1
00:00:00,350 --> 00:00:01,051
>> THE SOLAR PANELS THAT

2
00:00:01,051 --> 00:00:02,218
WE ARE-ARE CREATING THAT

3
00:00:02,218 --> 00:00:04,120
WE ARE DEVELOPING ARE ACTUALLY

4
00:00:04,120 --> 00:00:05,789
THE THICKNESS OF A HUMAN HAIR

5
00:00:05,789 --> 00:00:06,723
OR LESS.

6
00:00:07,490 --> 00:00:14,030
[MUSIC]

7
00:00:14,030 --> 00:00:15,131
HERE AT NASA, WE'RE WORKING ON

8
00:00:15,131 --> 00:00:16,433
THIN FILM SOLAR ARRAYS

9
00:00:16,433 --> 00:00:17,867
FOR OUR SPACECRAFT.

10
00:00:17,867 --> 00:00:18,768
AS THE NAME SUGGESTS,

11
00:00:18,768 --> 00:00:19,636
THEY'RE VERY THIN,

12
00:00:19,636 --> 00:00:22,272
VERY LOW MASS, VERY LOW VOLUME.

13
00:00:22,272 --> 00:00:24,207

SO THESE THIN FILM SOLAR PANELS,

14
00:00:24,207 --> 00:00:25,842
TO DATE WE'VE MADE THEM ALL

15
00:00:25,842 --> 00:00:26,710
BY HAND.

16
00:00:26,710 --> 00:00:28,745
WE CALL IT TOUCH LABOR, UM,

17
00:00:28,745 --> 00:00:29,579
WHICH, AS YOU CAN IMAGINE,

18
00:00:29,579 --> 00:00:30,847
GETS VERY EXPENSIVE,

19
00:00:30,847 --> 00:00:31,915
AND IT'S HARD TO DO

20
00:00:31,915 --> 00:00:34,084
IN-IN VERY LARGE AREAS.

21
00:00:34,084 --> 00:00:35,385
SO THIS PROJECT, WE CALL IT

22
00:00:35,385 --> 00:00:36,920
PAPA-- PRINT-ASSISTED

23
00:00:36,920 --> 00:00:38,888
PHOTOVOLTAIC ASSEMBLY.

24
00:00:38,888 --> 00:00:40,757
AND OUR THOUGHT WAS, UH,

25
00:00:40,757 --> 00:00:43,359
CAN WE USE ROBOTICS, UM,

26
00:00:43,359 --> 00:00:44,894
AND 3D PRINTING

27
00:00:44,894 --> 00:00:46,129
TO GO AND ASSEMBLE

28
00:00:46,129 --> 00:00:48,298
THESE THIN FILM SOLAR PANELS

29
00:00:48,298 --> 00:00:49,766
TO BOTH LOWER COSTS,

30
00:00:49,766 --> 00:00:50,600
GET RID OF ALL THAT

31
00:00:50,600 --> 00:00:52,802
TOUCH LABOR, UH, AND ENABLE

32
00:00:52,802 --> 00:00:55,138
VERY LARGE SCALE PRODUCTION?

33
00:00:55,138 --> 00:00:56,806
THE IDEA REALLY CAME FROM

34
00:00:56,806 --> 00:00:58,675
WORK IN SOLAR SAILS--

35
00:00:58,675 --> 00:01:00,276
UH, S-A-I-L.

36
00:01:00,276 --> 00:01:01,344
SO SOLAR SAILS ARE

37
00:01:01,344 --> 00:01:03,713
VERY LARGE SCALE, VERY THIN,

38
00:01:03,713 --> 00:01:05,515

VERY LIGHTWEIGHT MEMBRANE

39
00:01:05,515 --> 00:01:08,151
THAT WE ACTUALLY USE TO, UH,

40
00:01:08,151 --> 00:01:09,486
PROPEL SPACECRAFT.

41
00:01:09,486 --> 00:01:11,554
WE ACTUALLY SAIL, UH,

42
00:01:11,554 --> 00:01:13,490
OFF OF THE MOMENTUM OF PHOTONS

43
00:01:13,490 --> 00:01:15,825
REFLECTING OFF OF THE SURFACE.

44
00:01:15,825 --> 00:01:17,260
OKAY, AND AS WE WERE WORKING ON

45
00:01:17,260 --> 00:01:19,863
THESE SOLAR SAILS, WE REALIZED

46
00:01:19,863 --> 00:01:21,531
WITH ADVANCEMENTS IN THIN FILM

47
00:01:21,531 --> 00:01:24,567
SOLAR CELLS, NOW C-E-L-L,

48
00:01:24,567 --> 00:01:25,401
UH, THAT THERE WAS

49
00:01:25,401 --> 00:01:26,636
A NATURAL MARRIAGE THERE,

50
00:01:26,636 --> 00:01:27,570
THAT WE COULD EMBED

51
00:01:27,570 --> 00:01:29,773
THESE THIN, FLEXIBLE SOLAR CELLS

52
00:01:29,773 --> 00:01:31,307
ONTO THESE VERY LARGE SCALE

53
00:01:31,307 --> 00:01:34,043
THIN SOLAR SAILS AND MAKE,

54
00:01:34,043 --> 00:01:36,179
UH, A VERY LARGE,

55
00:01:36,179 --> 00:01:38,181
COMPLETELY THIN FILM, LOW MASS

56
00:01:38,181 --> 00:01:41,151
SOLAR PANEL FOR OUR SPACECRAFT.

