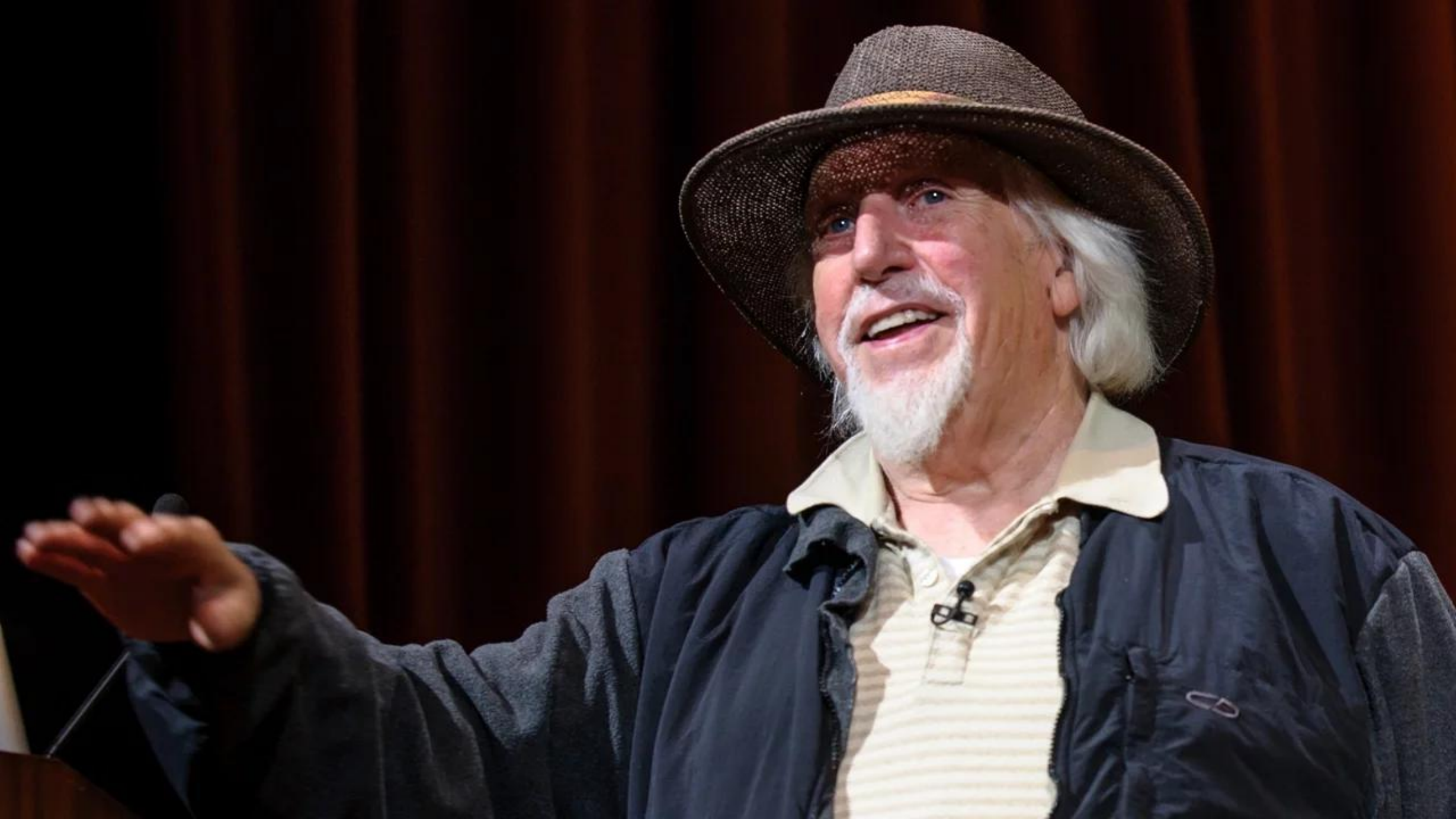

1
00:00:01,000 --> 00:00:07,000
[music playing]

2
00:00:17,733 --> 00:00:21,866
- So welcome to the
2015 NASA Ames Summer Series.

3
00:00:21,866 --> 00:00:26,066
When we think
of Saturn, Apollo,

4
00:00:26,066 --> 00:00:28,933
when we think of those missions
and that time,

5
00:00:28,933 --> 00:00:30,833
we think
of a great time

6
00:00:30,833 --> 00:00:34,866
for rocketry
and space exploration.

7
00:00:34,866 --> 00:00:38,366
We also look at it as an era
where we could do--

8
00:00:38,366 --> 00:00:40,666
and we do in this point--

9
00:00:40,666 --> 00:00:42,966
have a lot of lessons
learned from.

10
00:00:42,966 --> 00:00:47,266
Complex machines were built
to get us into space

11
00:00:47,266 --> 00:00:51,066

and have humans go to places
as far as the moon.

12
00:00:53,900 --> 00:00:55,966
Today's talk,
entitled

13
00:00:55,966 --> 00:01:01,266
"Destroy Saturn V!
and other Apollo Topics,"

14
00:01:01,266 --> 00:01:06,366
will be given
by Bill Colburn.

15
00:01:06,366 --> 00:01:07,933
It is actually
quite interesting,

16
00:01:07,933 --> 00:01:11,733
the career of Bill,
Bill's career.

17
00:01:11,733 --> 00:01:14,733
He thought of and looked at
science fiction

18
00:01:14,733 --> 00:01:17,900
at the age of 11
and said,

19
00:01:17,900 --> 00:01:21,700
"Wow, I want to go
into that area,

20
00:01:21,700 --> 00:01:26,533
drive science fiction to
reality, make it real."

21
00:01:26,533 --> 00:01:31,300

He enlisted in
the US Air Force in 1954,

22
00:01:31,300 --> 00:01:34,933
still with the interest
of following that dream.

23
00:01:36,633 --> 00:01:40,800
He worked for
three and a half years in NSA,

24
00:01:40,800 --> 00:01:45,466
serving the USSR development
in rocketry,

25
00:01:45,466 --> 00:01:48,333
then after that went
to Livermore,

26
00:01:48,333 --> 00:01:51,633
and then Ted Parker
brought him over

27
00:01:51,633 --> 00:01:57,533
to the test range
in China Lake.

28
00:01:57,533 --> 00:02:02,533
He was a staff engineer
for Space Ordnance Systems.

29
00:02:02,533 --> 00:02:05,966
He has worked and designed
and developed,

30
00:02:05,966 --> 00:02:08,233
as part of the Saturn V,

31
00:02:08,233 --> 00:02:11,833
the propellant dispersion sys--

uh, system

32
00:02:11,833 --> 00:02:15,900
and the--
an air abort launch.

33
00:02:15,900 --> 00:02:18,800
What is really interesting is,

34
00:02:18,800 --> 00:02:22,933
he has made major contributions
to complex systems,

35
00:02:22,933 --> 00:02:26,600
started as a kid,
thinking about the approach,

36
00:02:27,600 --> 00:02:29,766
and went through there,

37
00:02:29,766 --> 00:02:33,366
going to a mission
without the formal education

38
00:02:33,366 --> 00:02:35,100
that you would think
somebody like that will have

39
00:02:35,100 --> 00:02:36,566
in a normal system.

40
00:02:36,566 --> 00:02:39,100
So following the dream
is really important,

41
00:02:39,100 --> 00:02:41,700
and you could contribute
to the complexity

42

00:02:41,700 --> 00:02:44,233
of missions like Saturn
and Apollo and make history.

43
00:02:44,233 --> 00:02:47,866
So please join me
in welcoming Bill Colburn.

44
00:02:47,866 --> 00:02:50,866
[applause]

45
00:02:52,900 --> 00:02:55,700
- Thank you,
Dr. Cohen.

46
00:02:55,700 --> 00:02:58,133
Uh, before any talk
on Apollo,

47
00:02:58,133 --> 00:03:02,633
we really have to honor
the--the, uh, five men

48
00:03:02,633 --> 00:03:05,166
who gave their life--
three of which actually,

49
00:03:05,166 --> 00:03:08,533
gave their life
on a mission-related task,

50
00:03:08,533 --> 00:03:11,533
and that's
Grissom, Chaffee, and White.

