 01:34:57,109

picture on the upper right shows the icy

2489
01:35:01,990 --> 01:34:59,600
areas and again joe will talk more about

2490
01:35:06,149 --> 01:35:04,149
right below that picture on the upper

2491
01:35:08,709 --> 01:35:06,159
right are pictures of where the gas is

2492
01:35:11,350 --> 01:35:08,719
coming out the black spot in the center

2493
01:35:14,550 --> 01:35:11,360
is where the nucleus has been removed

2494
01:35:17,910 --> 01:35:14,560
these were taken with our spectrometer

2495
01:35:19,590 --> 01:35:17,920
and the upper image is an image of where

2496
01:35:21,270 --> 01:35:19,600
the water is coming out and the bottom

2497
01:35:23,350 --> 01:35:21,280
one is an image of where the carbon

2498
01:35:25,669 --> 01:35:23,360
dioxide is coming out the water ice and

2499
01:35:27,910 --> 01:35:25,679
the dry eyes

2500
01:35:30,070 --> 01:35:27,920
and you notice that the water ice is

2501
01:35:33,030 --> 01:35:30,080
coming out mainly to the right that's

2502
01:35:35,030 --> 01:35:33,040
where it's noontime on the comet

2503
01:35:36,709 --> 01:35:35,040
carbon dioxide has got a whole bunch

2504
01:35:38,790 --> 01:35:36,719
coming out in the lower left that's

2505
01:35:39,830 --> 01:35:38,800
coming out the south pole

2506
01:35:42,149 --> 01:35:39,840
where it's

2507
01:35:44,790 --> 01:35:42,159
been in winter permanent darkness for

2508
01:35:49,109 --> 01:35:46,950
now is this because

2509
01:35:51,350 --> 01:35:49,119
of modern evolution or is that telling

2510
01:35:53,270 --> 01:35:51,360
us we brought together

2511
01:35:54,830 --> 01:35:53,280
pieces of the comet from different parts

2512
01:35:57,750 --> 01:35:54,840
of the solar

2513
01:36:00,550 --> 01:35:57,760

nebula stardust discovered

2514
01:36:03,510 --> 01:36:00,560
mixing of microscopic materials is this

2515
01:36:05,430 --> 01:36:03,520
a sign of mixing of the really big stuff

2516
01:36:09,109 --> 01:36:05,440
the final the comitesmals that came

2517
01:36:13,030 --> 01:36:11,270
uh on the left

2518
01:36:14,790 --> 01:36:13,040
uh

2519
01:36:17,910 --> 01:36:14,800
just in from the left you see a picture

2520
01:36:19,990 --> 01:36:17,920
with a bunch of yellow on it

2521
01:36:22,470 --> 01:36:20,000
there's a dark band going across the

2522
01:36:25,350 --> 01:36:22,480
nucleus that extends all the way back

2523
01:36:27,430 --> 01:36:25,360
parallel to that upper surface

2524
01:36:29,910 --> 01:36:27,440
uh some of us would like to interpret

2525
01:36:32,229 --> 01:36:29,920
that as an original comitezmo where the

2526
01:36:36,070 --> 01:36:32,239
two pieces of last couple of pieces of

2527
01:36:41,510 --> 01:36:38,070
you also see a bunch of jets in a

2528
01:36:43,350 --> 01:36:41,520
picture to the uh to the right of that

2529
01:36:45,510 --> 01:36:43,360
those jets aren't coming from the icy

2530
01:36:48,070 --> 01:36:45,520
areas all the models said

2531
01:36:49,990 --> 01:36:48,080
we get jets in comets

2532
01:36:52,870 --> 01:36:50,000
where you have exposed ice on the

2533
01:36:55,109 --> 01:36:52,880
surface well you do get

2534
01:36:57,030 --> 01:36:55,119
really tiny jets from the exposed ice on

2535
01:37:00,310 --> 01:36:57,040
the surface but most of those jets

2536
01:37:04,550 --> 01:37:00,320
aren't where there's any exposed ice

2537
01:37:11,189 --> 01:37:08,229
in the upper left you see a graph that

2538
01:37:16,310 --> 01:37:13,510

the comet temple one had a random

2539
01:37:18,629 --> 01:37:16,320
outburst roughly every two weeks roughly

2540
01:37:20,629 --> 01:37:18,639
twice a week

2541
01:37:22,470 --> 01:37:20,639
we knew we've known for almost a century

2542
01:37:24,470 --> 01:37:22,480
that comets have outburst but we never

2543
01:37:27,109 --> 01:37:24,480
had the really continuous coverage to

2544
01:37:28,709 --> 01:37:27,119
show how often and to show really small

2545
01:37:31,109 --> 01:37:28,719
outbursts

2546
01:37:33,350 --> 01:37:31,119
uh these seem to be correlated with the

2547
01:37:35,910 --> 01:37:33,360
orientation of the nucleus they probably

2548
01:37:38,070 --> 01:37:35,920
only come from a couple of areas

2549
01:37:39,750 --> 01:37:38,080
on the nucleus

2550
01:37:41,030 --> 01:37:39,760
but outbursts twice a week were quite

2551
01:37:42,390 --> 01:37:41,040
surprising

2552
01:37:45,990 --> 01:37:42,400
don't know if that's common to all

2553
01:37:51,750 --> 01:37:48,950
so these are some of the results

2554
01:37:53,270 --> 01:37:51,760
uh heterogeneity ice

2555
01:37:55,030 --> 01:37:53,280
is a little bit on the surface but most

2556
01:37:57,189 --> 01:37:55,040
of the water has to come from ice that's

2557
01:37:59,590 --> 01:37:57,199
buried under the surface that says the

2558
01:38:03,750 --> 01:37:59,600
ice is very close to the surface

2559
01:38:06,790 --> 01:38:05,270
so

2560
01:38:10,550 --> 01:38:06,800
the

2561
01:38:13,189 --> 01:38:10,560
we're going on to comet hartley 2

2562
01:38:15,430 --> 01:38:13,199
which is shown here

2563
01:38:18,550 --> 01:38:15,440

that's a picture from lowell observatory

2564
01:38:21,510 --> 01:38:18,560
in july of this year

2565
01:38:23,910 --> 01:38:21,520
uh we have been enroute we've spent the

2566
01:38:25,830 --> 01:38:23,920
last several years

2567
01:38:28,149 --> 01:38:25,840
orbiting the sun flying back by the

2568
01:38:30,709 --> 01:38:28,159
earth every six months

2569
01:38:32,870 --> 01:38:30,719
we studied the the

2570
01:38:35,189 --> 01:38:32,880
lunar hydration the the water on the

2571
01:38:36,790 --> 01:38:35,199
moon showed that it comes and goes every

2572
01:38:39,350 --> 01:38:36,800
time the uh

2573
01:38:41,590 --> 01:38:39,360
moon goes through a day

2574
01:38:43,350 --> 01:38:41,600
uh but now we're

2575
01:38:45,270 --> 01:38:43,360
we're not coming back to the earth again

2576
01:38:48,310 --> 01:38:45,280
we're off to the comet

2577
01:38:51,030 --> 01:38:48,320
and we just started observing the comet

2578
01:38:52,070 --> 01:38:51,040
on this past sunday

2579
01:38:54,390 --> 01:38:52,080
and

2580
01:38:58,229 --> 01:38:54,400
here's a picture of the comet that we

2581
01:39:01,510 --> 01:38:58,239
took from the spacecraft last sunday

2582
01:39:04,229 --> 01:39:01,520
uh it's that fuzzy thing in the middle

2583
01:39:07,590 --> 01:39:04,239
doesn't look very impressive

2584
01:39:09,189 --> 01:39:07,600
but that's a ten inch telescope

2585
01:39:13,030 --> 01:39:09,199
that's further from the comet than the

2586
01:39:16,550 --> 01:39:15,750
and the fuzz that you see around there

2587
01:39:18,070 --> 01:39:16,560
if you

2588
01:39:19,590 --> 01:39:18,080

look carefully and play with the image

2589
01:39:22,709 --> 01:39:19,600
you can see that it extends at least

2590
01:39:24,830 --> 01:39:22,719
thirty to forty thousand kilometers

2591
01:39:27,109 --> 01:39:24,840
so this comet is really

2592
01:39:28,950 --> 01:39:27,119
active there's plenty of stuff there for

2593
01:39:30,629 --> 01:39:28,960
us to look at

2594
01:39:33,189 --> 01:39:30,639
as i say that's

2595
01:39:35,510 --> 01:39:33,199
an average of uh seven images from the

2596
01:39:38,149 --> 01:39:35,520
first day of observing

2597
01:39:40,790 --> 01:39:38,159
uh we've now got half a dozen days of

2598
01:39:43,109 --> 01:39:40,800
