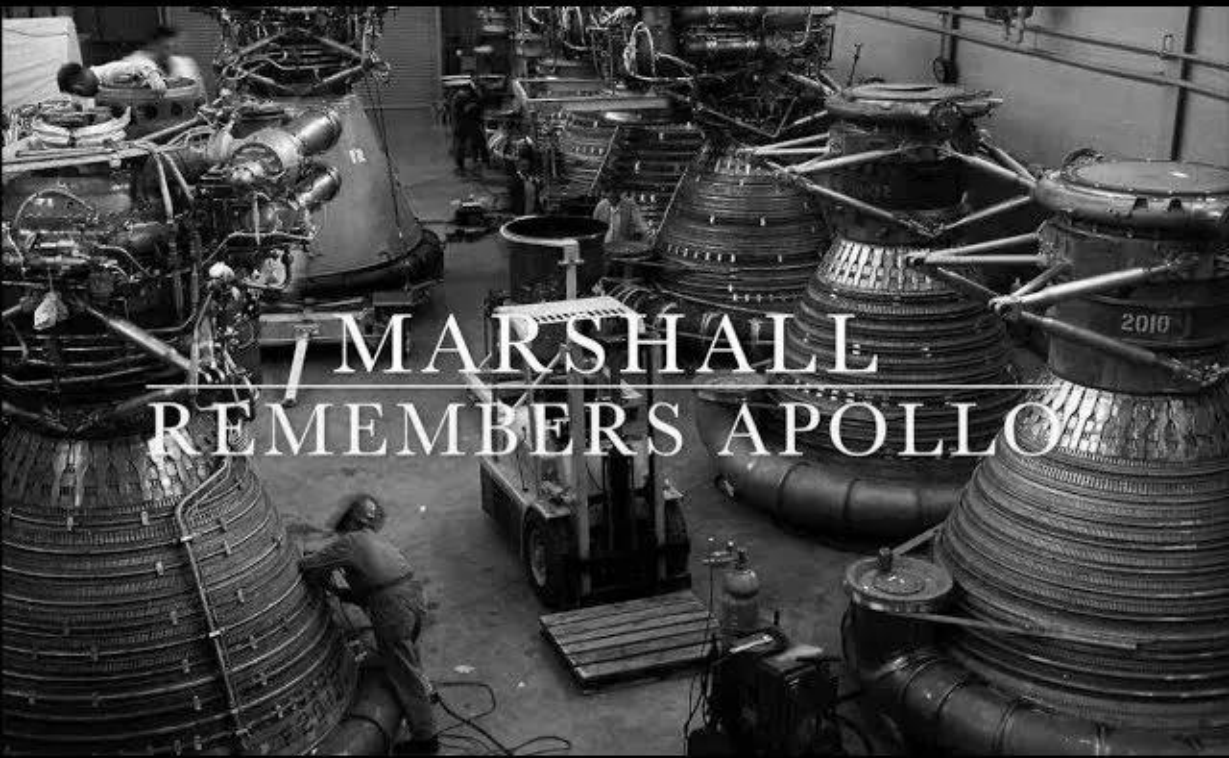
MARSHALL
REMEMBERS APOLLO

1
00:00:01,130 --> 00:00:15,760
[Music]