51
00:03:11,533 --> 00:03:15,833
So my heart to them
and their heroic wives.

52
00:03:17,533 --> 00:03:19,600

Well, "Destroy Saturn V!"

53
00:03:19,600 --> 00:03:22,200
Well, if Saturn V
were this size,

54
00:03:22,200 --> 00:03:25,033
you'd use
a Black Cat firecracker.

55
00:03:25,033 --> 00:03:27,166
You could blow that up easily.

56
00:03:27,166 --> 00:03:28,500
How about one this size?

57
00:03:28,500 --> 00:03:30,400
You could use two cherry bombs,

58
00:03:30,400 --> 00:03:32,733
but Dave would not like
me to do that.

59
00:03:32,733 --> 00:03:35,100
So how about the huge thing?

60
00:03:35,100 --> 00:03:36,733
Look at this.

61
00:03:36,733 --> 00:03:40,666
Uh, but--
but let me give you a--

62
00:03:40,666 --> 00:03:42,100
here I am.

63
00:03:42,100 --> 00:03:44,800
Dr. Cohen intro--he made
a very nice introduction,

64
00:03:44,800 --> 00:03:49,433
but here I am on
the Apollo Walk of Fame

65
00:03:49,433 --> 00:03:51,666
at Titusville, Florida.

66
00:03:51,666 --> 00:03:54,500
I'm the third name
on the first--

67
00:03:54,500 --> 00:03:57,366
uh, on the
first trident there,

68
00:03:57,366 --> 00:03:58,600
and looking at that,

69
00:03:58,600 --> 00:04:00,866
I thought, "Boy,
that's really a great honor."

70
00:04:00,866 --> 00:04:02,066
Until I realized,

71
00:04:02,066 --> 00:04:04,933
"Oh, it's
in alphabetical order."

72
00:04:04,933 --> 00:04:06,233
[laughter]

73
00:04:06,233 --> 00:04:09,666
Well, here it is,
Saturn IC.

74
00:04:09,666 --> 00:04:13,766
So Boeing comes to us

when we were General Precision.

75
00:04:13,766 --> 00:04:15,833
We started
as Precision Technology

76
00:04:15,833 --> 00:04:17,900
in Livermore
with some very heavies

77
00:04:17,900 --> 00:04:20,866
from Lawrence Lab
who started the company.

78
00:04:20,866 --> 00:04:23,066
Well, Boeing comes to us
and said,

79
00:04:23,066 --> 00:04:25,566
"We want to destroy
this thing,"

80
00:04:25,566 --> 00:04:28,300
which is 33 feet
in diameter,

81
00:04:28,300 --> 00:04:29,833
the entire vehicle,
of course,

82
00:04:29,833 --> 00:04:32,333
360 feet long,

83
00:04:32,333 --> 00:04:37,033
4,880,000 pounds of propellant
in the complete vehicle.

84
00:04:38,700 --> 00:04:44,200
How do you do that without,
say, taking out the entire cape,

85
00:04:44,200 --> 00:04:45,933
uh, taking out Cuba,

86
00:04:45,933 --> 00:04:48,533
which happens to be
in the launch area,

87
00:04:48,533 --> 00:04:51,333
44 degrees to 110 degrees.

88
00:04:51,333 --> 00:04:54,533
Cuba's right in there
and so are the Bahamas.

89
00:04:54,533 --> 00:04:56,233
Well, you don't want
to do that.

90
00:04:56,233 --> 00:04:58,200
Even though JFK
might've thought,

91
00:04:58,200 --> 00:05:00,766
"Eh, it's all right
to take out Cuba."

92
00:05:00,766 --> 00:05:03,400
But, uh, so
what do you do with--with that?

93
00:05:03,400 --> 00:05:06,900
488,000 pounds--

94
00:05:06,900 --> 00:05:11,166
4,880,000 pounds,
that's the equivalent

95
00:05:11,166 --> 00:05:16,666

of 1 inch of propellant
across 36 football fields.

96
00:05:16,666 --> 00:05:19,333
That's a lot of propellant.
Okay.

97
00:05:19,333 --> 00:05:23,000
Now, what happens if, um--
if that ignites in the air?

98
00:05:24,266 --> 00:05:27,500
Four and a half million pounds,
what happens?

99
00:05:27,500 --> 00:05:32,333
32 football fields, equivalent
of 400,000 pounds of TNT.

100
00:05:32,333 --> 00:05:34,000
What is that like?

101
00:05:34,000 --> 00:05:36,833
There we are.
Really not quite.

102
00:05:36,833 --> 00:05:38,166
More like this one.

103
00:05:40,633 --> 00:05:45,800
So outside of protecting the,
um--any cities

104
00:05:45,800 --> 00:05:48,233
that you might be in--
in the range,

105
00:05:48,233 --> 00:05:49,733
you want to get rid
of everything

106
00:05:49,733 --> 00:05:54,800
before it has the possibility
of going 350 miles to Cuba,

107
00:05:54,800 --> 00:05:57,333
928 miles to the Bahamas,

108
00:05:57,333 --> 00:06:00,166
960 miles to New York City,

109
00:06:00,166 --> 00:06:01,700
so let's get rid of it

110
00:06:01,700 --> 00:06:03,833
before it even
has an opportunity to do that.

111
00:06:03,833 --> 00:06:07,200
Well, of course
they have the radar,

112
00:06:07,200 --> 00:06:12,600
and if radar detects any
abnormality in the flight path,

113
00:06:12,600 --> 00:06:16,000
they can start
a flight abort sequence.

114
00:06:16,000 --> 00:06:19,266
Uh, they also
use a very interesting technique

115
00:06:19,266 --> 00:06:23,966
which had been used for tracking
V-2s at White Sands,

116
00:06:23,966 --> 00:06:25,433

and that was a wire frame.

117
00:06:25,433 --> 00:06:28,133
And the wire frame
had two wires at an angle

118
00:06:28,133 --> 00:06:31,133
and then the optimum
trajectory wire down the center.

119
00:06:31,133 --> 00:06:34,266
So the guy
optically watched the vehicle.

120
00:06:34,266 --> 00:06:39,933
If it went outside
of those wire-defined areas,

121
00:06:39,933 --> 00:06:42,833
then that would initiate
an abort sequence.

122
00:06:42,833 --> 00:06:45,266
Well, who was in charge
of the abort sequence?

123
00:06:45,266 --> 00:06:48,433
I've read in some places
that it was totally automatic.

124
00:06:48,433 --> 00:06:51,200
No, it was not automatic
in all cases.

125
00:06:51,200 --> 00:06:54,700
It would be automatic
if the wire--

126
00:06:54,700 --> 00:06:58,266
wire running down the length

of the Saturn V here and here,

127
00:06:58,266 --> 00:07:01,266
if those wires
ever lost continuity,

128
00:07:01,266 --> 00:07:03,266
abort sequence
would be automatic

129
00:07:03,266 --> 00:07:07,600
because that indicates
a major rupture in a tank.

130
00:07:07,600 --> 00:07:11,966
Otherwise, the abort sequence
was partially manual,

131
00:07:11,966 --> 00:07:15,533
and it was manual
on the part of the--

132
00:07:15,533 --> 00:07:17,866
of the range safety officer

133
00:07:17,866 --> 00:07:22,200
and on
the command module commander.

134
00:07:22,200 --> 00:07:26,733
So what happens,
and how do you do this?

135
00:07:26,733 --> 00:07:32,533
Well, this is what we came up
with, with Boeing.

136
00:07:32,533 --> 00:07:36,933
It took 5 pounds
of high explosive

137
00:07:36,933 --> 00:07:39,833
to destroy the V-2.

138
00:07:39,833 --> 00:07:43,566
In the Saturn V,
we used 9 pounds of explosive

139
00:07:43,566 --> 00:07:47,266
to destroy
the entire S-IC stage.

140
00:07:47,266 --> 00:07:48,700
And how is that done?

141
00:07:48,700 --> 00:07:53,000
Two runs of 175 grains per foot

142
00:07:53,000 --> 00:07:54,966
flexible linear shaped charge,

143
00:07:54,966 --> 00:07:57,666
which I'll show you
how that works in a moment.