observing of the comet and already we're

2599
01:39:44,229 --> 01:39:43,119
seeing brightness variations

2600
01:39:45,830 --> 01:39:44,239
don't know whether we've seen an

2601
01:39:47,510 --> 01:39:45,840
outburst or not but we're certainly

2602
01:39:49,350 --> 01:39:47,520
seeing variations

2603
01:39:51,990 --> 01:39:49,360
we can right now we can only look at the

2604
01:39:53,350 --> 01:39:52,000
comet once every six hours

2605
01:39:55,510 --> 01:39:53,360
because if we look at the comet

2606
01:39:56,310 --> 01:39:55,520
continuously everything heats up too

2607
01:39:58,550 --> 01:39:56,320
much

2608
01:40:00,390 --> 01:39:58,560
uh in another couple of weeks the

2609
01:40:02,070 --> 01:40:00,400
geometry will change and we'll be able

2610
01:40:03,510 --> 01:40:02,080
to look at the comet uh almost

2611
01:40:05,830 --> 01:40:03,520
continuously

2612
01:40:07,030 --> 01:40:05,840
uh but for the first uh 20 days of

2613
01:40:09,030 --> 01:40:07,040

observing we're only looking

2614
01:40:11,270 --> 01:40:09,040
intermittently

2615
01:40:12,390 --> 01:40:11,280
so we are on our way

2616
01:40:16,229 --> 01:40:12,400
to

2617
01:40:17,109 --> 01:40:16,239
why comets are different from each other

2618
01:40:18,950 --> 01:40:17,119
and

2619
01:40:21,990 --> 01:40:18,960
which parts of them are really telling

2620
01:40:32,070 --> 01:40:22,000
us about the origin of the solar system

2621
01:40:35,669 --> 01:40:33,750
thank you dr ahern

2622
01:40:37,910 --> 01:40:35,679
just two quick questions if i may the

2623
01:40:39,590 --> 01:40:37,920
first what is the approximate mass of

2624
01:40:41,189 --> 01:40:39,600
the spacecraft

2625
01:40:43,669 --> 01:40:41,199
the flyby spacecraft it's about

2626
01:40:45,590 --> 01:40:43,679
two-thirds of a ton okay and the second

2627
01:40:48,149 --> 01:40:45,600
question is can you explain what the

2628
01:40:49,510 --> 01:40:48,159
difference is i'm a layman in this area

2629
01:40:53,750 --> 01:40:49,520
but what's the difference between a

2630
01:40:54,550 --> 01:40:53,760
non-active comet and a meteor

2631
01:40:55,990 --> 01:40:54,560
oh

2632
01:40:57,990 --> 01:40:56,000
a meteor

2633
01:40:59,830 --> 01:40:58,000
is a phenomenon in the earth's

2634
01:41:02,310 --> 01:40:59,840
atmosphere

2635
01:41:06,629 --> 01:41:02,320
and when you see a meteor mostly what

2636
01:41:09,109 --> 01:41:06,639
you're seeing is the trail of

2637
01:41:11,030 --> 01:41:09,119
ionized gas in the earth's atmosphere

2638
01:41:12,390 --> 01:41:11,040

that's made by the meteor moving through

2639
01:41:14,310 --> 01:41:12,400
it that's the primary thing you're

2640
01:41:16,149 --> 01:41:14,320
seeing is you're seeing some glow from

2641
01:41:19,590 --> 01:41:16,159
the meteor

2642
01:41:21,270 --> 01:41:19,600
break off

2643
01:41:23,109 --> 01:41:21,280
but those are solid particles that come

2644
01:41:24,870 --> 01:41:23,119
into the earth's atmosphere

2645
01:41:26,870 --> 01:41:24,880
some of those particles come originally

2646
01:41:37,270 --> 01:41:26,880
from comets others come originally from

2647
01:41:41,350 --> 01:41:38,709
how much mass

2648
01:41:43,910 --> 01:41:41,360
would a typical comet lose

2649
01:41:45,030 --> 01:41:43,920
on a single circuit of the sun i mean it

2650
01:41:47,109 --> 01:41:45,040
has a

2651
01:41:49,830 --> 01:41:47,119
finite

2652
01:41:51,430 --> 01:41:49,840
body of water water ice gases and so

2653
01:41:54,470 --> 01:41:51,440
forth

2654
01:41:56,790 --> 01:41:54,480
well in the case in the case of comet

2655
01:41:57,910 --> 01:41:56,800
temple one

2656
01:41:59,910 --> 01:41:57,920
that's about

2657
01:42:01,750 --> 01:41:59,920
three kilometers in radius i mean it's

2658
01:42:03,350 --> 01:42:01,760
not a sphere but

2659
01:42:04,629 --> 01:42:03,360
on average it's about three kilometer

2660
01:42:05,669 --> 01:42:04,639
radius

2661
01:42:07,350 --> 01:42:05,679
and

2662
01:42:09,189 --> 01:42:07,360
if you just look at how much material

2663
01:42:11,830 --> 01:42:09,199

comes out as it goes around the sun it

2664
01:42:14,870 --> 01:42:11,840
has to lose somewhere between a third

2665
01:42:16,470 --> 01:42:14,880
and a half a meter of material

2666
01:42:23,990 --> 01:42:16,480
every time it goes around the sun

2667
01:42:28,870 --> 01:42:26,790
did the impactor on deep impact impart

2668
01:42:30,470 --> 01:42:28,880
any measurable discernible delta v to

2669
01:42:31,830 --> 01:42:30,480
the comet itself or was it just too

2670
01:42:33,510 --> 01:42:31,840
small

2671
01:42:36,790 --> 01:42:33,520
yeah

2672
01:42:38,149 --> 01:42:36,800
we have done the calculation

2673
01:42:41,109 --> 01:42:38,159
um

2674
01:42:43,510 --> 01:42:41,119
it's not measurable uh this is actually

2675
01:42:46,709 --> 01:42:43,520
important for the issue of

2676
01:42:48,229 --> 01:42:46,719
deflecting potential impactors

2677
01:42:49,910 --> 01:42:48,239
uh on earth

2678
01:42:52,310 --> 01:42:49,920
um chain

2679
01:42:54,870 --> 01:42:52,320
the change in speed

2680
01:42:57,030 --> 01:42:54,880
of the nucleus

2681
01:43:01,270 --> 01:42:57,040
should have been less than uh

2682
01:43:05,510 --> 01:43:03,030
if you do a crude estimate of how much

2683
01:43:07,510 --> 01:43:05,520
it should have changed

2684
01:43:10,310 --> 01:43:07,520
at the next perihelion passage when

2685
01:43:11,270 --> 01:43:10,320
joe's going to go back and look again

2686
01:43:15,109 --> 01:43:11,280
it should

2687
01:43:17,350 --> 01:43:15,119
be displaced from its original orbit by

2688
01:43:19,109 --> 01:43:17,360

less than 100 meters by less than the

2689
01:43:20,070 --> 01:43:19,119
size of one of those craters on the

2690
01:43:24,390 --> 01:43:20,080
surface

2691
01:43:27,990 --> 01:43:25,910
and

2692
01:43:30,709 --> 01:43:28,000
the real thing is it was a small

2693
01:43:32,470 --> 01:43:30,719
impactor into a relatively large

2694
01:43:34,390 --> 01:43:32,480
cometary nucleus

2695
01:43:35,910 --> 01:43:34,400
not as large as halle but relatively

2696
01:43:38,310 --> 01:43:35,920
large

2697
01:43:39,270 --> 01:43:38,320
and for the near-earth object hazard

2698
01:43:40,950 --> 01:43:39,280
issue

2699
01:43:43,510 --> 01:43:40,960
you're typically going to try and send

2700
01:43:53,750 --> 01:43:43,520
as much mass as you can and most of them

2701
01:43:58,870 --> 01:43:56,470
okay

2702
01:44:01,910 --> 01:43:58,880
uh

2703
01:44:03,830 --> 01:44:01,920
final speaker for today's program

2704
01:44:05,510 --> 01:44:03,840
he reminds me actually of one of my

2705
01:44:07,350 --> 01:44:05,520
favorite professors while i was in

2706
01:44:09,990 --> 01:44:07,360
school dr joe

2707
01:44:14,709 --> 01:44:12,470
received his phd from harvard

2708
01:44:15,830 --> 01:44:14,719
working under the mentorship of fred

2709
01:44:17,030 --> 01:44:15,840
whipple

2710
01:44:20,709 --> 01:44:17,040
who you

2711
01:44:22,950 --> 01:44:20,719
was mentioned earlier today and now

2712
01:44:25,109 --> 01:44:22,960
joe is professor

2713
01:44:26,070 --> 01:44:25,119

at cornell university ladies and

2714
01:44:34,550 --> 01:44:26,080
gentlemen

2715
01:44:37,990 --> 01:44:36,310
thank you duane and good morning

2716
01:44:39,669 --> 01:44:38,000
everyone uh

2717
01:44:41,590 --> 01:44:39,679
i am up here this morning to tell you a

