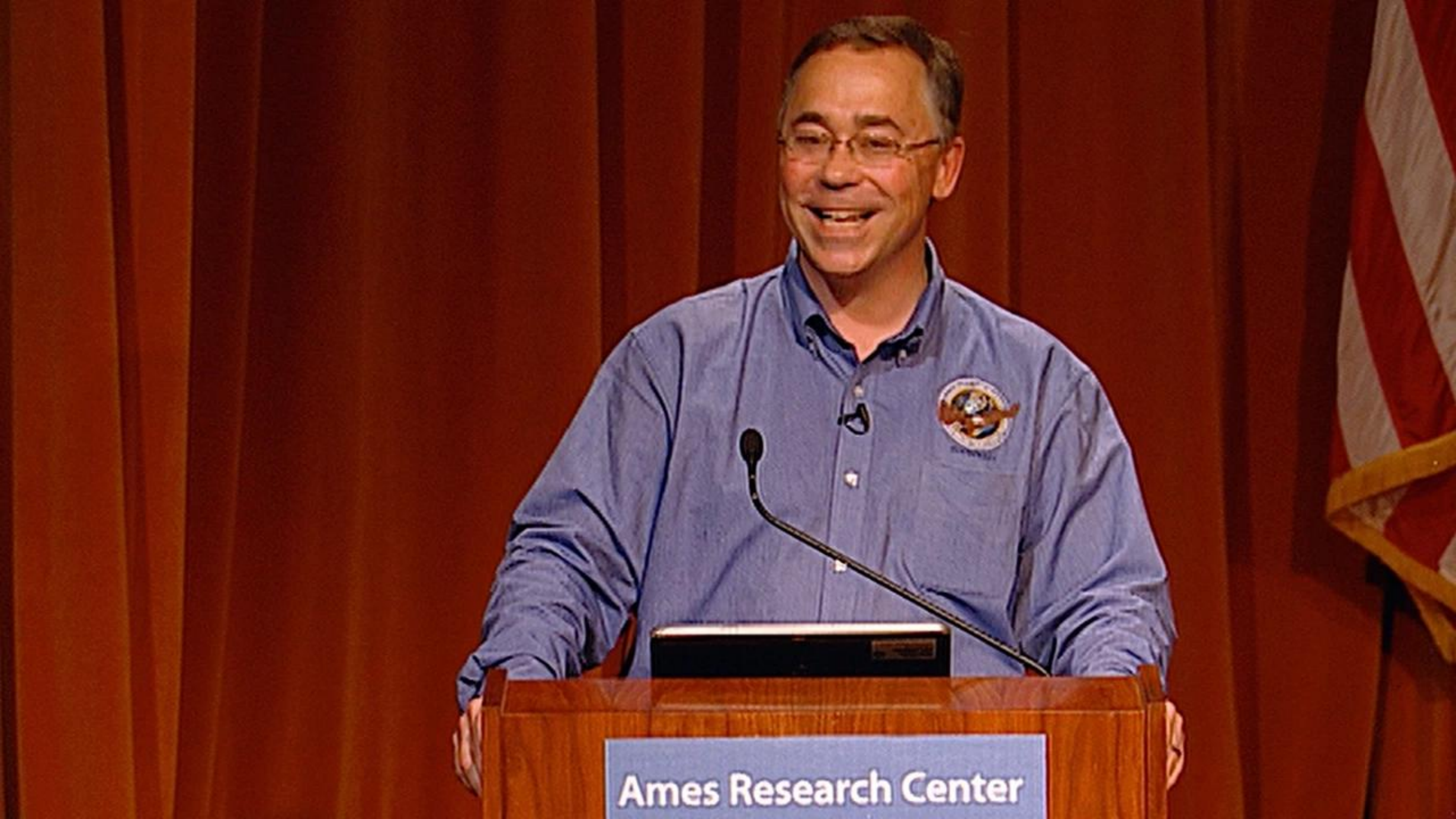
Ames Research Center

1
00:00:00,666 --> 00:00:07,666
[music playing]

2
00:00:17,200 --> 00:00:19,766
- I'M A SCIENCE-FICTION FAN,

3
00:00:19,766 --> 00:00:21,400
AND I'VE LONG FELT
THAT THIS AGENCY

4
00:00:21,400 --> 00:00:23,200
OUGHT TO BE ON OUR WAY
TO THE STARS.

5
00:00:23,200 --> 00:00:26,400
SO--AND WE ARE.

6
00:00:26,400 --> 00:00:27,933
BUT I THINK SOME OF THE THINGS
YOU'RE GONNA HEAR TODAY

7
00:00:27,933 --> 00:00:30,200
MAY GET US THERE
A LOT FASTER.

8
00:00:30,200 --> 00:00:33,300
SO THIS, YOU KNOW, OUR--

9
00:00:33,300 --> 00:00:37,333
I THINK IT'S THE PENULTIMATE
TALK IN THE SUMMER SERIES.

10
00:00:37,333 --> 00:00:42,100
THIS IS A SERIES TO CELEBRATE
NASA AMES' 75TH ANNIVERSARY.

11
00:00:42,100 --> 00:00:43,800
BY THE WAY,
AT THE PICNIC THE OTHER DAY,

12
00:00:43,800 --> 00:00:45,600
I MET A FELLOW
THAT STARTED WORKING HERE

13
00:00:45,600 --> 00:00:47,266
RIGHT AFTER WE WERE FOUNDED
IN 1940,

14
00:00:47,266 --> 00:00:49,066
SO, REALLY COOL.

15
00:00:49,066 --> 00:00:51,000
SO AMES IS GOOD FOR YOUR HEALTH.

16
00:00:51,000 --> 00:00:54,133
[laughter]

17
00:00:54,133 --> 00:00:57,666
THAT DOESN'T WORK STATISTICALLY?

18
00:00:57,666 --> 00:01:01,266
BUT TODAY WE HAVE
DR. HAROLD "SONNY" WHITE,

19
00:01:01,266 --> 00:01:03,133
IS OUR GUEST.

20
00:01:03,133 --> 00:01:06,200
HE HOLDS A Ph.D. IN PHYSICS
FROM RICE UNIVERSITY,

21
00:01:06,200 --> 00:01:09,200
A MASTER OF SCIENCE
IN MECHANICAL ENGINEERING

22
00:01:09,200 --> 00:01:11,000
FROM WICHITA STATE UNIVERSITY,

23
00:01:11,000 --> 00:01:13,466
AND A BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

24
00:01:13,466 --> 00:01:15,366
FROM THE UNIVERSITY
OF SOUTH ALABAMA.

25
00:01:15,366 --> 00:01:16,466
HE CURRENTLY SERVES

26
00:01:16,466 --> 00:01:18,433
AS THE ADVANCED PROPULSION
THEME LEAD

27
00:01:18,433 --> 00:01:20,566
FOR THE NASA
ENGINEERING DIRECTORATE

28
00:01:20,566 --> 00:01:22,400
AND IS THE JSC REPRESENTATIVE

29
00:01:22,400 --> 00:01:24,233
TO THE NUCLEAR SYSTEMS
WORKING GROUP.

30
00:01:24,233 --> 00:01:26,500
KIND OF COOL STUFF.

31
00:01:26,500 --> 00:01:28,100
HE IS SERVING TO HELP THE AGENCY

32
00:01:28,100 --> 00:01:30,200
INCORPORATE HIGH TRL
ADVANCED POWER

33
00:01:30,200 --> 00:01:31,700
AND PROPULSION TECHNOLOGIES

34
00:01:31,700 --> 00:01:34,766
INTO NEAR AND MID-TERM
HUMAN EXPLORATION ARCHITECTURES.

35
00:01:34,766 --> 00:01:35,966
BUT HE'S ALSO PURSUING

36
00:01:35,966 --> 00:01:37,933
THEORETICAL AND
LABORATORY RESEARCH

37
00:01:37,933 --> 00:01:42,733
ON DEVELOPING LOWER TRL
ADVANCED PROPULSION

38
00:01:42,733 --> 00:01:43,933
AND POWER TECHNOLOGIES

39
00:01:43,933 --> 00:01:45,666
IN THE ADVANCED PROPULSION
PHYSICS LABORATORY

40
00:01:45,666 --> 00:01:47,100
KNOWN AS EAGLEWORKS.

41
00:01:47,100 --> 00:01:48,700
THAT IS LOCATED
AT THE JOHNSON SPACE CENTER,

42
00:01:48,700 --> 00:01:50,466
WHICH I'M ON MY WAY TO
THIS AFTERNOON,

43
00:01:50,466 --> 00:01:52,866
WHERE IT'S 98 DEGREES
WHEN I LOOKED AT THE--

44
00:01:52,866 --> 00:01:54,200
AND THE HUMIDITY, I THINK,

IS ABOUT THE SAME.

45
00:01:54,200 --> 00:01:56,366
SO BE GLAD
YOU'RE IN CALIFORNIA.

46
00:01:56,366 --> 00:01:58,200
OH, BY THE WAY,
BEFORE I GO ON,

47
00:01:58,200 --> 00:02:02,233
TOMORROW IS A TALK
ON A LOT LESS FUN TOPIC,

48
00:02:02,233 --> 00:02:03,233
BUT ONE YOU ALL NEED TO KNOW.

49
00:02:03,233 --> 00:02:05,266
IT'S ABOUT EXPORT CONTROL.

50
00:02:05,266 --> 00:02:09,833
SO I DO URGE ALL THE STAFF
TO BE HERE.

51
00:02:09,833 --> 00:02:15,200
THE--CHUCK DUFF WILL BE TAKING,
YOU KNOW, ATTENDANCE.

52
00:02:15,200 --> 00:02:18,166
I PARTICULARLY WANT
THE MANAGERS TO BE HERE.

53
00:02:18,166 --> 00:02:20,766
I GOT IN TROUBLE
OVER THAT STUFF A FEW YEARS AGO.

54
00:02:20,766 --> 00:02:22,533
SO WE'RE GONNA DO
A LOT BETTER.

55
00:02:22,533 --> 00:02:26,133
BUT, WITHOUT FURTHER ADO,

56
00:02:26,133 --> 00:02:30,100
LET ME SAY HELLO
TO MY FRIEND AND MY COLLEAGUE,

57
00:02:30,100 --> 00:02:32,533
SONNY WHITE
FROM JOHNSON SPACE CENTER.

58
00:02:32,533 --> 00:02:33,800
THE STAGE IS YOURS.

59
00:02:33,800 --> 00:02:35,233
- THANKS, PETE;
APPRECIATE IT.

60
00:02:35,233 --> 00:02:36,533
[applause]

61
00:02:36,533 --> 00:02:37,933
THANK YOU, EVERYBODY.

62
00:02:37,933 --> 00:02:40,366
[applause]

63
00:02:40,366 --> 00:02:42,133
THANKS FOR COMING
TO JOIN ME TODAY.

64
00:02:42,133 --> 00:02:45,100
AS PART OF COMING
INTO THIS SERIES,

65
00:02:45,100 --> 00:02:46,566
I WAS ASKED TO MAYBE TALK
A LITTLE BIT

66
00:02:46,566 --> 00:02:50,566
ABOUT WHAT GOT ME INTO WORKING
IN THE SPACE INDUSTRY,

67
00:02:50,566 --> 00:02:53,133
WHAT WAS SOME OF THE BACKGROUND
THAT INSPIRED ME.

68
00:02:53,133 --> 00:02:56,266
I GREW UP IN WASHINGTON, D.C.,

69
00:02:56,266 --> 00:02:58,500
JUST OUTSIDE OF D.C.,
IN VIRGINIA,

70
00:02:58,500 --> 00:03:00,633
AND SPENT QUITE A BIT OF TIME

71
00:03:00,633 --> 00:03:05,833
GOING TO THE AIR AND SPACE
SMITHSONIAN IN D.C.,

72
00:03:05,833 --> 00:03:07,266
AND I WAS REALLY INSPIRED

73
00:03:07,266 --> 00:03:11,533
BY ALL OF THE DISPLAYS
THAT THEY HAD THERE

74
00:03:11,533 --> 00:03:15,766
OF THE APOLLO PROGRAM,
A LOT OF THE AIRCRAFT.

75
00:03:15,766 --> 00:03:18,700
SO I THINK I GOT THE BUG
AT A VERY EARLY AGE

76
00:03:18,700 --> 00:03:21,833
TO WANT TO GET

INTO THE SPACE PROGRAM.

77
00:03:21,833 --> 00:03:23,900
SO IT WAS QUITE A TREAT
TO BE ABLE

78
00:03:23,900 --> 00:03:27,500
TO EVENTUALLY FIND MY WAY
WORKING AT NASA

79
00:03:27,500 --> 00:03:31,466
ON HUMAN SPACEFLIGHT
BACK IN 2000.

80
00:03:31,466 --> 00:03:34,333
SO HOPEFULLY WE'LL HAVE
A LOT OF YEARS IN THE FUTURE

81
00:03:34,333 --> 00:03:35,766
TO TRY AND CONTRIBUTE
TO THE CAUSE

82
00:03:35,766 --> 00:03:37,700
THAT WE ALL KIND OF CARE ABOUT,

83
00:03:37,700 --> 00:03:39,166
IN TERMS OF TRYING
TO GO AND EXPLORE

84
00:03:39,166 --> 00:03:41,400
AND FIGURE OUT SOME NEW THINGS.

85
00:03:41,400 --> 00:03:43,933
JUST A LITTLE BIT OF BACKGROUND
ON SOME OF THE STUFF THAT I DO

86
00:03:43,933 --> 00:03:45,433
THAT'S A LITTLE BIT HIGHER
IN THE TRL.

87
00:03:45,433 --> 00:03:47,333
PETE TALKED ABOUT THE FACT
THAT I DO WORK

88
00:03:47,333 --> 00:03:49,666
WITH SOME HIGHER TRL STUFF.

89
00:03:49,666 --> 00:03:51,866
I'VE DONE SOME WORK
WITH TRYING TO INTEGRATE

90
00:03:51,866 --> 00:03:54,733
THINGS LIKE HALL THRUSTERS
INTO HUMAN SPACEFLIGHT.

91
00:03:54,733 --> 00:03:56,033
AND YOU SEE A LITTLE--

92
00:03:56,033 --> 00:03:58,500
A MONTAGE OF SOME
OF THE PROJECTS I'VE WORKED

93
00:03:58,500 --> 00:04:00,433
OVER THE LAST COUPLE YEARS,

94
00:04:00,433 --> 00:04:04,200
TRYING TO INTEGRATE
THINGS LIKE HALL THRUSTERS

95
00:04:04,200 --> 00:04:06,400
INTO HUMAN SPACEFLIGHT
PLATFORMS.

96
00:04:06,400 --> 00:04:11,100
YOU SEE, ON THE TOP LEFT THERE,
THE INTERNATIONAL SPACE STATION.

97
00:04:11,100 --> 00:04:14,066
WE LOOKED AT USING

HALL THRUSTERS

98
00:04:14,066 --> 00:04:15,700
TO PROVIDE SOME DRAG MAKEUP.

99
00:04:15,700 --> 00:04:17,566
SO WE SPENT SOME TIME
TRYING TO FIGURE OUT

100
00:04:17,566 --> 00:04:21,166
HOW TO INTEGRATE THOSE
ONTO THE SPACE STATION.

101
00:04:21,166 --> 00:04:22,533
TYPICALLY,
IN HUMAN SPACEFLIGHT,

102
00:04:22,533 --> 00:04:25,366
WE ALWAYS THINK OF ROCKETS
THAT HAVE NOZZLES,

103
00:04:25,366 --> 00:04:27,500
AND THEY MAKE A LOT OF SMOKE
AND A LOT OF NOISE

104
00:04:27,500 --> 00:04:29,333
AND HAVE A THRUST-TO-WEIGHT
RATIO GREATER THAN ONE.

105
00:04:29,333 --> 00:04:32,866
SO IT TOOK A LITTLE BIT
OF TIME AND EFFORT

106
00:04:32,866 --> 00:04:36,500
TO HELP PEOPLE OVERCOME
THE PERSPECTIVE

107
00:04:36,500 --> 00:04:38,066
THAT LOW THRUST
MIGHT NOT NECESSARILY

108
00:04:38,066 --> 00:04:39,266
BE SOMETHING THAT WE CAN USE,

109
00:04:39,266 --> 00:04:42,100
BUT IT TURNS OUT
IT REALLY CAN HELP

110
00:04:42,100 --> 00:04:43,700
WITH HUMAN SPACE EXPLORATION.

111
00:04:43,700 --> 00:04:45,600
AND SO WE LOOKED
AT SEVERAL OTHER THINGS

112
00:04:45,600 --> 00:04:49,800
ABOUT USING LOW THRUST
IN SPACE PROPULSION SYSTEMS.

113
00:04:49,800 --> 00:04:52,600
ON THE BOTTOM RIGHT,
YOU SEE A CONCEPT

114
00:04:52,600 --> 00:04:55,200
THAT LOOKED AT TRYING
TO USE HALL THRUSTERS

115
00:04:55,200 --> 00:04:58,600
WITH SOME ASSETS IN THE
EARTH-MOON LAGRANGE POINT AREA.

116
00:04:58,600 --> 00:05:01,466
THIS WAS KIND OF A PRECURSOR
TO THE ASTEROID MISSION.

117
00:05:01,466 --> 00:05:04,133
AND WE ALSO DID SOME WORK
WITH DARPA

118

00:05:04,133 --> 00:05:06,066
TO KIND OF THINK ABOUT WAYS

119
00:05:06,066 --> 00:05:10,233
THAT WE MIGHT BE ABLE TO DO
SOME COLLABORATIVE EFFORTS.

120
00:05:10,233 --> 00:05:11,766
BUT THESE ARE ALL CONCEPTS

121
00:05:11,766 --> 00:05:14,866
THAT TRY AND ADDRESS
GETTING OUT OF LOW EARTH ORBIT

122
00:05:14,866 --> 00:05:17,033
INTO CIS/TRANS LUNAR SPACE,

123
00:05:17,033 --> 00:05:19,333
MAYBE ONE DAY OUT TO MARS.

124
00:05:19,333 --> 00:05:21,400
IT'S AT 1 1/2 A.U.

125
00:05:21,400 --> 00:05:22,600
BUT WHAT IF WE WANT
TO GO THROUGH

126
00:05:22,600 --> 00:05:24,233
AND EXPLORE THE REST
OF THE SOLAR SYSTEM?

127
00:05:24,233 --> 00:05:27,833
WHAT IF WE WANT TO GET OUT TO
SOME OTHER LOCATIONS WITH PEOPLE

128
00:05:27,833 --> 00:05:29,066
IN THE OUTER SOLAR SYSTEM?

129
00:05:29,066 --> 00:05:31,533

WHAT IF WE REALLY WANT
TO TRY AND GO

130
00:05:31,533 --> 00:05:33,800
TO SOMEPLACE
THAT'S EVEN FURTHER,

131
00:05:33,800 --> 00:05:35,933
SOME TYPE OF
AN INTERSTELLAR DESTINATION?

132
00:05:35,933 --> 00:05:39,200
I THINK YOU HAVE A TALK
ON KEPLER IN A COUPLE OF DAYS.

133
00:05:39,200 --> 00:05:40,500
AND KEPLER'S IDENTIFYING

134
00:05:40,500 --> 00:05:42,400
A LOT OF VERY NEAT THINGS
THAT ARE OUT THERE,

135
00:05:42,400 --> 00:05:43,633
AND WE'RE FINDING OUT

136
00:05:43,633 --> 00:05:45,733
THAT THERE'S A LOT
OF PLANETS OUT THERE,

137
00:05:45,733 --> 00:05:48,200
AND OUR SOLAR SYSTEM
IS NOT UNIQUE

138
00:05:48,200 --> 00:05:50,966
FROM THE STANDPOINT
THAT IT HAS BODIES

139
00:05:50,966 --> 00:05:52,000
THAT ORBIT THE SUN.

140
00:05:52,000 --> 00:05:55,033
SO THAT TENDS
TO MAKE YOU THINK ABOUT,

141
00:05:55,033 --> 00:05:57,333
"WHAT DOES IT TAKE
TO ACTUALLY ACCOMPLISH THAT?"

142
00:05:57,333 --> 00:06:01,000
SO LET'S SEGUE INTO
A MUCH LOWER TRL DISCUSSION.

143
00:06:01,000 --> 00:06:02,633
I'LL TALK ABOUT TWO THINGS:

144
00:06:02,633 --> 00:06:04,400
A LITTLE BIT ABOUT THE IDEA
OF A SPACEWARP,

145
00:06:04,400 --> 00:06:07,766
AND THEN WE'LL TALK ABOUT
A FORM OF ELECTRIC PROPULSION

146
00:06:07,766 --> 00:06:09,166
YOU MIGHT HAVE SEEN IN THE NEWS

147
00:06:09,166 --> 00:06:11,033
WE'RE WORKING ON AT JSC
CALLED Q-THRUSTERS.

148
00:06:11,033 --> 00:06:12,600
AND SO WE'LL TALK TO YOU GUYS
A LITTLE BIT ABOUT THAT

149
00:06:12,600 --> 00:06:14,333
AND SOME OF THE DATA
WE PRESENTED

150
00:06:14,333 --> 00:06:18,400

AT THE JOINT PROPULSION
CONFERENCE IN OHIO.