144
00:07:57,666 --> 00:08:00,766
And there were 40-foot--
40-foot lengths

145
00:08:00,766 --> 00:08:03,266
on each side
of the Saturn V.

146
00:08:03,266 --> 00:08:07,133
On this model, they would be
about half the size

147
00:08:07,133 --> 00:08:09,666
of a paper clip

in a cross section,

148
00:08:09,666 --> 00:08:13,900
running 40 feet here
and 40 feet here.

149
00:08:13,900 --> 00:08:15,833
The reason
they were on opposite sides is,

150
00:08:15,833 --> 00:08:21,066
when they--when they did
the ballistic calculations,

151
00:08:21,066 --> 00:08:24,533
it, um--
if the propellants had mixed,

152
00:08:24,533 --> 00:08:27,233
then you would've
had that sub-nuclear explosion.

153
00:08:27,233 --> 00:08:31,433
By ejecting the LOX out one side
and the RP-1 out the other side,

154
00:08:31,433 --> 00:08:36,233
you would have less mixing
and a much lesser explosion.

155
00:08:36,233 --> 00:08:41,133
Well, and that--
those two FLSC lines,

156
00:08:42,566 --> 00:08:45,100
shown here
on their aluminum carrier--

157
00:08:45,100 --> 00:08:47,333
the rectangle

on the outside,

158
00:08:47,333 --> 00:08:50,033
that's the channel
that ran up.

159
00:08:50,033 --> 00:08:53,466
Again, as I said, that's the--
about the size of--

160
00:08:53,466 --> 00:08:55,433
of a half of a paper clip
that would run up the side here.

161
00:08:56,433 --> 00:08:58,800
That was 2 inches by 1 inch,

162
00:08:58,800 --> 00:09:01,366
just to give you an idea
of the scale,

163
00:09:01,366 --> 00:09:04,033
and inside of that was
an aluminum carrier

164
00:09:04,033 --> 00:09:05,466
that had that shape,

165
00:09:05,466 --> 00:09:09,533
and the red parts are the FLSC
that were bonded in place there.

166
00:09:09,533 --> 00:09:12,666
Now, this is an interesting
assembly because everything

167
00:09:12,666 --> 00:09:14,766
was done with adhesives.

168

00:09:14,766 --> 00:09:17,766
There's not a single
mechanical joint

169
00:09:17,766 --> 00:09:21,366
in that
propellant dispersion system,

170
00:09:21,366 --> 00:09:23,233
which is extremely interesting.

171
00:09:23,233 --> 00:09:25,333
Even the Skunk Works,

172
00:09:25,333 --> 00:09:27,300
I understand
when they used adhesive,

173
00:09:27,300 --> 00:09:30,366
they always put in
what they call chicken rivets,

174
00:09:30,366 --> 00:09:32,700
just to make sure that
their adhesive doesn't fail.

175
00:09:32,700 --> 00:09:34,866
This entire thing
was held together with adhesive.

176
00:09:34,866 --> 00:09:39,366
It was a urethane that was
qualified to -280 degrees

177
00:09:39,366 --> 00:09:41,500
for the LOX tank.

178
00:09:41,500 --> 00:09:42,800
So what happens?

179
00:09:42,800 --> 00:09:45,933
Well, when we initiate that,
this is what happens.

180
00:09:45,933 --> 00:09:49,166
It cuts a 1-inch wide gap

181
00:09:49,166 --> 00:09:53,233
in the
2019 aluminum tank structure.

182
00:09:53,233 --> 00:09:55,200
And do you see the little ribs
in that tank?

183
00:09:55,200 --> 00:09:56,700
That's an amazing thing.

184
00:09:56,700 --> 00:10:00,066
We may not be able to make
a tank like that right now.

185
00:10:00,066 --> 00:10:04,666
That was made by taking
enormous sheets of 2019 aluminum

186
00:10:04,666 --> 00:10:09,366
and then milling a pattern
to reduce the wall thickness

187
00:10:09,366 --> 00:10:13,100
but retain the ribs
for stiffening.

188
00:10:13,100 --> 00:10:16,166
That was about roughly 1/4 inch
in the thin section

189
00:10:16,166 --> 00:10:18,633

and 1/2 inch on the ribs,

190
00:10:18,633 --> 00:10:20,433
and then they would roll
that and weld

191
00:10:20,433 --> 00:10:24,366
that into these enormous tanks
that were 33 feet in diameter.

192
00:10:24,366 --> 00:10:26,666
Incredible technology.

193
00:10:26,666 --> 00:10:30,900
Now--so now we have--
we have that happening.

194
00:10:30,900 --> 00:10:35,166
We have the propellant squirting
out each side of the vehicle.

195
00:10:35,166 --> 00:10:37,466
But wait a minute,
we forgot the astronauts

196
00:10:37,466 --> 00:10:40,433
in the command module.
We can blow up--

197
00:10:40,433 --> 00:10:44,500
we can blow up the S-IC
and the upper stages.

198
00:10:44,500 --> 00:10:45,566
That's fine.

199
00:10:45,566 --> 00:10:46,966
But how about these guys
up here?

200
00:10:46,966 --> 00:10:48,733
We got to get them
out of the way.

201
00:10:48,733 --> 00:10:50,300
Well, already,

202
00:10:50,300 --> 00:10:54,766
they had the escape tower
and the escape rocket

203
00:10:54,766 --> 00:11:00,833
designed and built for
emergency abort from the pad.

204
00:11:00,833 --> 00:11:03,333
Now, they wanted to determine
if we could--

205
00:11:03,333 --> 00:11:05,133
if they
could also use that

206
00:11:05,133 --> 00:11:09,133
in various stages
of altitude and velocity.

207
00:11:09,133 --> 00:11:13,166
Um--incidentally,
the Saturn manual calls--

208
00:11:13,166 --> 00:11:16,133
the Saturn V manual
calls this a small rocket.

209
00:11:16,133 --> 00:11:20,833
This rocket had 147,000 pounds
of thrust for four seconds.

210

00:11:20,833 --> 00:11:22,933
I don't call
that a small rocket.

211
00:11:22,933 --> 00:11:27,133
That's three times the thrust
of the V-2,

212
00:11:27,133 --> 00:11:29,966
and that burned for,
as I said, for four seconds,

213
00:11:29,966 --> 00:11:34,100
and that would, uh, from a--
from a standing start,

214
00:11:34,100 --> 00:11:38,600
that would take
the command module to 4,100 feet

215
00:11:38,600 --> 00:11:40,166
in 11 seconds.

216
00:11:40,166 --> 00:11:45,233
So they determined
that with a manual--

217
00:11:45,233 --> 00:11:46,600
even with a manual abort,

218
00:11:46,600 --> 00:11:49,633
they could get the command
module far enough away

219
00:11:49,633 --> 00:11:53,900
that the ignition
of the RP-1 and LOX

220
00:11:53,900 --> 00:11:57,666
would not affect

it detrimentally.

221
00:11:57,666 --> 00:11:58,800
So then what happens?

222
00:11:58,800 --> 00:12:01,066
Well, canards pop out.

223
00:12:01,066 --> 00:12:04,866
If it's a low-altitude abort,
canards pop out,

224
00:12:04,866 --> 00:12:08,200
and the canards
veer the command module

225
00:12:08,200 --> 00:12:12,333
away from the direct trajectory
of the--of the vehicle.

226
00:12:12,333 --> 00:12:13,833
If it's at high altitude,

227
00:12:13,833 --> 00:12:18,500
there's a pitch motor, a small,
solid-propellant pitch motor.

228
00:12:18,500 --> 00:12:20,433
So if it's at 280,000 feet,

229
00:12:20,433 --> 00:12:23,300
which is the maximum feet
for an abort,

230
00:12:23,300 --> 00:12:27,666
the pitch motor--
the pitch motor would tilt

231
00:12:27,666 --> 00:12:31,433

the command module
and get it out of the way.

232
00:12:31,433 --> 00:12:35,800
Then they would fire the bolts
that held the, um--

233
00:12:35,800 --> 00:12:39,166
the, uh, rocket tower
to the command module,

234
00:12:39,166 --> 00:12:41,633
and that would pull off
the ablative heat shield.