2718
01:44:43,910 --> 01:44:41,600
little bit about the stardust next

2719
01:44:47,510 --> 01:44:43,920
mission and uh

2720
01:44:49,189 --> 01:44:47,520
in fact start us next is the tale of two

2721
01:44:50,470 --> 01:44:49,199
missions that you've already heard a

2722
01:44:54,070 --> 01:44:50,480
little bit about

2723
01:44:54,950 --> 01:44:54,080
uh deep impact and the original stardust

2724
01:45:00,310 --> 01:44:54,960
mission

2725
01:45:01,109 --> 01:45:00,320
launched in 1999

2726
01:45:03,430 --> 01:45:01,119
and

2727
01:45:08,070 --> 01:45:03,440
the objective of the stardust mission

2728
01:45:10,950 --> 01:45:08,080
was to encounter comet built to

2729
01:45:13,590 --> 01:45:10,960
collect dust from the coma of the comet

2730
01:45:14,629 --> 01:45:13,600
and return that dust for analysis on the

2731
01:45:16,950 --> 01:45:14,639
earth

2732
01:45:19,270 --> 01:45:16,960
and that happened successfully in

2733
01:45:22,629 --> 01:45:19,280
january of 2004

2734
01:45:25,590 --> 01:45:22,639
when the sort of spacecraft flew within

2735
01:45:27,910 --> 01:45:25,600
something like 140 miles of the nucleus

2736
01:45:31,189 --> 01:45:27,920
of uh bill 2

2737
01:45:33,830 --> 01:45:31,199
successfully collected dust and then was

2738
01:45:36,390 --> 01:45:33,840

on a trajectory that took the spacecraft

2739
01:45:38,709 --> 01:45:36,400
back to the earth the spacecraft had the

2740
01:45:40,550 --> 01:45:38,719
main body the spacecraft and a capsule

2741
01:45:42,390 --> 01:45:40,560
that contained the dust

2742
01:45:44,390 --> 01:45:42,400
and when

2743
01:45:47,830 --> 01:45:44,400
the two of them got close to the earth

2744
01:45:51,669 --> 01:45:47,840
the the capsule separated and landed in

2745
01:45:54,070 --> 01:45:51,679
the utah desert in january 2006

2746
01:45:55,990 --> 01:45:54,080
uh containing all this precious dust

2747
01:45:57,510 --> 01:45:56,000
from the coma that had been collected

2748
01:45:59,189 --> 01:45:57,520
earlier

2749
01:46:01,510 --> 01:45:59,199
in the meantime the main spacecraft

2750
01:46:02,310 --> 01:46:01,520
stayed in orbit around the sun

2751
01:46:03,270 --> 01:46:02,320
now

2752
01:46:05,910 --> 01:46:03,280
the

2753
01:46:08,550 --> 01:46:05,920
dust that was brought back

2754
01:46:11,750 --> 01:46:08,560
has been and continues to be

2755
01:46:12,709 --> 01:46:11,760
analyzed in great detail

2756
01:46:15,590 --> 01:46:12,719
it

2757
01:46:18,790 --> 01:46:15,600
continues to provide insights into not

2758
01:46:20,790 --> 01:46:18,800
only how comets formed but as anita

2759
01:46:22,310 --> 01:46:20,800
mentioned it provides important

2760
01:46:24,310 --> 01:46:22,320
information about

2761
01:46:27,350 --> 01:46:24,320
some of the physical and the chemical

2762
01:46:30,149 --> 01:46:27,360
processes that were going on in the

2763
01:46:32,550 --> 01:46:30,159

earliest phases of the nebula at which

2764
01:46:34,629 --> 01:46:32,560
the solar system formed 4.6 billion

2765
01:46:37,350 --> 01:46:34,639
years ago

2766
01:46:38,709 --> 01:46:37,360
so the original part of the stardust

2767
01:46:41,510 --> 01:46:38,719
mission

2768
01:46:42,709 --> 01:46:41,520
was accomplished and but

2769
01:46:45,830 --> 01:46:42,719
still

2770
01:46:48,470 --> 01:46:45,840
uh there was this wonderful spacecraft

2771
01:46:50,790 --> 01:46:48,480
left in orbit around the sun

2772
01:46:54,149 --> 01:46:50,800
which is in perfectly good shape working

2773
01:46:56,870 --> 01:46:54,159
very well and so in 2006

2774
01:47:00,390 --> 01:46:56,880
some of us decided to propose to nasa

2775
01:47:04,149 --> 01:47:00,400
that we could use the spacecraft to

2776
01:47:05,189 --> 01:47:04,159
explore some more about comets

2777
01:47:07,030 --> 01:47:05,199
and

2778
01:47:10,390 --> 01:47:07,040
this proposal

2779
01:47:12,950 --> 01:47:10,400
was accepted by nasa in 2007 and so that

2780
01:47:15,109 --> 01:47:12,960
was the beginning of the stardust next

2781
01:47:18,149 --> 01:47:15,119
mission next standing for the next

2782
01:47:21,350 --> 01:47:18,159
exploration of temple one because yes

2783
01:47:24,229 --> 01:47:21,360
indeed the comet we are going back to

2784
01:47:25,830 --> 01:47:24,239
is micah hearn's comment temple one

2785
01:47:27,669 --> 01:47:25,840
and so one of the questions you might

2786
01:47:29,990 --> 01:47:27,679
want to ask is

2787
01:47:32,470 --> 01:47:30,000
given the great success

2788
01:47:35,109 --> 01:47:32,480

that deep impact had in visiting temple

2789
01:47:37,109 --> 01:47:35,119
one why in the world would you want to

2790
01:47:39,590 --> 01:47:37,119
go back there again

2791
01:47:41,590 --> 01:47:39,600
and i think there are important reasons

2792
01:47:42,470 --> 01:47:41,600
so let me just sort of tell you some of

2793
01:47:43,350 --> 01:47:42,480
them

2794
01:47:45,669 --> 01:47:43,360
uh

2795
01:47:49,109 --> 01:47:45,679
probably the most and obvious and

2796
01:47:51,830 --> 01:47:49,119
simplest one comes from just looking at

2797
01:47:54,470 --> 01:47:51,840
one of the deep impact pictures of

2798
01:47:57,430 --> 01:47:54,480
temple one

2799
01:48:00,390 --> 01:47:57,440
this is an amazing comet

2800
01:48:01,590 --> 01:48:00,400
it has tremendous geologic diversity on

2801
01:48:03,910 --> 01:48:01,600
the surface

2802
01:48:06,149 --> 01:48:03,920
if you look carefully near the bottom of

2803
01:48:09,270 --> 01:48:06,159
the picture you will see some very

2804
01:48:11,750 --> 01:48:09,280
heavily eroded terrain places where isis

2805
01:48:14,390 --> 01:48:11,760
has sublimated and left the comet

2806
01:48:16,149 --> 01:48:14,400
a little bit higher up you see some very

2807
01:48:18,950 --> 01:48:16,159
smooth areas

2808
01:48:22,310 --> 01:48:18,960
areas that look very much as if

2809
01:48:24,470 --> 01:48:22,320
material erupted from the subsurface and

2810
01:48:26,310 --> 01:48:24,480
flowed across the surface leaving a very

2811
01:48:27,830 --> 01:48:26,320
very smooth deposit

2812
01:48:31,430 --> 01:48:27,840
if you go a little bit higher up in the

2813
01:48:34,629 --> 01:48:31,440

picture you will actually see layers

2814
01:48:36,310 --> 01:48:34,639
in the structure of the comet

2815
01:48:38,629 --> 01:48:36,320
i should say that in this particular

2816
01:48:41,189 --> 01:48:38,639
rendition this is a false color image

2817
01:48:43,350 --> 01:48:41,199
and the blue areas that you see

2818
01:48:45,910 --> 01:48:43,360
are the few areas

2819
01:48:47,669 --> 01:48:45,920
on the surface where water ice is

2820
01:48:50,149 --> 01:48:47,679
actually exposed

2821
01:48:52,149 --> 01:48:50,159
otherwise this is a very dark almost

2822
01:48:53,990 --> 01:48:52,159
black surface and those blue areas the

2823
01:48:56,870 --> 01:48:54,000
few places where you actually could see

2824
01:48:59,109 --> 01:48:56,880
water ice so it's a very very amazing

2825
01:49:02,149 --> 01:48:59,119
comet geologically and to sort of make

2826
01:49:03,590 --> 01:49:02,159
that point a little bit uh more clear

2827
01:49:07,030 --> 01:49:03,600
i'm going to show you

2828
01:49:09,189 --> 01:49:07,040
a geologic map of the comet this is what

2829
01:49:10,390 --> 01:49:09,199
geologists like to do where you

2830
01:49:13,350 --> 01:49:10,400