151
00:06:18,400 --> 00:06:22,133
SO, WHEN WE TALK
ABOUT INTERSTELLAR SPACEFLIGHT,

152
00:06:22,133 --> 00:06:24,166
A LOT OF PEOPLE
REALLY HAVE NO GRASP

153
00:06:24,166 --> 00:06:26,600
ON HOW FAR THESE DISTANCES ARE,

154
00:06:26,600 --> 00:06:29,733
COMPARED TO WHAT
WE CAN DO TODAY.

155
00:06:29,733 --> 00:06:32,133
SO I THINK,
IN TERMS OF STATE-OF-THE-ART,

156
00:06:32,133 --> 00:06:34,966
THE "VOYAGER 1" SPACECRAFT
IS A REALLY GOOD ILLUSTRATION

157
00:06:34,966 --> 00:06:36,633
OF THE BEST
THAT WE'VE DONE SO FAR

158
00:06:36,633 --> 00:06:40,666
IN TERMS OF
AN INTERSTELLAR MISSION.

159
00:06:40,666 --> 00:06:43,866
SO THE "VOYAGER 1" SPACECRAFT
WAS LAUNCHED IN THE LATE '70s.

160
00:06:43,866 --> 00:06:45,566
IT GAVE US ALL THOSE

REALLY NICE PICTURES

161
00:06:45,566 --> 00:06:47,366
OF THE OUTER PLANETS
IN THE SOLAR SYSTEM

162
00:06:47,366 --> 00:06:49,000
THAT KIND OF INSPIRED US.

163
00:06:49,000 --> 00:06:51,433
IT'S BEEN ON ITS WAY
FOR ABOUT 30 YEARS.

164
00:06:51,433 --> 00:06:53,933
IT'S MOVING AT ABOUT
3.6 A.U. PER YEAR.

165
00:06:53,933 --> 00:06:57,133
AN A.U. IS THE DISTANCE
FROM THE EARTH TO THE SUN.

166
00:06:57,133 --> 00:06:59,866
IT'S CURRENTLY AT ABOUT
120 ASTRONOMICAL UNITS

167
00:06:59,866 --> 00:07:01,766
OUT INTO THE SOLAR SYSTEM.

168
00:07:04,500 --> 00:07:06,700
SO WE COULD ASK THE QUESTION:

169
00:07:06,700 --> 00:07:08,666
HOW LONG WOULD IT TAKE
"VOYAGER 1"

170
00:07:08,666 --> 00:07:10,166
TO MAKE IT TO OUR NEAREST STAR

171
00:07:10,166 --> 00:07:11,866

IF IT HAPPENED TO BE GOING
IN THE RIGHT DIRECTION?

172
00:07:11,866 --> 00:07:13,166
IT TURNS OUT IT'S NOT.

173
00:07:13,166 --> 00:07:16,633
ALPHA CENTAURI IS ALMOST
DUE SOUTH FROM THE PLANET.

174
00:07:16,633 --> 00:07:19,366
BUT IF IT HAPPENED TO BE POINTED
IN THE RIGHT DIRECTION,

175
00:07:19,366 --> 00:07:21,566
HOW LONG WOULD IT TAKE FOR IT
TO GET TO ALPHA CENTAURI?

176
00:07:21,566 --> 00:07:22,600
IT TURNS OUT IT WOULD TAKE

177
00:07:22,600 --> 00:07:24,533
A RIDICULOUSLY LONG
PERIOD OF TIME,

178
00:07:24,533 --> 00:07:26,766
75,000 YEARS.

179
00:07:26,766 --> 00:07:28,133
AND SO,
I DON'T KNOW ABOUT YOU GUYS.

180
00:07:28,133 --> 00:07:32,766
THAT'S A REALLY LONG TIME
TO SIT ON CONSOLE, SO...

181
00:07:32,766 --> 00:07:34,633
BUT ANYWAY, IT REALLY DOES
HIGHLIGHT THE FACT

182
00:07:34,633 --> 00:07:37,600
THAT INTERSTELLAR DISTANCES
ARE VERY, VERY DIFFICULT

183
00:07:37,600 --> 00:07:40,166
COMPARED TO ANYTHING
THAT WE'VE DONE

184
00:07:40,166 --> 00:07:42,133
OR EVER THOUGHT ABOUT DOING.

185
00:07:42,133 --> 00:07:45,733
TO KIND OF CONTINUE
TO HIGHLIGHT THE CHALLENGES

186
00:07:45,733 --> 00:07:49,066
ASSOCIATED WITH
INTERSTELLAR SPACEFLIGHT,

187
00:07:49,066 --> 00:07:50,900
I WANT TO TALK ABOUT A PROJECT
THAT WAS CONVENED

188
00:07:50,900 --> 00:07:53,533
BY THE BRITISH
INTERPLANETARY SOCIETY

189
00:07:53,533 --> 00:07:55,666
BACK IN THE '70s

190
00:07:55,666 --> 00:07:57,966
TO LOOK AT GOING
TO BARNARD'S STAR.

191
00:07:57,966 --> 00:08:00,800
THAT'S ABOUT 6 LIGHT-YEARS AWAY.

192
00:08:00,800 --> 00:08:04,066
THEY WANTED TO GET THERE

IN 50 YEARS.

193
00:08:04,066 --> 00:08:08,600
THE SPACECRAFT THAT THEY
DEVELOPED AS PART OF THAT STUDY,

194
00:08:08,600 --> 00:08:13,333
USING--I THINK THIS WAS
PULSED FUSION PROPULSION.

195
00:08:13,333 --> 00:08:16,333
THE SPACECRAFT THEY DEVELOPED
AND PUBLISHED IN THEIR PAPER

196
00:08:16,333 --> 00:08:20,300
WAS PRETTY BIG,
AROUND 54,000 METRIC TONS.

197
00:08:20,300 --> 00:08:21,866
AND YOU KIND OF SEE
A PHOTO THERE

198
00:08:21,866 --> 00:08:26,100
THAT COMPARES TO THE "DAEDELUS"
TO THE SATURN V ROCKET

199
00:08:26,100 --> 00:08:27,333
TO SCALE.

200
00:08:27,333 --> 00:08:28,800
AND I'VE ALSO INTERPOSED

201
00:08:28,800 --> 00:08:32,900
A PICTURE OF THE INTERNATIONAL
SPACE STATION AS A COMPARISON.

202
00:08:32,900 --> 00:08:35,933
AND SO I SAT ON CONSOLE
FOR ALMOST ALL THE MISSIONS

203
00:08:35,933 --> 00:08:37,500
THAT BUILT THE
INTERNATIONAL SPACE STATION,

204
00:08:37,500 --> 00:08:39,033
AND IT TOOK ALL THE RESOURCES

205
00:08:39,033 --> 00:08:41,366
OF ALL THE MAJOR
SPACE-FARING NATIONS

206
00:08:41,366 --> 00:08:44,100
OVER TEN YEARS
TO ASSEMBLE THE SPACE STATION.

207
00:08:44,100 --> 00:08:45,733
AND THAT'S ONLY 450 TONS.

208
00:08:45,733 --> 00:08:49,166
SO THAT'S OVER 100 TIMES
MORE MASS

209
00:08:49,166 --> 00:08:51,633
THAN THE INTERNATIONAL
SPACE STATION.

210
00:08:51,633 --> 00:08:54,166
SO INTERSTELLAR FLIGHT
IS EXTREMELY DIFFICULT

211
00:08:54,166 --> 00:08:59,633
AND CAN BE A VERY
TIME-CONSUMING PURSUIT.

212
00:08:59,633 --> 00:09:01,633
SO YOU COULD ASK THE QUESTION:

213
00:09:01,633 --> 00:09:03,400
WHAT IF YOU WANTED TO GET

SOMEWHERE VERY QUICKLY?

214
00:09:03,400 --> 00:09:06,066
WHAT IF YOU WANTED TO TRY
AND COVER THAT DISTANCE

215
00:09:06,066 --> 00:09:07,966
FROM ALPHA CENTAURI
IN SOME TIME PERIOD

216
00:09:07,966 --> 00:09:12,266
THAT'S NOT MEASURED IN DECADES,
CENTURIES, OR MILLENNIA?

217
00:09:12,266 --> 00:09:16,833
WHAT IF YOU WANTED TO MAKE IT
IN LESS THAN FOUR YEARS?

218
00:09:16,833 --> 00:09:19,500
IT TURNS OUT
THAT THE SAME FRAMEWORK

219
00:09:19,500 --> 00:09:21,933
THAT ESTABLISHES
THE SPEED LIMIT,

220
00:09:21,933 --> 00:09:23,500
THE COSMIC SPEED LIMIT--

221
00:09:23,500 --> 00:09:25,700
YOU CANNOT EXCEED
THE SPEED OF LIGHT.

222
00:09:25,700 --> 00:09:27,266
THERE ARE TWO LOOPHOLES

223
00:09:27,266 --> 00:09:30,600
WITHIN THE MATHEMATICS
OF GENERAL RELATIVITY

224
00:09:30,600 --> 00:09:34,266
THAT POTENTIALLY ALLOW YOU
TO GO SOMEWHERE VERY QUICKLY

225
00:09:34,266 --> 00:09:37,666
WITHOUT LOCALLY
LEAVING YOUR LOCAL LIGHT CONE.

226
00:09:37,666 --> 00:09:39,800
ONE IS THE IDEA OF A WORMHOLE,

227
00:09:39,800 --> 00:09:41,166
AND THE OTHER IS THE IDEA
OF A SPACEWARP.

228
00:09:41,166 --> 00:09:44,033
AND I'LL TALK A LITTLE BIT
ABOUT THAT.

229
00:09:44,033 --> 00:09:46,200
SO THE IDEA OF A SPACEWARP
WORKS ON THE PRINCIPLE

230
00:09:46,200 --> 00:09:49,366
THAT YOU EXPAND AND CONTRACT
SPACE AT ANY SPEED.

231
00:09:49,366 --> 00:09:52,766
IT'S NOT RESTRICTED TO "C."

232
00:09:52,766 --> 00:09:55,933
WE KNOW THAT INFLATION OCCURS
IN NATURE.

233
00:09:55,933 --> 00:09:58,866
WHEN WE LOOK AT LIGHT
THAT COMES TO US

234
00:09:58,866 --> 00:10:02,133

FROM STARS THAT ARE IN GALAXIES
VERY FAR AWAY FROM US,

235
00:10:02,133 --> 00:10:05,533
THAT LIGHT HAS BEEN RED-SHIFTED
SINCE THE BIG BANG

236
00:10:05,533 --> 00:10:08,100
13.7 BILLION YEARS AGO.

237
00:10:08,100 --> 00:10:10,633
SO WE KNOW THAT INFLATION
IS A REAL PHENOMENON,

238
00:10:10,633 --> 00:10:13,366
AND IT'S PART
OF GENERAL RELATIVITY.

239
00:10:13,366 --> 00:10:14,966
AND SO NATURE CAN DO IT.

240
00:10:14,966 --> 00:10:17,566
CAN WE DO IT
IN SOME PURPOSEFUL WAY?

241
00:10:17,566 --> 00:10:21,133
AND SO IT WAS THIS IDEA
THAT MOTIVATED MIGUEL ALCUBIERRE

242
00:10:21,133 --> 00:10:24,400
TO PUBLISH A PAPER IN THE '90s

243
00:10:24,400 --> 00:10:27,266
THAT KIND OF CAPTURED THIS IDEA
IN MATHEMATICS.

244
00:10:27,266 --> 00:10:30,833
AND YOU SEE THE CONCEPT HERE
ON THE SCREEN.

245
00:10:30,833 --> 00:10:32,366
AND SO, WHEN YOU LOOK
AT THE MATH

246
00:10:32,366 --> 00:10:35,600
AND YOU TRY AND ENVISION
WHAT IT MIGHT REQUIRE,

247
00:10:35,600 --> 00:10:37,333
YOU SEE A LITTLE
SURFACE PLOT THERE

248
00:10:37,333 --> 00:10:40,366
THAT REPRESENTS THE EXPANSION
AND CONTRACTION OF SPACE.

249
00:10:40,366 --> 00:10:44,033
SPACE IS CONTRACTING HERE
IN THE FRONT OF THE SPACECRAFT.

250
00:10:44,033 --> 00:10:47,266
AND SPACE IS EXPANDING HERE
IN THE BACK.

251
00:10:47,266 --> 00:10:49,233
WHEN YOU LOOK
AT THE ENERGY DENSITY TERM,

252
00:10:49,233 --> 00:10:50,433
YOU END UP WITH A SPACECRAFT

253
00:10:50,433 --> 00:10:54,566
THAT HAS THIS DONUT
TYPE OF APPARATUS

254
00:10:54,566 --> 00:10:58,333
THAT SURROUNDS THIS LITTLE
FOOTBALL-SHAPED SPACECRAFT.

255

00:10:58,333 --> 00:10:59,800
AND SO THE FOOTBALL SHAPE

256
00:10:59,800 --> 00:11:03,600
MIGHT BE WHERE YOU'D HAVE
YOUR SENSITIVE INSTRUMENTATION

257
00:11:03,600 --> 00:11:07,700
OR ANY PAYLOAD
THAT YOU'RE VERY WORRIED ABOUT,

258
00:11:07,700 --> 00:11:09,266
OR IF YOU WANTED TO BE BOLD,

259
00:11:09,266 --> 00:11:13,733
MAYBE SOME TYPE
OF A HUMAN CREW.

260
00:11:13,733 --> 00:11:16,500
NOW, THE METRIC HAD A LOT OF
GOOD, APPEALING CHARACTERISTICS

261
00:11:16,500 --> 00:11:18,533
WHEN YOU THINK ABOUT THE IDEA.

262
00:11:18,533 --> 00:11:20,833
THAT LITTLE CENTER AREA,

263
00:11:20,833 --> 00:11:23,800
THAT BLUE DISC
YOU SEE ON THE SCREEN,

264
00:11:23,800 --> 00:11:26,333
IT HAS A COUPLE
OF GOOD CHARACTERISTICS

265
00:11:26,333 --> 00:11:28,700
FOR THE CONCEPT
OF A MISSION LIKE THIS.

266
00:11:28,700 --> 00:11:31,533
IT HAS--
THE DIVERGENCE OF PHI IS ZERO.

267
00:11:31,533 --> 00:11:34,833
SO THE--
IT HAS FLAT SPACE-TIME

268
00:11:34,833 --> 00:11:36,000
INSIDE OF THE BUBBLE.

269
00:11:36,000 --> 00:11:38,233
THE COORDINATE TIME
IS EQUAL TO PROPER TIME

270
00:11:38,233 --> 00:11:40,366
INSIDE OF THAT FLAT REGION.

271
00:11:40,366 --> 00:11:43,733
SO THE MISSION CONTROL CLOCKS
WOULD BE SYNCHRONIZED

272
00:11:43,733 --> 00:11:46,333
WITH THE CLOCKS
ONBOARD THE SPACECRAFT.

273
00:11:46,333 --> 00:11:48,833
THEN THE PROPER
ACCELERATION ALPHA IN THE BUBBLE

274
00:11:48,833 --> 00:11:50,666
IS FORMALLY ZERO.

275
00:11:50,666 --> 00:11:55,666
SO WHEN YOU TURNED ON
THE SPACEWARP SYSTEM,

276
00:11:55,666 --> 00:11:58,366
THE WHOLE CREW WOULD NOT FEEL

AN INFINITE ACCELERATION

277
00:11:58,366 --> 00:12:00,400
AND GO SMACKING
AGAINST THE BULKHEAD

278
00:12:00,400 --> 00:12:02,766
AND KILLING EVERYBODY ONBOARD

279
00:12:02,766 --> 00:12:08,233
AND MAKING FOR A VERY SAD
EPISODE OF "STAR TREK."

280
00:12:08,233 --> 00:12:11,600
NOW, IT DOES HAVE ONE
UNAPPEALING CHARACTERISTIC.

281
00:12:11,600 --> 00:12:13,833
AFTER MIGUEL PUBLISHED HIS PAPER

282
00:12:13,833 --> 00:12:15,700
AND PEOPLE WENT TO GO TRY
AND FIGURE OUT,

283
00:12:15,700 --> 00:12:19,033
"HOW MUCH STUFF WOULD IT TAKE
TO MAKE THIS CONCEPT WORK?"

284
00:12:19,033 --> 00:12:21,666
BECAUSE IT REQUIRES
EXOTIC MATTER

285
00:12:21,666 --> 00:12:23,600
OR NEGATIVE VACUUM ENERGY.

286
00:12:23,600 --> 00:12:25,900
AND SO THEY DID
SOME CALCULATIONS TO FIGURE OUT,

287

00:12:25,900 --> 00:12:29,133
"WHAT WOULD YOU NEED
TO MAKE SOME TYPE OF A SYSTEM

288
00:12:29,133 --> 00:12:31,200
THAT WE WOULD THINK ABOUT
ACTUALLY WORK?"

289
00:12:31,200 --> 00:12:35,000
AND SO THE BEST ESTIMATES
THAT WERE DONE PRIOR TO 2011

290
00:12:35,000 --> 00:12:36,733
WERE DONE BY SOME COLLEAGUES
OF MINE,

291
00:12:36,733 --> 00:12:39,633
DR. RICHARD OBOUSY
AND DR. JERRY CLEAVER.

292
00:12:39,633 --> 00:12:42,366
THEY REDUCED THE AMOUNT
OF STUFF THAT'S REQUIRED

293
00:12:42,366 --> 00:12:46,033
TO SOMETHING THAT'S
ABOUT THE SIZE OF JUPITER.

294
00:12:46,033 --> 00:12:49,100
AND SO THAT'S JUST
QUITE IMPRACTICAL.

295
00:12:49,100 --> 00:12:51,566
AND SO THE CONCEPT
WAS REALLY CONSIDERED

296
00:12:51,566 --> 00:12:53,466
MAYBE NATURE CAN DO IT
ON A GRAND SCALE,

297

00:12:53,466 --> 00:12:57,366
BUT IT'S UNLIKELY THAT WE COULD
EVER DO SOMETHING LIKE THIS

298
00:12:57,366 --> 00:13:00,266
IN A PURPOSEFUL SENSE.

299
00:13:00,266 --> 00:13:02,266
AND SO I GOT ASKED TO COME

300
00:13:02,266 --> 00:13:04,300
TO THE 100 YEAR
STARSHIP SYMPOSIUM

301
00:13:04,300 --> 00:13:07,966
AND GIVE A LITTLE BIT OF A TALK
ON THE CONCEPT OF A SPACEWARP.

302
00:13:07,966 --> 00:13:11,000
SO, AS A RESULT OF PETE WORDEN
AND SOME OTHERS

303
00:13:11,000 --> 00:13:12,333
KIND OF BEING VISIONARY

304
00:13:12,333 --> 00:13:15,366
AND ASKING FOR FOLKS
TO KIND OF THINK ABOUT THIS

305
00:13:15,366 --> 00:13:17,200
RATHER THAN JUST KIND OF
RELAY EVERYTHING

306
00:13:17,200 --> 00:13:20,400
THAT HAD BEEN DONE BEFORE
BY MYSELF AND OTHERS,

307
00:13:20,400 --> 00:13:22,900
I DECIDED TO DO
A SENSITIVITY ANALYSIS.

308
00:13:22,900 --> 00:13:26,600
I WANTED TO LOOK AT WHAT HAPPENS
TO THE MATHEMATICS

309
00:13:26,600 --> 00:13:29,966
WHEN I CHANGE
SOME OF THE INPUT PARAMETERS.

310
00:13:29,966 --> 00:13:32,766
AND SO I LOOKED AT
AND FOCUSED ON, IN THIS CASE,

311
00:13:32,766 --> 00:13:35,633
THE SHELL THICKNESS PARAMETER.

312
00:13:35,633 --> 00:13:37,266
AND SO YOU SEE
A COUPLE OF STILLS THERE

313
00:13:37,266 --> 00:13:39,833
FROM SOME VIDEOS WE'LL LOOK AT
IN JUST A SECOND.

314
00:13:39,833 --> 00:13:44,133
SO THIS IS FOR
A 10-METER DIAMETER SPACECRAFT

315
00:13:44,133 --> 00:13:47,433
WITH AN EFFECTIVE VELOCITY
OF 10C.

316
00:13:47,433 --> 00:13:48,533
AND THE ONLY THING I'M CHANGING

317
00:13:48,533 --> 00:13:51,100
IS THE SHELL THICKNESS
PARAMETER,

318

00:13:51,100 --> 00:13:53,833
SO, INSTEAD OF HAVING
THAT FOOTBALL

319
00:13:53,833 --> 00:13:56,000
WITH THE RING
THAT GOES AROUND IT,

320
00:13:56,000 --> 00:13:59,533
INSTEAD OF THAT RING,
BEING A VERY THIN ASPECT RATIO

321
00:13:59,533 --> 00:14:01,166
OF, SAY, LIKE A WEDDING BAND,

322
00:14:01,166 --> 00:14:02,366
IF I CHANGE IT WHERE IT LOOKS

323
00:14:02,366 --> 00:14:05,733
MORE LIKE A LIFESAVER
OR AN INNER TUBE,

324
00:14:05,733 --> 00:14:09,233
I CAN GREATLY CHANGE
THE MAGNITUDE OF THE YORK TIME.