235
00:12:41,633 --> 00:12:43,333
There was
an ablative heat shield

236
00:12:43,333 --> 00:12:46,700
over the forward heat shield,
pull that off.

237
00:12:46,700 --> 00:12:47,933
[coughs]

238
00:12:47,933 --> 00:12:49,966
Then they had to get rid
of the forward heat shield

239
00:12:49,966 --> 00:12:52,333
because that was covering up
the parachutes.

240
00:12:52,333 --> 00:12:55,233
So let's use
the parachutes next, all right.

241
00:12:55,233 --> 00:12:56,633
That's a very good idea.

242
00:12:56,633 --> 00:12:58,533
Then the drogue mortars
would fire.

243
00:12:58,533 --> 00:12:59,666
The drogues would go out.

244
00:12:59,666 --> 00:13:02,733
Reefing line cutters would open
the drogues,

245
00:13:02,733 --> 00:13:04,533
and then the drogues
would pull out the mains,

246
00:13:04,533 --> 00:13:06,233
and you would have
a recovery.

247
00:13:06,233 --> 00:13:08,900
Now, boy, how did they know
that was going to happen?

248
00:13:08,900 --> 00:13:11,366
Oh, this is the CDF carrier,
incidentally.

249
00:13:11,366 --> 00:13:15,900
This is, um, CDF,
a confined detonating fuse.

250
00:13:15,900 --> 00:13:17,400
It's two grains per foot.

251
00:13:17,400 --> 00:13:18,866
It looks like solder.

252
00:13:18,866 --> 00:13:23,233

It looks just like
a little lead solder

253
00:13:23,233 --> 00:13:26,466
and, uh [coughs]--
two grains per foot.

254
00:13:26,466 --> 00:13:30,600
That was inside of a--
of a polymer coating,

255
00:13:30,600 --> 00:13:34,233
and then the polymer
had fiberglass tubing over that

256
00:13:34,233 --> 00:13:35,533
and then another polymer

257
00:13:35,533 --> 00:13:37,966
coating and then another layer
of fiberglass.

258
00:13:37,966 --> 00:13:41,533
So when the confined
detonating fuse detonated,

259
00:13:41,533 --> 00:13:47,066
and that's detonation
that's extremely rapid process,

260
00:13:47,066 --> 00:13:50,233
the detonation
would be completely confined

261
00:13:50,233 --> 00:13:54,033
and wouldn't--wouldn't disrupt
any of the mechanical

262
00:13:54,033 --> 00:13:57,133
or electronic components nearby.

263
00:13:57,133 --> 00:14:01,733
The CDF is what started

264
00:14:01,733 --> 00:14:04,066
most of the processes

265
00:14:04,066 --> 00:14:07,333
onboard the Saturn V
and onboard Apollo

266
00:14:07,333 --> 00:14:09,866
because it
was virtually instantaneous.

267
00:14:09,866 --> 00:14:15,733
At 8,000 meters per second,
that--that's pretty fast.

268
00:14:15,733 --> 00:14:19,166
So the, uh--
and the CDF in all cases

269
00:14:19,166 --> 00:14:22,833
was initiated by what's called
an EBW detonator.

270
00:14:22,833 --> 00:14:25,366
That's exploding bridge
wire detonator,

271
00:14:25,366 --> 00:14:28,266
and the reason they use
exploding bridge wire detonator,

272
00:14:28,266 --> 00:14:32,033
it is completely insensitive
to electrostatic discharge,

273

00:14:32,033 --> 00:14:35,533
completely insensitive
to low current.

274
00:14:35,533 --> 00:14:37,733
In fact, you could take
an EBW detonator

275
00:14:37,733 --> 00:14:40,800
and plug it in the wall,
and it would not initiate.

276
00:14:40,800 --> 00:14:44,166
It would fizzle and burn,
but it would not detonate.

277
00:14:44,166 --> 00:14:45,866
So they used EBW detonators,

278
00:14:45,866 --> 00:14:49,200
the safest possible way
to initiate the CDF

279
00:14:49,200 --> 00:14:51,866
and initiate
all of the various functions

280
00:14:51,866 --> 00:14:55,833
that had to happen in the Sat--
the stage separation,

281
00:14:55,833 --> 00:14:58,433
the command module separation.

282
00:14:58,433 --> 00:15:01,666
The docking ring separation was
also done with--

283
00:15:01,666 --> 00:15:03,266
with detonating cord.

284
00:15:03,266 --> 00:15:04,600
[clears throat]

285
00:15:04,600 --> 00:15:07,333
So--so here we are.

286
00:15:07,333 --> 00:15:09,733
We've protected
the astronauts.

287
00:15:09,733 --> 00:15:11,533
We've dumped the propellant.

288
00:15:12,533 --> 00:15:13,866
We're pretty safe.

289
00:15:17,600 --> 00:15:20,566
This is the crossover
we're talking about, the CDF,

290
00:15:20,566 --> 00:15:23,233
and you notice
the manifold paths.

291
00:15:24,766 --> 00:15:29,366
We have two CDF lines
coming in, simple redundancy,

292
00:15:29,366 --> 00:15:31,666
but each line has
a crossover,

293
00:15:31,666 --> 00:15:34,400
so we have double redundancy
in this connector.

294
00:15:34,400 --> 00:15:37,466
We have two FLSC runs.

295
00:15:37,466 --> 00:15:42,066
Pretty much
a very high-reliable system

296
00:15:42,066 --> 00:15:47,500
because if any one
of these, uh, paths failed,

297
00:15:47,500 --> 00:15:51,266
you'd still initiate
both of the FLSC lines,

298
00:15:51,266 --> 00:15:53,633
and you'd still
cut the tank,

299
00:15:53,633 --> 00:15:55,166
uh, and that's
extremely important

300
00:15:55,166 --> 00:15:59,900
because one FLSC line
would not open the tank.

301
00:15:59,900 --> 00:16:01,700
It would just make a slit,

302
00:16:01,700 --> 00:16:03,433
and it would dribble out
over time,

303
00:16:03,433 --> 00:16:05,966
but it would not--
not be a true abort.

304
00:16:08,033 --> 00:16:09,833
That's a CDF connector.

305

00:16:12,133 --> 00:16:13,766
That has a curious thing.

306
00:16:13,766 --> 00:16:16,500
It's a--
it's a spring-loaded lock.

307
00:16:16,500 --> 00:16:18,066
You can see the grooves
on there,

308
00:16:18,066 --> 00:16:21,100
and that was--
as far as I know,

309
00:16:21,100 --> 00:16:24,866
that's peculiar
only to CDF connectors.

310
00:16:24,866 --> 00:16:26,733
I haven't seen it on
a hydraulic system,

311
00:16:26,733 --> 00:16:28,700
for instance.

312
00:16:28,700 --> 00:16:29,966
Now this is getting--

313
00:16:32,900 --> 00:16:36,600
moving over to the rest of
the Apollo pyrotechnic systems.

314
00:16:36,600 --> 00:16:40,166
This is the basic standard
for initiating

315
00:16:40,166 --> 00:16:46,066
nearly all of the pyrotechnic
systems outside of the EBW,

316
00:16:46,066 --> 00:16:48,500
and that's called
the NASA Standard Initiator.

317
00:16:49,500 --> 00:16:52,333
Um, the last I checked,

318
00:16:52,333 --> 00:16:55,100
this has
a reliability of 99.9995

319
00:16:55,100 --> 00:16:57,566
at a 95% confidence level,

320
00:16:57,566 --> 00:17:00,266
which is astounding,
astounding.

321
00:17:00,266 --> 00:17:03,966
And so that--that may be
the most reliable component

322
00:17:03,966 --> 00:17:06,833
in the entire--oh, except
maybe a few resistors, yes.

323
00:17:06,833 --> 00:17:10,366
So--

324
00:17:10,366 --> 00:17:16,233
So here's how we determined
if that escape system

325
00:17:16,233 --> 00:17:20,066
is going to work at altitude
and at velocity, the Little Joe.

326
00:17:21,366 --> 00:17:23,233

There's the Little Joe.