basically

2831
01:49:15,350 --> 01:49:13,360
look at the morphology of the surface

2832
01:49:17,750 --> 01:49:15,360
the kinds of things that you see

2833
01:49:19,830 --> 01:49:17,760
and assign different colors to things

2834
01:49:22,390 --> 01:49:19,840
that look different and so in this view

2835
01:49:25,270 --> 01:49:22,400
for example the heavily eroded terrains

2836
01:49:27,270 --> 01:49:25,280
are shown in orange the smooth flows

2837
01:49:28,709 --> 01:49:27,280
there are two of them in this view are

2838
01:49:31,350 --> 01:49:28,719

shown in yellow

2839
01:49:33,589 --> 01:49:31,360
and what you see in green are the areas

2840
01:49:35,990 --> 01:49:33,599
of layered terrains

2841
01:49:37,750 --> 01:49:36,000
so what this is very very interesting

2842
01:49:39,669 --> 01:49:37,760
and obviously we would like to learn

2843
01:49:42,149 --> 01:49:39,679
more because deep impact during its

2844
01:49:43,990 --> 01:49:42,159
flyby only saw about a third of the

2845
01:49:45,589 --> 01:49:44,000
surface of the comet

2846
01:49:47,830 --> 01:49:45,599
so

2847
01:49:49,669 --> 01:49:47,840
what we would very much like to do

2848
01:49:52,629 --> 01:49:49,679
is for example

2849
01:49:54,390 --> 01:49:52,639
to have a better look at these layered

2850
01:49:56,550 --> 01:49:54,400
terrains which are shown in this picture

2851
01:49:58,790 --> 01:49:56,560
near the top

2852
01:50:00,950 --> 01:49:58,800
how extensive are these terrains are

2853
01:50:02,870 --> 01:50:00,960
they global in extent

2854
01:50:04,470 --> 01:50:02,880
what do they tell us about how the comet

2855
01:50:06,229 --> 01:50:04,480
was actually put together

2856
01:50:07,750 --> 01:50:06,239
those are important questions and by

2857
01:50:11,189 --> 01:50:07,760
seeing more of the surface we can

2858
01:50:13,109 --> 01:50:11,199
perhaps answer some of those similarly

2859
01:50:15,189 --> 01:50:13,119
we have questions about these smooth

2860
01:50:18,310 --> 01:50:15,199
flows that i mentioned

2861
01:50:20,950 --> 01:50:18,320
places where it really does seem that a

2862
01:50:23,830 --> 01:50:20,960
fluid came from the subsurface and

2863
01:50:25,030 --> 01:50:23,840

deposited material downhill on the

2864
01:50:26,550 --> 01:50:25,040
surface

2865
01:50:29,270 --> 01:50:26,560
deep impact

2866
01:50:31,030 --> 01:50:29,280
saw about two of us saw about a third of

2867
01:50:31,910 --> 01:50:31,040
the surface about two of these kinds of

2868
01:50:33,350 --> 01:50:31,920
flows

2869
01:50:35,990 --> 01:50:33,360
are there more

2870
01:50:38,790 --> 01:50:36,000
on this nucleus

2871
01:50:40,550 --> 01:50:38,800
but the main reason why we really want

2872
01:50:42,709 --> 01:50:40,560
to go back to temple

2873
01:50:44,149 --> 01:50:42,719
is to do something that has never been

2874
01:50:46,629 --> 01:50:44,159
done before

2875
01:50:49,189 --> 01:50:46,639
we've heard several times this morning

2876
01:50:51,030 --> 01:50:49,199
that when a comet approaches the sun the

2877
01:50:55,669 --> 01:50:51,040
surface heats up

2878
01:51:01,189 --> 01:50:58,390
but we've never seen this happen

2879
01:51:03,589 --> 01:51:01,199
here we have an opportunity to go to a

2880
01:51:07,350 --> 01:51:03,599
comet that was previously observed in

2881
01:51:09,510 --> 01:51:07,360
2005 by a deep impact

2882
01:51:11,830 --> 01:51:09,520
look at the surface one comet year later

2883
01:51:13,030 --> 01:51:11,840
in 2011 when the comet's going back to

2884
01:51:15,990 --> 01:51:13,040
the sun again

2885
01:51:17,830 --> 01:51:16,000
and see where the changes have occurred

2886
01:51:19,669 --> 01:51:17,840
we've heard this morning that for a

2887
01:51:22,950 --> 01:51:19,679
comet like temple

2888
01:51:25,350 --> 01:51:22,960

on average the amount of ice that's lost

2889
01:51:26,229 --> 01:51:25,360
during one orbit around the sun

2890
01:51:28,790 --> 01:51:26,239
is

2891
01:51:30,229 --> 01:51:28,800
roughly about a foot or so or maybe a

2892
01:51:33,189 --> 01:51:30,239
little bit more

2893
01:51:34,950 --> 01:51:33,199
but that loss does not occur uniformly

2894
01:51:36,870 --> 01:51:34,960
over the surface

2895
01:51:40,310 --> 01:51:36,880
we suspect that it's concentrated in

2896
01:51:41,430 --> 01:51:40,320
certain areas so there are places that

2897
01:51:42,550 --> 01:51:41,440
lose

2898
01:51:44,390 --> 01:51:42,560
much more

2899
01:51:46,709 --> 01:51:44,400
ice than other places

2900
01:51:48,390 --> 01:51:46,719
we'd like to know where does this occur

2901
01:51:50,070 --> 01:51:48,400
does this occur for example in that

2902
01:51:51,830 --> 01:51:50,080
heavily eroded terrain in the bottom of

2903
01:51:52,790 --> 01:51:51,840
the picture does it occur in smooth

2904
01:51:54,629 --> 01:51:52,800
areas

2905
01:51:57,270 --> 01:51:54,639
right now we don't know

2906
01:51:59,510 --> 01:51:57,280
and one of our major objectives the

2907
01:52:02,790 --> 01:51:59,520
single major objective for our mission

2908
01:52:05,669 --> 01:52:02,800
is to go back to temple one one comment

2909
01:52:07,910 --> 01:52:05,679
year later and see what has happened to

2910
01:52:10,629 --> 01:52:07,920
the surface where has the surface

2911
01:52:12,310 --> 01:52:10,639
changed and by how much and that will be

2912
01:52:14,790 --> 01:52:12,320
an important step and actually figure

2913
01:52:18,229 --> 01:52:14,800

out figuring out how comets work

2914
01:52:20,470 --> 01:52:18,239
so that's that's really what we're after

2915
01:52:22,950 --> 01:52:20,480
now uh

2916
01:52:25,589 --> 01:52:22,960
to achieve our objectives we really have

2917
01:52:27,109 --> 01:52:25,599
two different things i talked about

2918
01:52:28,709 --> 01:52:27,119
we talked about

2919
01:52:30,790 --> 01:52:28,719
wanting to

2920
01:52:32,629 --> 01:52:30,800
look at the places that had already been

2921
01:52:33,669 --> 01:52:32,639
seen by deep impact to look for the

2922
01:52:36,149 --> 01:52:33,679
changes

2923
01:52:38,629 --> 01:52:36,159
but we also talked about

2924
01:52:41,350 --> 01:52:38,639
exploring some more of the surface the

2925
01:52:43,109 --> 01:52:41,360
part that wasn't seen by by deep impact

2926
01:52:45,990 --> 01:52:43,119
so we have two things that we have to

2927
01:52:47,350 --> 01:52:46,000
balance and what this little sketch map

2928
01:52:49,910 --> 01:52:47,360
shows you

2929
01:52:52,870 --> 01:52:49,920
in grey is a mosaic

2930
01:52:54,790 --> 01:52:52,880
of the pictures taken by deep impact

2931
01:52:56,950 --> 01:52:54,800
during its encounter

2932
01:52:59,510 --> 01:52:56,960
you can see some of the surface features

2933
01:53:02,470 --> 01:52:59,520
and superimposed in yellow is this

2934
01:53:03,830 --> 01:53:02,480
little blob which is the coverage that

2935
01:53:10,629 --> 01:53:03,840
we are planning

2936
01:53:11,589 --> 01:53:10,639
our encounter in on february 14 2011.

2937
01:53:14,390 --> 01:53:11,599
okay

2938
01:53:16,550 --> 01:53:14,400

and please notice two things there is an

2939
01:53:19,270 --> 01:53:16,560
overlap in yellow

2940
01:53:21,350 --> 01:53:19,280
those are the places that have already

2941
01:53:25,189 --> 01:53:21,360
been seen had been seen by deep back to

2942
01:53:26,629 --> 01:53:25,199
2005 which we will see again in 2011.