325
00:14:09,233 --> 00:14:12,166
AND TO KIND OF PUT THAT
IN ENGINEERING PARLANCE,

326
00:14:12,166 --> 00:14:17,100
KIND OF LIKE A STRAIN RATE,
SO TO SPEAK, ON SPACE-TIME.

327
00:14:17,100 --> 00:14:20,166
AND WHEN YOU LOOK AT THE ENERGY
DENSITY ASSOCIATED WITH THAT,

328
00:14:20,166 --> 00:14:23,733
THE ENERGY DENSITY

CHANGES SIGNIFICANTLY.

329
00:14:23,733 --> 00:14:26,566
SO JUST SHOW YOU SOME OF
THE ANIMATIONS TO HELP YOU SEE.

330
00:14:26,566 --> 00:14:30,066
SO, AS THE THICKNESS
OF THE BUBBLE GETS THICKER,

331
00:14:30,066 --> 00:14:31,733
BECAUSE THE RING
IS GETTING THICKER,

332
00:14:31,733 --> 00:14:35,766
THE MAGNITUDE OF THE YORK TIME
DECREASES SIGNIFICANTLY.

333
00:14:35,766 --> 00:14:38,133
AND SIMILARLY,
FOR THE ENERGY DENSITY,

334
00:14:38,133 --> 00:14:39,533
FOR THAT SAME SET OF CASES,

335
00:14:39,533 --> 00:14:43,666
THE ENERGY DENSITY COLLAPSES
MANY ORDERS OF MAGNITUDE.

336
00:14:43,666 --> 00:14:46,566
SO WHAT'S POTENTIALLY GOING ON
WITH THIS FINDING

337
00:14:46,566 --> 00:14:49,800
IS THAT, BY CHANGING
THE STRAIN RATE

338
00:14:49,800 --> 00:14:51,166
THAT WE'RE HAVING
TO PUT ON SPACE-TIME,

339
00:14:51,166 --> 00:14:53,266
WE'RE CHANGING
HOW MUCH ENERGY IS REQUIRED

340
00:14:53,266 --> 00:14:55,266
TO ACHIEVE THAT STRAIN RATE.

341
00:14:55,266 --> 00:14:56,900
SO IF I WERE TO--

342
00:14:56,900 --> 00:14:58,666
THIS PODIUM IS MADE OUT OF WOOD,

343
00:14:58,666 --> 00:15:01,333
AND SO IT'S ABOUT, I DON'T KNOW,
3/4 OF AN INCH THICK.

344
00:15:01,333 --> 00:15:04,266
IF I WERE TO TRY AND TAKE
MY THUMB AND MY FOREFINGER

345
00:15:04,266 --> 00:15:06,900
AND COMPRESS THE WOOD,

346
00:15:06,900 --> 00:15:08,833
AGAIN USING
AN ENGINEERING EXAMPLE,

347
00:15:08,833 --> 00:15:11,866
COMPRESS THE WOOD
BY A QUARTER INCH,

348
00:15:11,866 --> 00:15:13,066
YOU KNOW, I--

349
00:15:13,066 --> 00:15:14,633
ALTHOUGH I'M FROM TEXAS,
I CAN'T DO THAT.

350
00:15:14,633 --> 00:15:16,533
MAYBE PETE CAN, BUT...

351
00:15:16,533 --> 00:15:18,100
IT'S BEYOND MY CAPACITY.

352
00:15:18,100 --> 00:15:21,300
BUT IF I REDUCE THE STRAIN
THAT I HAVE TO PUT ON THE WOOD

353
00:15:21,300 --> 00:15:22,933
TO MAYBE JUST A NANOMETER
OR TWO,

354
00:15:22,933 --> 00:15:24,333
THEN MAYBE I COULD DO THAT.

355
00:15:24,333 --> 00:15:25,666
SO THAT'S KIND OF
WHAT YOU'RE SEEING THERE,

356
00:15:25,666 --> 00:15:29,366
IS, BY CHANGING THE STRAIN RATE
FOR THE SAME CASE,

357
00:15:29,366 --> 00:15:31,700
WE ARE REDUCING THE ENERGY
THAT'S REQUIRED.

358
00:15:31,700 --> 00:15:35,233
NOW, GOING BACK JUST TO
POINT SOMETHING OUT HERE,

359
00:15:35,233 --> 00:15:38,100
THE--YOU'RE SACRIFICING
SOME REAL ESTATE

360
00:15:38,100 --> 00:15:39,900

IN THE CENTER OF THE BUBBLE.

361
00:15:39,900 --> 00:15:41,533
SO YOU SEE
THAT LITTLE FLAT ISLAND

362
00:15:41,533 --> 00:15:43,033
WHERE THOSE IDEAL CONDITIONS ARE

363
00:15:43,033 --> 00:15:44,866
IS CHANGING ITS OVERALL SIZE.

364
00:15:44,866 --> 00:15:46,900
SO IT IS A LITTLE BIT
OF A TRADE.

365
00:15:46,900 --> 00:15:48,566
HOW MUCH VOLUME DO YOU NEED

366
00:15:48,566 --> 00:15:51,666
TO HOUSE WHATEVER
YOU'RE TRYING TO DO

367
00:15:51,666 --> 00:15:54,466
IN SOME FICTIONAL SPACECRAFT?

368
00:15:54,466 --> 00:15:55,966
NOW, SPACE-TIME
IS PRETTY STIFF.

369
00:15:55,966 --> 00:15:59,366
THIS WOOD IS
A FAIRLY STIFF MATERIAL.

370
00:15:59,366 --> 00:16:01,566
IF I COULD CHANGE
THE MATERIAL PROPERTIES

371
00:16:01,566 --> 00:16:05,600

AND MAKE THE WOOD SEEM
MORE LIKE A FOAM,

372
00:16:05,600 --> 00:16:08,600
THEN, FOR THE SAME STRAIN RATE,

373
00:16:08,600 --> 00:16:10,500
I CAN FURTHER REDUCE
THE AMOUNT OF ENERGY

374
00:16:10,500 --> 00:16:13,133
THAT'S NECESSARY
TO INDUCE THE AMOUNT OF STRAIN

375
00:16:13,133 --> 00:16:15,166
ON THAT PIECE OF MATERIAL.

376
00:16:15,166 --> 00:16:17,233
SO THE QUESTION
THAT I LOOKED AT NEXT:

377
00:16:17,233 --> 00:16:18,766
IS THERE SOMETHING
THAT WE CAN DO

378
00:16:18,766 --> 00:16:22,466
TO TRY AND LOOK AT THIS TERM
THAT'S IN THE EINSTEIN TENSOR,

379
00:16:22,466 --> 00:16:24,566
IN THE ENERGY DENSITY TENSOR.

380
00:16:24,566 --> 00:16:26,233
AND SO,
WHAT I DID NEXT

381
00:16:26,233 --> 00:16:29,266
WAS LOOK AT EXPANDING
THE ALCUBIERRE METRIC

382
00:16:29,266 --> 00:16:32,100
INTO A HIGHER-DIMENSIONAL
MANIFOLD.

383
00:16:32,100 --> 00:16:34,833
AND SO I LOOKED
AT THE CHUNG-FREESE METRIC

384
00:16:34,833 --> 00:16:37,300
AND DID SOME WORK WITH SOME
OF THE NULL-LIKE GEODESICS

385
00:16:37,300 --> 00:16:39,366
BETWEEN THE TWO MODELS

386
00:16:39,366 --> 00:16:43,400
AND FOUND THAT
IF YOU WERE TO GO THROUGH

387
00:16:43,400 --> 00:16:47,166
AND VARY THE INTENSITY
IN THE RING,

388
00:16:47,166 --> 00:16:49,566
YOU CAN CHANGE THE STIFFNESS
PROPERTIES OF SPACE

389
00:16:49,566 --> 00:16:53,366
AND POTENTIALLY FURTHER REDUCE
THE AMOUNT OF STUFF

390
00:16:53,366 --> 00:16:59,500
THAT'S NECESSARY
TO MAYBE MAKE THIS CONCEPT WORK.

391
00:16:59,500 --> 00:17:02,933
SO I CULMINATED THE EFFORT
WITH A TABLE

392

00:17:02,933 --> 00:17:06,233
THAT KIND OF LOOKED AT THIS
10-METER DIAMETER SPACECRAFT,

393
00:17:06,233 --> 00:17:08,566
VARYING THE SHELL
THICKNESS PARAMETER

394
00:17:08,566 --> 00:17:12,066
AND THE TIME-VARYING POTENTIAL,
D-PHI/DT.

395
00:17:12,066 --> 00:17:15,300
AND I WANTED
TO DUPLICATE THE WORK

396
00:17:15,300 --> 00:17:17,433
DONE BY RICHARD OBOUSY
AND JERRY CLEAVER,

397
00:17:17,433 --> 00:17:23,333
SO I SET THE PARAMETERS
SUCH THAT I COULD REQUIRE

398
00:17:23,333 --> 00:17:26,900
A JUPITER AMOUNT
OF EXOTIC MATTER UP HERE.

399
00:17:26,900 --> 00:17:29,400
SO YOU CAN SEE ON THE BOTTOM
THERE'S SOME LITTLE CARTOONS

400
00:17:29,400 --> 00:17:33,333
THAT SHOW THE RELATIVE
ASPECT RATIO OF THE RING

401
00:17:33,333 --> 00:17:36,866
RELATIVE TO THE LITTLE
LOG SCALE HERE.

402

00:17:36,866 --> 00:17:38,233
AND AS YOU GET FURTHER
TO THE LEFT,

403
00:17:38,233 --> 00:17:40,933
THE RING IS GETTING
INFINITELY THIN.

404
00:17:40,933 --> 00:17:42,033
AND SO WE CAN--

405
00:17:42,033 --> 00:17:43,433
FOR THIS 10-METER DIAMETER
SPACECRAFT

406
00:17:43,433 --> 00:17:45,400
WITH AN EFFECTIVE VELOCITY
OF 10C,

407
00:17:45,400 --> 00:17:46,833
I CAN YIELD A SOLUTION

408
00:17:46,833 --> 00:17:49,766
THAT REQUIRES A JUPITER AMOUNT
OF EXOTIC MATTER.

409
00:17:49,766 --> 00:17:52,400
I COULD FORMALLY DRIVE IT
TO INFINITY.

410
00:17:52,400 --> 00:17:54,966
BUT BY USING THESE
OPTIMIZATION TECHNIQUES,

411
00:17:54,966 --> 00:17:57,733
WE CAN REDUCE IT,
NONTRIVIALLY,

412
00:17:57,733 --> 00:17:59,300
TO, IN THIS CASE,

413
00:17:59,300 --> 00:18:01,833
SOMETHING ABOUT THE SIZE
OF THE "VOYAGER 1" SPACECRAFT

414
00:18:01,833 --> 00:18:04,033
IN TERMS OF THE EFFECTIVE MASS

415
00:18:04,033 --> 00:18:06,266
OF WHAT YOU NEED
TO MAKE THE TRICK WORK.

416
00:18:06,266 --> 00:18:08,233
SO, WHAT THIS DOES IS,

417
00:18:08,233 --> 00:18:10,266
IT MOVES THE IDEA
FROM THE CATEGORY

418
00:18:10,266 --> 00:18:12,333
OF COMPLETELY IMPOSSIBLE

419
00:18:12,333 --> 00:18:13,533
TO MAYBE PLAUSIBLE.

420
00:18:13,533 --> 00:18:15,866
IT DOESN'T SAY ANYTHING
ABOUT FEASIBLE.

421
00:18:15,866 --> 00:18:18,366
SO, UNFORTUNATELY, THAT POINT
USUALLY GETS MISSED A LOT.

422
00:18:18,366 --> 00:18:20,233
BUT AT LEAST
IT OPENS UP THE DOOR

423
00:18:20,233 --> 00:18:21,433
THAT MAYBE IT'S INTERESTING

424
00:18:21,433 --> 00:18:23,933
TO GO TRY AND PERFORM
SOME SMALL EXPERIMENTS

425
00:18:23,933 --> 00:18:26,100
TO TRY AND SEE IF WE CAN CREATE

426
00:18:26,100 --> 00:18:28,233
SOME TYPE OF CHANGES
IN OPTICAL PROPERTIES

427
00:18:28,233 --> 00:18:30,500
IN A VERY SMALL SCALE
IN THE LABORATORY.

428
00:18:30,500 --> 00:18:31,866
AND SO THAT'S SOME OF THE STUFF

429
00:18:31,866 --> 00:18:34,666
WE'RE KIND OF ROLLING THE ROCK
DOWN THE ROAD WITH

430
00:18:34,666 --> 00:18:35,933
AT OUR LAB AT JSC.

431
00:18:35,933 --> 00:18:41,066
AND SO WE'VE GOT TWO APPARATUSES
THAT WE USE.

432
00:18:41,066 --> 00:18:46,666
WE HAVE A TWYMAN-GREEN
INTERFEROMETER.

433
00:18:46,666 --> 00:18:48,500
AND SO THIS IS WHERE
WE HAVE A TEST ARTICLE

434
00:18:48,500 --> 00:18:50,866

THAT WE PUT ON ONE
OF THE REFERENCE LEGS

435
00:18:50,866 --> 00:18:52,333
OF THE INTERFEROMETER,

436
00:18:52,333 --> 00:18:54,133
AND WE CAN ENERGIZE
THE TEST ARTICLE

437
00:18:54,133 --> 00:18:55,866
TO TRY AND CREATE A--

438
00:18:55,866 --> 00:18:58,433
IN THIS CASE, WITH OUR
LOW-FIDELITY TEST ARTICLES,

439
00:18:58,433 --> 00:19:02,400
CREATE A BLUE-SHIFTED FRAME
RELATIVE TO THE LAB

440
00:19:02,400 --> 00:19:04,466
AND CHANGE THE PERCEIVED
PATH LENGTH

441
00:19:04,466 --> 00:19:06,133
FOR THE PHOTONS
THAT MOVE THROUGH THIS REGION

442
00:19:06,133 --> 00:19:07,600
ON THE INTERFEROMETER.

443
00:19:07,600 --> 00:19:09,366
AND SO THERE'LL BE
A SLIGHT CHANGE

444
00:19:09,366 --> 00:19:12,333
IN THE INTERFERENCE PATTERN
ON THE INTERFEROMETER

445
00:19:12,333 --> 00:19:15,066
THAT WE CAN TRY AND DETECT

446
00:19:15,066 --> 00:19:18,000
USING SOME OF THE SOFTWARE
ANALYSIS TECHNIQUES

447
00:19:18,000 --> 00:19:22,400
AND MAYBE SEE IF WE CAN'T SEE
A MANIFESTATION OF THIS

448
00:19:22,400 --> 00:19:23,833
IN A VERY SMALL SENSE.

449
00:19:23,833 --> 00:19:27,233
THIS SHOWS A PICTURE
OF ONE OF THE TEST SETUPS

450
00:19:27,233 --> 00:19:28,833
ON THE TWYMAN-GREEN.

451
00:19:28,833 --> 00:19:31,966
SEE THE TEST ARTICLE THERE
ON ONE OF THE BEAM PATHS.

452
00:19:31,966 --> 00:19:34,000
YOU'VE GOT THE LASER
ON THE LEFT.

453
00:19:34,000 --> 00:19:36,533
IT'S A VERY STANDARD SETUP
FOR A TWYMAN-GREEN.

454
00:19:36,533 --> 00:19:37,866
WE'VE GOT THE DETECTOR
ON THE RIGHT

455
00:19:37,866 --> 00:19:41,133
THAT GOES THROUGH THE COMPUTER

THAT COLLECTS THE DATA

456
00:19:41,133 --> 00:19:44,033
FOR THE DATA RUNS.

457
00:19:44,033 --> 00:19:46,333
AND THEN THE OTHER TEST SETUP
THAT WE HAVE

458
00:19:46,333 --> 00:19:47,666
IS A SLIGHTLY DIFFERENT
PERMUTATION

459
00:19:47,666 --> 00:19:48,700
ON THE INTERFEROMETER.

460
00:19:48,700 --> 00:19:51,400
WE HAVE A FABRY-PEROT
INTERFEROMETER.

461
00:19:51,400 --> 00:19:53,666
AND SO THE ADVANTAGE
OF A FABRY-PEROT INTERFEROMETER

462
00:19:53,666 --> 00:19:55,533
OVER A TWYMAN-GREEN

463
00:19:55,533 --> 00:19:58,000
IS THAT YOU CAN
PASS A LIGHT BEAM

464
00:19:58,000 --> 00:20:01,833
THROUGH A PARTICULAR REGION
OF INTEREST MANY, MANY TIMES.

465
00:20:01,833 --> 00:20:04,866
AND SO, THAT INCREASES
THE MEASURED MAGNITUDE

466

00:20:04,866 --> 00:20:08,566
OF THE EFFECT BY A COUPLE
OF ORDERS OF MAGNITUDE.

467
00:20:08,566 --> 00:20:11,600
SO IT'S A WAY TO TAKE
A TEST IMPLEMENTATION

468
00:20:11,600 --> 00:20:14,900
AND GET TO A LITTLE BIT HIGHER
LEVEL OF FIDELITY.

469
00:20:14,900 --> 00:20:18,100
AND SO YOU CAN SEE ON
THE BOTTOM TWO PICTURES THERE,

470
00:20:18,100 --> 00:20:21,533
THERE'S AN EXAMPLE
OF A SODIUM SOURCE

471
00:20:21,533 --> 00:20:23,466
BEING RUN THROUGH
A MICHELSON-MORLEY TYPE

472
00:20:23,466 --> 00:20:25,200
OF INTERFEROMETER.

473
00:20:25,200 --> 00:20:27,866
YOU CAN SEE
THE INTERFERENCE PATTERN.

474
00:20:27,866 --> 00:20:30,200
BUT IN THE FABRY-PEROT,

475
00:20:30,200 --> 00:20:33,200
BECAUSE OF THESE MULTIPLE
CONSTRUCTIVE AND DESTRUCTIVE

476
00:20:33,200 --> 00:20:35,100
INTERFERENCE PASSES,

477
00:20:35,100 --> 00:20:38,066
YOU START TO SEE
THE ATOMIC STRUCTURE

478
00:20:38,066 --> 00:20:39,933
OF THE SODIUM SOURCE,

479
00:20:39,933 --> 00:20:42,566
AND SO YOU SEE THE DOUBLET
IN THE FABRY-PEROT.

480
00:20:42,566 --> 00:20:44,266
AND SO YOU SEE
A TEST SETUP THERE

481
00:20:44,266 --> 00:20:47,033
WITH THE LASER AND THE IMAGER
AND THEN THE FABRY-PEROT.

482
00:20:47,033 --> 00:20:48,633
THAT'S IN THE REGION

483
00:20:48,633 --> 00:20:51,033
WHERE WE WERE TRYING TO INDUCE
THE BLUE-SHIFTED FRAME

484
00:20:51,033 --> 00:20:54,033
WITH THE LOW-FIDELITY
TEST ARTICLE.

485
00:20:54,033 --> 00:20:55,533
NOW, THE PROCESS
OF DOING THE TEST--

486
00:20:55,533 --> 00:20:57,900
WE DO TURN THE TEST ARTICLE
ON AND OFF

487

00:20:57,900 --> 00:20:59,466
WITH A GIVEN FREQUENCY,

488
00:20:59,466 --> 00:21:01,400
AND WE GO THROUGH INFOR--

489
00:21:01,400 --> 00:21:02,833
YOU SEE AN IMAGE
ON THE TOP RIGHT

490
00:21:02,833 --> 00:21:06,900
THAT SHOWS AN INTERFERENCE
PATTERN FROM THE IMAGER.

491
00:21:06,900 --> 00:21:08,466
AND WE'LL GO THROUGH
AND RUN A TEST CYCLE

492
00:21:08,466 --> 00:21:11,933
WHERE WE RUN IT
OVER AN EXTENDED PERIOD OF TIME.

493
00:21:11,933 --> 00:21:15,966
AND THEN WE WILL DO AN FFT
FOR EACH AND EVERY PIXEL,

494
00:21:15,966 --> 00:21:19,100
AND THEN WE WILL LOOK
FOR ENERGY IN THE SPECTRUM

495
00:21:19,100 --> 00:21:22,266
BASED ON HOW WE WERE ENERGIZING
AND DE-ENERGIZING

496
00:21:22,266 --> 00:21:24,033
THE TEST ARTICLE.

497
00:21:24,033 --> 00:21:25,766
AND YOU SEE ON THE BOTTOM RIGHT,

498
00:21:25,766 --> 00:21:28,400
THAT IS AN FFT
OF THE ENTIRE IMAGER--

499
00:21:28,400 --> 00:21:31,000
THE FREQUENCY OF INTEREST.

500
00:21:31,000 --> 00:21:33,433
IF THERE WERE
NO PHENOMENA PRESENT,

501
00:21:33,433 --> 00:21:34,700
THEN, IN PRINCIPLE,

502
00:21:34,700 --> 00:21:37,533
THAT SHOULD JUST SIMPLY BE
A FLAT, BLUE SURFACE.