327
00:17:23,233 --> 00:17:24,533
You can't quite see it,

328
00:17:24,533 --> 00:17:28,000
but in this, um, mockup

329
00:17:28,000 --> 00:17:31,066
in a, um--
in a rocket graveyard,

330
00:17:31,066 --> 00:17:34,000
the nozzles
are put in upside-down,

331
00:17:34,000 --> 00:17:35,033
but there we are.

332
00:17:35,033 --> 00:17:36,300
So that's the Little Joe.

333
00:17:38,933 --> 00:17:40,566
That was 86 feet tall,

334
00:17:40,566 --> 00:17:42,933
8 1/2 feet in diameter,

335
00:17:42,933 --> 00:17:46,633
and look,
176,000 pounds.

336
00:17:46,633 --> 00:17:49,600
Pretty big rocket.

337
00:17:49,600 --> 00:17:53,166
It had a couple
of Algol motors,

338
00:17:53,166 --> 00:17:55,966
and then I believe it--
it had different combinations,

339
00:17:55,966 --> 00:17:58,500
depending upon
what the mission called for.

340
00:18:01,466 --> 00:18:05,266
That was, for all
of you model rocketry people,

341
00:18:05,266 --> 00:18:11,033
this is the world's largest
clustered high-powered rocket,

342
00:18:11,033 --> 00:18:15,233
and there it goes.

343
00:18:15,233 --> 00:18:18,466
Now, at altitude,
what would happen is, um,

344
00:18:18,466 --> 00:18:20,700
they would go through
all of the abort functions

345
00:18:20,700 --> 00:18:23,333
at a different altitude
and different velocity.

346
00:18:23,333 --> 00:18:28,200
In every case, the command
module was recovered safely.

347
00:18:28,200 --> 00:18:31,466
In fact, in one case,
the Little Joe--

348

00:18:31,466 --> 00:18:35,633
due to a--a problem
in the flight computer,

349
00:18:35,633 --> 00:18:38,466
the Little Joe exploded,

350
00:18:38,466 --> 00:18:40,633
and so they had
a real emergency

351
00:18:40,633 --> 00:18:43,900
and the command module
safely recovered,

352
00:18:43,900 --> 00:18:45,466
even in a real emergency,

353
00:18:45,466 --> 00:18:50,766
so they counted that as sort
of a--an unexpected--

354
00:18:50,766 --> 00:18:56,066
unexpected win.

355
00:18:56,066 --> 00:18:57,366
Now, the Little Joe--

356
00:18:57,366 --> 00:18:59,466
we mentioned
the drogue mortars

357
00:18:59,466 --> 00:19:00,933
The drogue mortars--

358
00:19:00,933 --> 00:19:03,200
what I'm going through
is in my personal history,

359

00:19:03,200 --> 00:19:06,233
so it might be a little
disconnected to you.

360
00:19:06,233 --> 00:19:09,433
But the drogue mortars
had reefing line cutters.

361
00:19:09,433 --> 00:19:11,933
The reefing line--
what the reefing line would do,

362
00:19:11,933 --> 00:19:16,966
it would hold the--the drogue
closed for eight seconds,

363
00:19:16,966 --> 00:19:20,433
until, uh--
until everything became stable.

364
00:19:20,433 --> 00:19:24,400
Then the reefing line would cut
the, um, the reefing line.

365
00:19:24,400 --> 00:19:26,400
The reefing line cutter
would cut the line,

366
00:19:26,400 --> 00:19:28,633
and the drogue
could open fully.

367
00:19:28,633 --> 00:19:32,166
And then after that point,
at the proper altitude,

368
00:19:32,166 --> 00:19:35,100
the drogues would pull
the mains out,

369

00:19:35,100 --> 00:19:39,000
the three main chutes.

370
00:19:39,000 --> 00:19:42,266
Now, to remove
that forward heat shield,

371
00:19:42,266 --> 00:19:45,366
we designed this:
the type VI pressure cartridge.

372
00:19:45,366 --> 00:19:49,333
Now Hi-Shear had tried--
this is an amazing cartridge

373
00:19:49,333 --> 00:19:51,900
because it produces

374
00:19:51,900 --> 00:19:56,400
up to 20,000 PSI in a plenum.

375
00:19:56,400 --> 00:19:58,966
There are two 1/2
inch stainless steel tubes

376
00:19:58,966 --> 00:20:03,666
that run off to, um,
essentially, pyro pistons,

377
00:20:03,666 --> 00:20:07,033
and those pistons
force the heat shield off

378
00:20:07,033 --> 00:20:08,533
at 80 feet per second.

379
00:20:08,533 --> 00:20:13,200
That's a 280-pound heat shield,
so that's a lot of force.

380
00:20:13,200 --> 00:20:17,466
If any--if any
two of these cartridges fired,

381
00:20:17,466 --> 00:20:19,700
the heat shield would be
ejected safely.

382
00:20:19,700 --> 00:20:21,800
And the reason you wanted
to get that velocity is,

383
00:20:21,800 --> 00:20:24,666
you didn't want that forward
heat shield, 280 pounds,

384
00:20:24,666 --> 00:20:27,366
to come back
and hit the command module

385
00:20:27,366 --> 00:20:31,300
and perhaps, um, injure it
in some way,

386
00:20:31,300 --> 00:20:35,066
like the heat shield--
its own heat shield.

387
00:20:35,066 --> 00:20:36,900
[coughs]

388
00:20:36,900 --> 00:20:38,833
So, uh, there were
four of those.

389
00:20:38,833 --> 00:20:42,233
Four of those
and four, uh, pistons

390

00:20:42,233 --> 00:20:46,366
that ejected the command module
forward heat shield.

391
00:20:48,900 --> 00:20:51,933
And the type VI pressure
cartridge had--it had a--

392
00:20:53,600 --> 00:20:56,600
since it was so unusual,
it had to produce

393
00:20:56,600 --> 00:20:59,966
that 20,000
PSI in a few milliseconds,

394
00:20:59,966 --> 00:21:02,900
so it was
what we would call brisance.

395
00:21:02,900 --> 00:21:07,100
It was a very
rapidly operating cartridge--

396
00:21:07,100 --> 00:21:08,400
so a high burning rate.

397
00:21:08,400 --> 00:21:10,333
The burning rate
of the propellant we used

398
00:21:10,333 --> 00:21:13,233
at this pressure
was 1,600 inches per second.

399
00:21:13,233 --> 00:21:16,033
That's unheard
of in solid propellants,

400
00:21:16,033 --> 00:21:19,066

but we used permeable burning
to get that rate.

401
00:21:20,433 --> 00:21:23,066
Uh, and we're talking
a 5-inch long grain.

402
00:21:23,066 --> 00:21:24,366
That 5-inch long grain

403
00:21:24,366 --> 00:21:27,333
would burn in
a couple of milliseconds.

404
00:21:27,333 --> 00:21:28,666
Amazing.

405
00:21:28,666 --> 00:21:30,800
And in order to ignite it,

406
00:21:30,800 --> 00:21:33,566
since it had a very high--

407
00:21:33,566 --> 00:21:36,800
it's called burning rate coef--
the burning rate exponent.

408
00:21:36,800 --> 00:21:39,800
The burning rate exponent
of a good propellant

409
00:21:39,800 --> 00:21:42,833
would be around
0.25, 0.3, 0.4.

410
00:21:42,833 --> 00:21:45,733
It means that's its sensitivity
to pressure.

411

00:21:45,733 --> 00:21:48,733
This propellant had a burning
rate exponent of 0.83.

412
00:21:48,733 --> 00:21:51,766
It means that it's
highly sensitive to pressure.

413
00:21:51,766 --> 00:21:53,600
So because of that,

414
00:21:53,600 --> 00:21:57,300
uh, it was prone
to what we call a DPDT failure.

415
00:21:57,300 --> 00:21:59,666
That's the rate
of pressure drop.

416
00:21:59,666 --> 00:22:01,466
If you had a high rate
of pressure drop.

417
00:22:01,466 --> 00:22:03,333
This propellant could quench

418
00:22:03,333 --> 00:22:07,166
because of its high--
high burning rate exponent.

419
00:22:07,166 --> 00:22:10,466
So what we did to ignite
it satisfactorily is,

420
00:22:10,466 --> 00:22:13,566
we had a two-phase opening
of the closure,

421
00:22:13,566 --> 00:22:15,333
and that's

a chemically-milled closure,

422
00:22:15,333 --> 00:22:17,266
which was a first
at that time.