2943
01:53:28,550 --> 01:53:26,639
that's where we'll be looking for the

2944
01:53:30,149 --> 01:53:28,560
changes that have occurred that's part

2945
01:53:33,189 --> 01:53:30,159
of the experiment

2946
01:53:36,470 --> 01:53:33,199
the other part of the outline that had

2947
01:53:39,669 --> 01:53:36,480
the great part going upwards is the part

2948
01:53:41,510 --> 01:53:39,679
of the comet that deep impact didn't see

2949
01:53:44,870 --> 01:53:41,520
that we will see for the first time

2950
01:53:46,629 --> 01:53:44,880
where we can for example uh see how much

2951
01:53:48,149 --> 01:53:46,639
farther the lighter terrains extend and

2952
01:53:49,830 --> 01:53:48,159
things of the start

2953
01:53:51,510 --> 01:53:49,840
now if you've been looking at this

2954
01:53:53,510 --> 01:53:51,520
carefully you also notice there is a

2955
01:53:55,109 --> 01:53:53,520
bullseye there is a there is

2956
01:53:57,350 --> 01:53:55,119
a red thing there

2957
01:54:00,950 --> 01:53:57,360
and what is that well

2958
01:54:03,189 --> 01:54:00,960
that is nothing else but the place where

2959
01:54:04,229 --> 01:54:03,199
the deep impactor hit the surface of the

2960
01:54:06,149 --> 01:54:04,239
comet

2961
01:54:08,470 --> 01:54:06,159
and one of the original

2962
01:54:09,750 --> 01:54:08,480
hopes on a deep impact mission

2963
01:54:11,990 --> 01:54:09,760

was to see

2964
01:54:13,910 --> 01:54:12,000
how large a crater would be made because

2965
01:54:15,990 --> 01:54:13,920
the energy of the impact is well known

2966
01:54:17,830 --> 01:54:16,000
you know the speed of the impactor you

2967
01:54:19,270 --> 01:54:17,840
know the mass of the impactor

2968
01:54:21,189 --> 01:54:19,280
and so

2969
01:54:23,430 --> 01:54:21,199
you would like to know how big the

2970
01:54:25,189 --> 01:54:23,440
crater is

2971
01:54:27,510 --> 01:54:25,199
and as you can see

2972
01:54:30,709 --> 01:54:27,520
during the deep impact mission

2973
01:54:33,589 --> 01:54:30,719
the collision threw up so much material

2974
01:54:34,950 --> 01:54:33,599
that one never actually saw the actual

2975
01:54:39,109 --> 01:54:34,960
crater

2976
01:54:41,669 --> 01:54:39,119
150 feet across

2977
01:54:43,109 --> 01:54:41,679
is it 300 feet across some people

2978
01:54:45,750 --> 01:54:43,119
speculate

2979
01:54:47,910 --> 01:54:45,760
why would anybody care

2980
01:54:50,550 --> 01:54:47,920
well the reason that you would care is

2981
01:54:52,709 --> 01:54:50,560
that the size of the crater and perhaps

2982
01:54:54,870 --> 01:54:52,719
the depth the crater contains

2983
01:54:58,470 --> 01:54:54,880
information about the mechanical

2984
01:55:00,550 --> 01:54:58,480
properties of the surface of the comet

2985
01:55:01,750 --> 01:55:00,560
well why would you care about that

2986
01:55:04,390 --> 01:55:01,760
well the reason you would care about

2987
01:55:06,310 --> 01:55:04,400
that is that as

2988
01:55:07,430 --> 01:55:06,320

bob farquhar said we're always planning

2989
01:55:09,669 --> 01:55:07,440
ahead

2990
01:55:10,870 --> 01:55:09,679
and we are planning missions

2991
01:55:15,030 --> 01:55:10,880
that

2992
01:55:16,709 --> 01:55:15,040
are intended to land on a comet nucleus

2993
01:55:19,189 --> 01:55:16,719
and excavate material from the

2994
01:55:21,109 --> 01:55:19,199
subsurface and bring those materials

2995
01:55:23,510 --> 01:55:21,119
back to earth for analysis if you're

2996
01:55:25,270 --> 01:55:23,520
going to dig into a comet an exclave

2997
01:55:27,350 --> 01:55:25,280
material you need to know something

2998
01:55:29,990 --> 01:55:27,360
about mechanical properties so it is

2999
01:55:32,070 --> 01:55:30,000
important to complete the deep impact

3000
01:55:33,990 --> 01:55:32,080
experiment by actually trying to image

3001
01:55:37,030 --> 01:55:34,000
the crater and figure out how big it is

3002
01:55:39,589 --> 01:55:37,040
so that is also one of our objectives

3003
01:55:42,709 --> 01:55:39,599
uh so how are we going to do this

3004
01:55:44,550 --> 01:55:42,719
well uh briefly uh we are on a

3005
01:55:47,589 --> 01:55:44,560
trajectory that will take us to the

3006
01:55:50,229 --> 01:55:47,599
vicinity of comet temple one

3007
01:55:52,149 --> 01:55:50,239
late in the evening on february 14

3008
01:55:55,750 --> 01:55:52,159
valentine's day

3009
01:55:59,189 --> 01:55:55,760
we have selected a trajectory that will

3010
01:56:00,629 --> 01:55:59,199
get us within 200 kilometers 120 miles

3011
01:56:02,790 --> 01:56:00,639
of the surface

3012
01:56:05,430 --> 01:56:02,800
at that point our camera

3013
01:56:07,589 --> 01:56:05,440

can resolve things that are about 30 or

3014
01:56:09,669 --> 01:56:07,599
40 feet across it's roughly the size of

3015
01:56:12,390 --> 01:56:09,679
the stage that i'm standing on here

3016
01:56:14,550 --> 01:56:12,400
and that is sufficient to address these

3017
01:56:17,109 --> 01:56:14,560
questions that we have

3018
01:56:18,950 --> 01:56:17,119
in this little graphic what you see is a

3019
01:56:20,950 --> 01:56:18,960
trajectory of spacecraft as it

3020
01:56:24,310 --> 01:56:20,960
approaches its closest approach

3021
01:56:27,350 --> 01:56:24,320
the gray areas are the areas mapped by

3022
01:56:29,669 --> 01:56:27,360
deep impact the blue areas

3023
01:56:32,149 --> 01:56:29,679
are new terrain that we will see that

3024
01:56:33,109 --> 01:56:32,159
has not been seen before and as you can

3025
01:56:36,390 --> 01:56:33,119
see

3026
01:56:39,510 --> 01:56:36,400
as we come in to close this approach the

3027
01:56:40,870 --> 01:56:39,520
picture on the upper right

3028
01:56:44,709 --> 01:56:40,880
you're looking

3029
01:56:47,350 --> 01:56:44,719
area that had been has been seen before

3030
01:56:49,510 --> 01:56:47,360
by deep impact that's the experiment to

3031
01:56:51,270 --> 01:56:49,520
look for changes and then as we get

3032
01:56:53,669 --> 01:56:51,280
closer and closer to

3033
01:56:56,390 --> 01:56:53,679
closer approach we see more and more

3034
01:56:58,709 --> 01:56:56,400
blue area which is the new territory

3035
01:57:02,709 --> 01:56:58,719
so we have a balance between looking for

3036
01:57:04,070 --> 01:57:02,719
changes in uh what we see before and

3037
01:57:05,830 --> 01:57:04,080
mapping

3038
01:57:08,629 --> 01:57:05,840

new territory

3039
01:57:10,149 --> 01:57:08,639
although i emphasized imaging uh

3040
01:57:12,310 --> 01:57:10,159
during the flyby we also have

3041
01:57:15,030 --> 01:57:12,320
instruments that will be uh

3042
01:57:17,750 --> 01:57:15,040
collecting dust and analyzing dust but

3043
01:57:19,750 --> 01:57:17,760
the principal focus is on the imaging

3044
01:57:23,109 --> 01:57:19,760
and i just want to make the point that

3045
01:57:25,189 --> 01:57:23,119
our camera is working very very well

3046
01:57:27,589 --> 01:57:25,199
this is a picture taken by the camera

3047
01:57:30,229 --> 01:57:27,599
six years ago or so at the time of build

3048
01:57:32,950 --> 01:57:30,239
to flyby we have

3049
01:57:35,910 --> 01:57:32,960
tested the camera everything is working

3050
01:57:37,990 --> 01:57:35,920
just fantastically well and we do expect

3051
01:57:39,910 --> 01:57:38,000
to be able to take very high resolution

3052
01:57:41,430 --> 01:57:39,920
images uh during this particular

3053
01:57:44,070 --> 01:57:41,440
encounter

3054
01:57:45,990 --> 01:57:44,080
so let me just finish up by telling you

3055
01:57:47,070 --> 01:57:46,000
where we are right now

3056
01:57:51,109 --> 01:57:47,080
we are

3057
01:57:52,870 --> 01:57:51,119