503
00:21:37,533 --> 00:21:39,800
WE SHOULDN'T SEE ANYTHING THERE.

504
00:21:39,800 --> 00:21:41,233
HOWEVER, THERE ARE STILL--

505
00:21:41,233 --> 00:21:42,900
WHEN YOU'RE WORKING WITH STUFF
OF THIS MAGNITUDE,

506
00:21:42,900 --> 00:21:44,300
THERE ARE STILL FALSE POSITIVES.

507
00:21:44,300 --> 00:21:47,366
SO WE WOULD, BY NO MEANS,
CONSIDER THIS DEFINITIVE.

508
00:21:47,366 --> 00:21:48,600
THIS IS JUST INTERESTING,

509

00:21:48,600 --> 00:21:51,100
AND WE'RE CONTINUING
TO TRY AND ELIMINATE

510
00:21:51,100 --> 00:21:54,866
OTHER SOURCES
OF FALSE POSITIVES.

511
00:21:54,866 --> 00:21:58,266
NOW, WE HAVE--
THERE'S A LAB AT JSC

512
00:21:58,266 --> 00:22:00,700
THAT WAS BUILT
FOR THE APOLLO PROGRAM

513
00:22:00,700 --> 00:22:03,533
WORKING WITH
INERTIAL MEASUREMENT UNITS.

514
00:22:03,533 --> 00:22:06,666
WE KIND OF WERE ABLE

515
00:22:06,666 --> 00:22:08,866
TO GET A LITTLE
SMALL FOOTPRINT IN THAT LAB

516
00:22:08,866 --> 00:22:11,633
TO BE ABLE TO DO SOME WORK
AND TAKE ADVANTAGE

517
00:22:11,633 --> 00:22:14,200
OF THE SEISMIC ISOLATION
THAT IT HAS.

518
00:22:14,200 --> 00:22:16,700
YOU CAN SEE THE BIG
PNEUMATIC PIERS

519
00:22:16,700 --> 00:22:18,833

THAT FLOATS THAT ENTIRE FLOOR.

520
00:22:18,833 --> 00:22:20,166
IT'S A PRETTY SIZABLE LAB,

521
00:22:20,166 --> 00:22:23,266
PROBABLY ABOUT
30 FEET BY 40 FEET,

522
00:22:23,266 --> 00:22:24,533
SOMETHING LIKE THAT.

523
00:22:24,533 --> 00:22:25,966
AND SO WE CAN FLOAT
THE WHOLE LAB

524
00:22:25,966 --> 00:22:27,300
WHEN WE'RE DOING TESTING.

525
00:22:27,300 --> 00:22:29,433
AND ALTHOUGH THE LAB,
WITHOUT BEING FLOATED,

526
00:22:29,433 --> 00:22:31,866
IS PRETTY SEISMICALLY QUIET,

527
00:22:31,866 --> 00:22:34,766
FLOATING IT DOES
MAKE A DIFFERENCE.

528
00:22:34,766 --> 00:22:36,066
I WILL SAY THIS.

529
00:22:36,066 --> 00:22:39,900
WHEN WE FIRST BROUGHT THE LAB
OUT OF THE RETIREMENT--

530
00:22:39,900 --> 00:22:41,933
EXCUSE ME--THE FLOATING LAB

OUT OF RETIREMENT,

531
00:22:41,933 --> 00:22:45,366
WE CLIMBED DOWN
INTO THE AREA THERE

532
00:22:45,366 --> 00:22:47,366
WHERE YOU SEE THE GENTLEMAN
UNDERNEATH THE FLOOR.

533
00:22:47,366 --> 00:22:51,633
WE FOUND A COUPLE OF SUITCASES
OF LUGGAGE DOWN THERE,

534
00:22:51,633 --> 00:22:53,366
AND WE WERE A LITTLE NERVOUS
WHEN WE PULLED THOSE UP

535
00:22:53,366 --> 00:22:56,800
AND WE OPENED THOSE,
WHAT MIGHT BE IN THOSE, BUT...

536
00:22:56,800 --> 00:22:57,833
THERE WAS NOTHING IN THEM,

537
00:22:57,833 --> 00:23:00,833
SO IT WAS NOTHING EXCITING,
SO...

538
00:23:00,833 --> 00:23:04,233
SO, ANYWAY, THIS SHOWS
AN INTERFERENCE PATTERN

539
00:23:04,233 --> 00:23:07,900
WITH THE LAB ISOLATED
AND THE LAB NOT ISOLATED,

540
00:23:07,900 --> 00:23:09,466
IN TERMS OF THAT FLOATING LAB.

541
00:23:09,466 --> 00:23:11,233
SO IT DOES MAKE
A LITTLE BIT OF DIFFERENCE

542
00:23:11,233 --> 00:23:14,633
IN THE QUALITY OF THE DATA
THAT WE COLLECT.

543
00:23:14,633 --> 00:23:16,166
BUT WE DO HAVE
BOTH OPTIONS OPEN,

544
00:23:16,166 --> 00:23:18,300
DEPENDING UPON
HOW MUCH TIME WE HAVE

545
00:23:18,300 --> 00:23:19,666
BEFORE WE RUN A CAMPAIGN

546
00:23:19,666 --> 00:23:22,800
TO GET THE CENTER FOLKS OUT
TO FLOAT THE FLOOR.

547
00:23:22,800 --> 00:23:24,266
I WILL SAY THIS.

548
00:23:24,266 --> 00:23:26,866
THE FLOOR HAD NOT BEEN FLOATED
IN SUCH A LONG PERIOD OF TIME

549
00:23:26,866 --> 00:23:29,000
THAT APPARENTLY
THAT HAD CHANGED THE DOORS,

550
00:23:29,000 --> 00:23:31,233
AND WHEN WE FLOATED THE FLOOR
THE FIRST TIME,

551
00:23:31,233 --> 00:23:32,766

IT ACTUALLY LOCKED US
IN THE ROOM,

552
00:23:32,766 --> 00:23:35,300
BECAUSE IT FLOATED UP ABOVE
WHERE THE DOORS COULDN'T OPEN,

553
00:23:35,300 --> 00:23:38,566
SO IT WAS--ANYWAY...

554
00:23:38,566 --> 00:23:40,266
SO THE NEXT THING
WE'VE BEEN DOING

555
00:23:40,266 --> 00:23:43,666
IS TRYING TO GET AWAY
FROM AN ENCAPSULATED FABRY-PEROT

556
00:23:43,666 --> 00:23:46,500
AND GO TO AN OPEN-AIR
ETALON SET OF MIRRORS

557
00:23:46,500 --> 00:23:48,400
WHERE POSITION THE MIRRORS

558
00:23:48,400 --> 00:23:50,766
BASICALLY IN THE SAME
ORIENTATION THAT THEY WERE

559
00:23:50,766 --> 00:23:53,666
INSIDE OF THE ENCAPSULATED
FABRY-PEROT,

560
00:23:53,666 --> 00:23:57,066
JUST TRY TO GO THROUGH AND
ADDRESS SOME SOURCES OF MIMICRY

561
00:23:57,066 --> 00:23:59,766
TO MAKE SURE,
"IS THE SIGNAL STILL THERE?

562
00:23:59,766 --> 00:24:01,600
"CAN WE KILL THE SIGNAL

563
00:24:01,600 --> 00:24:05,233
OR ATTRIBUTE IT
TO SOME BORING EXPLANATION?"

564
00:24:05,233 --> 00:24:07,466
SO WE WENT THROUGH THE PROCESS
OF TAKING A LOOK

565
00:24:07,466 --> 00:24:10,966
AT TESTING
WITH AN OPEN-AIR ETALON,

566
00:24:10,966 --> 00:24:14,700
AND WE STILL SEE SOME ENERGY
IN THE SPECTRUM

567
00:24:14,700 --> 00:24:17,500
WHERE WE WOULD ANTICIPATE
TO SEE IT.

568
00:24:17,500 --> 00:24:22,900
BUT, AGAIN, THIS IS DEFINITELY
NOT DEFINITIVE, BY ANY STRETCH.

569
00:24:22,900 --> 00:24:25,100
ANOTHER WAY TO TEST
AT SOME POINT

570
00:24:25,100 --> 00:24:28,366
TO MAYBE ALSO ADDRESS
OTHER SOURCES OF MIMICRY

571
00:24:28,366 --> 00:24:30,266
WOULD BE
A TIME-OF-FLIGHT APPROACH,

572
00:24:30,266 --> 00:24:33,900
WHERE WE COULD TAKE
A HELIUM-NEON LASER

573
00:24:33,900 --> 00:24:36,100
AND WE COULD RUN IT
THROUGH AN OPTICAL CHOPPER

574
00:24:36,100 --> 00:24:37,733
THAT WOULD CREATE LIGHT PULSES

575
00:24:37,733 --> 00:24:41,466
THAT WE COULD THEN SEND
THROUGH THIS RACETRACK

576
00:24:41,466 --> 00:24:45,466
AND TIME HOW LONG IT TAKES
FOR A PHOTON

577
00:24:45,466 --> 00:24:48,866
TO RUN THROUGH
THE TEST APPARATUS

578
00:24:48,866 --> 00:24:51,800
WITH A TEST DEVICE
NOT ENERGIZED,

579
00:24:51,800 --> 00:24:54,033
AND THEN TIME HOW LONG IT TAKES
FOR A PHOTON

580
00:24:54,033 --> 00:24:56,266
TO RUN THROUGH
THE TEST APPARATUS

581
00:24:56,266 --> 00:24:59,600
WITH THE DEVICE OFF--OR ON,
BACK AND FORTH,

582

00:24:59,600 --> 00:25:00,766
AND COMPARE THE TWO,

583
00:25:00,766 --> 00:25:02,400
AND THAT CAN BE A DIFFERENT WAY

584
00:25:02,400 --> 00:25:04,833
OF DETECTING THE PHENOMENA.

585
00:25:04,833 --> 00:25:07,400
IF YOU SAW SOME DATA THAT LOOKED
LIKE WHAT YOU WANTED

586
00:25:07,400 --> 00:25:08,766
ON THIS APPARATUS,

587
00:25:08,766 --> 00:25:10,633
IF YOU DIDN'T SEE
COMMENSURATE BEHAVIOR HERE,

588
00:25:10,633 --> 00:25:11,966
THAT MIGHT BE A WAY
FOR YOU TO SAY

589
00:25:11,966 --> 00:25:16,766
IT'S SOME OTHER,
BORING EXPLANATION.

590
00:25:16,766 --> 00:25:19,733
NOW, THE ONE THING THAT, TO ME--

591
00:25:19,733 --> 00:25:22,266
EVERYONE ALWAYS THINKS
ABOUT THE ROMANTIC VISION

592
00:25:22,266 --> 00:25:23,533
ON THE RIGHT, RIGHT,

593
00:25:23,533 --> 00:25:27,300

IN TERMS OF BEING ON THE BRIDGE
OF SOME SPACESHIP

594
00:25:27,300 --> 00:25:29,833
GOING OFF TO DESTINATIONS
VERY, VERY FAR AWAY.

595
00:25:29,833 --> 00:25:33,000
AND I THINK THAT'S IMPORTANT,

596
00:25:33,000 --> 00:25:37,033
AND IT IS SOMETHING THAT KIND OF
MOTIVATES US IN SOME WAY,

597
00:25:37,033 --> 00:25:39,600
BUT, YOU KNOW, I ALSO LOOK AT,
HOW DO WE--

598
00:25:39,600 --> 00:25:42,300
YOU KNOW, WHAT DO WE DO
TO GET OUT OF LOW EARTH ORBIT?

599
00:25:42,300 --> 00:25:45,933
WHAT DO WE NEED TO DO
TO SUPPORT AN ASTEROID MISSION

600
00:25:45,933 --> 00:25:47,266
IN A DISTANT RETROGRADE ORBIT?

601
00:25:47,266 --> 00:25:50,500
WHAT DO WE NEED TO DO
TO GET OUT TO MARS?

602
00:25:50,500 --> 00:25:52,766
AND SO, IN TERMS OF
INTERSTELLAR PRECURSORS, RIGHT,

603
00:25:52,766 --> 00:25:56,566
WE ONLY HAVE A SPACECRAFT
AT 120 A.U.,

604
00:25:56,566 --> 00:26:01,300
SO WHILE I TALKED ABOUT 10C

605
00:26:01,300 --> 00:26:04,766
FOR SOME OF THE STUFF I DID
FOR THE CALCULATIONS,

606
00:26:04,766 --> 00:26:07,500
WHAT ABOUT 0.01C?

607
00:26:07,500 --> 00:26:10,766
THAT'S A SIGNIFICANTLY LOWER
VELOCITY COMPARED TO THAT,

608
00:26:10,766 --> 00:26:13,566
BUT COMPARED TO ANYTHING
WE'VE DONE TO DATE,

609
00:26:13,566 --> 00:26:15,500
THAT'S UNBELIEVABLY FAST.

610
00:26:15,500 --> 00:26:18,300
SO THAT MAY STILL HAVE
SOME INTEREST AT SOME POINT,

611
00:26:18,300 --> 00:26:20,733
IF WE COULD EVER START
TO MATURE THIS

612
00:26:20,733 --> 00:26:24,900
PAST JUST THE CONCEPT
IN A LAB PERSPECTIVE.

613
00:26:24,900 --> 00:26:28,866
SO, YOU KNOW, IF WE WERE EVER
TO MOVE THINGS FORWARD,

614
00:26:28,866 --> 00:26:30,400

THAT'S SOMETHING, TO ME,

615
00:26:30,400 --> 00:26:32,766
THAT I THINK THERE'D BE PLENTY
OF INTERESTING APPLICATIONS

616
00:26:32,766 --> 00:26:36,200
WITH SPEEDS LIKE THAT, SO...

617
00:26:38,833 --> 00:26:42,800
NOW, THIS WAS--THIS IS KIND OF
LIKE AN EDUCATION OUTREACH PIECE

618
00:26:42,800 --> 00:26:45,100
THAT I DID WITH SOME FOLKS
FROM CBS.

619
00:26:45,100 --> 00:26:49,300
I WORKED WITH MIKE OKUDA
AND MARK RADEMAKER.

620
00:26:49,300 --> 00:26:53,100
THE CONCEPT YOU SEE HERE
IS BASED ON SOME ARTWORK

621
00:26:53,100 --> 00:26:56,266
THAT MATT JEFFRIES DID
BACK IN THE '60s

622
00:26:56,266 --> 00:26:57,966
FOR THE TV SHOW.

623
00:26:57,966 --> 00:26:59,066
HE'S THE GUY
THAT KIND OF CAME UP

624
00:26:59,066 --> 00:27:00,933
WITH THE FAMILIAR SOMBRERO LOOK

625

00:27:00,933 --> 00:27:03,900
THAT WE ALL KNOW
FROM THE TV SHOW.

626
00:27:03,900 --> 00:27:07,166
AND SO HE HAD ANOTHER VERSION
THAT HE GENERATED

627
00:27:07,166 --> 00:27:09,600
THAT, I THINK,
WAS ONE OF HIS FAVORITE.

628
00:27:09,600 --> 00:27:12,000
AND SO THIS IS
A MODERN RENDERING

629
00:27:12,000 --> 00:27:14,000
DONE BY MARK RADEMAKER

630
00:27:14,000 --> 00:27:18,833
BASED ON THAT ARTISTIC CONCEPT
THAT HE DEVELOPED.

631
00:27:18,833 --> 00:27:21,433
NOW, THE THING
THAT'S COOL TO ME IS,

632
00:27:21,433 --> 00:27:23,900
YOU KNOW, JUST GOING
THROUGH THE MATH WITH YOU GUYS,

633
00:27:23,900 --> 00:27:27,333
YOU CAN SEE
THAT THIS CONCEPT IS--

634
00:27:27,333 --> 00:27:29,200
IT'S GOT SOME THINGS

635
00:27:29,200 --> 00:27:31,500
THAT ARE ALMOST

WHAT THE MATHEMATICS REQUIRE.

636
00:27:31,500 --> 00:27:35,200
IT'S GOT THESE RINGS
THAT GO AROUND THE SPACECRAFT,

637
00:27:35,200 --> 00:27:37,733
AND IT'S GOT THIS
CENTRALLY LOCATED SPACECRAFT.

638
00:27:37,733 --> 00:27:41,100
BUT IT DOES HAVE A FEW THINGS
THAT ARE NOT CORRECT,

639
00:27:41,100 --> 00:27:43,600
BASED ON THE ENERGY
OPTIMIZATION FINDINGS

640
00:27:43,600 --> 00:27:47,200
AND WHERE THE WORK BUBBLE
WOULD ACTUALLY BE.

641
00:27:47,200 --> 00:27:49,666
THE RINGS ON THIS SPACECRAFT
ARE TOO THIN,

642
00:27:49,666 --> 00:27:51,500
SO THEY'RE GONNA DRIVE
THE ENERGY REQUIREMENTS

643
00:27:51,500 --> 00:27:53,366
TO BE NONTRIVIAL.

644
00:27:53,366 --> 00:27:55,833
SO YOU'D WANT THE RINGS
TO BE A LITTLE DIFFERENT.

645
00:27:55,833 --> 00:27:57,466
AND THEN THE CENTRAL PORTION
OF THE SPACECRAFT

646
00:27:57,466 --> 00:28:00,166
IS NOT LOCATED PROPERLY.

647
00:28:00,166 --> 00:28:02,233
AND SO, WHEN THE BUBBLE
WERE TO FORM,

648
00:28:02,233 --> 00:28:05,633
IT WOULD ACTUALLY CUT THE BRIDGE
OFF THE SPACECRAFT,

649
00:28:05,633 --> 00:28:06,866
AND THE BRIDGE WOULD FLOAT AWAY,

650
00:28:06,866 --> 00:28:10,633
AND SCOTTY WOULD
PROBABLY BE FIRED.

651
00:28:10,633 --> 00:28:13,266
SO I WORKED WITH THE GUYS
TO KIND OF UPGRADE THIS CONCEPT

652
00:28:13,266 --> 00:28:14,333
WITH THE MATHEMATICS,

653
00:28:14,333 --> 00:28:16,166
AND SO WE DID
AN EDUCATION OUTREACH

654
00:28:16,166 --> 00:28:17,833
FOR, LIKE,
A SHIPS OF THE LINE CALENDAR,

655
00:28:17,833 --> 00:28:20,766
WHERE WE HAD A LITTLE PARAGRAPH
THAT REMINDED PEOPLE,

656
00:28:20,766 --> 00:28:21,933

"WE'RE STILL IN LOW EARTH ORBIT.

657
00:28:21,933 --> 00:28:23,100
"WE'VE GOT A LOT
OF WORK TO GO DO.

658
00:28:23,100 --> 00:28:25,000
"IF THIS IS INTERESTING TO YOU,

659
00:28:25,000 --> 00:28:27,400
"THERE'S PLENTY OF OTHER WORK
THAT WE NEED TO WORK ON,

660
00:28:27,400 --> 00:28:30,200
"SO PLEASE FOLLOW YOUR PASSION

661
00:28:30,200 --> 00:28:33,600
AND WORK ON SCIENCE, TECHNOLOGY,
ENGINEERING, AND MATHEMATICS."

662
00:28:33,600 --> 00:28:36,666
BUT THE CONCEPT'S GOT
THESE MUCH THICKER RINGS,

663
00:28:36,666 --> 00:28:39,300
SO THAT'S CONSIDERABLY
MORE ATHLETIC-LOOKING.

664
00:28:39,300 --> 00:28:43,200
AND THEN THE LITTLE SPACESHIP
IS KIND OF MORE PROPERLY LOCATED

665
00:28:43,200 --> 00:28:45,933
WITHIN WHAT WOULD BE CALLED
THE FITTING REGION.

666
00:28:45,933 --> 00:28:47,600
SO IT'S IN THAT LITTLE
FLAT SPACE-TIME,

667
00:28:47,600 --> 00:28:53,200
SO THINGS WOULD BE A LITTLE BIT
BETTER FOR THE CREW.

668
00:28:53,200 --> 00:28:55,366
NOW, AS WE MOVE FORWARD,
WHAT WE WANT TO DO IS,

669
00:28:55,366 --> 00:28:59,833
WE WANT TO MOVE TO
A HIGHER-FIDELITY TEST ARTICLE.

670
00:28:59,833 --> 00:29:02,733
SO YOU SEE A CONCEPT
WE'RE STILL WORKING ON RIGHT NOW

671
00:29:02,733 --> 00:29:05,433
IN TERMS OF SOME
OF THE ANALYSIS.

672
00:29:05,433 --> 00:29:08,133
WE WANT TO EXPLORE
THE D-PHI/DT DEPENDENCY.

673
00:29:08,133 --> 00:29:10,100
REMEMBER, I SAID THAT
THAT WAS ONE OF THE TWO

674
00:29:10,100 --> 00:29:12,433
ENERGY OPTIMIZATION TECHNIQUES.

675
00:29:12,433 --> 00:29:13,433
AND SO WE WANT TO GO THROUGH

676
00:29:13,433 --> 00:29:16,633
AND EXPLORE
THE D-PHI/DT DEPENDENCY.