2
00:00:21,560 --> 00:00:18,349
well I was born in Fort Wayne Indiana

3
00:00:23,749 --> 00:00:21,570
and by coming to Huntsville it was

4
00:00:25,760 --> 00:00:23,759
really considering Dippet us as a matter

5
00:00:28,519 --> 00:00:25,770
of being at the right place at the right

6
00:00:30,650 --> 00:00:28,529
time and a number of events in high

7
00:00:32,659 --> 00:00:30,660
school I had already planned my career I

8
00:00:34,340 --> 00:00:32,669
was going into the nuclear field because

9
00:00:37,250 --> 00:00:34,350
that was the new kid on the block it was

10
00:00:40,369 --> 00:00:37,260
exciting challenging thing to do with

11
00:00:42,020 --> 00:00:40,379
three other sophomores in high school we

12
00:00:46,160 --> 00:00:42,030
decided it would be a neat thing to do

13
00:00:48,890 --> 00:00:46,170

to build an atom spaceship nicer so with

14
00:00:50,810 --> 00:00:48,900
the support of our physics teacher and

15
00:00:53,299 --> 00:00:50,820
the cooperation of the principal we got

16
00:00:55,759 --> 00:00:53,309
approval to build a cyclotron in the

17
00:00:56,750 --> 00:00:55,769
basement of the School of course that

18
00:00:59,390 --> 00:00:56,760
would never happen today but

19
00:01:02,660 --> 00:00:59,400
nevertheless we were fortunate in that

20
00:01:05,000 --> 00:01:02,670
regard when we graduated yes it was not

21
00:01:08,179 --> 00:01:05,010
operational yet but I was carried on by

22
00:01:09,710 --> 00:01:08,189
students for several years so I did my

23
00:01:13,160 --> 00:01:09,720
undergraduate work in physics and

24
00:01:15,550 --> 00:01:13,170
chemistry Purdue University and graduate

25
00:01:17,929 --> 00:01:15,560
work at the University of Minnesota

26
00:01:21,490 --> 00:01:17,939
during my tenure at Purdue University

27
00:01:24,740 --> 00:01:21,500
again I was very fortunate to get a job

28
00:01:27,260 --> 00:01:24,750
almost a dream job with the general

29
00:01:29,660 --> 00:01:27,270
electric company working on a project

30
00:01:33,110 --> 00:01:29,670
for the Atomic Energy Commission and the

31
00:01:34,790 --> 00:01:33,120
US Air Force in the cold war days there

32
00:01:36,740 --> 00:01:34,800
was a desire to have a bomber that you

33
00:01:38,570 --> 00:01:36,750
could keep up indefinitely like a

34
00:01:44,930 --> 00:01:38,580
nuclear submarine so we were building a

35
00:01:47,149 --> 00:01:44,940
nuclear-powered bomber that led to my

36
00:01:50,420 --> 00:01:47,159
ultimately coming to Huntsville because

37
00:01:53,600 --> 00:01:50,430
that project was canceled early in 1961

38
00:01:56,390 --> 00:01:53,610

just as the lunar program was being

39
00:02:00,469 --> 00:01:56,400
approved so I was fortunate to come to

40
00:02:03,440 --> 00:02:00,479
Huntsville and interviewed and was given

41
00:02:08,350 --> 00:02:03,450
a job by Bill Lucas and the materials

42
00:02:12,830 --> 00:02:08,360
organization so from that point on I

43
00:02:14,539 --> 00:02:12,840
worked on the all the materials for the

44
00:02:17,030 --> 00:02:14,549
development of the Saturn booster

45
00:02:19,699 --> 00:02:17,040
actually I was chief of the projects

46
00:02:21,800 --> 00:02:19,709
office in the materials group so that

47
00:02:23,300 --> 00:02:21,810
got us involved in everything was going

48
00:02:26,720 --> 00:02:23,310
on not just Saturn but all the other

49
00:02:28,610 --> 00:02:26,730
projects it was our job to coordinate

50
00:02:31,190 --> 00:02:28,620
the Materials Research

51
00:02:32,780 --> 00:02:31,200
with the designers to make sure that

52
00:02:35,570 --> 00:02:32,790
they had the materials that they needed

53
00:02:40,550 --> 00:02:35,580
in order to do build and design a

54
00:02:46,430 --> 00:02:43,940
while I was in graduate school at the

55
00:02:49,880 --> 00:02:46,440
University of Minnesota on October 4th

56
00:02:52,220 --> 00:02:49,890
1957 I came home from school to hear on

57
00:02:56,300 --> 00:02:52,230
the news that the Russians had launched

58
00:02:58,610 --> 00:02:56,310
a satellite that somewhat irritated me

59
00:03:00,530 --> 00:02:58,620
because I'd had my undergraduate work in

60
00:03:02,600 --> 00:03:00,540
physics I was in graduate school physics

61
00:03:05,470 --> 00:03:02,610
that nobody had ever mentioned the

62
00:03:09,410 --> 00:03:05,480
possibility of an artificial satellite

63
00:03:11,479 --> 00:03:09,420

so it turned out to that Minneapolis was

64
00:03:13,340 --> 00:03:11,489
right on the flight path so every 90

65
00:03:16,580 --> 00:03:13,350
minutes that guy I went out and watched

66
00:03:18,620 --> 00:03:16,590
button he came over immediately that

67
00:03:21,830 --> 00:03:18,630
didn't have an effect on my career but

68
00:03:23,870 --> 00:03:21,840
ultimately it did as I say when the

69
00:03:25,070 --> 00:03:23,880
project I was working on for the Atomic

70
00:03:30,500 --> 00:03:25,080
Energy Commission and the Air Force

71
00:03:32,540 --> 00:03:30,510
petered out my next emphasis of course

72
00:03:35,479 --> 00:03:32,550
turned to space because that was the

73
00:03:37,729 --> 00:03:35,489
most exciting and challenging job on the

74
00:03:38,930 --> 00:03:37,739
market and I was very very fortunate to

75
00:03:41,330 --> 00:03:38,940
get a job here at the Marshall Space

76
00:03:43,190 --> 00:03:41,340
Flight Center in fact when I meet and

77
00:03:45,770 --> 00:03:43,200
talk to children today they often ask

78
00:03:47,479 --> 00:03:45,780
well what classes did you take how did

79
00:03:49,430 --> 00:03:47,489
you prepare for a job on the lunar

80
00:03:53,600 --> 00:03:49,440
program well you can't because there was

81
00:03:56,780 --> 00:03:53,610
no such thing and the reality today is

82
00:03:59,420 --> 00:03:56,790
there's a large number of the children

83
00:04:02,840 --> 00:03:59,430
are going to end up in jobs that do not

84
00:04:05,180 --> 00:04:02,850
even exist today so I try to encourage

85
00:04:06,979 --> 00:04:05,190
them to get a very good solid broad

86
00:04:12,289 --> 00:04:06,989
background to take advantage when these

87
00:04:15,140 --> 00:04:12,299
things come along but in those days the

88
00:04:16,909 --> 00:04:15,150

stimulus of the space program and the

89
00:04:19,520 --> 00:04:16,919
Manhattan Project and other things that

90
00:04:21,590 --> 00:04:19,530
we're going on had a dramatic effect on

91
00:04:24,529 --> 00:04:21,600
education if you look at the history of

92