423
00:22:17,266 --> 00:22:22,200
So the, um, the light gray area
would open first.

424
00:22:22,200 --> 00:22:24,133
We're talking milliseconds
now too.

425
00:22:24,133 --> 00:22:26,033
The light gray area
would open first.

426
00:22:26,033 --> 00:22:28,466
Then burning
would be established

427
00:22:28,466 --> 00:22:30,633
while the other petals
were still there,

428
00:22:30,633 --> 00:22:32,166
and then they would open,

429
00:22:32,166 --> 00:22:37,033
and you'd have the continued
burning of that grain.

430
00:22:38,533 --> 00:22:42,266
Type VI pressure cartridge.

431
00:22:42,266 --> 00:22:47,366
So the docking ring
had to be beefed up for the--

432
00:22:49,400 --> 00:22:51,966
the docking ring
had to be beefed up for the--

433
00:22:54,166 --> 00:22:56,533
to separate the LEM.

434
00:22:56,533 --> 00:22:57,966
Originally,
it wasn't strong enough,

435
00:22:57,966 --> 00:23:01,433
so just before the, um,
the first--

436
00:23:01,433 --> 00:23:06,466
before Apollo 8, they
had an emergency development

437
00:23:06,466 --> 00:23:09,366
to develop
a long-reach detonator

438
00:23:09,366 --> 00:23:12,800
to, um--to fit
in the new docking ring.

439
00:23:12,800 --> 00:23:16,366
Well, we did that,
and--very simple.

440
00:23:16,366 --> 00:23:18,633
We just added an extension,

441
00:23:18,633 --> 00:23:21,600
but that extension couldn't
be filled with explosive

442
00:23:21,600 --> 00:23:23,533

because then it
would be too much explosive,

443
00:23:23,533 --> 00:23:25,700
and it would've distorted
the ring.

444
00:23:25,700 --> 00:23:27,233
Not a good idea.

445
00:23:27,233 --> 00:23:30,000
So that's the
long-reach detonator,

446
00:23:30,000 --> 00:23:31,466
so it had essentially
what we call

447
00:23:31,466 --> 00:23:35,833
a flash tube
from the NSI to the explosive.

448
00:23:35,833 --> 00:23:37,233
It was just an empty tube.

449
00:23:39,666 --> 00:23:45,666
And then the, um,
thru-bulkhead escape motor.

450
00:23:45,666 --> 00:23:48,800
That, yes, okay.

451
00:23:48,800 --> 00:23:51,800
The, um--
for maximum reliability,

452
00:23:51,800 --> 00:23:56,366
we decided not to use
a glass seal or a ceramic seal,

453
00:23:56,366 --> 00:24:00,333
although they work perfectly
well in most rocket motors.

454
00:24:00,333 --> 00:24:02,733
This was a metal-to-metal seal,

455
00:24:02,733 --> 00:24:04,600
so there were no--

456
00:24:04,600 --> 00:24:07,133
[clears throat]
there were no, um--

457
00:24:07,133 --> 00:24:10,766
everything in that rocket motor
was metal-to-metal sealed,

458
00:24:10,766 --> 00:24:12,666
and this is how that works.

459
00:24:12,666 --> 00:24:16,300
If you see,
the upper part of this drawing

460
00:24:16,300 --> 00:24:19,066
is where the
CDF connector attached,

461
00:24:19,066 --> 00:24:23,266
and that CDF initiated
the first little red zone.

462
00:24:23,266 --> 00:24:26,700
That's a--
that's a PETN explosive.

463
00:24:26,700 --> 00:24:29,633
The shockwave would go

across the little bulkhead,

464
00:24:29,633 --> 00:24:33,933
and that shockwave would
initiate the second PETN charge,

465
00:24:33,933 --> 00:24:36,300
and then that would initiate
the output charge,

466
00:24:36,300 --> 00:24:39,433
which is--would start
the rocket motor,

467
00:24:39,433 --> 00:24:44,066
and that's
a thru-bulkhead igniter,

468
00:24:44,066 --> 00:24:46,800
And I think we're gonna have a
lot of time for questions here.

469
00:24:49,533 --> 00:24:50,633
Dr. Cohen?

470
00:24:53,166 --> 00:24:54,833
- Thank you very much.

471
00:24:54,833 --> 00:24:56,500
So we have time
for questions.

472
00:24:56,500 --> 00:24:59,233
If you have a question,
please raise your hand

473
00:24:59,233 --> 00:25:01,600
and wait for your mic--
the microphone to get--

474
00:25:01,600 --> 00:25:03,133
to get to you.

475
00:25:07,800 --> 00:25:09,033
There's a--mic.

476
00:25:13,266 --> 00:25:14,333
All right, go ahead.

477
00:25:15,500 --> 00:25:18,800
- Um, how much of this
did you design yourself

478
00:25:18,800 --> 00:25:20,800
of these devices?

479
00:25:20,800 --> 00:25:22,333
- I'm sorry.
Can you--can you--

480
00:25:22,333 --> 00:25:24,233
- I can repeat it if you want.

481
00:25:24,233 --> 00:25:27,900
- How many of these devices
have you designed yourself?

482
00:25:27,900 --> 00:25:33,033
- Oh, all of them,
excepting for the, uh, NSI.

483
00:25:33,033 --> 00:25:34,400
I did not design the NSI,

484
00:25:34,400 --> 00:25:38,066
but everything you saw here,
I designed, yes,

485

00:25:38,066 --> 00:25:39,800
and followed
through production.

486
00:25:39,800 --> 00:25:42,366
In some cases,
hand-delivered.

487
00:25:42,366 --> 00:25:44,500
Hand-delivered to
White Sands

488
00:25:44,500 --> 00:25:47,333
in time
for the Little Joe II tests.

489
00:25:47,333 --> 00:25:51,633
Uh, we hand-delivered
the first FLSC

490
00:25:51,633 --> 00:25:53,566
to the Cape--

491
00:25:53,566 --> 00:25:55,533
not to the Cape.

492
00:25:55,533 --> 00:25:59,933
Um, that was the F-series,
the F-500 series,

493
00:25:59,933 --> 00:26:01,400
which was a fit-up.

494
00:26:01,400 --> 00:26:03,900
I assume F stands for fit-up.

495
00:26:03,900 --> 00:26:07,233
And we delivered the, um--

496

00:26:07,233 --> 00:26:09,900
the propellant dispersion system

497
00:26:09,900 --> 00:26:12,066
to them for fit-up.

498
00:26:12,066 --> 00:26:14,200
Incidentally, that, um--

499
00:26:14,200 --> 00:26:19,700
that 2-inch by 1-inch aluminum,
rectangular tube,

500
00:26:19,700 --> 00:26:24,300
that was slotted at intervals
to take care of the contraction.

501
00:26:24,300 --> 00:26:27,900
As the LOX tank was filled,
the tube, of course,

502
00:26:27,900 --> 00:26:29,500
would contract
a couple of inches,

503
00:26:29,500 --> 00:26:34,600
and so those slots would aid
in--in that contraction.

504
00:26:34,600 --> 00:26:37,366
Well, they forgot to, um--

505
00:26:37,366 --> 00:26:41,266
to, um, take the--

506
00:26:41,266 --> 00:26:43,066
when they milled through,

507
00:26:43,066 --> 00:26:47,166

they didn't deburr the interior
of the slots.

508
00:26:47,166 --> 00:26:50,866
So when we tried to insert
the FLSC carrier in,

509
00:26:50,866 --> 00:26:53,500
it got halfway in and stuck.

510
00:26:53,500 --> 00:26:57,033
Well, good thing
they did the fit-up test first.

511
00:26:57,033 --> 00:27:00,166
So after they cleaned
those all out, we were fine.

512
00:27:00,166 --> 00:27:01,400
But we also had--

513
00:27:01,400 --> 00:27:07,166
the specification
was for 220-pound pull.

514
00:27:07,166 --> 00:27:10,900
We had to make connectors like
this that would take 220 pounds

515
00:27:10,900 --> 00:27:12,966
to connect each 4-foot length,

516
00:27:12,966 --> 00:27:16,833
so we'd have ten 4-foot lengths
connected like this.