677
00:29:16,633 --> 00:29:18,600

AND SOME OF THE STUFF
THAT WE'RE DOING

678
00:29:18,600 --> 00:29:19,866
WITH THE Q-THRUSTER TECHNOLOGY

679
00:29:19,866 --> 00:29:22,800
HAS SOME POTENTIAL PERTINENCE
TO THIS.

680
00:29:22,800 --> 00:29:26,200
AND SO WE'RE USING
THE PHYSICS MODELS FOR THAT

681
00:29:26,200 --> 00:29:28,533
TO KIND OF GUIDE
THE CONSTRUCTION

682
00:29:28,533 --> 00:29:29,833
AND DEVELOPMENT
OF A TEST ARTICLE

683
00:29:29,833 --> 00:29:32,400
TO GO THROUGH AND SEE
IF WE CAN'T EXPLORE

684
00:29:32,400 --> 00:29:35,300
A MUCH LARGER MAGNITUDE
OF D-PHI/DT.

685
00:29:35,300 --> 00:29:37,166
AND YOU KIND OF SEE
A LITTLE CARTOON

686
00:29:37,166 --> 00:29:38,466
OF SOME OF THE MODES
WE'RE LOOKING AT

687
00:29:38,466 --> 00:29:40,766
AND SOME OF THE SPECIFIC DETAILS

WE'RE LOOKING AT

688
00:29:40,766 --> 00:29:45,733
TO PUT ON THE INSIDE
OF THE TEST APPARATUS.

689
00:29:45,733 --> 00:29:47,066
SO THAT TAKES ME THROUGH
TO THE NEXT ONE.

690
00:29:47,066 --> 00:29:50,466
THAT'S KIND OF THE INTERSTELLAR
PORTION OF THE TALK.

691
00:29:50,466 --> 00:29:52,166
I WANT TO SWITCH GEARS NOW
AND TALK A LITTLE BIT

692
00:29:52,166 --> 00:29:55,166
ABOUT THE TECHNOLOGY
THAT WE'RE WORKING ON.

693
00:29:55,166 --> 00:29:57,933
IT'S A LITTLE BIT HIGHER
IN TRL, POTENTIALLY.

694
00:29:57,933 --> 00:30:00,100
A CONCEPT CALLED Q-THRUSTERS.

695
00:30:00,100 --> 00:30:01,433
AND I WANT TO TALK
ABOUT SOME OF THE DATA

696
00:30:01,433 --> 00:30:04,900
THAT I PRESENTED AT
THE JOINT PROPULSION CONFERENCE

697
00:30:04,900 --> 00:30:06,733
SEVERAL WEEKS AGO.

698
00:30:06,733 --> 00:30:09,366
SO A Q-THRUSTER IS A FORM
OF ELECTRIC PROPULSION

699
00:30:09,366 --> 00:30:10,733
ANALOGOUS TO A HALL THRUSTER,

700
00:30:10,733 --> 00:30:12,700
SO IT'S LOW-THRUST.

701
00:30:12,700 --> 00:30:14,466
IT USES ELECTRIC
AND MAGNETIC FIELDS

702
00:30:14,466 --> 00:30:16,033
TO WORK WITH CHARGED PARTICLES.

703
00:30:16,033 --> 00:30:20,066
IN THIS CASE, WE'RE WORKING
ON THE QUANTUM VACUUM,

704
00:30:20,066 --> 00:30:22,900
THE VIRTUAL ELECTRONS
AND POSITRONS,

705
00:30:22,900 --> 00:30:24,500
PUSHING THEM IN ONE DIRECTION,

706
00:30:24,500 --> 00:30:26,533
AND THE Q-THRUSTER RECOILS
IN THE OTHER DIRECTION

707
00:30:26,533 --> 00:30:28,100
TO CONSERVE MOMENTUM.

708
00:30:28,100 --> 00:30:31,933
SO A CLASSICAL ANALOGY
TO THINK ABOUT WITH THIS CONCEPT

709
00:30:31,933 --> 00:30:35,866
IS TO IMAGINE A SUBMARINE THAT
HAS A PROPELLER ON THE BACK.

710
00:30:35,866 --> 00:30:38,800
A SUBMARINE DOES NOT GO
TO ALL THE TROUBLE

711
00:30:38,800 --> 00:30:43,033
TO PULL UP TO A DOCK
AND FILL UP A TANK FULL OF WATER

712
00:30:43,033 --> 00:30:45,466
AND THEN EXPEL THAT WATER
THROUGH A NOZZLE

713
00:30:45,466 --> 00:30:47,166
IN THE BACK OF THE SUBMARINE.

714
00:30:47,166 --> 00:30:49,533
IT CAPITALIZES ON THE FACT

715
00:30:49,533 --> 00:30:51,633
THAT IT'S EMBEDDED
IN ITS PROPELLANT.

716
00:30:51,633 --> 00:30:52,966
SO THE PROPELLANT
IS ALL AROUND IT

717
00:30:52,966 --> 00:30:54,266
IN THE FORM OF THE SEA WATER.

718
00:30:54,266 --> 00:30:56,766
SO IT USES THE PROPELLER
ON THE BACK OF THE SUBMARINE

719
00:30:56,766 --> 00:31:00,633
TO GENERATE A HYDRODYNAMIC

PRESSURE GRADIENT IN THE WATER,

720
00:31:00,633 --> 00:31:02,100
AND SO THE WATER MOVES
IN ONE DIRECTION,

721
00:31:02,100 --> 00:31:03,466
AND THE SUBMARINE MOVES
IN THE OTHER.

722
00:31:03,466 --> 00:31:04,900
SO, ANALOGOUSLY,

723
00:31:04,900 --> 00:31:07,733
A Q-THRUSTER IS PUSHING
OFF THE QUANTUM VACUUM,

724
00:31:07,733 --> 00:31:10,266
PUSHING THE QUANTUM PARTICLES
IN ONE DIRECTION,

725
00:31:10,266 --> 00:31:11,533
AND IN ORDER
TO CONSERVE MOMENTUM,

726
00:31:11,533 --> 00:31:14,266
THE Q-THRUSTER MOVES
IN THE OTHER DIRECTION.

727
00:31:14,266 --> 00:31:16,600
I LIKE THIS QUOTE
FROM ARTHUR C. CLARKE.

728
00:31:16,600 --> 00:31:17,966
THIS WAS DONE IN 1980,

729
00:31:17,966 --> 00:31:20,266
SO BACK WHEN I WAS
IN MIDDLE SCHOOL.

730
00:31:20,266 --> 00:31:22,566
"IF VACUUM FLUCTUATIONS
CAN BE HARNESSED FOR PROPULSION

731
00:31:22,566 --> 00:31:24,900
"BY ANYONE BESIDES
SCIENCE-FICTION WRITERS,

732
00:31:24,900 --> 00:31:27,600
"THE PURELY ENGINEERING PROBLEMS
OF INTERSTELLAR FLIGHT

733
00:31:27,600 --> 00:31:28,666
WOULD BE SOLVED."

734
00:31:28,666 --> 00:31:30,133
BUT I'D ALSO BE KEEN

735
00:31:30,133 --> 00:31:34,766
TO USE IT FOR MARS MISSIONS
AS WELL.

736
00:31:34,766 --> 00:31:37,766
THIS SHOWS OUR TEST APPARATUS
THAT WE USE

737
00:31:37,766 --> 00:31:40,833
TO MEASURE AND QUANTIFY
THE FORCE

738
00:31:40,833 --> 00:31:42,600
FOR THE TEST ARTICLES,

739
00:31:47,366 --> 00:31:49,533
THIS IS A LOW-THRUST
TORSION PENDULUM.

740
00:31:49,533 --> 00:31:52,533
IT HAS ALL THE SIMILAR ELEMENTS

THAT YOU WOULD FIND

741
00:31:52,533 --> 00:31:56,533
IN THE OTHER HIGH-FIDELITY
TORSION PENDULUMS THAT ARE USED

742
00:31:56,533 --> 00:32:00,766
BY THE AGENCY AND ACADEMIA
AND INDUSTRY.

743
00:32:00,766 --> 00:32:04,300
ON THE LEFT OVER HERE,

744
00:32:04,300 --> 00:32:07,366
YOU SEE THESE THINGS
CALLED LINEAR FLEXURE BEARINGS.

745
00:32:07,366 --> 00:32:11,066
SO THESE ARE THESE TWO
LITTLE BOXES RIGHT HERE.

746
00:32:11,066 --> 00:32:13,800
THIS IS THE ACTUAL BAR
OF THE TORSION PENDULUM

747
00:32:13,800 --> 00:32:17,900
THAT MOVES HORIZONTALLY
THIS WAY.

748
00:32:17,900 --> 00:32:21,800
WE DO NOT HAVE ANY CABLES
ACROSS THE INTERFACE.

749
00:32:21,800 --> 00:32:23,600
THE INTERFACE
IS A CABLE-FREE INTERFACE.

750
00:32:23,600 --> 00:32:27,700
WE USE LIQUID METAL CONTACTS
WITH A LIQUID GALLON STAND,

751
00:32:27,700 --> 00:32:31,933
SO WE PASS DC POWER,
DIGITAL AND ANALOG DATA

752
00:32:36,100 --> 00:32:33,400
ACROSS THE INTERFACE.

753
00:32:36,100 --> 00:32:38,133
WE ACTUALLY HAVE THE--
YOU'LL SEE IN A MINUTE,

754
00:32:38,133 --> 00:32:41,500
THE RF SOURCES ARE ACTUALLY
ON THE TORSION PENDULUM.

755
00:32:41,500 --> 00:32:44,266
WE HAVE THE ABILITY
TO TEST DOWN TO VACUUM,

756
00:32:44,266 --> 00:32:46,333
TO A FEW MICROTORR.

757
00:32:46,333 --> 00:32:47,933
AND THEN THIS IS OUR--

758
00:32:47,933 --> 00:32:51,000
IN TERMS OF MEASURING
AND QUANTIFYING THE FORCE,

759
00:32:51,000 --> 00:32:53,566
THIS IS THE ELECTROSTATIC FIN
SYSTEM THAT WE USE

760
00:32:53,566 --> 00:32:56,733
TO INPUT A CALIBRATION FORCE.

761
00:32:56,733 --> 00:33:01,333
SO WE WOULD PUT IN A VOLTAGE

OF 100, 300 VOLTS,

762
00:33:01,333 --> 00:33:04,400
AND THE BENEFIT
OF USING ELECTROSTATIC FINS,

763
00:33:04,400 --> 00:33:06,800
IT'S NON-CONTACT WAY
TO INPUT A FORCE

764
00:33:06,800 --> 00:33:08,233
INTO THE TORSION PENDULUM.

765
00:33:08,233 --> 00:33:10,666
THE ADVANTAGE OF USING
THE ELECTROSTATIC FINS

766
00:33:10,666 --> 00:33:12,166
IS THAT THE FORCE IS CONSTANT,

767
00:33:12,166 --> 00:33:15,900
WHETHER YOU'RE 90% ENGAGED
OR 10% ENGAGED,

768
00:33:15,900 --> 00:33:19,900
WHICH IS WHY IT'S USED
IN THIS PARTICULAR APPARATUS.

769
00:33:19,900 --> 00:33:22,100
SO WHEN YOU TURN
ON THE CALIBRATION FORCE,

770
00:33:22,100 --> 00:33:23,933
IT STAYS CONSTANT.

771
00:33:23,933 --> 00:33:27,333
AND THEN WE MEASURE--

772
00:33:27,333 --> 00:33:28,566

WE MEASURE DISPLACEMENT

773
00:33:28,566 --> 00:33:31,166
USING THIS OPTICAL
DISPLACEMENT SENSOR HERE.

774
00:33:31,166 --> 00:33:32,633
AND SO THIS MEASURES
DISPLACEMENT

775
00:33:32,633 --> 00:33:33,966
AS A FUNCTION OF TIME,

776
00:33:33,966 --> 00:33:37,100
AND THEN, THAT WAY, WE CAN
INPUT A CALIBRATION FORCE,

777
00:33:37,100 --> 00:33:40,466
WE CAN TEST
SOME TEST APPARATUS,

778
00:33:40,466 --> 00:33:43,200
AND THEN WE CAN QUANTIFY
WHAT TYPE OF FORCE WAS PRESENT

779
00:33:43,200 --> 00:33:45,733
WHEN WE TESTED
THE TEST APPARATUS.

780
00:33:45,733 --> 00:33:48,066
AND THEN WE HAVE
A MAGNETIC DAMPER HERE

781
00:33:48,066 --> 00:33:52,433
THAT CONVERTS ROTATIONAL ENERGY
INTO HEAT ENERGY.

782
00:33:55,600 --> 00:33:58,633
SO ONE OF THE TESTS
THAT WE DID BACK IN AUGUST,

783
00:33:58,633 --> 00:34:03,000
WE PARTNERED WITH CANNAE
TO TEST A RF TEST ARTICLE

784
00:34:03,000 --> 00:34:05,833
THAT THEY WERE KEEN TO EXPLORE,

785
00:34:05,833 --> 00:34:08,300
SOME DEPENDENCY
ON GENERATING THRUST

786
00:34:08,300 --> 00:34:12,000
WITH THE PRESENCE OF SOME
OF THESE RADIAL GROOVES

787
00:34:12,000 --> 00:34:13,866
THAT GO AROUND THE PERIPHERY
OF THE THRUSTER.

788
00:34:13,866 --> 00:34:17,433
SO YOU SEE, THIS IS A PICTURE
OF THE THRUSTER HERE.

789
00:34:17,433 --> 00:34:19,900
THIS IS A--KIND OF LIKE
AN IMAGINARY CUT

790
00:34:19,900 --> 00:34:22,366
THROUGH THE CENTER
OF THAT THRUSTER.

791
00:34:22,366 --> 00:34:24,900
AND SO THESE RADIAL GROOVES
WOULD BE IN THE PERIPHERY

792
00:34:24,900 --> 00:34:26,666
OF THIS BODY OF THE THRUSTER.

793

00:34:26,666 --> 00:34:30,866
THIS IS THE RF POWER INPUT,
AND THIS IS THE SENSE ANTENNA.

794
00:34:30,866 --> 00:34:33,833
SO THE CANNAE FOLKS FELT
THERE MIGHT BE SOME DEPENDENCY

795
00:34:33,833 --> 00:34:40,166
ON THE PRESENCE OF THE SLOTS
IN THE TEST ARTICLE.

796
00:34:40,166 --> 00:34:43,433
SO WE ASKED THEM TO BRING
A SLOTTED TEST ARTICLE

797
00:34:43,433 --> 00:34:47,866
AND A NON-SLOTTED
TEST ARTICLE.

798
00:34:47,866 --> 00:34:49,466
SO THIS GOES THROUGH AND SHOWS

799
00:34:49,466 --> 00:34:51,400
TESTING SOME
OF THE TEST ARTICLES

800
00:34:51,400 --> 00:34:53,333
ON THE TORSION PENDULUM.

801
00:34:53,333 --> 00:34:54,666
YOU'VE GOT A PICTURE THERE.

802
00:34:54,666 --> 00:34:58,666
THERE'S A BLOCK DIAGRAM
THAT SHOWS THE TEST ARTICLE.

803
00:34:58,666 --> 00:35:01,766
WE'VE GOT THE VOLTAGE-CONTROLLED
OSCILLATOR,

804
00:35:01,766 --> 00:35:04,266
THE VARIABLE-VOLTAGE ATTENUATOR

805
00:35:04,266 --> 00:35:06,133
GOING INTO THE
DUAL-DIRECTIONAL COUPLER,

806
00:35:06,133 --> 00:35:08,533
AND WE MEASURE THE FORWARD
AND REFLECTED POWER

807
00:35:08,533 --> 00:35:10,166
ON THE TORSION PENDULUM,

808
00:35:10,166 --> 00:35:12,100
AND THEN WE USE A WHIP ANTENNA

809
00:35:12,100 --> 00:35:15,333
THROUGH ONE OF THE GLASS PORTS
IN THE VACUUM CHAMBER

810
00:35:15,333 --> 00:35:18,766
FOR REAL-TIME TUNING.

811
00:35:18,766 --> 00:35:20,933
THIS SHOWS A TYPICAL DATA RUN.

812
00:35:20,933 --> 00:35:22,966
THIS IS THE OPTICAL
DISPLACEMENT SENSOR.

813
00:35:22,966 --> 00:35:25,566
WE WOULD PUT IN
A CALIBRATION PULSE

814
00:35:25,566 --> 00:35:26,600
FOR SOME PERIOD OF TIME,

815
00:35:26,600 --> 00:35:28,666
TURN OFF THE CALIBRATION PULSE,

816
00:35:28,666 --> 00:35:33,500
ENERGIZE THE TEST ARTICLE
FOR 30, 60, 90 SECONDS,

817
00:35:33,500 --> 00:35:36,733
TURN THAT OFF, AND THEN RUN
ANOTHER CALIBRATION PULSE.

818
00:35:36,733 --> 00:35:40,366
AND THAT WOULD BE CONSIDERED
A DATA RUN FOR THE TEST ARTICLE.

819
00:35:43,900 --> 00:35:45,600
WE TOOK SOME INFRARED IMAGERY

820
00:35:45,600 --> 00:35:47,566
OF THE TEST ARTICLE
ON THE TORSION PENDULUM

821
00:35:47,566 --> 00:35:52,333
TO TRY AND UNDERSTAND WHAT TYPE
OF HEAT THE SYSTEM GENERATED.

822
00:35:52,333 --> 00:35:54,433
IT'S A HIGH-Q RESONANCE SYSTEM,

823
00:35:54,433 --> 00:35:56,800
SO THE TEST ARTICLE
IS NOT GOING TO GENERATE

824
00:35:56,800 --> 00:35:58,833
A SIGNIFICANT AMOUNT OF HEAT.

825
00:35:58,833 --> 00:36:02,133
MOST OF THE HEAT
WAS IN THE HEAT SINK

826
00:36:02,133 --> 00:36:03,566
FOR THE RF AMPLIFIER,

827
00:36:03,566 --> 00:36:06,800
AND WE ALWAYS KEPT THE AMPLIFIER
BELOW 100 DEGREES FAHRENHEIT.

828
00:36:06,800 --> 00:36:10,033
WE DIDN'T WANT TO GET IT
TO OVER 100 DEGREES FAHRENHEIT.

829
00:36:10,033 --> 00:36:11,400
SO YOU JUST KIND OF SEE
THE BREAKDOWN

830
00:36:11,400 --> 00:36:12,600
OF THE TEMPERATURE THERE.

831
00:36:12,600 --> 00:36:17,333
IT'S ABOUT 85 DEGREES
ON THE AMPLIFIER.

832
00:36:17,333 --> 00:36:20,000
THIS SHOWS A SYNOPSIS
OF THE TEST RESULTS

833
00:36:20,000 --> 00:36:22,133
WITH THE CANNAE TEST ARTICLE.

834
00:36:22,133 --> 00:36:27,266
WE TESTED EACH TEST ARTICLE
IN A FORWARD AND REVERSE SENSE.

835
00:36:27,266 --> 00:36:29,066
SO YOU SEE
IN THE PICTURES THERE,

836
00:36:29,066 --> 00:36:31,400

WITH THE THRUST GOING
TO THE LEFT IN THE PICTURE

837
00:36:31,400 --> 00:36:32,933
AND THE THRUST GOING
TO THE RIGHT.

838
00:36:32,933 --> 00:36:34,933
BASICALLY, WE FLIPPED
THE TEST ARTICLE.

839
00:36:34,933 --> 00:36:36,866
ALL THE OTHER
SUPPORTING ELEMENTS

840
00:36:36,866 --> 00:36:39,733
WERE KEPT
IN THE SAME ORIENTATION.

841
00:36:39,733 --> 00:36:42,333
THE--ON THE BACK
OF THE TORSION PENDULUM,

842
00:36:42,333 --> 00:36:46,933
AS I NOTED, THE RF AMPLIFIER
SERVED AS THE COUNTERBALANCE

843
00:36:46,933 --> 00:36:48,133
FOR THE TEST ARTICLE

844
00:36:48,133 --> 00:36:50,633
THAT'S ON THE FRONT
OF THE TORSION PENDULUM.

845
00:36:50,633 --> 00:36:53,933
AND WE ONLY PIPED ACROSS
DC POWER

846
00:36:53,933 --> 00:36:59,233
AND DIGITAL AND ANALOG DATA

ACROSS THE INTERFACE.

847
00:36:59,233 --> 00:37:01,233
SO FOR THE SLOTTED
TEST ARTICLE,

848
00:37:01,233 --> 00:37:03,566
THE AVERAGE STRESS
WAS AROUND 40 MICRONEWTONS

849
00:37:03,566 --> 00:37:05,266
IN THE FORWARD DIRECTION

850
00:37:05,266 --> 00:37:08,366
AND ABOUT 49 MICRONEWTONS
IN THE REVERSE DIRECTION.

851
00:37:08,366 --> 00:37:10,866
THE UN-SLOTTED
ALSO GENERATED THRUST

852
00:37:10,866 --> 00:37:12,300
IN THE FORWARD
AND REVERSE DIRECTION

853
00:37:12,300 --> 00:37:16,500
AT ABOUT 41
AND 23 MICRONEWTONS.