00:04:27,830 --> 00:04:24,539
just say graduates with advanced degree

93
00:04:30,260 --> 00:04:27,840
or PhDs there is a huge spike in the 60s

94
00:04:34,100 --> 00:04:30,270
and of course unfortunately it dropped

95
00:04:36,219 --> 00:04:34,110
off in later years so the problem

96
00:04:39,620 --> 00:04:36,229
programs like the Apollo program like

97
00:04:41,810 --> 00:04:39,630
the Manhattan Project stimulated

98
00:04:43,909 --> 00:04:41,820
interest in research and education in

99
00:04:49,410 --> 00:04:43,919
not just those particular areas but

100
00:04:55,750 --> 00:04:53,500
we had to either requalified existing

101
00:04:57,040 --> 00:04:55,760
commercial materials for the more severe

102
00:04:59,470 --> 00:04:57,050
environments that we were going to

103
00:05:01,720 --> 00:04:59,480
experience or create new materials and

104
00:05:04,480 --> 00:05:01,730
we did particularly in the engines

105
00:05:06,460 --> 00:05:04,490
because of the temperature extremes the

106
00:05:08,500 --> 00:05:06,470
vibrations and all of the actions that

107
00:05:11,080 --> 00:05:08,510
are going on there simply were not

108
00:05:13,090 --> 00:05:11,090
materials that were strong enough had to

109
00:05:14,950 --> 00:05:13,100
high temperature capability that we

110
00:05:20,190 --> 00:05:14,960
needed so we invented a lot of new

111
00:05:23,800 --> 00:05:20,200
materials very simple things like you

112
00:05:25,660 --> 00:05:23,810
you can't use wd-40 as a lubricant in

113
00:05:27,850 --> 00:05:25,670

space so we developed solid film

114
00:05:30,310 --> 00:05:27,860
lubricants of course we use solid film

115
00:05:33,220 --> 00:05:30,320
room lubricants and everything today so

116
00:05:34,870 --> 00:05:33,230
it's like that in every area that even

117
00:05:38,020 --> 00:05:34,880
though there were materials that were

118
00:05:43,840 --> 00:05:38,030
used that we had to wreak wala fie them

119
00:05:46,270 --> 00:05:43,850
and that entailed a great deal of work

120
00:05:48,340 --> 00:05:46,280
it necessitated our working with the

121
00:05:51,340 --> 00:05:48,350
mind in fact what the Ultima suppliers

122
00:05:53,260 --> 00:05:51,350
of the materials to stabilize the

123
00:05:54,970 --> 00:05:53,270
specification so that we knew we were

124
00:05:58,810 --> 00:05:54,980
going to get the same material with

125
00:06:01,750 --> 00:05:58,820
every batch that came in there was also

126
00:06:03,910 --> 00:06:01,760
the necessity to develop techniques for

127
00:06:05,890 --> 00:06:03,920
evaluating the materials both as a

128
00:06:08,290 --> 00:06:05,900
receive them and then after there have

129
00:06:12,820 --> 00:06:08,300
been used and particularly when we had

130
00:06:15,130 --> 00:06:12,830
failures failure analysis is something

131
00:06:18,250 --> 00:06:15,140
people don't think about but I think

132
00:06:21,670 --> 00:06:18,260
that's one of the major accomplishments

133
00:06:23,140 --> 00:06:21,680
of the Apollo program when you stop to

134
00:06:25,560 --> 00:06:23,150
think because you got a vehicle with

135
00:06:28,990 --> 00:06:25,570
three million parts give or take some

136
00:06:30,850 --> 00:06:29,000
and you have a failure and you're trying

137
00:06:33,040 --> 00:06:30,860
to figure out when we're wrong what went

138
00:06:35,560 --> 00:06:33,050

wrong particularly when you can't get

139
00:06:38,640 --> 00:06:35,570
the hardware back it is a real challenge

140
00:06:40,900 --> 00:06:38,650
and there was not any real discipline

141
00:06:42,730 --> 00:06:40,910
approach to failure analysis when we

142
00:06:44,560 --> 00:06:42,740
started but we developed failure mode

143
00:06:47,140 --> 00:06:44,570
effects analyses we developed all the

144
00:06:52,510 --> 00:06:47,150
techniques that are common today to

145
00:06:56,130 --> 00:06:52,520
allowed us to evaluate and and then pin

146
00:06:59,470 --> 00:06:56,140
down what actual the causes were

147
00:07:01,150 --> 00:06:59,480
so there are many attributes of the

148
00:07:03,460 --> 00:07:01,160
materials area that people don't think

149
00:07:05,050 --> 00:07:03,470
about the same earlier analysis is one

150
00:07:10,150 --> 00:07:05,060
of them another one is non-destructive

151
00:07:15,460 --> 00:07:10,160
testing there's 20 miles of welds on the

152
00:07:17,620 --> 00:07:15,470
launch vehicle we x-rayed every inch of

153
00:07:20,140 --> 00:07:17,630
those wells and the x-rays in those days

154
00:07:23,320 --> 00:07:20,150
the old folks will remember going to the

155
00:07:26,140 --> 00:07:23,330
dentist and getting little x-ray films

156
00:07:30,250 --> 00:07:26,150
of their teeth and that's what we use to

157
00:07:32,410 --> 00:07:30,260
x-ray 20 miles of welds and technicians

158
00:07:35,140 --> 00:07:32,420
went over every inch of those x-rays

159
00:07:38,500 --> 00:07:35,150
looking for defects and we had to then

160
00:07:40,690 --> 00:07:38,510
fix them among other things that nobody

161
00:07:43,750 --> 00:07:40,700
had ever encountered when we went to

162
00:07:46,210 --> 00:07:43,760
hydrogen fuel hydrogen has such a very

163
00:07:48,370 --> 00:07:46,220

very small molecule that it'll get

164
00:07:50,980 --> 00:07:48,380
through the smallest of defects and the

165
00:07:55,390 --> 00:07:50,990
smallest of cracks so you had to have a

166
00:07:57,460 --> 00:07:55,400
perfect weld nobody had ever made welds

167
00:07:59,140 --> 00:07:57,470
of the length and the quality that we

168
00:08:01,930 --> 00:07:59,150
needed for the launch vehicle so we had

169
00:08:03,460 --> 00:08:01,940
to not only develop the materials we had

170
00:08:05,080 --> 00:08:03,470
to develop the welding techniques the

171
00:08:07,540 --> 00:08:05,090
inspection technique the casting

172
00:08:10,240 --> 00:08:07,550
techniques all of the things from from

173
00:08:13,060 --> 00:08:10,250
beginning to end that was a major

174
00:08:16,030 --> 00:08:13,070
challenge but it was a very interesting

175
00:08:20,020 --> 00:08:16,040
challenge while say having to make 20

176
00:08:22,120 --> 00:08:20,030
miles worth of welding on a vehicle was

177
00:08:23,980 --> 00:08:22,130
a tremendous challenge among other

178
00:08:27,340 --> 00:08:23,990
things when you had things like a

179
00:08:29,050 --> 00:08:27,350
bulkhead the weld land changes from

180
00:08:30,909 --> 00:08:29,060
maybe an inch and a quarter down to

181
00:08:34,300 --> 00:08:30,919