517
00:27:16,833 --> 00:27:19,133
220 pounds was not enough,

518

00:27:19,133 --> 00:27:21,133
even though
that was the specification,

519
00:27:21,133 --> 00:27:22,166
so we changed that.

520
00:27:22,166 --> 00:27:26,700
We put a single bar
of A286 steel

521
00:27:26,700 --> 00:27:29,700
with a eye at one end
and a hook at the other end,

522
00:27:29,700 --> 00:27:32,700
and that had a--probably
a breaking strength

523
00:27:32,700 --> 00:27:36,033
of maybe 2,000, 3,000 pounds
of force.

524
00:27:36,033 --> 00:27:37,733
I hope
that answers your question.

525
00:27:42,566 --> 00:27:44,866
- Um, I understand that

526
00:27:44,866 --> 00:27:48,333
before the shuttle project
was started,

527
00:27:48,333 --> 00:27:51,433
the goal was to have no
pyrotechnic devices

528
00:27:51,433 --> 00:27:55,066
on the shuttle,

and it ended up having over 300.

529
00:27:55,066 --> 00:27:56,533
I was wondering,
it seems to me

530
00:27:56,533 --> 00:27:59,800
that pyrotechnic devices
are the--

531
00:27:59,800 --> 00:28:01,600
have the highest specific power

532
00:28:01,600 --> 00:28:07,066
out of any way
you can actuate or ignite,

533
00:28:07,066 --> 00:28:10,800
and--and also, the reliability
is extremely high.

534
00:28:10,800 --> 00:28:13,400
Why would one not use
pyrotechnics?

535
00:28:14,633 --> 00:28:17,133
It seems like a good approach
to me.

536
00:28:17,133 --> 00:28:20,566
- Probably because of the--
of the regulatory--

537
00:28:20,566 --> 00:28:22,300
the regulatory problems

538
00:28:22,300 --> 00:28:28,100
and the fact that when you arm
pyrotechnics on a launch site,

539
00:28:28,100 --> 00:28:30,766
then everybody else
has to clear away.

540
00:28:30,766 --> 00:28:32,833
And so when the pyrotechnic
is armed,

541
00:28:32,833 --> 00:28:36,200
that's a--that's a specific
safety condition,

542
00:28:37,333 --> 00:28:40,133
and you have to observe
that condition.

543
00:28:40,133 --> 00:28:44,333
So if you don't have them,
maybe it's a little better.

544
00:28:45,333 --> 00:28:46,900
Maybe.

545
00:28:46,900 --> 00:28:47,933
But you're right.

546
00:28:47,933 --> 00:28:49,733
Reliability is incredible.

547
00:28:58,000 --> 00:28:59,600
- Thank you.
Very interesting talk.

548
00:28:59,600 --> 00:29:03,300
Did North American design
the first stage,

549
00:29:03,300 --> 00:29:06,433
and how many detonation tests

were run,

550
00:29:06,433 --> 00:29:09,066
and was any type
of stress analysis

551
00:29:09,066 --> 00:29:11,433
done during the development,

552
00:29:11,433 --> 00:29:13,800
or was it more
of a trial-and-error process?

553
00:29:13,800 --> 00:29:16,500
- Could you repeat that?

554
00:29:16,500 --> 00:29:19,966
- Did North American
build the first stage?

555
00:29:19,966 --> 00:29:22,933
How many detonation tests
were done,

556
00:29:22,933 --> 00:29:25,966
and was any stress analysis
done in the development,

557
00:29:25,966 --> 00:29:29,500
or was it more
of a trial-and-error process?

558
00:29:29,500 --> 00:29:32,000
- So did North American
build the first stage,

559
00:29:32,000 --> 00:29:33,933
how many detonation tests
were used,

560
00:29:33,933 --> 00:29:35,433
and was any stress analysis
done?

561
00:29:36,433 --> 00:29:37,766
- Oh.

562
00:29:40,433 --> 00:29:45,166
Well, if you look the SW--
the NASA SPs of that era, oh,

563
00:29:45,166 --> 00:29:47,966
my heavens, yes,
stress analyses were done.

564
00:29:47,966 --> 00:29:52,466
There--there's an SP
for almost every type

565
00:29:52,466 --> 00:29:53,633
of structure, you know,

566
00:29:53,633 --> 00:29:57,300
conical, cylindrical, whatever.

567
00:29:57,300 --> 00:30:01,000
So yes, I'm sure
stress analyses were done.

568
00:30:01,000 --> 00:30:03,233
There's also pyro shock,

569
00:30:03,233 --> 00:30:06,100
and pyro shock
was a major problem.

570
00:30:06,100 --> 00:30:08,200
In fact,
it's been a problem in

571
00:30:08,200 --> 00:30:11,200
some of the--
I believe on maybe

572
00:30:11,200 --> 00:30:13,833
on the Mars Observer,
possibly.

573
00:30:13,833 --> 00:30:18,266
And so a lot of studies
were done on pyro shock,

574
00:30:18,266 --> 00:30:20,900
and Larry Beament
was at Langley.

575
00:30:20,900 --> 00:30:25,900
And Larry Beament was
responsible for--

576
00:30:25,900 --> 00:30:28,633
for really bringing pyro--

577
00:30:28,633 --> 00:30:31,933
the pyro black art
down to a science,

578
00:30:31,933 --> 00:30:35,466
and if you look up some
of Larry Beament's publications,

579
00:30:35,466 --> 00:30:38,666
you'll see that he did
an excellent job in that arena.

580
00:30:50,400 --> 00:30:53,533
- Hi, Bill.
Um, I know Bill.

581
00:30:53,533 --> 00:30:54,800
He's a great guy,

582
00:30:54,800 --> 00:30:57,000
and I've been down to his shop
in Hollister,

583
00:30:57,000 --> 00:30:58,533
and my question is,

584
00:30:58,533 --> 00:31:01,533
you've worked on a lot
of these projects

585
00:31:01,533 --> 00:31:04,766
for this program,
but currently,

586
00:31:04,766 --> 00:31:10,500
you're still designing
various rocketry programs

587
00:31:10,500 --> 00:31:12,666
at your offices in Hollister.

588
00:31:12,666 --> 00:31:15,833
Can you just give us
a real quick, brief description

589
00:31:15,833 --> 00:31:17,733
of what you're doing
down there now?

590
00:31:17,733 --> 00:31:20,766
- Okay, do you want a check
or a money order?

591
00:31:20,766 --> 00:31:23,166
[laughter]

592
00:31:23,166 --> 00:31:24,666
Well, thank you, Charlie.

593
00:31:24,666 --> 00:31:26,900
Yeah, Charlie
has been to our--

594
00:31:26,900 --> 00:31:28,400
yeah, what we're doing
in Hollister,

595
00:31:28,400 --> 00:31:30,900
we're working
on hybrid propulsion systems.

596
00:31:30,900 --> 00:31:35,200
And, uh, in 1951,

597
00:31:35,200 --> 00:31:39,733
this little rocketry group we
had in Watsonville, California,

598
00:31:39,733 --> 00:31:43,900
fired a hypergolic hybrid,
probably the first one ever,

599
00:31:43,900 --> 00:31:47,633
and we used, um--used a--

600
00:31:47,633 --> 00:31:50,366
a German oxidizer

601
00:31:50,366 --> 00:31:55,533
which is 90% nitric acid,
10% sulfuric acid.

602
00:31:55,533 --> 00:31:57,133
Since it has sulfuric acid,

603
00:31:57,133 --> 00:31:59,766
we knew that it would react
with potassium chlorate,

604
00:31:59,766 --> 00:32:03,333
so we put a little potassium
chlorate in the asphalt,

605
00:32:03,333 --> 00:32:05,866
and we had a hypergolic hybrid.

606
00:32:07,100 --> 00:32:09,233
So what we're doing is,
we want,

607
00:32:09,233 --> 00:32:12,466
since hybrids are
incredibly safe

608
00:32:12,466 --> 00:32:14,766
until they're loaded,
as are bi-liquids, too,

609
00:32:16,200 --> 00:32:19,533
they, um...