854
00:37:16,500 --> 00:37:18,366
WE DID TEST A RF DUMMY LOAD

855
00:37:18,366 --> 00:37:19,966
WHERE WE WOULD TAKE OFF
THE TEST ARTICLE

856
00:37:19,966 --> 00:37:22,833
AND PUT THE DUMMY LOAD
ON THE TORSION PENDULUM,

857
00:37:22,833 --> 00:37:24,533
ENERGIZE THE SYSTEM,

858
00:37:24,533 --> 00:37:28,900
AND RUN ALL THE RF DRIVE
ELECTRONICS AT FULL POWER,

859
00:37:28,900 --> 00:37:31,833
AND THAT GENERATED
NO DETECTABLE THRUST

860
00:37:31,833 --> 00:37:33,866
WITH THIS CONFIGURATION.

861
00:37:33,866 --> 00:37:38,666
SO THERE WAS NO OTHER
SYSTEMIC DEPENDENCIES

862
00:37:38,666 --> 00:37:41,500
WITH THE RF EQUIPMENT.

863
00:37:41,500 --> 00:37:44,933
NOW, THE--WE DID SOME WORK
IN COMSOL

864
00:37:44,933 --> 00:37:46,333
TO TRY AND UNDERSTAND
WHAT WAS HAPPENING

865
00:37:46,333 --> 00:37:50,466
WITH THE ELECTROMAGNETIC FIELDS
IN THE THRUSTER,

866
00:37:50,466 --> 00:37:54,133
AND WE LOOKED
AT THE RF FEED SYSTEM

867
00:37:54,133 --> 00:37:55,866
FOR THE TEST ARTICLE.

868
00:37:55,866 --> 00:38:00,300
THE RF FEED SYSTEMS
HAD A DIELECTRIC SLUG

869
00:38:00,300 --> 00:38:02,566
INSIDE AS PART
OF THE MATCHING NETWORK,

870
00:38:02,566 --> 00:38:05,233
A DIELECTRIC SLUG, A PTFE.

871
00:38:05,233 --> 00:38:07,600
AND WHEN WE LOOKED AT
THE ELECTRIC AND MAGNETIC FIELDS

872
00:38:07,600 --> 00:38:08,700
IN THAT REGION,

873
00:38:08,700 --> 00:38:10,333
THERE WAS A NET POINTING VECTOR,

874
00:38:10,333 --> 00:38:12,333
AND SO WE SPECULATED

875
00:38:12,333 --> 00:38:14,200
THAT THAT MIGHT BE
A QUARTER WAVE,

876
00:38:14,200 --> 00:38:15,833
A RESONANCE SYSTEM
THAT MIGHT BE EXHIBITING

877
00:38:15,833 --> 00:38:17,466
SOME Q-THRUSTER PHYSICS.

878
00:38:17,466 --> 00:38:20,000
SO WE TOOK THE COMSOL
ANALYSIS RESULTS,

879
00:38:20,000 --> 00:38:24,800
AND WE PLUGGED THEM INTO OUR
ANALYTICAL Q-THRUSTER MODEL,

880
00:38:24,800 --> 00:38:27,833
AND BASED ON THE AS-TESTED
CONDITIONS FOR 25 WATTS

881
00:38:27,833 --> 00:38:30,233
WITH A QUALITY FACTOR OF 8,000,

882
00:38:30,233 --> 00:38:32,833
IT PREDICTED A POTENTIALLY
OBSERVED THRUST

883
00:38:32,833 --> 00:38:34,600
OF 34 MICRONEWTONS.

884
00:38:34,600 --> 00:38:35,933
THAT'S NOT DEFINITIVE,

885
00:38:35,933 --> 00:38:38,966
BUT IT'S AT LEAST
WITHIN AN ORDER OF MAGNITUDE,

886
00:38:38,966 --> 00:38:40,233
SO IT WAS INTERESTING TO US,

887
00:38:40,233 --> 00:38:41,733
AND THAT MIGHT EXPLAIN

888
00:38:41,733 --> 00:38:44,400
WHY THE SLOTTED
AND THE UN-SLOTTED

889
00:38:44,400 --> 00:38:45,700
BOTH GENERATED THRUST.

890
00:38:45,700 --> 00:38:47,633
TO US,
FROM THE Q-THRUSTER PERSPECTIVE,

891
00:38:47,633 --> 00:38:49,766
THE BIG BELL THERE IS
JUST SIMPLY A MATCHING NETWORK

892
00:38:49,766 --> 00:38:51,866
TO ESTABLISH
THE RIGHT CONDITIONS

893
00:38:51,866 --> 00:38:54,166
IN THAT QUARTER WAVE
RESONANCE SYSTEM

894
00:38:54,166 --> 00:38:57,866
THAT YOU SEE THERE ON THE RIGHT.

895
00:38:57,866 --> 00:38:59,833
SO WE ALSO LOOKED
AT ANOTHER TOPOLOGY,

896
00:38:59,833 --> 00:39:02,933
SO WE EXPLORED
A TAPERED THRUSTER APPROACH

897
00:39:02,933 --> 00:39:04,033
BASED ON SOME WORK DONE

898
00:39:04,033 --> 00:39:06,166
BY NORTHWEST POLYTECHNICAL
UNIVERSITY.

899
00:39:06,166 --> 00:39:08,500
SEE YOU IN HOUSTON, PETE.

900
00:39:08,500 --> 00:39:12,466
WE OPTIMIZED THE CONSTRUCTION

AND THE LOCATION

901
00:39:12,466 --> 00:39:14,533
OF THE DIELECTRIC
AND THE ANTENNAS

902
00:39:14,533 --> 00:39:16,700
USING COMSOL
AND THE Q-THRUSTER PHYSICS

903
00:39:16,700 --> 00:39:18,600
TO TRY AN UNDERSTAND, YOU KNOW,

904
00:39:18,600 --> 00:39:22,233
"CAN WE DEVELOP SOMETHING
THAT WITHIN 25 TO 30 WATTS

905
00:39:22,233 --> 00:39:25,333
"CAN GENERATE FORCES

906
00:39:25,333 --> 00:39:29,466
THAT WE CAN CLEARLY SEE
ON THE TORSION PENDULUM?"

907
00:39:29,466 --> 00:39:31,200
SO IN THE PROCESS
OF DOING THAT,

908
00:39:31,200 --> 00:39:32,900
WHEN YOU DEAL
WITH A TAPERED SYSTEM,

909
00:39:32,900 --> 00:39:34,066
THERE'S A LOT OF DIFFERENT MODES

910
00:39:34,066 --> 00:39:36,266
THAT YOU CAN EXHIBIT
IN A TAPERED SYSTEM,

911

00:39:36,266 --> 00:39:39,766
SO WE USED COMSOL
TO GENERATE

912
00:39:39,766 --> 00:39:43,633
ALL THE PREDICTED
NETWORK PARAMETERS

913
00:39:43,633 --> 00:39:45,166
WHEN WE USE A VECTOR
NETWORK ANALYZER

914
00:39:45,166 --> 00:39:48,066
TO GO THROUGH AND TAKE A LOOK
AT THE AS-BUILT SYSTEM

915
00:39:48,066 --> 00:39:50,533
AND COMPARE IT
TO THE THEORETICAL SYSTEM

916
00:39:50,533 --> 00:39:52,833
TO MAKE SURE WE'RE EXCITING
THE PARTICULAR MODES

917
00:39:52,833 --> 00:39:53,933
THAT WE WANT TO EXCITE.

918
00:39:53,933 --> 00:39:56,233
AND SO YOU SEE A SNAPSHOT
OF THE ANALYSIS

919
00:39:56,233 --> 00:39:59,566
COMPARED TO THE OUTPUT FROM
THE VECTOR NETWORK ANALYZER.

920
00:39:59,566 --> 00:40:06,066
THE ONE THING I WILL HIGHLIGHT
IS, THESE TYPES OF SITUATIONS

921
00:40:06,066 --> 00:40:08,200

ARE A LITTLE PROBLEMATIC
FROM A TUNING PERSPECTIVE.

922
00:40:08,200 --> 00:40:11,466
THAT'S WHERE YOU HAVE
POTENTIALLY TWO MODES

923
00:40:11,466 --> 00:40:13,300
IN VERY CLOSE PROXIMITY
TO ONE ANOTHER.

924
00:40:13,300 --> 00:40:15,766
AND SO, IF YOU TRY AND COUPLE
TO ONE OF THOSE TWO MODES,

925
00:40:15,766 --> 00:40:17,666
IT CAN MAKE TUNING
A LITTLE DIFFICULT,

926
00:40:17,666 --> 00:40:19,633
AND YOU CAN BOUNCE
BACK AND FORTH BETWEEN MODES,

927
00:40:19,633 --> 00:40:21,766
AND THAT CAN BE
A LITTLE CHALLENGING

928
00:40:21,766 --> 00:40:25,300
WHEN YOU'RE TRYING
TO GATHER DATA.

929
00:40:25,300 --> 00:40:28,300
THIS SHOWS THE TEST ARTICLE
LOADED ON THE TORSION PENDULUM.

930
00:40:28,300 --> 00:40:32,100
ON THE BOTTOM LEFT THERE,
YOU SEE THE TEST ARTICLE.

931
00:40:32,100 --> 00:40:35,466

THE RF AMPLIFIER
IS ON THE FAR RIGHT.

932
00:40:35,466 --> 00:40:38,366
IT'S GOT--IT GOES
TO THE DUAL-DIRECTIONAL COUPLER,

933
00:40:38,366 --> 00:40:39,633
WHERE WE MEASURE
THE POWER FORWARD

934
00:40:39,633 --> 00:40:41,200
AND POWER REFLECTED.

935
00:40:41,200 --> 00:40:42,966
IT GOES THROUGH
SOME SHIELDED CABLING

936
00:40:42,966 --> 00:40:44,800
INTO THE TEST ARTICLE.

937
00:40:44,800 --> 00:40:49,466
WE DID GO THROUGH AND MEASURE
ALL OF THE LEAKING RF FIELDS.

938
00:40:49,466 --> 00:40:52,066
THE SYSTEM WAS VERY RF QUIET.

939
00:40:52,066 --> 00:40:53,433
ALL THE LEAKING FIELDS WERE LESS

940
00:40:53,433 --> 00:40:57,300
THAN WHAT A CELL PHONE
WOULD PUT OUT.

941
00:40:57,300 --> 00:41:00,866
SO WE HAD A VERY CLEAN
RF SYSTEM.

942

00:41:05,133 --> 00:41:06,433
LET'S GO INTO THE DATA.

943
00:41:06,433 --> 00:41:09,333
I THINK I'M RUNNING
A LITTLE LOW ON TIME HERE.

944
00:41:09,333 --> 00:41:14,200
THIS SHOWS US TESTING
AT THE TE012 MODE.

945
00:41:14,200 --> 00:41:19,000
USING THE COMSOL ANALYSIS,

946
00:41:19,000 --> 00:41:22,600
IT PREDICTED FOR--

947
00:41:22,600 --> 00:41:26,466
IT PREDICTED A QUALITY FACTOR
OF 22,000--

948
00:41:26,466 --> 00:41:31,566
OR 21,800 COMPARED
TO THE 22,000 OBSERVED.

949
00:41:31,566 --> 00:41:33,800
WE WERE ABLE TO GET
ABOUT 2.6 WATTS OF POWER

950
00:41:33,800 --> 00:41:36,766
INTO THE TEST ARTICLE
IN THIS CONFIGURATION.

951
00:41:36,766 --> 00:41:41,300
WITH THE COMSOL ANALYSIS
OF THE Q-THRUSTER PHYSICS,

952
00:41:41,300 --> 00:41:46,400
IT PREDICTED A THRUST MAGNITUDE
OF ABOUT 50 MICRONEWTONS.

953
00:41:46,400 --> 00:41:49,066
WE MEASURED
JUST A LITTLE OVER 55.

954
00:41:49,066 --> 00:41:52,833
YOU SEE A THRUST RUN
UP THERE IN THE INSET

955
00:41:52,833 --> 00:41:57,100
WITH A CALIBRATION PULSE,
ENERGIZING THE THRUSTER,

956
00:41:57,100 --> 00:41:58,933
AND THEN ANOTHER
CALIBRATION PULSE.

957
00:41:58,933 --> 00:42:02,033
THEN YOU SEE THE COMSOL ANALYSIS
OF THE FIELD CONDITIONS

958
00:42:02,033 --> 00:42:03,133
ON THE TOP RIGHT,

959
00:42:03,133 --> 00:42:04,133
AND THEN, AGAIN,

960
00:42:04,133 --> 00:42:05,200
ANOTHER PICTURE
OF THE TEST ARTICLE

961
00:42:05,200 --> 00:42:09,100
ON THE TORSION PENDULUM,
END ON.

962
00:42:09,100 --> 00:42:11,233
THE TE012 MODE HAD--

963
00:42:11,233 --> 00:42:12,900

IT WAS IN ONE OF THOSE AREAS

964
00:42:12,900 --> 00:42:16,666
WHERE WE HAD ANOTHER MODE
IN VERY CLOSE PROXIMITY,

965
00:42:16,666 --> 00:42:18,633
SO THAT MADE OPERATION MODE
DIFFICULT.

966
00:42:18,633 --> 00:42:21,000
SO WE SWITCHED
TO THE TM211 MODE.

967
00:42:21,000 --> 00:42:22,133
THERE'S ACTUALLY TWO OF THEM

968
00:42:22,133 --> 00:42:25,300
ABOUT A FEW MEGAHERTZ
FROM ONE ANOTHER.

969
00:42:25,300 --> 00:42:27,866
AND SO WE INVESTIGATED
THE TM211 MODE,

970
00:42:27,866 --> 00:42:29,866
THE FIRST ONE
AND THE SECOND ONE.

971
00:42:29,866 --> 00:42:33,133
FOR THE FIRST MODE,

972
00:42:33,133 --> 00:42:37,033
THE AS-TESTED QUALITY FACTOR
WAS JUST A LITTLE OVER 7,000.

973
00:42:37,033 --> 00:42:38,866
WE WERE ABLE TO GET
A LITTLE BIT MORE POWER

974
00:42:38,866 --> 00:42:43,100
INTO THE TEST ARTICLE,
JUST ABOUT 17 WATTS.

975
00:42:43,100 --> 00:42:45,433
THE PEAK THRUST THAT WE OBSERVED
WAS A LITTLE HIGHER,

976
00:42:45,433 --> 00:42:47,566
116 MICRONEWTONS.

977
00:42:47,566 --> 00:42:51,133
THE AVERAGE THRUST
WAS ABOUT 91 MICRONEWTONS.

978
00:42:51,133 --> 00:42:53,466
WHEN WE DID THE NULL FORCE TEST,

979
00:42:53,466 --> 00:42:58,933
WE MEASURED A 9.6 MICRONEWTON
NULL FORCE.

980
00:42:58,933 --> 00:43:01,100
THAT'S, AGAIN,
WITH THAT RF LOAD BRICK

981
00:43:01,100 --> 00:43:05,600
THAT WE SHOWED YOU
WITH THE CANNAE TEST ARTICLE.

982
00:43:05,600 --> 00:43:07,233
THE COMSOL ANALYSIS PREDICTED

983
00:43:07,233 --> 00:43:10,800
A QUALITY FACTOR
OF JUST A LITTLE UNDER 8,000.

984
00:43:10,800 --> 00:43:13,666
AND WITH AN INPUT POWER

OF 17 WATTS,

985
00:43:13,666 --> 00:43:17,833
IT PREDICTED AN OBSERVED THRUST
OF 313 MICRONEWTONS.

986
00:43:17,833 --> 00:43:20,300
SO WE WERE A LITTLE OFF
BY ABOUT A FACTOR OF THREE

987
00:43:20,300 --> 00:43:23,700
WITH THAT PARTICULAR MODE.

988
00:43:23,700 --> 00:43:25,766
AND THIS GOES THROUGH AND SHOWS
SOME OF THE DATA RUNS

989
00:43:25,766 --> 00:43:27,766
FOR THE TM211 MODE.

990
00:43:27,766 --> 00:43:29,600
YOU SEE THE CALIBRATION PULSE,

991
00:43:29,600 --> 00:43:32,566
AND THEN TURNING
THE RF AMPLIFIER ON,

992
00:43:32,566 --> 00:43:35,133
DOING A LITTLE BIT
OF MANUAL TUNING.

993
00:43:35,133 --> 00:43:36,433
YOU CAN ALSO SEE,

994
00:43:36,433 --> 00:43:37,800
WHEN YOU'RE GETTING
INTO THE 100 MICRONEWTONS,

995
00:43:37,800 --> 00:43:40,033

IT'S--IN COMPARISON
TO THE CALIBRATION PULSE,

996
00:43:40,033 --> 00:43:45,000
IT'S STARTING TO BE
PRETTY LARGE.

997
00:43:45,000 --> 00:43:46,400
THIS SHOWS THE NULL TEST,

998
00:43:46,400 --> 00:43:49,400
PUTTING THE RF LOAD ON THERE,

999
00:43:49,400 --> 00:43:51,966
JUST TO GO THROUGH AND SEE
WHAT TYPE OF SYSTEMIC SOURCES

1000
00:43:51,966 --> 00:43:53,833
OR AIR WE MIGHT HAVE,

1001
00:43:53,833 --> 00:43:55,666
AND SO THAT GOES THROUGH
AND SHOWS YOU

1002
00:43:55,666 --> 00:43:59,766
THAT JUST A LITTLE OVER
9 MICRONEWTONS OF FORCE

1003
00:43:59,766 --> 00:44:01,466
IS A RESULT OF THE--

1004
00:44:01,466 --> 00:44:08,400
MAY BE TIED TO THE 5.6 AMPS
THAT WENT TO THE RF AMPLIFIER.

1005
00:44:08,400 --> 00:44:12,000
WE ALSO TESTED
AT THE SECOND TM211 MODE.

1006

00:44:12,000 --> 00:44:14,866
THIS ONE WAS A BETTER RF MODE,

1007
00:44:14,866 --> 00:44:18,166
BUT IT WAS A LESS CAPABLE
Q-THRUSTER MODE

1008
00:44:18,166 --> 00:44:21,433
BASED ON THE ANALYSIS
AND WHAT WE SAW WITH THE DATA.

1009
00:44:21,433 --> 00:44:25,500
SO THE AS-TESTED QUALITY FACTOR
WAS 18,100,

1010
00:44:25,500 --> 00:44:30,100
VERSUS THE ABOUT 8,000
FOR THE PREVIOUS TM211 MODE.

1011
00:44:30,100 --> 00:44:32,333
ABOUT THE SAME POWER LEVEL.

1012
00:44:32,333 --> 00:44:33,866
THE NET AVERAGE STRESS
WE PICKED UP

1013
00:44:33,866 --> 00:44:39,166
WITH THIS PARTICULAR MODE
WAS JUST ABOUT 50 MICRONEWTONS.

1014
00:44:39,166 --> 00:44:41,233
AND THE COMSOL ANALYSIS
FOR THE TM211

1015
00:44:41,233 --> 00:44:43,500
DOES PREDICT
IT IS A BETTER RF SYSTEM,

1016
00:44:43,500 --> 00:44:46,400
AT 32,000 QUALITY FACTOR.

1017
00:44:46,400 --> 00:44:50,533
AND WITH AN INPUT POWER OF 16,
JUST A LITTLE UNDER 17 WATTS,

1018
00:44:50,533 --> 00:44:52,933
CORRECTING FOR THE DIFFERENCE
IN THE AS-BUILT QUALITY FACTOR

1019
00:44:52,933 --> 00:44:54,766
VERSUS A THEORETICAL,

1020
00:44:54,766 --> 00:44:57,866
WE'RE PREDICTING A THRUST
OF AROUND 47 MICRONEWTONS.

1021
00:45:01,166 --> 00:45:03,033
SO, WHAT WE FOUND FROM THIS

1022
00:45:03,033 --> 00:45:07,233
IS THAT THERE DOES SEEM TO BE
TWO DIFFERENT SETS

1023
00:45:07,233 --> 00:45:11,300
OF OPTIMIZATION DIALS WE HAVE
TO TRY AND FURTHER EXPLORE.

1024
00:45:11,300 --> 00:45:14,466
ONE HAS TO DO
WITH RF OPTIMIZATION,

1025
00:45:14,466 --> 00:45:16,233
AND THE OTHER HAS TO DO
WITH THE Q-THRUSTER PHYSICS.

1026
00:45:16,233 --> 00:45:22,200
AND THEY DON'T NECESSARILY
HAVE THE SAME DEPENDENCIES.

1027

00:45:22,200 --> 00:45:24,400
WE DID FIND
THAT HAVING A DIELECTRIC

1028
00:45:24,400 --> 00:45:26,866
IN THE TAPERED PORTION
OF THE THRUSTER

1029
00:45:26,866 --> 00:45:29,933
WAS EXTREMELY IMPORTANT
ON THE MAGNITUDE OF THE THRUST.