maybe five-eighths of an inch so it's

182
00:08:36,909 --> 00:08:34,310
constantly changing causing the the

183
00:08:39,490 --> 00:08:36,919
welding head to have to adapt to that

184
00:08:41,800 --> 00:08:39,500
change we had to develop all new welding

185
00:08:44,110 --> 00:08:41,810
equipment we had to develop backup bars

186
00:08:45,370 --> 00:08:44,120
in order to take the cooling we got the

187
00:08:48,970 --> 00:08:45,380
cooling in order to get the right

188
00:08:51,040 --> 00:08:48,980

temperatures for the welds this entailed

189
00:08:53,290 --> 00:08:51,050
a great deal who continued to develop

190
00:08:57,120 --> 00:08:53,300
welding techniques and welding machines

191
00:08:59,860 --> 00:08:57,130
to the point that you know 20 years ago

192
00:09:02,710 --> 00:08:59,870
we developed what's now called friction

193
00:09:04,670 --> 00:09:02,720
stir welding which is now being used on

194
00:09:09,140 --> 00:09:04,680
the latest vehicles

195
00:09:11,900 --> 00:09:09,150
so the whole process was try to get the

196
00:09:14,270 --> 00:09:11,910
best quality weld with putting the least

197
00:09:18,740 --> 00:09:14,280
amount of heat in in the minimum amount

198
00:09:24,600 --> 00:09:22,560
okay well Saturn Saturn 1b kind of get

199
00:09:25,950 --> 00:09:24,610
ignored when we talk about going to the

200
00:09:31,080 --> 00:09:25,960
moon but they were very very important

201
00:09:33,420 --> 00:09:31,090
part of it the reality is in 1961 all we

202
00:09:35,190 --> 00:09:33,430
had were little ballistic missiles like

203
00:09:37,980 --> 00:09:35,200
the Redstone de Jupiter

204
00:09:41,070 --> 00:09:37,990
we had nothing large enough to put the

205
00:09:43,680 --> 00:09:41,080
service module and the command module

206
00:09:46,380 --> 00:09:43,690
into orbit to develop it so the Saturn

207
00:09:48,090 --> 00:09:46,390
one was Cluj together by using a jupiter

208
00:09:50,220 --> 00:09:48,100
center tank and then eight Redstone

209
00:09:51,900 --> 00:09:50,230
tanks around it and then we took the

210
00:09:54,330 --> 00:09:51,910
largest engine in the world which was a

211
00:09:56,190 --> 00:09:54,340
Titan engine but it wasn't big enough so

212
00:09:58,410 --> 00:09:56,200
we had to upgrade it and we had to put

213
00:10:00,590 --> 00:09:58,420

eight of them on the vehicle to get us

214
00:10:05,220 --> 00:10:00,600
one and a half million pounds of thrust

215
00:10:07,620 --> 00:10:05,230
had we used those engines on the Saturn

216
00:10:09,750 --> 00:10:07,630
5 there would have been 40 engines on

217
00:10:11,580 --> 00:10:09,760
the first stage well it's hard enough to

218
00:10:17,040 --> 00:10:11,590
get five of them started let alone 40 of

219
00:10:19,560 --> 00:10:17,050
them and the transition of the upgrading

220
00:10:22,670 --> 00:10:19,570
from that sized engine to the f1 engine

221
00:10:25,950 --> 00:10:22,680
was a major problem as we talked earlier

222
00:10:29,640 --> 00:10:25,960
we had to develop new materials the

223
00:10:31,590 --> 00:10:29,650
whole thing was was a mystery much of it

224
00:10:34,230 --> 00:10:31,600
you couldn't analyze so we had to learn

225
00:10:36,440 --> 00:10:34,240
a lot by test and we blew up a number of

226
00:10:38,820 --> 00:10:36,450
engines learning those lessons

227
00:10:40,680 --> 00:10:38,830
unfortunately the Saturn one 1b kind of

228
00:10:43,650 --> 00:10:40,690
get ignored in the whole history of

229
00:10:46,590 --> 00:10:43,660
things but they were very very important

230
00:10:48,720 --> 00:10:46,600
elements in our success and getting to

231
00:10:51,630 --> 00:10:48,730
the moon both in terms of giving the

232
00:10:54,150 --> 00:10:51,640
astronauts time and space to really

233
00:10:58,050 --> 00:10:54,160
learn what they can do we developed a

234
00:11:00,480 --> 00:10:58,060
lot of materials for this one and one B

235
00:11:03,420 --> 00:11:00,490
program that ultimately we used in the

236
00:11:06,360 --> 00:11:03,430
Saturn 5 a lot of techniques the

237
00:11:08,340 --> 00:11:06,370
insulation on the s4 B stage on that one

238
00:11:09,870 --> 00:11:08,350

bit was small enough we used an internal

239
00:11:11,940 --> 00:11:09,880
insulation where of course we used the

240
00:11:14,310 --> 00:11:11,950
s4 B stage not only on the Saturn one

241
00:11:15,960 --> 00:11:14,320
but on the Saturn 5 that is an

242
00:11:17,880 --> 00:11:15,970
overlooked part of the program and of

243
00:11:21,510 --> 00:11:17,890
course even late in the program we

244
00:11:25,500 --> 00:11:21,520
launched the crew to Skylab on a Saturn

245
00:11:29,260 --> 00:11:25,510
1b so it was used nobody have something

246
00:11:31,970 --> 00:11:29,270
like 13 launches on each one of those so

247
00:11:33,710 --> 00:11:31,980
they were very very significant very

248
00:11:38,270 --> 00:11:33,720
fundamental in our achieving the overall

249
00:11:42,830 --> 00:11:40,640
we had a vehicle being stacked at the

250
00:11:45,310 --> 00:11:42,840
cave and we were ready to ship the s4b

251
00:11:48,320 --> 00:11:45,320
stage from Huntington Beach California

252
00:11:51,440 --> 00:11:48,330
the last thing we do is an acceptance

253
00:11:54,110 --> 00:11:51,450
test firing so we had the vehicle and in

254
00:11:56,720 --> 00:11:54,120
the stand just before the engines lit

255
00:11:58,850 --> 00:11:56,730
the whole stage blew up wiped out the

256
00:12:01,240 --> 00:11:58,860
stage and the stand we had to do a

257
00:12:03,830 --> 00:12:01,250
failure analysis that by reconstructing

258
00:12:05,750 --> 00:12:03,840
the whole stage piecing things together

259
00:12:07,490 --> 00:12:05,760
to trace down where the explosions

260
00:12:09,680 --> 00:12:07,500
started and how it would be propagated

261
00:12:11,900 --> 00:12:09,690
and it turned out in that case it was a

262
00:12:15,890 --> 00:12:11,910
very simple thing a welder

263
00:12:18,620 --> 00:12:15,900

had used the wrong weld wire and joining

264
00:12:20,450 --> 00:12:18,630
the two hemispheres of one of the helium

265
00:12:22,610 --> 00:12:20,460
spheres that was used for pressurization

266
00:12:23,930 --> 00:12:22,620
and cooling and that didn't have the

267
00:12:29,120 --> 00:12:23,940
strength that it should have and it

268
00:12:31,880 --> 00:12:29,130
wiped out the entire stage so very

269
00:12:34,040 --> 00:12:31,890
simple things can come back and bite you

270