610
00:32:19,533 --> 00:32:24,066
they represent a, uh--
an arena between

611
00:32:24,066 --> 00:32:27,500
an area between
solids and--and liquids,

612
00:32:27,500 --> 00:32:30,666
and they have about
half the complexity of a liquid,

613

00:32:30,666 --> 00:32:34,300
so they're kind of attractive
from that viewpoint.

614
00:32:34,300 --> 00:32:36,100
ISPs--

615
00:32:36,100 --> 00:32:41,266
My partner is a Harvard chemist,
um, Ron Winston,

616
00:32:41,266 --> 00:32:44,833
and he has developed
several propellant additives

617
00:32:44,833 --> 00:32:50,200
which boost it right over 300
seconds ISP at sea level,

618
00:32:50,200 --> 00:32:52,300
so that's pretty incredible,

619
00:32:52,300 --> 00:32:54,433
and that's what we're working--
that's what we're working

620
00:32:54,433 --> 00:32:57,933
towards is very high
ISP hybrids.

621
00:32:59,000 --> 00:33:00,400
That's it.

622
00:33:09,566 --> 00:33:10,700
- Hello, um--

623
00:33:10,700 --> 00:33:13,466
how did you guys
validate the analysis

624
00:33:13,466 --> 00:33:15,500
for the pyrotechnics
on the stages

625
00:33:15,500 --> 00:33:17,633
for detonating the stage
on abort?

626
00:33:18,933 --> 00:33:20,566
- Whoops.
I didn't hear that one.

627
00:33:20,566 --> 00:33:24,833
- In terms of the analysis
of coordinating the pyrotechnics

628
00:33:24,833 --> 00:33:28,266
of successive stages,
how did you verify them?

629
00:33:28,266 --> 00:33:29,600
- Ah.

630
00:33:32,400 --> 00:33:35,166
Well, that's Larry Beament's
favorite subject

631
00:33:35,166 --> 00:33:38,433
because Larry--Larry called
what we did black art,

632
00:33:38,433 --> 00:33:39,700
as I mentioned before.

633
00:33:40,733 --> 00:33:43,666
And we did--
what we would do,

634
00:33:45,600 --> 00:33:48,766

instead of approaching
it analytically,

635
00:33:48,766 --> 00:33:50,833
we would do off-limits testing,

636
00:33:50,833 --> 00:33:53,900
uh, qualification testing.

637
00:33:53,900 --> 00:33:57,966
Uh, so that's
primarily how--

638
00:33:57,966 --> 00:34:00,500
how the pyro systems developed.

639
00:34:02,433 --> 00:34:04,366
So off-limits testing would be--

640
00:34:04,366 --> 00:34:08,000
we'd change the loading
until it didn't work on one end,

641
00:34:08,000 --> 00:34:10,700
and it worked too well
on the other end,

642
00:34:10,700 --> 00:34:13,933
and that's the extent of it.

643
00:34:13,933 --> 00:34:15,533
Very--very little analysis.

644
00:34:16,533 --> 00:34:17,766
Now it's quite different

645
00:34:17,766 --> 00:34:22,500
since Larry attacked the problem
some 25 years ago.

646
00:34:29,700 --> 00:34:32,400
- Appreciate the discussions.

647
00:34:34,233 --> 00:34:37,833
Your comments on
Little Joe kind of reminded me

648
00:34:37,833 --> 00:34:39,333
of a long time ago

649
00:34:39,333 --> 00:34:41,766
where Little Joe
and an associated program

650
00:34:41,766 --> 00:34:45,200
called Little John

651
00:34:45,200 --> 00:34:49,900
uh, was gonna be used, uh,
not for space,

652
00:34:49,900 --> 00:34:51,833
but actually do a very--

653
00:34:51,833 --> 00:34:55,066
a multiple numbers
of Little Joes

654
00:34:55,066 --> 00:34:56,600
and Little Johns

655
00:34:56,600 --> 00:35:00,066
to actually thrust
and change the, um,

656
00:35:00,066 --> 00:35:02,200
rotation of the earth

657
00:35:02,200 --> 00:35:05,133
in the event
of a nuclear exchange.

658
00:35:05,133 --> 00:35:08,433
Do you have any comments
on that or remember that at all?

659
00:35:18,966 --> 00:35:20,166
- Oh, hmm.

660
00:35:23,133 --> 00:35:26,366
In the realm of my interest
but way outside of my expertise,

661
00:35:26,366 --> 00:35:27,700
sorry.

662
00:35:31,600 --> 00:35:33,233
- I have a question.

663
00:35:33,233 --> 00:35:34,533
I don't know
if my mic is up now,

664
00:35:34,533 --> 00:35:38,533
so the question
is in terms of risk culture.

665
00:35:38,533 --> 00:35:41,200
So, you know, when you look
at the era of Saturn and Apollo,

666
00:35:41,200 --> 00:35:44,633
you see that there were
accidents that occurred,

667
00:35:44,633 --> 00:35:46,933
both with humans

and without humans,

668
00:35:46,933 --> 00:35:49,766
but you saw a progression
of the rocket's design,

669
00:35:49,766 --> 00:35:51,833
the systems, or the--

670
00:35:51,833 --> 00:35:54,700
and so on your stage
of engineering,

671
00:35:54,700 --> 00:35:58,100
how had the culture of risk then
in terms of the ability

672
00:35:58,100 --> 00:36:00,900
of taking risks
to develop new technologies

673
00:36:00,900 --> 00:36:02,933
to move forward,
versus now

674
00:36:02,933 --> 00:36:04,033
as a culture that is,

675
00:36:04,033 --> 00:36:06,033
whether it's within NASA
or the industry

676
00:36:06,033 --> 00:36:08,100
that you're working on,
in terms of that?

677
00:36:08,100 --> 00:36:11,066
Are they the same
or different between those two?

678
00:36:11,066 --> 00:36:12,700
- Quite different, Doctor.

679
00:36:12,700 --> 00:36:14,666
The, um--

680
00:36:14,666 --> 00:36:17,533
we had--

681
00:36:17,533 --> 00:36:20,533
we had a whole section
of designers,

682
00:36:20,533 --> 00:36:24,866
and the designers were familiar
with MIL-SPECS, for instance,

683
00:36:24,866 --> 00:36:26,666
that we didn't have
to bother with.

684
00:36:26,666 --> 00:36:28,700
So if we wanted to use a certain
bolt, they'd go,

685
00:36:28,700 --> 00:36:30,100
"No, no, no,
you can't use that bolt.

686
00:36:30,100 --> 00:36:31,666
You got to use this bolt."

687
00:36:31,666 --> 00:36:35,766
And so we were--
had that kind of support.

688
00:36:35,766 --> 00:36:38,133
Uh, we had
a secretarial pool,

689
00:36:38,133 --> 00:36:41,233
and so that
took another load off of us,

690
00:36:41,233 --> 00:36:44,100
so we were free
pretty much to--

691
00:36:44,100 --> 00:36:47,966
to imagineer
our projects.

692
00:36:49,966 --> 00:36:52,366
The advent of the computer
changed all of that,

693
00:36:52,366 --> 00:36:58,200
and now each engineer
is his own draftsman,

694
00:36:58,200 --> 00:37:02,166
drawing guy,
secretary, you know, so yeah,

695
00:37:02,166 --> 00:37:03,866
it's considerably different.

696
00:37:03,866 --> 00:37:06,466
I think that an engineer now

697
00:37:06,466 --> 00:37:10,166
needs to have more skills
than we had.

698
00:37:10,166 --> 00:37:12,266
We were a lot
more focused though.

699

00:37:12,266 --> 00:37:16,400
We were, I think,
far more focused on the job

700
00:37:16,400 --> 00:37:17,700
than you can be now

701
00:37:17,700 --> 00:37:22,166
because you have to have
this wide panorama of skills,

702
00:37:22,166 --> 00:37:24,666
so that would be my answer.

703
00:37:29,433 --> 00:37:32,500
- Okay, so please join me
in thanking Will Colburn

704
00:37:32,500 --> 00:37:33,900
for an excellent seminar.
Thank you.

705
00:37:33,900 --> 00:37:35,933
[applause]

706
00:37:35,933 --> 00:37:37,000
- Thank you very much.
- Thank you.