1030
00:45:29,933 --> 00:45:31,800
WE SAW THAT BOTH
IN THE ANALYSIS

1031
00:45:31,800 --> 00:45:34,100
AND IN THE TEST,

1032
00:45:34,100 --> 00:45:37,033
BECAUSE WE DID TEST
THE TE012 MODE

1033
00:45:37,033 --> 00:45:40,466
WITH NO DIELECTRIC PRESENCE
IN THE THRUSTER,

1034
00:45:40,466 --> 00:45:41,933
AND IT DIDN'T GENERATE--

1035
00:45:41,933 --> 00:45:44,966
IT DID NOT GENERATE ANY FORCE
TO WITHIN THE RESOLUTION LEVEL

1036
00:45:44,966 --> 00:45:48,033
OF THE TORSION PENDULUM
UP TO 30 WATTS,

1037
00:45:48,033 --> 00:45:52,833
WHICH ALSO MATCHED

THE PREDICTED PERFORMANCE.

1038
00:45:56,300 --> 00:46:01,933
NOW, THE NPU WORK THAT WAS DONE
HERE IN THE LAST YEAR,

1039
00:46:01,933 --> 00:46:03,400
THEY PUBLISHED SOME RESULTS.

1040
00:46:03,400 --> 00:46:05,633
THEY'VE WORKED IN MUCH HIGHER
POWER LEVELS THAN WE HAVE.

1041
00:46:05,633 --> 00:46:08,333
I THINK WE'D LIKE TO CONTINUE
TO WORK IN THE LOW POWER.

1042
00:46:08,333 --> 00:46:10,100
OUR TORSION PENDULUM
REALLY HELPS US

1043
00:46:10,100 --> 00:46:12,766
KIND OF EXPLORE THE BASICS.

1044
00:46:12,766 --> 00:46:16,700
BUT THEY DID EXPLORE 80 WATTS
UP TO 2 1/2 KILOWATTS,

1045
00:46:16,700 --> 00:46:18,333
CONSIDERABLY MORE FORCE,

1046
00:46:18,333 --> 00:46:21,166
UP TO THE HUNDREDS OF MILLIONS,

1047
00:46:21,166 --> 00:46:23,700
WITH A THRUST TO POWER
THAT WAS A LITTLE BIT HIGHER

1048
00:46:23,700 --> 00:46:25,866

THAN ANYTHING WE'VE WORKED WITH,

1049
00:46:25,866 --> 00:46:27,900
UP TO 1 NEWTON PER KILOWATT.

1050
00:46:27,900 --> 00:46:31,833
THEY USED AN INVERTED
PENDULUM THRUST STAND,

1051
00:46:31,833 --> 00:46:33,266
KIND OF A STANDARD
DESIGN APPROACH

1052
00:46:33,266 --> 00:46:35,000
WHERE IT USES NULL DISPLACEMENT.

1053
00:46:35,000 --> 00:46:38,666
SO YOU SEE THE--

1054
00:46:38,666 --> 00:46:41,233
THIS IS THE INVERTED PENDULUM
THRUST STAND RIGHT HERE,

1055
00:46:41,233 --> 00:46:43,666
AND IT USES THESE COILS
TO HOLD THE INVERTED PENDULUM

1056
00:46:43,666 --> 00:46:45,033
AT THE ZERO DISPLACEMENT

1057
00:46:45,033 --> 00:46:48,100
BASED ON THE FEEDBACK
FROM THIS SENSOR SYSTEM,

1058
00:46:48,100 --> 00:46:49,300
AND THAT'S HOW THEY GO THROUGH

1059
00:46:49,300 --> 00:46:51,433
AND MEASURE

AND CHARACTERIZE FORCE.

1060
00:46:51,433 --> 00:46:54,433
IN THIS CASE,
THIS IS THE TEST ARTICLE.

1061
00:46:54,433 --> 00:46:57,366
THE MICROWAVE
WOULD BE DOWN HERE.

1062
00:46:57,366 --> 00:46:59,800
IT WOULD COME IN
THROUGH A CIRCULATOR.

1063
00:46:59,800 --> 00:47:03,200
THIS IS A LOAD OVER HERE,

1064
00:47:03,200 --> 00:47:07,600
AND THEN IT WOULD GO UP HERE
AND ENERGIZE A SYSTEM.

1065
00:47:07,600 --> 00:47:09,200
AND THIS GOES TO AND SHOWS
THEIR WORK THEY DID

1066
00:47:09,200 --> 00:47:14,566
WITH THE 80 TO 1.2 KILOWATTS.

1067
00:47:14,566 --> 00:47:18,133
AND THEY'VE GOT
UP TO 0.9 NEWTONS PER KILOWATT,

1068
00:47:18,133 --> 00:47:21,766
AND THEN THEY ALSO DID WORK
WITH ANOTHER MAGNETRON DESIGN

1069
00:47:21,766 --> 00:47:24,066
THAT WENT UP TO 2 1/2 KILOWATTS.

1070

00:47:24,066 --> 00:47:26,700
AND, AGAIN, THEY SAW
CONSIDERABLY HIGHER FORCES

1071
00:47:26,700 --> 00:47:28,333
THAN ANYTHING WE'VE LOOKED AT.

1072
00:47:28,333 --> 00:47:31,700
AGAIN, WE'RE CONTENT TO WORK
AT THE LOW POWER FOR NOW.

1073
00:47:31,700 --> 00:47:34,400
IN TERMS
OF THE VALUE PROPOSITION

1074
00:47:34,400 --> 00:47:38,233
WITH SOME OF THE EXPERIENCE
WE'VE SEEN WITH THESE THINGS,

1075
00:47:38,233 --> 00:47:39,366
A LOT OF PEOPLE
ALWAYS WANT TO KNOW,

1076
00:47:39,366 --> 00:47:40,566
"THIS IS INTERESTING AND FINE,

1077
00:47:40,566 --> 00:47:42,000
"BUT WHAT DOES IT LOOK LIKE

1078
00:47:42,000 --> 00:47:45,400
IF YOU TRY AND APPLY IT
TO AN APPLICATION?"

1079
00:47:45,400 --> 00:47:47,966
AND SO, IF YOU'VE GOT A SYSTEM
THAT'S CAPABLE

1080
00:47:47,966 --> 00:47:50,933
OF GENERATING 0.4 NEWTONS
PER KILOWATT,

1081
00:47:50,933 --> 00:47:54,266
IT'S CERTAINLY NOT GONNA
LIFT ITSELF OFF THE GROUND,

1082
00:47:54,266 --> 00:47:58,100
BUT IT IS POTENTIALLY A USEFUL
IN-SPACE PROPULSION SYSTEM.

1083
00:47:58,100 --> 00:48:00,500
AND SO WE LOOKED AT WHAT HAPPENS

1084
00:48:00,500 --> 00:48:03,233
IF YOU HAVE 0.4 NEWTONS
PER KILOWATT

1085
00:48:03,233 --> 00:48:04,666
WITH SOME TYPE OF A STACK

1086
00:48:04,666 --> 00:48:07,333
THAT'S IN A DISTANT RETROGRADE
ORBIT AROUND THE MOON.

1087
00:48:07,333 --> 00:48:10,600
SO THIS IS KIND OF LINKING BACK
TO THE ASTEROID MISSION.

1088
00:48:10,600 --> 00:48:12,066
AND SO YOU'VE GOT
SOME STACKED MASS

1089
00:48:12,066 --> 00:48:16,100
THAT'S ABOUT THE RIGHT MASS
FOR SOME TYPE OF AGGREGATE

1090
00:48:16,100 --> 00:48:21,233
OF MODULES THAT WE MIGHT USE
IN HUMAN SPACE FLIGHT.

1091

00:48:21,233 --> 00:48:23,733
BUT WE'RE CONSTRAINED
WITH ONLY 300 KILOWATTS

1092
00:48:23,733 --> 00:48:25,100
OF SOLAR POWER.

1093
00:48:25,100 --> 00:48:27,833
SO, IN TERMS OF THE THINGS
THAT WE HAVE ON THE HORIZON,

1094
00:48:27,833 --> 00:48:31,400
THAT'S ONE OF THE CONSTRAINTS
THAT WE HAVE TO REALLY SALUTE.

1095
00:48:31,400 --> 00:48:34,166
WE'RE NOT GONNA BE GIVEN
VERY BIG ARRAYS

1096
00:48:34,166 --> 00:48:37,200
THAT HAVE HUGE VALUES
ASSOCIATED WITH THEM.

1097
00:48:37,200 --> 00:48:40,266
300 KILOWATTS IS
A VERY REALISTIC CONSTRAINT

1098
00:48:40,266 --> 00:48:42,000
THAT WE NEED
TO TRY AND WORK WITH

1099
00:48:42,000 --> 00:48:44,833
AND TRY TO DO THE MOST WE CAN
WITH WHAT WE'VE GOT.

1100
00:48:44,833 --> 00:48:47,133
SO, IN THIS CASE,
WITH A 70-TON STACK

1101
00:48:47,133 --> 00:48:49,600

DEPARTING FROM
A DISTANT RETROGRADE ORBIT

1102
00:48:49,600 --> 00:48:52,266
WITH 300 KILOWATTS
OF SOLAR POWER,

1103
00:48:52,266 --> 00:48:56,866
WE CAN GO TO A 50-DAY MISSION
AROUND DEIMOS

1104
00:48:56,866 --> 00:49:01,000
AND GET BACK TO EARTH
IN 788 DAYS.

1105
00:49:01,000 --> 00:49:02,600
THE OTHER THING WE DID WAS,
WE CONSTRAINED IT

1106
00:49:02,600 --> 00:49:06,666
SO THAT YOU WOULD NOT GO
IN VENUS' ORBIT.

1107
00:49:06,666 --> 00:49:10,300
AND SO, IN ORDER TO KIND OF
MATCH THE PLANETARY BILLIARDS,

1108
00:49:10,300 --> 00:49:13,533
THE SPACECRAFT SWINGS OUT
TO 2 A.U.

1109
00:49:13,533 --> 00:49:15,466
TO TRY AND WAIT FOR EARTH

1110
00:49:15,466 --> 00:49:18,766
TO GET INTO
A MORE FAVORABLE ALIGNMENT,

1111
00:49:18,766 --> 00:49:20,533
KIND OF LIKE

A HIGH YO-YO MANEUVER,

1112
00:49:20,533 --> 00:49:24,100
FOR THE PILOTS
THE THAT ARE IN THE GROUP.

1113
00:49:24,100 --> 00:49:25,566
NOW, IF WE EVER DID
HAVE SOME TYPE

1114
00:49:25,566 --> 00:49:28,600
OF A CONSISTENT POWER SOURCE

1115
00:49:28,600 --> 00:49:32,700
THAT WERE UP TO
A COUPLE OF MEGAWATTS--

1116
00:49:32,700 --> 00:49:34,400
I LOOKED AT,

1117
00:49:34,400 --> 00:49:37,166
"WHAT COULD YOU DO
WITH 0.4 NEWTONS PER KILOWATT

1118
00:49:37,166 --> 00:49:40,533
WITH 2 MEGAWATTS OF POWER
FOR A 90-TON SPACECRAFT?"

1119
00:49:40,533 --> 00:49:42,866
OUT OF THAT,
50 TONS WOULD BE CARGO.

1120
00:49:42,866 --> 00:49:45,966
20 TONS WOULD BE ALLOCATED
TO THE NUCLEAR REACTOR,

1121
00:49:45,966 --> 00:49:48,500
SO THAT'S ABOUT 10 KILOGRAMS
PER KILOWATT.

1122
00:49:48,500 --> 00:49:49,733
FOR FOLKS THAT ARE FAMILIAR

1123
00:49:49,733 --> 00:49:51,833
WITH REACTORS WE'VE LOOKED AT
IN THE PAST,

1124
00:49:51,833 --> 00:49:53,400
WE'RE NOT TRYING
TO BE OVERLY AGGRESSIVE

1125
00:49:53,400 --> 00:49:55,366
IN TERMS OF WHAT
THE REACTOR WOULD HAVE TO BE

1126
00:49:55,366 --> 00:49:57,600
IN TERMS OF THE SPECIFIC MASS.

1127
00:49:57,600 --> 00:49:59,766
AND THEN 10 KILOGRAMS
PER KILOWATT FOR THE Q-THRUSTER.

1128
00:49:59,766 --> 00:50:01,233
SO THAT'S ABOUT TWICE
WHAT YOU'D DO

1129
00:50:01,233 --> 00:50:02,666
FOR A HALL THRUSTER,

1130
00:50:02,666 --> 00:50:05,833
SO WE TRIED TO BE
JUST A LITTLE SLOPPY WITH THAT.

1131
00:50:05,833 --> 00:50:07,800
YOU GET A LITTLE BIT DIFFERENT
LOOK AND FEEL

1132
00:50:07,800 --> 00:50:09,333
THAN WHAT WE SAW

IN THE PREVIOUS SLIDE.

1133
00:50:09,333 --> 00:50:10,500
THE PREVIOUS SLIDE LOOKS MORE

1134
00:50:10,500 --> 00:50:13,266
LIKE A TRADITIONAL
LOW-THRUST MISSION.

1135
00:50:13,266 --> 00:50:16,333
BUT WHAT HAPPENS HERE
IS THAT THE THRUST-TO-MASS

1136
00:50:16,333 --> 00:50:17,766
FOR THE SPACECRAFT

1137
00:50:17,766 --> 00:50:21,600
ACTUALLY BREAKS 0.6 MILLI-Gs.

1138
00:50:21,600 --> 00:50:25,533
SO WHEN YOU'RE IN HELIOCENTRIC
SPACE AT 1 A.U.,

1139
00:50:25,533 --> 00:50:28,633
0.6 MILLI-Gs IS THE ATTRACTION
TO THE SUN,

1140
00:50:28,633 --> 00:50:32,000
SO WHAT HAPPENS IF YOU HAVE
ANY SPACECRAFT OF ANY KIND

1141
00:50:32,000 --> 00:50:34,166
WITH POWER
AND ELECTRIC PROPULSION,

1142
00:50:34,166 --> 00:50:37,300
IF IT CAN EXCEED
THAT 0.6 MILLI-Gs,

1143

00:50:37,300 --> 00:50:39,466
THEN YOU MIGHT BE ABLE TO DO
INTERESTING THINGS LIKE THAT.

1144
00:50:39,466 --> 00:50:40,866
SO, INDEPENDENT
OF THE Q-THRUSTERS,

1145
00:50:40,866 --> 00:50:42,100
THAT'S JUST
AN INTERESTING METRIC

1146
00:50:42,100 --> 00:50:44,600
THAT WE FOUND IN THE PROCESS
OF EXPLORING THAT.

1147
00:50:44,600 --> 00:50:47,200
I THINK I'M RUNNING
REALLY LOW ON TIME,

1148
00:50:47,200 --> 00:50:50,000
SO LET ME JUST POP THROUGH
TO THE PLAN FORWARD.

1149
00:50:50,000 --> 00:50:52,666
SO, MOVING FORWARD,
WE WANT TO IMPLEMENT

1150
00:50:52,666 --> 00:50:55,933
A PHASE LOCK LOOP
THAT PREVENTS US--

1151
00:50:55,933 --> 00:50:58,933
THAT PRECLUDES US
FROM HAVING TO DO MANUAL TUNING.

1152
00:50:58,933 --> 00:51:02,900
WE CAN BASICALLY HAVE ALMOST
LIGHT SWITCH-LIKE RELIABILITY.

1153

00:51:02,900 --> 00:51:05,166
WE WANT TO BE ABLE TO GATHER
A CONSIDERABLE MORE--

1154
00:51:05,166 --> 00:51:09,166
A LARGER AMOUNT OF DATA OVER
MULTIPLE OPERATING CONDITIONS.

1155
00:51:09,166 --> 00:51:10,933
WE WANT TO DO
SOME POWER SCANNING.

1156
00:51:10,933 --> 00:51:14,533
WE WANT TO CONTINUE TO EVALUATE
SOME DIFFERENT RF MODES

1157
00:51:14,533 --> 00:51:18,033
AND EXPLORE SOME DIFFERENT
ANTENNA CONFIGURATIONS.

1158
00:51:18,033 --> 00:51:19,633
AND THEN THE TEST SYSTEM
THAT WE HAVE NOW,

1159
00:51:19,633 --> 00:51:22,133
THE AMPLIFIER THAT WE PROCURED

1160
00:51:22,133 --> 00:51:23,866
HAS THE ABILITY TO BE TESTED
AT VACUUM,

1161
00:51:23,866 --> 00:51:26,800
AND SO THAT'S OUR NEXT STEP.

1162
00:51:26,800 --> 00:51:32,066
THEN, INSTEAD OF DOING
A TEST WITH AN RF DUMMY LOAD,

1163
00:51:32,066 --> 00:51:33,633
WE WANT TO PERFORM

FUTURE NULL TESTS

1164
00:51:33,633 --> 00:51:37,266
WITH THE THRUSTER
ACTUALLY ROTATED ORTHOGONAL

1165
00:51:37,266 --> 00:51:38,533
TO THE THRUST EXIT.

1166
00:51:38,533 --> 00:51:41,133
SO WE WANT TO LEAVE THE THRUSTER
ON THE TORSION PENDULUM,

1167
00:51:41,133 --> 00:51:43,100
TEST IN ONE DIRECTION,
THE OTHER DIRECTION,

1168
00:51:43,100 --> 00:51:45,200
AND THEN ROTATE IT
WHERE IT'S ORTHOGONAL

1169
00:51:45,200 --> 00:51:47,100
TO THE THRUST VECTOR.

1170
00:51:47,100 --> 00:51:49,233
AND THEN, ONCE WE'VE POUNDED
ALL THAT FLAT, UH,

1171
00:51:49,233 --> 00:51:51,133
WE'VE BEEN TALKING
WITH GLENN RESEARCH CENTER

1172
00:51:51,133 --> 00:51:54,200
ABOUT DOING SOME INDEPENDENT
VERIFICATION AND VALIDATION

1173
00:51:54,200 --> 00:51:55,500
IN THEIR VACUUM CHAMBER.

1174

00:51:55,500 --> 00:51:57,500
THEY HAVE A LOW-THRUST
TORSION PENDULUM

1175
00:51:57,500 --> 00:52:01,033
THAT WE CAN UTILIZE
TO GO THROUGH AND EXPLORE

1176
00:52:01,033 --> 00:52:03,166
WHAT IT DOES IN THAT FACILITY.

1177
00:52:03,166 --> 00:52:04,633
AND JOHNS HOPKINS
HAS ALSO TALKED

1178
00:52:04,633 --> 00:52:07,366
ABOUT DOING SOME TYPE
OF CAVENDISH BALANCE TEST

1179
00:52:07,366 --> 00:52:09,400
WITH THE IV&V SHIPSET.

1180
00:52:09,400 --> 00:52:11,666
SO I THINK WITH THAT,

1181
00:52:11,666 --> 00:52:13,766
I'M JUST ABOUT ALMOST
UP TO MY TIME.

1182
00:52:13,766 --> 00:52:15,833
SO I'LL HAND IT OVER
TO QUESTIONS.

1183
00:52:15,833 --> 00:52:18,833
[applause]

1184
00:52:23,700 --> 00:52:26,733
- OKAY, QUESTIONS, EVERYBODY.

1185

00:52:26,733 --> 00:52:28,133
- THANK YOU FOR COMING HERE.

1186
00:52:28,133 --> 00:52:29,566
- YES, SIR.

1187
00:52:29,566 --> 00:52:31,766
- I HAVE A HYPOTHETICAL FOR YOU.

1188
00:52:31,766 --> 00:52:34,133
IF YOU HAD AN UNLIMITED BUDGET

1189
00:52:34,133 --> 00:52:38,000
AND A MISSION TO GET YOURSELF
TO ALPHA CENTAURI

1190
00:52:38,000 --> 00:52:42,233
AND HAD TO CHOOSE BETWEEN
AN ALCUBIERRE TYPE WARP DRIVE

1191
00:52:42,233 --> 00:52:45,066
AND AN ANTIMATTER DRIVE--

1192
00:52:45,066 --> 00:52:47,066
IT WOULD BE, OF COURSE,
SUBLUMINAL--

1193
00:52:47,066 --> 00:52:51,233
WHICH WOULD YOU THINK WOULD BE
THE MORE PRACTICAL CHOICE?

1194
00:52:53,400 --> 00:52:55,700
- THAT'S A GREAT QUESTION.

1195
00:52:55,700 --> 00:52:57,933
I WOULD--I'M GONNA ANSWER
YOUR QUESTION.

1196
00:52:57,933 --> 00:52:59,233

I'M NOT GONNA PICK A HORSE.

1197
00:52:59,233 --> 00:53:01,800
I WOULD PROBABLY DO BOTH,
FROM THE STANDPOINT--

1198
00:53:01,800 --> 00:53:05,166
IF I HAD THE UNLIMITED BUDGET
THAT YOU'RE TALKING ABOUT,

1199
00:53:05,166 --> 00:53:07,333
I WOULD LIKE TO HAVE
MULTIPLE PATHS

1200
00:53:07,333 --> 00:53:09,200
TO MAYBE GREATER--

1201
00:53:09,200 --> 00:53:11,133
OR EXCUSE ME--INCREASE
THE LIKELIHOOD OF SUCCESS.

1202
00:53:11,133 --> 00:53:13,166
- OKAY, LET ME FRAME IT;
YOU ONLY GET TO PICK ONE.

1203
00:53:13,166 --> 00:53:16,000
- I ONLY GET--OH, I ONLY
GET TO PICK ONE.

1204
00:53:16,000 --> 00:53:18,200
I DON'T KNOW THAT I'M
PREPARED TO ANSWER THAT.