00:12:36,080 --> 00:12:34,050
and cost a lot of money because it's a

271
00:12:39,710 --> 00:12:36,090
we wiped out an entire stage for that

272
00:12:43,520 --> 00:12:39,720
now insulation was another really major

273
00:12:51,290 --> 00:12:43,530
headache liquid hydrogen has to be kept

274
00:12:52,970 --> 00:12:51,300
at 423 degrees below zero we used well

275
00:12:54,470 --> 00:12:52,980
people always ask what what's the

276
00:12:56,060 --> 00:12:54,480
vehicle made out of well it's made out

277
00:12:58,700 --> 00:12:56,070
of aluminum but that's just a

278
00:13:00,860 --> 00:12:58,710
superficial statement there are many

279
00:13:02,660 --> 00:13:00,870
different alloys of aluminium that are

280
00:13:06,110 --> 00:13:02,670
used and every material that went into

281
00:13:09,770 --> 00:13:06,120
that vehicle was a picked and designed

282
00:13:11,930 --> 00:13:09,780
for that particular application for the

283
00:13:15,530 --> 00:13:11,940
hydrogen tank we wanted to use the

284
00:13:17,150 --> 00:13:15,540
highest strength alloy at liquid

285
00:13:21,590 --> 00:13:17,160
hydrogen temperatures so we used the

286
00:13:23,210 --> 00:13:21,600
material called 2014 aluminum in order

287
00:13:25,820 --> 00:13:23,220
to take advantage of that strength we

288
00:13:28,340 --> 00:13:25,830

wanted the hydrogen in direct contact

289
00:13:32,120 --> 00:13:28,350
with the skin and that allowed us to use

290
00:13:34,400 --> 00:13:32,130
very thin very thin walls since the

291
00:13:36,440 --> 00:13:34,410
hydrogen had to be kept 423 degrees

292
00:13:38,980 --> 00:13:36,450
below zero it meant we had to put the

293
00:13:41,390 --> 00:13:38,990
insulation on the outside of the vehicle

294
00:13:43,040 --> 00:13:41,400
well every time you tank the vehicle

295
00:13:44,420 --> 00:13:43,050
which we did over and over and over

296
00:13:46,400 --> 00:13:44,430
again before we ever flew it

297
00:13:48,170 --> 00:13:46,410
the tank was shrink it would shrink

298
00:13:50,510 --> 00:13:48,180
about three inches in diameter and eight

299
00:13:51,250 --> 00:13:50,520
inches in length but the insulation on

300
00:13:53,260 --> 00:13:51,260
the outside

301
00:13:54,820 --> 00:13:53,270
wouldn't shrink at the same rate so we

302
00:13:56,770 --> 00:13:54,830
had to develop special that he sees an

303
00:14:00,040 --> 00:13:56,780
attachment techniques to hold the

304
00:14:03,400 --> 00:14:00,050
insulation on the tank and even with

305
00:14:06,250 --> 00:14:03,410
that due to the shrinkage we would get

306
00:14:07,480 --> 00:14:06,260
microscopic cracks in the insulation

307
00:14:09,640 --> 00:14:07,490
that you couldn't even see them with the

308
00:14:11,880 --> 00:14:09,650
naked eye but the next time you put

309
00:14:14,380 --> 00:14:11,890
hydrogen in that tank it pumped air

310
00:14:17,320 --> 00:14:14,390
through the insulation and you got

311
00:14:21,070 --> 00:14:17,330
frozen air on the skin of the tank and

312
00:14:23,350 --> 00:14:21,080
then say during launch the friction due

313
00:14:25,420 --> 00:14:23,360

to the heating due to friction going

314
00:14:28,060 --> 00:14:25,430
through the atmosphere would cause that

315
00:14:31,090 --> 00:14:28,070
ice to sublime it will go from solid to

316
00:14:34,120 --> 00:14:31,100
gas in one step and it will blow divots

317
00:14:35,920 --> 00:14:34,130
out the side of the insulation and then

318
00:14:37,990 --> 00:14:35,930
we had to figure out how big a hole can

319
00:14:40,000 --> 00:14:38,000
you stand before the aerodynamic strip

320
00:14:41,770 --> 00:14:40,010
all the insulation off the vehicle how

321
00:14:44,230 --> 00:14:41,780
do you repair it and all of these things

322
00:14:46,090 --> 00:14:44,240
there was far more that we did not know

323
00:14:49,300 --> 00:14:46,100
about going to the moon and what we did

324
00:14:50,860 --> 00:14:49,310
and every day was a new challenge facing

325
00:14:51,730 --> 00:14:50,870
questions that nobody had ever thought

326
00:14:55,180 --> 00:14:51,740
about before

327
00:14:56,770 --> 00:14:55,190
and it seemed like every time you solved

328
00:14:57,970 --> 00:14:56,780
one problem it created three more

329
00:15:00,340 --> 00:14:57,980
problems that nobody had ever thought

330
00:15:01,870 --> 00:15:00,350
about so that was really a challenge but

331
00:15:04,420 --> 00:15:01,880
it really was part of the excitement of

332
00:15:09,400 --> 00:15:04,430
the project of dealing with this on a

333
00:15:14,590 --> 00:15:12,060
I think one of the most amazing

334
00:15:17,920 --> 00:15:14,600
opportunities that we had was working

335
00:15:19,600 --> 00:15:17,930
with the German team now when people

336
00:15:22,210 --> 00:15:19,610
like myself came to work here we were

337
00:15:24,310 --> 00:15:22,220
twenty year old kids the German team was

338
00:15:26,860 --> 00:15:24,320

probably eight to ten years older than

339
00:15:28,390 --> 00:15:26,870
we of course there were our mentors but

340
00:15:31,720 --> 00:15:28,400
the important thing there was never any

341
00:15:33,790 --> 00:15:31,730
we or they between the groups we were

342
00:15:35,620 --> 00:15:33,800
working on one project we do what we had

343
00:15:38,490 --> 00:15:35,630
to do everybody had the same job

344
00:15:42,100 --> 00:15:38,500
description getting the same pay and

345
00:15:44,440 --> 00:15:42,110
there was total harmony if you will in

346
00:15:47,560 --> 00:15:44,450
terms of dedicating oneself to

347
00:15:50,290 --> 00:15:47,570
accomplishing that objective today for

348
00:15:53,020 --> 00:15:50,300
example they teach systems engineering

349
00:15:55,150 --> 00:15:53,030
as a class in college there was no such

350
00:15:57,460 --> 00:15:55,160
thing in that day everybody was a

351
00:15:59,440 --> 00:15:57,470
systems engineer every single person

352
00:16:00,730 --> 00:15:59,450
when you were working on a problem you

353
00:16:02,350 --> 00:16:00,740
were thinking about what effect does

354
00:16:03,730 --> 00:16:02,360
this have on the guidance control what

355
00:16:05,140 --> 00:16:03,740
is the fact to have on this thing what

356
00:16:07,990 --> 00:16:05,150
does it have effect does that have on

357
00:16:11,200 --> 00:16:08,000
something else and I'm quite different

358
00:16:15,040 --> 00:16:11,210
than what I understand is done in some

359
00:16:18,100 --> 00:16:15,050
places today we had a very efficient way

360