158 days from encounter at this point

3058
01:57:54,870 --> 01:57:52,880
the uh

3059
01:57:58,070 --> 01:57:54,880
spacecraft is uh

3060
01:58:00,310 --> 01:57:58,080
about something like 91 million uh miles

3061
01:58:01,350 --> 01:58:00,320
from the sun about twice as far from the

3062
01:58:03,669 --> 01:58:01,360
earth

3063
01:58:06,070 --> 01:58:03,679

it's about a hundred and i'm told 113

3064
01:58:07,910 --> 01:58:06,080
million miles from the comet the comet

3065
01:58:10,070 --> 01:58:07,920
itself is coming in closer to the sun is

3066
01:58:12,629 --> 01:58:10,080
just outside the earth of mars right now

3067
01:58:13,669 --> 01:58:12,639
and uh over the next 158 days we're

3068
01:58:14,629 --> 01:58:13,679
going to get closer and closer and

3069
01:58:17,109 --> 01:58:14,639
closer

3070
01:58:19,510 --> 01:58:17,119
and we're looking to

3071
01:58:21,669 --> 01:58:19,520
forward to a very successful encounter

3072
01:58:23,189 --> 01:58:21,679
we have a lot of people who are working

3073
01:58:25,910 --> 01:58:23,199
very very hard

3074
01:58:28,550 --> 01:58:25,920
the spacecraft is an excellent shape

3075
01:58:31,350 --> 01:58:28,560
uh we have a group of very hard-working

3076
01:58:34,310 --> 01:58:31,360
people at loghead martin in denver who

3077
01:58:36,709 --> 01:58:34,320
operate the spacecraft and are right now

3078
01:58:38,709 --> 01:58:36,719
verifying all the commands that will be

3079
01:58:40,709 --> 01:58:38,719
used during the encounter to make sure

3080
01:58:42,229 --> 01:58:40,719
we get all the data that we are looking

3081
01:58:44,229 --> 01:58:42,239
for

3082
01:58:45,910 --> 01:58:44,239
we have a hard-working group of

3083
01:58:47,510 --> 01:58:45,920
navigators at the jet propulsion

3084
01:58:49,990 --> 01:58:47,520
laboratory who are keeping the

3085
01:58:52,390 --> 01:58:50,000
spacecraft on this trajectory to get us

3086
01:58:56,310 --> 01:58:52,400
to this flyby that we

3087
01:58:58,390 --> 01:58:56,320
want to want to effect on february 14th

3088
01:58:59,510 --> 01:58:58,400

and of course we have

3089
01:59:34,149 --> 01:58:59,520
a

3090
01:59:37,430 --> 01:59:34,159
120

3091
01:59:40,149 --> 01:59:37,440
surface

3092
01:59:43,669 --> 01:59:40,159
late on february 14. and so that is

3093
01:59:45,350 --> 01:59:43,679
briefly an update on stardust next

3094
01:59:51,830 --> 01:59:45,360
a great mission that we're all looking

3095
02:00:02,870 --> 01:59:53,750
if there are questions i will be

3096
02:00:06,870 --> 02:00:04,550
i guess i'm going to key off a question

3097
02:00:08,470 --> 02:00:06,880
that was asked behind me earlier because

3098
02:00:11,270 --> 02:00:08,480
you've got a lot of classrooms around

3099
02:00:13,750 --> 02:00:11,280
the world or at least the us looking in

3100
02:00:16,550 --> 02:00:13,760
um i think the real question is the

3101
02:00:18,470 --> 02:00:16,560
difference between the non-active comets

3102
02:00:20,390 --> 02:00:18,480
and asteroids i mean we're learning a

3103
02:00:23,669 --> 02:00:20,400
lot from fragments from the creation of

3104
02:00:25,030 --> 02:00:23,679
the solar system sure and for students

3105
02:00:27,270 --> 02:00:25,040
out there what's the real difference

3106
02:00:29,350 --> 02:00:27,280
between those two and is there like a

3107
02:00:30,950 --> 02:00:29,360
team comment and a team asteroid group

3108
02:00:33,350 --> 02:00:30,960
that's both trying to find out the best

3109
02:00:34,629 --> 02:00:33,360
they can from what they can learn from

3110
02:00:36,550 --> 02:00:34,639
each of those on the creation of the

3111
02:00:38,390 --> 02:00:36,560
solar system

3112
02:00:41,030 --> 02:00:38,400
the question is

3113
02:00:42,550 --> 02:00:41,040

basically what what is the diff

3114
02:00:44,070 --> 02:00:42,560
the mic

3115
02:00:45,990 --> 02:00:44,080
right okay

3116
02:00:48,470 --> 02:00:46,000
uh question is what is the difference if

3117
02:00:51,830 --> 02:00:48,480
you incumbent an asteroid basically

3118
02:00:53,510 --> 02:00:51,840
and uh so to first order uh one is

3119
02:00:56,229 --> 02:00:53,520
mostly made of ice and the other one is

3120
02:00:58,550 --> 02:00:56,239
mostly made of rock and why is that and

3121
02:01:01,189 --> 02:00:58,560
why should we care well i think anita

3122
02:01:02,870 --> 02:01:01,199
was talking about the early stages of

3123
02:01:04,070 --> 02:01:02,880
the solar system when the sun was

3124
02:01:07,030 --> 02:01:04,080
forming

3125
02:01:10,149 --> 02:01:07,040
around the sun there was a cloud of gas

3126
02:01:13,350 --> 02:01:10,159
and as uh the cloud cooled

3127
02:01:15,430 --> 02:01:13,360
various things could turn from gas to

3128
02:01:17,270 --> 02:01:15,440
solid basically freeze out

3129
02:01:19,109 --> 02:01:17,280
if you were close to the sun where it

3130
02:01:21,030 --> 02:01:19,119
was hot

3131
02:01:23,430 --> 02:01:21,040
isis couldn't freeze out only rocks

3132
02:01:25,669 --> 02:01:23,440
could freeze out if you're farther away

3133
02:01:28,550 --> 02:01:25,679
or it's colder then you could also get

3134
02:01:30,550 --> 02:01:28,560
ices and so there are things that form

3135
02:01:33,189 --> 02:01:30,560
close to the sun like in the asteroid

3136
02:01:34,550 --> 02:01:33,199
belt which are mostly rocks okay

3137
02:01:36,070 --> 02:01:34,560
and there are things that form farther

3138
02:01:38,950 --> 02:01:36,080

out in the kuiper belt or the earth

3139
02:01:40,390 --> 02:01:38,960
cloud which have a lot of ice okay

3140
02:01:47,589 --> 02:01:40,400
and

3141
02:01:49,990 --> 02:01:47,599
left over from the formation of the

3142
02:01:51,830 --> 02:01:50,000
solar system things that didn't

3143
02:01:53,350 --> 02:01:51,840
accumulate into planets

3144
02:01:54,629 --> 02:01:53,360
and the reason are different is because

3145
02:01:56,950 --> 02:01:54,639
they formed in different places

3146
02:02:02,629 --> 02:01:56,960
different environments

3147
02:02:08,470 --> 02:02:04,550
came from that discussion

3148
02:02:10,149 --> 02:02:08,480
if a comet uses up all its uh

3149
02:02:11,430 --> 02:02:10,159
vapor all the

3150
02:02:15,510 --> 02:02:11,440
the

3151
02:02:17,589 --> 02:02:15,520
conversion uh

3152
02:02:19,510 --> 02:02:17,599
and

3153
02:02:21,510 --> 02:02:19,520
moving away of the gases over the time

3154
02:02:23,750 --> 02:02:21,520
it disappears all the volatiles

3155
02:02:26,390 --> 02:02:23,760
eventually disappear

3156
02:02:29,510 --> 02:02:26,400
what's left would that be called a an

3157
02:02:31,030 --> 02:02:29,520
asteroid what is the what is a uh common

3158
02:02:33,270 --> 02:02:31,040
without

3159
02:02:35,669 --> 02:02:33,280
that the question is how does really how

3160
02:02:37,910 --> 02:02:35,679
does a comet die

3161
02:02:39,990 --> 02:02:37,920
and so in fact

3162
02:02:42,790 --> 02:02:40,000
there appear to be several ways in which

3163
02:02:46,550 --> 02:02:44,470

of course if a comet

3164
02:02:48,709 --> 02:02:46,560
stays out in the earth cloud where it's

3165
02:02:50,310 --> 02:02:48,719
distant and very cold nothing very much

3166
02:02:53,430 --> 02:02:50,320
happens so when it comes close to the

3167
02:02:55,589 --> 02:02:53,440
sun it heats up and volatiles water ice

3168
02:02:58,070 --> 02:02:55,599
coli just evaporate okay so so what

3169
02:03:00,310 --> 02:02:58,080
happens well we know of at least several

3170
02:03:02,550 --> 02:03:00,320
things that happen in some cases what

3171
02:03:05,030 --> 02:03:02,560
happens is that

3172
02:03:06,950 --> 02:03:05,040