1205
00:53:18,200 --> 00:53:19,633
IF YOU HAVE AN UNLIMITED BUDGET

1206
00:53:19,633 --> 00:53:20,866
AND YOU WANT TO COME BACK
AND TELL ME,

1207
00:53:20,866 --> 00:53:24,266
THEN I'LL MAKE A DECISION,
RIGHT?

1208
00:53:24,266 --> 00:53:25,333
YES.

1209
00:53:25,333 --> 00:53:27,200
I GUESS--OH, YEAH.

1210
00:53:27,200 --> 00:53:28,633
- THANK YOU.

1211
00:53:28,633 --> 00:53:30,200
MAYBE I MISSED IT.

1212
00:53:30,200 --> 00:53:32,266
WHAT EXACTLY PHYSICAL PHENOMENON

1213
00:53:32,266 --> 00:53:34,766
ARE YOU MEASURING
IN THESE FEW INTERFEROMETERS,

1214
00:53:34,766 --> 00:53:39,266
AND WHAT RESULTS WOULD YOU
CONSIDER POSITIVE OR NEGATIVE?

1215
00:53:39,266 --> 00:53:42,133
SO COULD YOU EXPLAIN THIS
A LITTLE BIT?

1216
00:53:42,133 --> 00:53:44,266
- YOU'RE ASKING, WHAT ARE WE
TRYING TO MEASURE--

1217
00:53:44,266 --> 00:53:46,533
- THESE INTERFEROMETERS...

1218

00:53:46,533 --> 00:53:47,700
- YEAH, AN INTERFEROMETER.

1219
00:53:47,700 --> 00:53:48,933
- YEAH.

1220
00:53:48,933 --> 00:53:50,666
- WE'RE TRYING TO CHANGE
THE OPTICAL PATH LENGTH

1221
00:53:50,666 --> 00:53:53,733
IN A VERY SMALL REGION
OF THE INTERFEROMETER

1222
00:53:53,733 --> 00:53:55,900
BY HAVING
THE APPROPRIATE CONDITIONS

1223
00:53:55,900 --> 00:53:58,233
WITH WHAT THE GENERAL
RELATIVITY REQUIRES,

1224
00:53:58,233 --> 00:54:00,100
AND THEN IT SAYS,
IN A LOCAL REGION,

1225
00:54:00,100 --> 00:54:01,666
IT'LL CHANGE
THE PERCEIVED PATH LENGTH

1226
00:54:01,666 --> 00:54:04,866
FOR THE PHOTON LINE INTEGRALS.

1227
00:54:04,866 --> 00:54:06,666
SO THEN THAT'LL MANIFEST ITSELF

1228
00:54:06,666 --> 00:54:09,166
IN THE FORM OF A SLIGHT CHANGE
OF THE INTERFERENCE PATTERN.

1229
00:54:09,166 --> 00:54:10,800
I MEAN, NOT SOMETHING YOU'RE
GONNA SEE WITH THE NAKED EYE.

1230
00:54:10,800 --> 00:54:12,933
IT REQUIRES COMPUTERS TO SEE.

1231
00:54:12,933 --> 00:54:15,600
- THANK YOU.

1232
00:54:15,600 --> 00:54:16,600
- YEAH, SORRY.

1233
00:54:16,600 --> 00:54:18,000
- SINCE I GOT THE MIC...

1234
00:54:18,000 --> 00:54:19,000
- HE'S GOT IT.

1235
00:54:19,000 --> 00:54:20,433
- COULD I--

1236
00:54:20,433 --> 00:54:22,500
REGARDING THE Q-THRUSTER,

1237
00:54:22,500 --> 00:54:24,833
COULD I GET YOU TO ADDRESS

1238
00:54:24,833 --> 00:54:27,400
THIS WHOLE CONSERVATION
OF MOMENTUM QUESTION?

1239
00:54:27,400 --> 00:54:28,733
- ABSOLUTELY, YEAH.

1240
00:54:28,733 --> 00:54:31,600
SO THE Q-THRUSTER
DOES CONSERVE MOMENTUM

1241
00:54:31,600 --> 00:54:35,566
IF IT WORKS AS WE THINK IT DOES,
BASED ON THE PHYSICS.

1242
00:54:35,566 --> 00:54:37,166
IF YOU'RE PUSHING
OFF THE QUANTUM VACUUM,

1243
00:54:37,166 --> 00:54:39,000
YOU'RE ESTABLISHING
AN ANISOTROPIC STATE

1244
00:54:39,000 --> 00:54:40,400
IN THE QUANTUM VACUUM,

1245
00:54:40,400 --> 00:54:43,500
AND SO IT IS PUTTING A WAKE
OUT OF THE BACK OF THE THRUSTER.

1246
00:54:43,500 --> 00:54:44,900
AND AT SOME POINT,

1247
00:54:44,900 --> 00:54:47,933
IF WE CONTINUE TO SEE GOOD DATA

1248
00:54:47,933 --> 00:54:50,233
AND WE RULE OUT
ALL OTHER FALSE POSITIVES,

1249
00:54:50,233 --> 00:54:52,266
ONE OF THE THINGS WE WOULD
LIKE TO GO THROUGH AND EXPLORE

1250
00:54:52,266 --> 00:54:54,700
IS, WHAT IS
THE MOMENTUM DISTRIBUTION

1251
00:54:54,700 --> 00:54:57,266

AND WHAT'S THE DIVERGENCE ANGLE
OF THE WAKE?

1252
00:54:57,266 --> 00:54:59,733
AND SO WE WOULD DO THAT
BY USING ANOTHER Q-THRUSTER

1253
00:54:59,733 --> 00:55:00,966
THAT WOULD KIND OF RECOUPLE

1254
00:55:00,966 --> 00:55:02,833
WITH THE WAKE
IN THE QUANTUM VACUUM

1255
00:55:02,833 --> 00:55:05,033
AND TRY AND MEASURE THE WAKE.

1256
00:55:07,633 --> 00:55:08,633
- OKAY.

1257
00:55:08,633 --> 00:55:09,833
OH, WAIT.

1258
00:55:09,833 --> 00:55:13,433
COULD YOU DO CAUSALITY
ON THE OTHER ONE TOO?

1259
00:55:13,433 --> 00:55:14,600
- CAUSALITY.

1260
00:55:14,600 --> 00:55:17,566
- ON THE WARP DRIVE, HOW--

1261
00:55:17,566 --> 00:55:20,466
DO YOU AVOID CAUSALITY
VIOLATION, OR DOES IT HAPPEN?

1262
00:55:20,466 --> 00:55:22,433
- YEAH, YOU NEVER LOCALLY

EXCEED THE SPEED OF LIGHT,

1263
00:55:22,433 --> 00:55:23,733
SO YOU CAN'T DO ANY--

1264
00:55:23,733 --> 00:55:25,566
I LIKE "DOCTOR WHO"
AS MUCH AS THE NEXT GUY,

1265
00:55:25,566 --> 00:55:27,566
BUT YOU CAN'T--
THERE'S NO TIME TRAVEL POSSIBLE

1266
00:55:27,566 --> 00:55:30,066
WITH THE SPACEWARP.

1267
00:55:33,800 --> 00:55:34,800
YEAH.

1268
00:55:34,800 --> 00:55:36,266
- THANKS.

1269
00:55:36,266 --> 00:55:41,200
THE ALCUBIERRE WARP METRIC
AND OTHER ONES

1270
00:55:41,200 --> 00:55:43,400
REQUIRE EXOTIC MATTER.

1271
00:55:43,400 --> 00:55:44,400
- MM-HMM.

1272
00:55:44,400 --> 00:55:45,400
- HOW--

1273
00:55:45,400 --> 00:55:46,800
AND SO, I PRESUME,

1274

00:55:46,800 --> 00:55:49,833
IF YOU'RE TRYING TO MAKE
SOME KIND OF ALCUBIERRE THING

1275
00:55:49,833 --> 00:55:53,200
ON THE OPTICAL BENCH
WITH THIS INTERFEROMETER,

1276
00:55:53,200 --> 00:55:58,566
ARE YOU TRYING TO MAKE EXOTIC
MATTER IN YOUR "TEST ARTICLE"?

1277
00:55:58,566 --> 00:56:00,300
WHICH YOU DIDN'T SAY
VERY MUCH ABOUT.

1278
00:56:00,300 --> 00:56:02,033
WHAT'S GOING ON
WITH THAT TEST ARTICLE,

1279
00:56:02,033 --> 00:56:05,633
AND WHY SHOULD IT BE
AN ALCUBIERRE-LIKE EFFECT?

1280
00:56:05,633 --> 00:56:07,500
- YEAH, SO THE LOW-FIDELITY
TEST ARTICLE IS TRYING

1281
00:56:07,500 --> 00:56:11,400
TO CREATE A BLUE-SHIFTED FRAME
RELATIVE TO THE LAB.

1282
00:56:11,400 --> 00:56:13,333
SO WE'RE JUST USING
A LARGE POTENTIAL ENERGY

1283
00:56:13,333 --> 00:56:15,166
WITH OUR LOW-FIDELITY
TEST ARTICLES.

1284

00:56:15,166 --> 00:56:16,566
THE HIGHER-FIDELITY TEST ARTICLE

1285
00:56:16,566 --> 00:56:17,833
THAT I SHOWED YOU GUYS
A PICTURE OF,

1286
00:56:17,833 --> 00:56:20,033
THAT IS BASED
ON THE Q-THRUSTER PHYSICS,

1287
00:56:20,033 --> 00:56:21,633
AND SO THAT'S
WHERE WE GO THROUGH

1288
00:56:21,633 --> 00:56:24,066
AND WE WORK ON USING
THE NEGATIVE VACUUM ENERGY

1289
00:56:24,066 --> 00:56:26,833
TO TRY AND SATISFY
ALL THE EXPLICIT REQUIREMENTS

1290
00:56:26,833 --> 00:56:28,566
OF THE FIELD EQUATIONS.

1291
00:56:28,566 --> 00:56:31,033
SO THAT TEST ARTICLE IS TRYING
TO ESTABLISH MORE ACCURATELY

1292
00:56:31,033 --> 00:56:33,566
THE REQUIREMENTS AS SET UP
BY THE MATHEMATICS,

1293
00:56:33,566 --> 00:56:34,833
WORKING WITH
NEGATIVE VACUUM ENERGY,

1294
00:56:34,833 --> 00:56:35,833
CASIMIR FORCE.

1295
00:56:35,833 --> 00:56:36,833
- BUT WAIT--

1296
00:56:36,833 --> 00:56:37,866
OH, AM I OFF?

1297
00:56:37,866 --> 00:56:39,900
OKAY, BUT--

1298
00:56:39,900 --> 00:56:42,100
MAYBE WE COULD TAKE THIS OFFLINE
IF IT'S TOO TECHNICAL.

1299
00:56:42,100 --> 00:56:46,300
BUT E-FIELDS, B-FIELDS,
THE KIND OF THINGS YOU GET

1300
00:56:46,300 --> 00:56:53,266
INSIDE OF A RESONANT CAVITY
OR WITH CAPACITORS AND COILS,

1301
00:56:53,266 --> 00:56:55,566
NONE OF THOSE ARE EXOTIC MATTER.

1302
00:56:55,566 --> 00:56:58,333
THOSE ARE ALL JUST
STANDARD MASS ENERGY,

1303
00:56:58,333 --> 00:57:01,000
NOT THE KIND THAT YOU NEED
FOR THE ALCUBIERRE METRIC,

1304
00:57:01,000 --> 00:57:02,633
WHICH HAS THE OPPOSITE SIGN,

1305
00:57:02,633 --> 00:57:03,866
WHICH NO ONE KNOWS HOW TO MAKE.

1306
00:57:03,866 --> 00:57:05,166
- LET ME ANSWER YOUR QUESTION.

1307
00:57:05,166 --> 00:57:06,800
AND WE HAD SOME OF THIS
DISCUSSION ACTUALLY YESTERDAY

1308
00:57:06,800 --> 00:57:08,100
IN YOUR OFFICE.

1309
00:57:08,100 --> 00:57:11,100
WE WERE TALKING ABOUT
SOME OF THE Q-THRUSTER PHYSICS.

1310
00:57:11,100 --> 00:57:13,466
SO, IN TERMS
OF THE Q-THRUSTER PHYSICS,

1311
00:57:13,466 --> 00:57:15,266
WE'RE NOT JUST LOOKING
AT CLASSICAL E&M.

1312
00:57:15,266 --> 00:57:17,133
WE'RE TALKING ABOUT
WHAT THAT POTENTIALLY DOES

1313
00:57:17,133 --> 00:57:20,000
IN THE QUANTUM VACUUM
BASED ON THE PHYSICS MODELS

1314
00:57:20,000 --> 00:57:22,000
ASSOCIATED WITH
THE Q-THRUSTER PHYSICS.

1315
00:57:22,000 --> 00:57:23,233
SO WITH THE Q-THRUSTER PHYSICS,

1316
00:57:23,233 --> 00:57:24,800
IT POTENTIALLY PROVIDES

A CONNECTION

1317
00:57:24,800 --> 00:57:27,600
TO A PERTURBED STATE
IN THE QUANTUM VACUUM.

1318
00:57:27,600 --> 00:57:29,566
SO, YES,
JUST THE PURE E&M FIELDS,

1319
00:57:29,566 --> 00:57:31,700
BY THE CLASSICAL SENSE,
THEY'RE REALLY NOT OF INTEREST.

1320
00:57:31,700 --> 00:57:33,366
WHAT'S OF INTEREST TO US IS,
WHAT DOES THAT MEAN

1321
00:57:33,366 --> 00:57:35,833
WHEN WE LOOK AT IT FROM THE
Q-THRUSTER PHYSICS PERSPECTIVE?

1322
00:57:35,833 --> 00:57:39,900
SO THAT'S THE ONLY REASON
WHY THERE'S INTEREST IN THAT.

1323
00:57:39,900 --> 00:57:41,933
- OKAY, SO LET ME SEE
IF I UNDERSTAND THIS.

1324
00:57:41,933 --> 00:57:45,266
IF YOU JUST HAD
THE E&B FIELDS,

1325
00:57:45,266 --> 00:57:48,766
YOU WOULD EXPECT
NO EXOTIC EFFECT,

1326
00:57:48,766 --> 00:57:52,366
BUT IF YOU HAVE

THESE DIELECTRICS, OR WHATEVER,

1327
00:57:52,366 --> 00:57:56,000
INSIDE OF IT SO THAT YOU'RE
GETTING THIS STRONG COUPLING,

1328
00:57:56,000 --> 00:57:58,500
THEN MAYBE YOU WOULD SEE
AN EXOTIC EFFECT?

1329
00:57:58,500 --> 00:57:59,800
- YOU MADE TOO STRONG
OF A STATEMENT.

1330
00:57:59,800 --> 00:58:01,300
I THINK THAT THERE'S--

1331
00:58:01,300 --> 00:58:03,733
IN THE PROCESS OF EXPLORING
WHAT Q-THRUSTER PHYSICS MEANS

1332
00:58:03,733 --> 00:58:06,266
FOR THE MAGNITUDE
OF E&B FIELDS

1333
00:58:06,266 --> 00:58:07,666
AND HOW THAT MIGHT BE COUPLED

1334
00:58:07,666 --> 00:58:11,400
TO WHAT'S POTENTIALLY GOING ON
IN THE QUANTUM VACUUM,

1335
00:58:11,400 --> 00:58:13,133
IN PRINCIPLE, RIGHT,

1336
00:58:13,133 --> 00:58:15,400
YOU HAVE TO HAVE
THE RIGHT CONDITIONS

1337

00:58:15,400 --> 00:58:20,133
TO GET THE MAGNITUDE OF
AN EFFECT THAT YOU CAN MEASURE.

1338
00:58:20,133 --> 00:58:22,233
BUT YOU WERE TOO GENERAL
WITH YOUR STATEMENT,

1339
00:58:22,233 --> 00:58:24,866
SO I CAN'T AGREE WITH YOU
COMPLETELY WITH THAT.

1340
00:58:24,866 --> 00:58:25,866
ANYWAY...

1341
00:58:25,866 --> 00:58:26,866
- OKAY, THANK YOU.

1342
00:58:26,866 --> 00:58:28,100
- WE HAVE ONE MORE
QUESTION HERE.

1343
00:58:28,100 --> 00:58:29,100
- OKAY.

1344
00:58:29,100 --> 00:58:30,900
- THIS IS VERY--
CAN YOU HEAR ME?

1345
00:58:30,900 --> 00:58:32,266
THIS IS VERY NON-TECHNICAL,

1346
00:58:32,266 --> 00:58:35,300
MORE OF A POPULAR SCIENCE
MAGAZINE TYPE QUESTION FOR YOU,

1347
00:58:35,300 --> 00:58:37,666
SO BE AMBIGUOUS IF YOU WANT TO.

1348

00:58:37,666 --> 00:58:41,233
BUT, ASSUMING THAT
ALL YOUR MEASUREMENTS

1349
00:58:41,233 --> 00:58:43,933
ARE NOT DOMINATED
BY SYSTEMATIC NOISES

1350
00:58:43,933 --> 00:58:45,500
THAT YOU MIGHT NOT HAVE REALIZED
AT THIS POINT,

1351
00:58:45,500 --> 00:58:48,033
ASSUMING THAT ALL THOSE
MEASUREMENTS ARE CORRECT,

1352
00:58:48,033 --> 00:58:49,166
AND--SORRY?

1353
00:58:49,166 --> 00:58:50,566
- I DIDN'T HEAR THAT LAST PART.

1354
00:58:50,566 --> 00:58:52,200
- OH, ASSUMING THAT ALL THOSE
MEASUREMENTS ARE CORRECT,

1355
00:58:52,200 --> 00:58:53,533
THAT THEY'RE NOT DOMINATED
BY NOISE

1356
00:58:53,533 --> 00:58:55,066
THAT YOU HAVEN'T ACCOUNTED FOR.

1357
00:58:55,066 --> 00:58:58,600
AND IN A FICTIONAL WORLD
WHERE YOU WILL HAVE FUNDING

1358
00:58:58,600 --> 00:59:03,166
TO CONTINUE PURSUING THIS
AT A COMFORTABLE LEVEL

1359
00:59:03,166 --> 00:59:04,800
FOR THE NEXT 20 YEARS,

1360
00:59:04,800 --> 00:59:06,500
WHERE DO YOU ENVISION
THIS TECHNOLOGY TO BE

1361
00:59:06,500 --> 00:59:07,833
IN 20 YEARS TIME?

1362
00:59:07,833 --> 00:59:09,033
IS THIS SOMETHING
THAT WE'LL BE ABLE TO USE

1363
00:59:09,033 --> 00:59:11,933
TO SEND SATELLITES
TO OTHER PLANETS?

1364
00:59:11,933 --> 00:59:13,300
- YOU KNOW,
THAT'S A BIG QUESTION.

1365
00:59:13,300 --> 00:59:15,500
I DON'T HAVE A GOOD ANSWER
FOR YOU.

1366
00:59:15,500 --> 00:59:17,900
I MEAN, CERTAINLY YOU'D LIKE
TO MAKE A LOT OF PROGRESS,

1367
00:59:17,900 --> 00:59:20,300
BUT, I MEAN,
THERE'S NO SHORTCUTS, RIGHT?

1368
00:59:20,300 --> 00:59:22,766
YOU KNOW, IT'S DEFINITELY
CRAWL, WALK, RUN.

1369

00:59:22,766 --> 00:59:24,833
WE'LL TRY AND MAKE
AS MUCH PROGRESS AS WE CAN

1370
00:59:24,833 --> 00:59:27,500
WITHIN THE RESOURCES
THAT WE HAVE.

1371
00:59:27,500 --> 00:59:29,866
AND, BASICALLY, THE DATA'S
REALLY GOING TO DRIVE

1372
00:59:29,866 --> 00:59:31,466
THAT DISCUSSION, RIGHT?

1373
00:59:31,466 --> 00:59:32,966
I MEAN, YOU KNOW,
IN GOD WE TRUST;

1374
00:59:32,966 --> 00:59:34,466
EVERYBODY ELSE, BRING DATA.

1375
00:59:34,466 --> 00:59:36,433
SO DATA'S REALLY GOING TO DRIVE
THAT DISCUSSION.

1376
00:59:36,433 --> 00:59:37,733
SO I'M SORRY IT'S NOT LIKE--

1377
00:59:37,733 --> 00:59:39,333
YOU KNOW, I CAN'T GIVE YOU
A GOOD QUIP ANSWER,

1378
00:59:39,333 --> 00:59:40,466
BUT, YEAH, JUST--

1379
00:59:40,466 --> 00:59:42,133
THERE'S NO SHORTCUTS,
RIGHT, SO...

1380
00:59:42,133 --> 00:59:43,166
- I TOLD YOU,
YOU COULD BE AMBIGUOUS.

1381
00:59:43,166 --> 00:59:44,166
THAT'S FINE.

1382
00:59:44,166 --> 00:59:45,366
- YEAH.

1383
00:59:45,366 --> 00:59:47,733
- OKAY, PLEASE JOIN ME
IN THANKING DR. WHITE.

1384
00:59:47,733 --> 00:59:50,733
[applause]