00:16:19,810 --> 00:16:18,110
of solving these problems you got on the

361
00:16:21,250 --> 00:16:19,820
telephone you called up everybody that

362
00:16:22,630 --> 00:16:21,260
she thought was involved you got him in

363
00:16:25,060 --> 00:16:22,640

the room and you sat down and you talked

364
00:16:27,460 --> 00:16:25,070
about it you argued about it and you

365
00:16:28,840 --> 00:16:27,470
came up with a solution and then you

366
00:16:32,830 --> 00:16:28,850
tried to have it didn't work and went to

367
00:16:35,410 --> 00:16:32,840
plan B everybody as I said was conscious

368
00:16:38,200 --> 00:16:35,420
of what everybody else's job was the

369
00:16:42,310 --> 00:16:38,210
other thing is that for most

370
00:16:45,010 --> 00:16:42,320
applications 96 98 percent reliability

371
00:16:47,830 --> 00:16:45,020
is is great we had to have a hundred

372
00:16:50,130 --> 00:16:47,840
percent reliability and every decision

373
00:16:52,780 --> 00:16:50,140
that you made was a life-or-death

374
00:16:55,390 --> 00:16:52,790
decision and you were conscious of that

375
00:16:58,360 --> 00:16:55,400
every single day you were always

376
00:17:00,160 --> 00:16:58,370
thinking about if this bolt fails or if

377
00:17:02,560 --> 00:17:00,170
that moiled fails or if something else

378
00:17:05,020 --> 00:17:02,570
goes wrong what effect these are going

379
00:17:08,320 --> 00:17:05,030
to have not only on the crew but on the

380
00:17:12,070 --> 00:17:08,330
people on the lost side and so on that

381
00:17:14,890 --> 00:17:12,080
was if they put stress on it on

382
00:17:17,020 --> 00:17:14,900
everybody but as I say I think that also

383
00:17:18,610 --> 00:17:17,030
was a major contributor in the success

384
00:17:20,230 --> 00:17:18,620
that we have because every problem every

385
00:17:23,049 --> 00:17:20,240
one of the launches that we had was six

386
00:17:26,199 --> 00:17:23,059
well let's say every launch we had met

387
00:17:29,080 --> 00:17:26,209
the mission we had problems there were

388
00:17:31,539 --> 00:17:29,090

failures most of people don't know about

389
00:17:34,299 --> 00:17:31,549
what those failures were because we had

390
00:17:36,970 --> 00:17:34,309
enough contingency and enough thrust

391
00:17:39,190 --> 00:17:36,980
control that we were able to compensate

392
00:17:43,530 --> 00:17:39,200
for them and still have a successful

393
00:17:47,570 --> 00:17:44,960
of course I was

394
00:17:49,610 --> 00:17:47,580
and the launches of the Saturn was in

395
00:17:52,010 --> 00:17:49,620
Saturn one bees because we were

396
00:17:54,950 --> 00:17:52,020
developing certain payloads I will never

397
00:17:58,460 --> 00:17:54,960
forget one night that we had a launch

398
00:18:03,290 --> 00:17:58,470
about midnight it was a perfectly clear

399
00:18:06,080 --> 00:18:03,300
night not a cloud in the sky when we

400
00:18:09,050 --> 00:18:06,090
lifted off of midnight and of course it

401
00:18:11,780 --> 00:18:09,060
was just like daylight but the most

402
00:18:15,950 --> 00:18:11,790
amazing thing is that you could actually

403
00:18:19,940 --> 00:18:15,960
see the s4b stage burned into orbit over

404
00:18:24,200 --> 00:18:19,950
Africa with the naked eye and that was

405
00:18:25,610 --> 00:18:24,210
an amazing experience I was doing my

406
00:18:28,070 --> 00:18:25,620
part as part of the Flight Readiness

407
00:18:30,920 --> 00:18:28,080
review for the first Saturn launch 2005

408
00:18:32,990 --> 00:18:30,930
launch when I got done dr. von Braun

409
00:18:35,120 --> 00:18:33,000
says you're going with me to the launch

410
00:18:37,100 --> 00:18:35,130
site and tell me whether were the

411
00:18:39,320 --> 00:18:37,110
criteria that you've just set out here

412
00:18:41,600 --> 00:18:39,330
are being met before we launched so I

413
00:18:45,620 --> 00:18:41,610

was part of the team for the very first

414
00:18:49,460 --> 00:18:45,630
launch it was November 7th 1967 7:00

415
00:18:52,700 --> 00:18:49,470
a.m. or approximately but that was that

416
00:18:55,010 --> 00:18:52,710
was quite an experience frankly I don't

417
00:18:57,140 --> 00:18:55,020
think that there was a dry eye in the

418
00:18:59,390 --> 00:18:57,150
control room it was like sending your

419
00:19:02,030 --> 00:18:59,400
child off to school I mean we'd worked

420
00:19:06,320 --> 00:19:02,040
on this thing for seven years now here

421
00:19:08,840 --> 00:19:06,330
was the final test go or no go and with

422
00:19:10,580 --> 00:19:08,850
the liquid rockets they lift off very

423
00:19:13,400 --> 00:19:10,590
very slowly because of all the mass and

424
00:19:15,080 --> 00:19:13,410
the building up of speed it looked like

425
00:19:18,050 --> 00:19:15,090
it was never gonna clear that launch

426
00:19:21,140 --> 00:19:18,060
tower and everybody was kind of helping

427
00:19:25,160 --> 00:19:21,150
it along but of course that was a

428
00:19:27,620 --> 00:19:25,170
extremely memorable event to see that

429
00:19:30,320 --> 00:19:27,630
first vehicle lift off and basically

430
00:19:32,930 --> 00:19:30,330
prove the success of all the things that

431
00:19:36,590 --> 00:19:32,940
we had done for all of those years and I

432
00:19:38,240 --> 00:19:36,600
frequently get asked well what were you

433
00:19:39,500 --> 00:19:38,250
doing doing during the Apollo so

434
00:19:43,520 --> 00:19:39,510
Poliquin I'm sorry what were you doing

435
00:19:45,380 --> 00:19:43,530
during Apollo 11 well we were quite

436
00:19:48,950 --> 00:19:45,390
confident that the vehicle is going to

437
00:19:52,730 --> 00:19:48,960
work that so my answer has always been

438
00:19:54,500 --> 00:19:52,740

we were working on 12 and 13 it was it

439
00:19:54,990 --> 00:19:54,510
was another launch we were confident it

440
00:19:57,990 --> 00:19:55,000
was going to

441
00:19:59,940 --> 00:19:58,000
work but our problem was we had another

442
00:20:02,549 --> 00:19:59,950
vehicle coming out to the launch pad and

443
00:20:04,049 --> 00:20:02,559
we had to have it ready so our focus was

444
00:20:10,670 --> 00:20:04,059
really not on Apollo 11

445
00:20:17,300 --> 00:20:13,970
well as I said I was born and raised in

446
00:20:21,320 --> 00:20:17,310
Yankee land and in Indiana and was

447
00:20:23,930 --> 00:20:21,330
working in Ohio I had certain

448
00:20:27,050 --> 00:20:23,940
trepidations trepidations about coming

449
00:20:29,330 --> 00:20:27,060