it's the surface layers of the comet

3173
02:03:09,830 --> 02:03:06,960
that lose the volatiles

3174
02:03:12,390 --> 02:03:09,840
and it gets harder and harder for ices

3175
02:03:14,790 --> 02:03:12,400
than deep to get hot enough and for

3176
02:03:17,350 --> 02:03:14,800
gases to escape so it appears in some

3177
02:03:19,189 --> 02:03:17,360
cases that the surface eventually seals

3178
02:03:22,870 --> 02:03:19,199
itself off where you have an inert

3179
02:03:25,589 --> 02:03:22,880
surface of rocky and organic stuff

3180
02:03:27,830 --> 02:03:25,599
and which is volatile poor and so we

3181
02:03:30,310 --> 02:03:27,840
know of examples of things that used to

3182
02:03:31,669 --> 02:03:30,320
look like comments and now no longer

3183
02:03:34,070 --> 02:03:31,679
show any activity they look like

3184
02:03:36,070 --> 02:03:34,080
asteroids okay that's one thing we also

3185
02:03:39,030 --> 02:03:36,080
know that some comets just completely

3186
02:03:41,109 --> 02:03:39,040
fall apart okay they disappear

3187
02:03:43,830 --> 02:03:41,119
so those are at least two ways in which

3188
02:03:44,709 --> 02:03:43,840

sort of comets come as common side but

3189
02:03:47,109 --> 02:03:44,719
your

3190
02:03:49,589 --> 02:03:47,119
basic point is correct that if you're a

3191
02:03:51,750 --> 02:03:49,599
comet uh being close to the sun is

3192
02:03:56,310 --> 02:03:51,760
dangerous because something bad will

3193
02:03:57,910 --> 02:03:56,320
happen to you over long time scales yes

3194
02:03:59,910 --> 02:03:57,920
yeah just a question that may be outside

3195
02:04:00,950 --> 02:03:59,920
of the baileywick of this discussion but

3196
02:04:04,870 --> 02:04:00,960
could you

3197
02:04:07,830 --> 02:04:04,880
explain what our gravity waves how they

3198
02:04:09,350 --> 02:04:07,840
are measured and how they may be useful

3199
02:04:12,149 --> 02:04:09,360
in future uh

3200
02:04:16,390 --> 02:04:14,550
observation the question is to explain

3201
02:04:19,430 --> 02:04:16,400
gravity waves

3202
02:04:21,750 --> 02:04:19,440
and how they are useful

3203
02:04:24,470 --> 02:04:21,760
i think where the question comes from is

3204
02:04:27,030 --> 02:04:24,480
that there is a experiment a foot called

3205
02:04:30,310 --> 02:04:27,040
ligo which tries to detect

3206
02:04:33,350 --> 02:04:30,320
gravitational waves uh i mean basically

3207
02:04:38,149 --> 02:04:35,990
when any massive object

3208
02:04:40,470 --> 02:04:38,159
does something like

3209
02:04:41,910 --> 02:04:40,480
collides with another massive object

3210
02:04:44,149 --> 02:04:41,920
then

3211
02:04:46,470 --> 02:04:44,159
gravity environment changes and there is

3212
02:04:49,030 --> 02:04:46,480
a there is a wave that propagates okay

3213
02:04:52,550 --> 02:04:50,069

it is

3214
02:04:54,550 --> 02:04:52,560
hoped by some people that

3215
02:04:56,870 --> 02:04:54,560
these kinds of perturbations that may be

3216
02:04:59,510 --> 02:04:56,880
caused from black holes coalescing

3217
02:05:01,910 --> 02:04:59,520
objects that are very very massive that

3218
02:05:04,950 --> 02:05:01,920
the signal can be detected at the earth

3219
02:05:09,189 --> 02:05:04,960
okay now

3220
02:05:13,350 --> 02:05:09,199
the question of why is this useful uh

3221
02:05:15,350 --> 02:05:13,360
i am not a uh physicist so i will i

3222
02:05:17,030 --> 02:05:15,360
can't honestly answer that question okay

3223
02:05:18,950 --> 02:05:17,040
if there's anybody in the audience who

3224
02:05:22,709 --> 02:05:18,960
wants to answer a question please go

3225
02:05:22,719 --> 02:05:25,830
okay

3226
02:05:30,390 --> 02:05:28,390
i have a question so this next mission

3227
02:05:32,310 --> 02:05:30,400
part of it is going to be to actually

3228
02:05:33,430 --> 02:05:32,320
look at the crater that deep impact

3229
02:05:36,229 --> 02:05:33,440
created

3230
02:05:38,310 --> 02:05:36,239
so how likely is it that there will be a

3231
02:05:40,470 --> 02:05:38,320
follow-up mission you mentioned um maybe

3232
02:05:42,709 --> 02:05:40,480
to go and excavate and get some some

3233
02:05:44,149 --> 02:05:42,719
sampling from uh that crater and how

3234
02:05:46,550 --> 02:05:44,159
excited can we get about that okay the

3235
02:05:49,430 --> 02:05:46,560
question is that uh you know there is a

3236
02:05:51,750 --> 02:05:49,440
crater on uh on temple one

3237
02:05:54,310 --> 02:05:51,760
and uh is it useful in the future

3238
02:05:57,430 --> 02:05:54,320

perhaps to go into that region and uh

3239
02:05:59,750 --> 02:05:57,440
excavate some of that material uh

3240
02:06:02,790 --> 02:05:59,760
i think the answer is yes it turns out

3241
02:06:05,350 --> 02:06:02,800
that uh temple one is one of the easier

3242
02:06:06,870 --> 02:06:05,360
comets to actually get a spacecraft to

3243
02:06:09,430 --> 02:06:06,880
and so

3244
02:06:12,629 --> 02:06:09,440
if one were planning a mission

3245
02:06:14,390 --> 02:06:12,639
to land on a nucleus dig out some ice

3246
02:06:16,870 --> 02:06:14,400
bring it back to earth

3247
02:06:19,669 --> 02:06:16,880
that is certainly a very reasonable

3248
02:06:21,830 --> 02:06:19,679
target and if you were to do that then a

3249
02:06:24,550 --> 02:06:21,840
very reasonable thing to do would be to

3250
02:06:26,870 --> 02:06:24,560
get a sample from a region which was not

3251
02:06:29,669 --> 02:06:26,880
modified by the impact and a region

3252
02:06:32,470 --> 02:06:29,679
which was modified be a very very good

3253
02:06:34,629 --> 02:06:32,480
uh experiment to do unfortunately i'm

3254
02:06:36,470 --> 02:06:34,639
too old to write such a proposal but i

3255
02:06:38,390 --> 02:06:36,480
suggest that you do that that would be a

3256
02:06:40,790 --> 02:06:38,400
great thing to do

3257
02:06:44,470 --> 02:06:42,790
okay um so

3258
02:06:46,870 --> 02:06:44,480
tying into that

3259
02:06:49,830 --> 02:06:46,880
as you're discovering more about what

3260
02:06:51,750 --> 02:06:49,840
the material is are is there plans to

3261
02:06:53,830 --> 02:06:51,760
compare you know from the meteorite

3262
02:06:56,950 --> 02:06:53,840
samples from what may have been dead

3263
02:06:59,109 --> 02:06:56,960

comets or asteroids to see if they're

3264
02:07:01,430 --> 02:06:59,119
very similar in composition

3265
02:07:04,149 --> 02:07:01,440
uh how different in composition

3266
02:07:06,629 --> 02:07:04,159
and maybe way off in the way future is

3267
02:07:09,510 --> 02:07:06,639
there you know the space mining ideas of

3268
02:07:12,390 --> 02:07:09,520
asteroids or whatnot i mean

3269
02:07:14,149 --> 02:07:12,400
what's the exciting place to go with all

3270
02:07:16,870 --> 02:07:14,159
the science and would you prefer to go

3271
02:07:19,030 --> 02:07:16,880
to comets i know this is team comet time

3272
02:07:21,910 --> 02:07:19,040
um or asteroids are they equally

3273
02:07:24,390 --> 02:07:21,920
exciting to everyone right uh so so the

3274
02:07:27,030 --> 02:07:24,400
question really has to do with sampling

3275
02:07:31,030 --> 02:07:27,040
asteroids sampling comets

3276
02:07:33,669 --> 02:07:31,040
the one big difference is that we do

3277
02:07:35,589 --> 02:07:33,679
have a lot of samples of asteroids

3278
02:07:37,669 --> 02:07:35,599
called meteorites and if you go to

3279
02:07:38,709 --> 02:07:37,679
smithsonian just down the road i mean

3280
02:07:40,709 --> 02:07:38,719
there are

3281
02:07:43,669 --> 02:07:40,719
dozens and dozens of varieties and we

3282
02:07:46,149 --> 02:07:43,679
have begun to be able to recognize

3283
02:07:47,669 --> 02:07:46,159