the hospital because the racial issues

450
00:20:36,470 --> 00:20:29,340
were quite prominent on the world world

451
00:20:39,500 --> 00:20:36,480
press but frankly NASA and the

452
00:20:42,560 --> 00:20:39,510
Department of Defense had a very major

453
00:20:46,100 --> 00:20:42,570
influence on Alabama's response to that

454
00:20:49,040 --> 00:20:46,110
problem it didn't take too long for the

455
00:20:50,690 --> 00:20:49,050
state leaders to recognize that all the

456
00:20:53,110 --> 00:20:50,700
money coming into the state of Alabama

457
00:20:56,300 --> 00:20:53,120
was coming in because of these programs

458
00:20:59,710 --> 00:20:56,310
and as a result of that there was a bore

459
00:21:03,140 --> 00:20:59,720
of a receptivity to follow the National

460
00:21:05,900 --> 00:21:03,150
objectives and desires to resolve this

461
00:21:07,370 --> 00:21:05,910
issue and the leaders recognized that if

462
00:21:09,170 --> 00:21:07,380
they didn't go along with it that money

463
00:21:11,720 --> 00:21:09,180

was quite likely was going to disappear

464
00:21:14,600 --> 00:21:11,730
so I was here at a time where I could

465
00:21:17,530 --> 00:21:14,610
see the shift in the attitudes about

466
00:21:20,990 --> 00:21:17,540
race relations

467
00:21:24,110 --> 00:21:21,000
fortunately huntsville has always been a

468
00:21:27,230 --> 00:21:24,120
very cosmopolitan city we have people

469
00:21:30,920 --> 00:21:27,240
from all over as a result of that I

470
00:21:34,570 --> 00:21:30,930
would say that we had little or no real

471
00:21:38,480 --> 00:21:34,580
racial issues in the city of Huntsville

472
00:21:41,810 --> 00:21:38,490
when the schools were integrated the

473
00:21:43,130 --> 00:21:41,820
public were out there supporting it even

474
00:21:45,380 --> 00:21:43,140
though there were police all over the

475
00:21:47,510 --> 00:21:45,390
place it was it was the public that was

476
00:21:49,520 --> 00:21:47,520
there escorting the children into the

477
00:21:51,650 --> 00:21:49,530
schools not to say that there weren't

478
00:21:53,990 --> 00:21:51,660
some issues and problems absolutely

479
00:21:59,110 --> 00:21:54,000
there were but compared to other places

480
00:22:02,000 --> 00:21:59,120
in Alabama Huntsville was spared the

481
00:22:07,280 --> 00:22:02,010
problems of integration that other

482
00:22:10,700 --> 00:22:07,290
places did did experience so certainly

483
00:22:13,250 --> 00:22:10,710
the presence of the federal programs

484
00:22:16,340 --> 00:22:13,260
here in hospital not only helped North

485
00:22:19,550 --> 00:22:16,350
Alabama but it ultimately led the state

486
00:22:22,730 --> 00:22:19,560
of Alabama into trying to resolve these

487
00:22:23,680 --> 00:22:22,740
issues perhaps perhaps sooner than they

488
00:22:29,400 --> 00:22:23,690

might have done otherwise

489
00:22:33,930 --> 00:22:30,810
cutting off the funds for the Apollo

490
00:22:36,510 --> 00:22:33,940
program Marshall was in a very desperate

491
00:22:39,690 --> 00:22:36,520
situation after all our whole business

492
00:22:41,190 --> 00:22:39,700
was smoking fire if you don't have any

493
00:22:43,860 --> 00:22:41,200
payloads you don't have missions you

494
00:22:47,010 --> 00:22:43,870
don't need launch vehicles so this was a

495
00:22:50,760 --> 00:22:47,020
very difficult time and the center was

496
00:22:52,890 --> 00:22:50,770
very very bright in recognizing we had

497
00:22:54,960 --> 00:22:52,900
to do marketing and of course Bill Lucas

498
00:22:57,210 --> 00:22:54,970
was put in charge of this new marketing

499
00:23:01,620 --> 00:22:57,220
organization called program development

500
00:23:04,980 --> 00:23:01,630
and it was our job to look at what areas

501
00:23:08,870 --> 00:23:04,990
can we imply the expertise of the center

502
00:23:11,420 --> 00:23:08,880
in order to attract new business here

503
00:23:14,370 --> 00:23:11,430
out of that course came Space Shuttle

504
00:23:18,510 --> 00:23:14,380
ultimately Space Station of a large

505
00:23:20,640 --> 00:23:18,520
observatories and also are getting

506
00:23:23,010 --> 00:23:20,650
involved in more into the operational

507
00:23:27,030 --> 00:23:23,020
end of the business rather than just

508
00:23:30,710 --> 00:23:27,040
building the hardware so that became a

509
00:23:33,330 --> 00:23:30,720
very significant effort I was fortunate

510
00:23:34,830 --> 00:23:33,340
after we began to get approval some of

511
00:23:36,900 --> 00:23:34,840
these programs course I went on to

512
00:23:39,390 --> 00:23:36,910
become a project manager in the space

513
00:23:42,000 --> 00:23:39,400

shuttle program and of course many other

514
00:23:45,780 --> 00:23:42,010
things really went from darienne's into

515
00:23:48,270 --> 00:23:45,790
project management so the future of the

516
00:23:50,250 --> 00:23:48,280
center really hinged on the work that

517
00:23:53,040 --> 00:23:50,260
came out of the program development

518
00:23:55,260 --> 00:23:53,050
activity it was a new experience for us

519
00:23:57,870 --> 00:23:55,270
we never had to sell ourselves before we

520
00:23:59,910 --> 00:23:57,880
never had to go out and market as soon

521
00:24:02,490 --> 00:23:59,920
as somebody said we need to have a

522
00:24:05,280 --> 00:24:02,500
payload Marshall was the center was

523
00:24:07,620 --> 00:24:05,290
going to get it into orbit so now we had

524
00:24:09,930 --> 00:24:07,630
to go out and really sell ourselves I

525
00:24:12,600 --> 00:24:09,940
have worked on more projects that have

526
00:24:15,900 --> 00:24:12,610
been canceled than most people have ever

527
00:24:18,390 --> 00:24:15,910
thought about working on so I'm quite

528
00:24:20,280 --> 00:24:18,400
familiar with with that aspect of it but

529
00:24:25,130 --> 00:24:20,290
yes we did look at the fifth stage

530
00:24:27,510 --> 00:24:25,140
centaur but found out that we had enough

531
00:24:30,000 --> 00:24:27,520
reserve enough capability in the loss

532
00:24:31,590 --> 00:24:30,010
vehicle we didn't really need that but

533
00:24:33,330 --> 00:24:31,600
there were all kinds of programs and

534
00:24:35,730 --> 00:24:33,340
projects that that we were looking at

535
00:24:39,600 --> 00:24:35,740
one of the most disappointing things is

536
00:24:43,430 --> 00:24:39,610
in the 70s we had laid out a complete

537
00:24:45,799 --> 00:24:43,440
plan for going to Mars we had designed

538
00:24:48,769 --> 00:24:45,809

the hardware that we thought we might

539
00:24:51,080 --> 00:24:48,779
need in going there we laid out

540
00:24:55,340 --> 00:24:51,090
schedules we laid out budgets we laid

541
00:24:58,759 --> 00:24:55,350
out the concepts of how you staged and

542
00:25:01,899 --> 00:24:58,769
getting to Mars and unfortunately it

543
00:25:04,759 --> 00:25:01,909
never got off the drawing board

544
00:25:07,249 --> 00:25:04,769
interestingly as I said I've been

545
00:25:09,769 --> 00:25:07,259
working on a aircraft nuclear propulsion

546
00:25:11,629 --> 00:25:09,779
program so when I came here the first

547
00:25:13,850 --> 00:25:11,639
project that I got working that I was

548
00:25:15,409 --> 00:25:13,860
working on was the nuclear stage to go

549
00:25:18,139 --> 00:25:15,419
to Mars

550
00:25:20,990 --> 00:25:18,149
dr. von Braun was very very perceptive

551
00:25:23,210 --> 00:25:21,000
and in the Space Act of 1958 that

552
00:25:25,249 --> 00:25:23,220
created NASA there is a paragraph in

553
00:25:27,860 --> 00:25:25,259
there that we will develop a nuclear

554
00:25:32,060 --> 00:25:27,870
stage to go to Mars well unfortunately

555
00:25:33,619 --> 00:25:32,070
the interest dropped off but yes their

556
00:25:35,720 --> 00:25:33,629
world there were a lot of false stars

557
00:25:39,110 --> 00:25:35,730
there are a lot of things that we looked

558
00:25:40,990 --> 00:25:39,120
at and either decided that really wasn't

559
00:25:44,330 --> 00:25:41,000
the right time to do it or more

560
00:25:53,040 --> 00:25:44,340
generally we couldn't get the financial

561
00:25:59,280 --> 00:25:55,770
that the Apollo program was a political

562
00:26:02,040 --> 00:25:59,290
victory but the real value of that

563
00:26:04,710 --> 00:26:02,050

program is all the technology that we

564
00:26:07,320 --> 00:26:04,720
had to develop to accomplish the job we

565
00:26:11,250 --> 00:26:07,330
today are living off of the technology

566
00:26:13,380 --> 00:26:11,260
of the 60s not only did this come from

567
00:26:15,900 --> 00:26:13,390
the space program the space program

568
00:26:17,940 --> 00:26:15,910
stimulated technology development

569
00:26:21,720 --> 00:26:17,950
experimentation scientific endeavors

570
00:26:24,630 --> 00:26:21,730
across the board and that is what we are

571
00:26:27,810 --> 00:26:24,640
living on today now I had an opportunity

572
00:26:29,790 --> 00:26:27,820
to be invited to be an adviser to the

573
00:26:32,310 --> 00:26:29,800
European Space Agency so I spent almost

574
00:26:36,360 --> 00:26:32,320
three years in Europe working with them

575
00:26:37,470 --> 00:26:36,370
and frankly I don't think is a question

576
00:26:38,850 --> 00:26:37,480
as I learn things that are more

577
00:26:40,290 --> 00:26:38,860
important than anything I taught them

578
00:26:42,570 --> 00:26:40,300
and most probably the most important

579
00:26:44,520 --> 00:26:42,580
thing is the only thing that this

580
00:26:47,850 --> 00:26:44,530
country has to sell on the world market

581
00:26:49,290 --> 00:26:47,860
is technology in the first place the

582
00:26:51,690 --> 00:26:49,300
third world countries are catching up

583
00:26:53,460 --> 00:26:51,700
with us in the second place there is no

584
00:26:56,850 --> 00:26:53,470
program in this country today driving

585
00:27:02,010 --> 00:26:56,860
technology like the programs in the past

586
00:27:06,710 --> 00:27:02,020
and that is it it for boats

587
00:27:11,390 --> 00:27:06,720
real problems for us among other things

588
00:27:15,270 --> 00:27:11,400

this country needs to commit to a very

589
00:27:18,510 --> 00:27:15,280
high-tech challenging program like going

590
00:27:20,340 --> 00:27:18,520
to Mars putting people on Mars will open

591
00:27:22,950 --> 00:27:20,350
the fields they're opened our knowledge

592
00:27:25,700 --> 00:27:22,960
to all kinds of science but just the

593
00:27:28,890 --> 00:27:25,710
technology to get us to Mars and back

594
00:27:31,350 --> 00:27:28,900
will fuel our economy for another 75 to

595
00:27:32,670 --> 00:27:31,360
100 years and we look at it from the

596
00:27:34,620 --> 00:27:32,680
standpoint or I look at it from the

597
00:27:38,040 --> 00:27:34,630
standpoint by not doing this we are

598
00:27:40,980 --> 00:27:38,050
cheating my great-grandchildren because

599
00:27:45,000 --> 00:27:40,990
we are living off the technology 60

600
00:27:47,160 --> 00:27:45,010
years ago and it is so important for our

601
00:27:49,830 --> 00:27:47,170
future that we once again

602
00:27:51,240 --> 00:27:49,840
take on significant challenges yes

603
00:27:53,910 --> 00:27:51,250
they're expensive there's no question

604
00:27:56,280 --> 00:27:53,920
about it but the payback from this is

605
00:27:58,950 --> 00:27:56,290
incalculable we barely scratched the

606
00:28:01,710 --> 00:27:58,960
surface of what we could and should

607
00:28:02,780 --> 00:28:01,720
learn by going to Mars you know it's a

608
00:28:05,320 --> 00:28:02,790
no-brainer

609
00:28:08,740 --> 00:28:05,330
the moon ought to simply be

610
00:28:10,000 --> 00:28:08,750
a stepping stone to Mars we can learn a

611
00:28:11,770 --> 00:28:10,010
great deal there are things that we can

612
00:28:13,270 --> 00:28:11,780
we know the composition of the moon we

613
00:28:14,950 --> 00:28:13,280

can mine certain things we know there's

614
00:28:16,650 --> 00:28:14,960
water there that can be used for

615
00:28:19,870 --> 00:28:16,660
habitability that can be used for

616
00:28:21,100 --> 00:28:19,880
hydrogen and oxygen fuel because of the

617
00:28:22,750 --> 00:28:21,110
gravity it takes a much much smaller

618
00:28:24,910 --> 00:28:22,760
rocket to go to Mars from the moon that

619
00:28:27,010 --> 00:28:24,920
it does to earth I mean there's no

620
00:28:29,350 --> 00:28:27,020
atmosphere so you can study the space

621
00:28:33,670 --> 00:28:29,360
radiation effects on materials and on

622
00:28:35,830 --> 00:28:33,680
people say it's a no-brainer that we

623
00:28:39,790 --> 00:28:35,840
ought to use the moon as a stepping

624
00:28:44,200 --> 00:28:39,800
stone and if we're willing to stop our

625
00:28:48,100 --> 00:28:44,210
curiosity and our exploration 250 250

626
00:28:50,260 --> 00:28:48,110
thousand miles from Earth and we're not

627
00:28:52,000 --> 00:28:50,270
really living up to our potential I mean

628
00:28:54,720 --> 00:28:52,010
we've got a whole solar system out there