where some of these samples come from

3284
02:07:51,109 --> 02:07:47,679
the objects that are associated with the

3285
02:07:55,030 --> 02:07:51,119
asteroid belt we have to date no one has

3286
02:07:56,310 --> 02:07:55,040
identified a meteorite that

3287
02:07:57,830 --> 02:07:56,320
believably

3288
02:07:58,629 --> 02:07:57,840

comes from a comet

3289
02:08:03,109 --> 02:07:58,639
so

3290
02:08:04,550 --> 02:08:03,119
question is on one side the asteroids

3291
02:08:05,830 --> 02:08:04,560
we've got lots of samples we don't have

3292
02:08:07,589 --> 02:08:05,840
everything but we've got lots of samples

3293
02:08:09,830 --> 02:08:07,599
in that case we've got nothing okay

3294
02:08:12,069 --> 02:08:09,840
essentially except maybe some of the

3295
02:08:14,149 --> 02:08:12,079
dust that we talked about start the

3296
02:08:17,830 --> 02:08:14,159
stardust returned but that doesn't

3297
02:08:20,229 --> 02:08:17,840
contain the ices okay so for that reason

3298
02:08:22,390 --> 02:08:20,239
uh people who study asteroids and comets

3299
02:08:25,830 --> 02:08:22,400
i think are generally agreed that the

3300
02:08:26,790 --> 02:08:25,840
next place to really return a sample

3301
02:08:29,350 --> 02:08:26,800
from

3302
02:08:34,950 --> 02:08:29,360
is a comet because we that's really

3303
02:08:40,310 --> 02:08:37,430
i really didn't uh grasp until today

3304
02:08:42,310 --> 02:08:40,320
just how many comets there are and have

3305
02:08:44,870 --> 02:08:42,320
been and there's a lot of discussion of

3306
02:08:47,030 --> 02:08:44,880
course about uh the threat to earth from

3307
02:08:49,350 --> 02:08:47,040
asteroids you don't hear much about the

3308
02:08:51,589 --> 02:08:49,360
threat to earth from comets

3309
02:08:52,870 --> 02:08:51,599
do comets threaten earth

3310
02:08:55,430 --> 02:08:52,880
well that's a

3311
02:08:56,950 --> 02:08:55,440
the question is uh we hear a lot about

3312
02:08:58,790 --> 02:08:56,960
asteroids running into the earth how

3313
02:09:02,550 --> 02:08:58,800

about comets running into the earth and

3314
02:09:05,109 --> 02:09:02,560
uh yes there are as anita pointed out a

3315
02:09:07,109 --> 02:09:05,119
lot there's large number of comets

3316
02:09:09,030 --> 02:09:07,119
fortunately most of them most of the

3317
02:09:10,470 --> 02:09:09,040
time behave themselves and stay in

3318
02:09:12,390 --> 02:09:10,480
places like the earth cloud but let me

3319
02:09:15,270 --> 02:09:12,400
just point out that uh

3320
02:09:18,470 --> 02:09:15,280
there are books and have been articles

3321
02:09:19,510 --> 02:09:18,480
on what might happen occasionally when

3322
02:09:21,510 --> 02:09:19,520
the sun

3323
02:09:24,310 --> 02:09:21,520
and its earth cloud is moving through

3324
02:09:25,990 --> 02:09:24,320
the galaxy it will pass

3325
02:09:28,790 --> 02:09:26,000
near another star

3326
02:09:30,470 --> 02:09:28,800
that star perturbs or changes the orbits

3327
02:09:32,870 --> 02:09:30,480
in the earth cloud now people have

3328
02:09:34,069 --> 02:09:32,880
written papers of what might happen if

3329
02:09:35,669 --> 02:09:34,079
that kind of

3330
02:09:38,069 --> 02:09:35,679
encounter

3331
02:09:40,870 --> 02:09:38,079
happens at a fairly close distance in

3332
02:09:42,550 --> 02:09:40,880
which case thousands or more of comets

3333
02:09:44,550 --> 02:09:42,560
will suddenly be perturbed into the

3334
02:09:46,790 --> 02:09:44,560
inner solar system and there are people

3335
02:09:48,870 --> 02:09:46,800
who predict uh claim that occasionally

3336
02:09:50,629 --> 02:09:48,880
there are things like comet showers at

3337
02:09:52,550 --> 02:09:50,639
which time sort of the impact rate on

3338
02:09:55,270 --> 02:09:52,560

the earth goes up by a factor of 10 or

3339
02:09:56,069 --> 02:09:55,280
100 from what it normally is okay

3340
02:10:00,149 --> 02:09:56,079
so

3341
02:10:01,589 --> 02:10:00,159
and

3342
02:10:03,669 --> 02:10:01,599
one of the

3343
02:10:05,669 --> 02:10:03,679
questions that's often debated is

3344
02:10:07,669 --> 02:10:05,679
whether the object that was responsible

3345
02:10:09,990 --> 02:10:07,679
for the extinction of the dinosaurs was

3346
02:10:11,750 --> 02:10:10,000
an asteroid or a comet and it certainly

3347
02:10:14,470 --> 02:10:11,760
could have been a comet so yes comets do

3348
02:10:17,350 --> 02:10:14,480
hit the earth and they should get as

3349
02:10:22,629 --> 02:10:17,360
much attention as asteroids do

3350
02:10:27,910 --> 02:10:25,030
jim green kept talking about you know

3351
02:10:30,709 --> 02:10:27,920
plagues and disasters but think of

3352
02:10:32,629 --> 02:10:30,719
comets as wonderful windows into the

3353
02:10:37,270 --> 02:10:32,639
past of the solar system they're things

3354
02:10:37,280 --> 02:10:46,709
i think we're done

3355
02:10:51,270 --> 02:10:49,109
well uh joe i have to disagree with you

3356
02:10:53,189 --> 02:10:51,280
uh you're not too old to write a

3357
02:10:54,870 --> 02:10:53,199
proposal and i've got just the one i'm

3358
02:10:56,709 --> 02:10:54,880
going to tell you about a little bit and

3359
02:10:58,550 --> 02:10:56,719
you're going to do this one

3360
02:11:08,830 --> 02:10:58,560
all right bob's gotten me into trouble

3361
02:11:13,910 --> 02:11:11,350
again wow

3362
02:11:15,750 --> 02:11:13,920
well i have good news class is going to

3363
02:11:18,149 --> 02:11:15,760

let out early we had scheduled to be

3364
02:11:20,229 --> 02:11:18,159
here until noon so we're going to have

3365
02:11:22,390 --> 02:11:20,239
uh early recess and that's for the

3366
02:11:24,390 --> 02:11:22,400
classrooms out there i'm just talking

3367
02:11:25,669 --> 02:11:24,400
about recess here okay

3368
02:11:27,510 --> 02:11:25,679
um

3369
02:11:29,669 --> 02:11:27,520
again ladies and gentlemen uh we're

3370
02:11:31,910 --> 02:11:29,679
gonna first of all as we wrap up let's

3371
02:11:33,270 --> 02:11:31,920
do a two for one here please give a

3372
02:11:35,350 --> 02:11:33,280
great round of applause for our

3373
02:11:37,270 --> 02:11:35,360
inspiring speakers and also for the

3374
02:11:46,790 --> 02:11:37,280
museum and for hosting us in this

3375
02:11:53,109 --> 02:11:49,350
if you want to get even more details

3376
02:11:55,750 --> 02:11:53,119
about our speakers and about comments

3377
02:11:59,910 --> 02:11:55,760
and the year of the solar system

3378
02:12:03,830 --> 02:12:01,750
but there's even a bigger picture with

3379
02:12:05,189 --> 02:12:03,840
the incredible science that's happening

3380
02:12:06,790 --> 02:12:05,199
at nasa

3381
02:12:09,510 --> 02:12:06,800
and the universities and other

3382
02:12:12,669 --> 02:12:09,520
organizations working with nasa not just

3383
02:12:15,189 --> 02:12:12,679
here in the u.s but around the world

3384
02:12:17,830 --> 02:12:15,199
www.nasa.gov ladies and gentlemen there

3385
02:12:19,589 --> 02:12:17,840
are some absolutely incredible missions

3386
02:12:22,069 --> 02:12:19,599
that are going to be coming out of the

3387
02:12:23,830 --> 02:12:22,079
nasa science department in all areas

3388
02:12:26,550 --> 02:12:23,840

particularly in dr green's planetary

3389
02:12:27,510 --> 02:12:26,560
division but all of science all over

3390
02:12:28,629 --> 02:12:27,520
nasa

3391
02:12:33,270 --> 02:12:28,639
and

3392
02:12:36,709 --> 02:12:33,280
next generation of explorers again go to

3393
02:12:41,510 --> 02:12:38,950
i want to thank you all for joining us

3394
02:12:42,709 --> 02:12:41,520
and for our students out there always

3395
02:12:45,109 --> 02:12:42,719
remember