57
00:01:41,151 --> 00:01:41,985
IN THE BEGINNING, THIS WAS

58
00:01:41,985 --> 00:01:43,186
JUST AN IDEA.

59
00:01:43,186 --> 00:01:44,254
AND WE'RE SORT OF TAKING A STEP

60
00:01:44,254 --> 00:01:45,355
INTO THE UNKNOWN, SOMETHING

61
00:01:45,355 --> 00:01:46,823
THAT HASN'T BEEN DONE BEFORE,

62
00:01:46,823 --> 00:01:47,690
AND SO THERE'S A LOT OF

63
00:01:47,690 --> 00:01:49,325

EXPERIMENTATION TO REALLY

64
00:01:49,325 --> 00:01:50,627
GET IT UP AND RUNNING.

65
00:01:50,627 --> 00:01:52,462
AND THIS WAS A FRIDAY PROJECT.

66
00:01:52,462 --> 00:01:53,930
WE SET EVERY FRIDAY ASIDE

67
00:01:53,930 --> 00:01:55,031
TO COME AND WORK ON IT,

68
00:01:55,031 --> 00:01:55,999
AND IT BECAME A FUN THING

69
00:01:55,999 --> 00:01:57,066
TO COME AND DO.

70
00:01:57,066 --> 00:01:58,168
AND YOU KNOW, EACH FRIDAY

71
00:01:58,168 --> 00:01:59,636
IT FELT LIKE WE, YOU KNOW--

72
00:01:59,636 --> 00:02:01,237
KINDA ONE OF THOSE TWO STEPS

73
00:02:01,237 --> 00:02:02,438
FORWARD, ONE STEP BACK,

74
00:02:02,438 --> 00:02:03,206
TWO STEPS FORWARD,

75
00:02:03,206 --> 00:02:04,474
ONE STEP BACK.

76
00:02:04,474 --> 00:02:06,576
UM, BUT SLOWLY BUT SURELY

77
00:02:06,576 --> 00:02:07,944
WE-WE STARTED WORKING THROUGH

78
00:02:07,944 --> 00:02:09,979
EACH OF THE PROBLEMS AND, UH,

79
00:02:09,979 --> 00:02:10,680
EVENTUALLY CAME OUT

80
00:02:10,680 --> 00:02:12,015
THE OTHER SIDE.

81
00:02:12,015 --> 00:02:13,383
TWO REALLY MAIN ADVANTAGES

82
00:02:13,383 --> 00:02:14,384
OF THESE THIN FILM

83
00:02:14,384 --> 00:02:16,553
SOLAR PANELS COME AT TWO ENDS

84
00:02:16,553 --> 00:02:17,687
OF THE SPECTRUM.

85
00:02:17,687 --> 00:02:19,389
SO IF YOU GO TO THE VERY SMALL,

86
00:02:19,389 --> 00:02:20,790
UH, SMALL SPACECRAFT, YOU KNOW,

87
00:02:20,790 --> 00:02:22,158
SATELLITE THE-THE SIZE OF

88
00:02:22,158 --> 00:02:23,526

A LOAF OF BREAD,

89
00:02:23,526 --> 00:02:24,694
AND YOU THINK ABOUT PUTTING

90
00:02:24,694 --> 00:02:26,963
THICK FILM SOLAR PANELS ON IT,

91
00:02:26,963 --> 00:02:28,131
UM, YOU CAN'T FIT A LOT

92
00:02:28,131 --> 00:02:28,932
ON THERE.

93
00:02:28,932 --> 00:02:30,266
BY THE TIME YOU FOLD 'EM UP,

94
00:02:30,266 --> 00:02:31,568
PUT 'EM INTO THE VOLUME,

95
00:02:31,568 --> 00:02:32,669
YOU'VE EATEN UP ALL OF YOUR

96
00:02:32,669 --> 00:02:33,903
RESOURCES AND DON'T HAVE MUCH

97
00:02:33,903 --> 00:02:35,772
FOR THE PAYLOAD, THE-THE THING

98
00:02:35,772 --> 00:02:37,407
YOU WANNA GO AND DO.

99
00:02:37,407 --> 00:02:39,008
SO, UH, BY SHRINKING

100
00:02:39,008 --> 00:02:40,643
THAT SOLAR PANEL-- LOWER MASS,

101
00:02:40,643 --> 00:02:42,245
LOWER VOLUME-- IT ENABLES US

102
00:02:42,245 --> 00:02:43,479
TO GO AND DO MORE

103
00:02:43,479 --> 00:02:45,248
FROM THESE SMALL SPACECRAFT.

104
00:02:45,248 --> 00:02:46,449
NOW, COMING TO THE OTHER END,

105
00:02:46,449 --> 00:02:48,017
THE VERY, VERY LARGE,

106
00:02:48,017 --> 00:02:48,952
WHEN YOU THINK ABOUT MAKING

107
00:02:48,952 --> 00:02:51,254
A SOLAR PANEL, UH, YOU KNOW,

108
00:02:51,254 --> 00:02:52,155
WE CAN DREAM A LITTLE BIT

109
00:02:52,155 --> 00:02:52,889
AND SAY THE SIZE OF

110
00:02:52,889 --> 00:02:54,057
A FOOTBALL FIELD, OR TEN

111
00:02:54,057 --> 00:02:55,925
FOOTBALL FIELDS, RIGHT--

112
00:02:55,925 --> 00:02:57,594
UH, DOING THAT WITH THICK FILMS

113
00:02:57,594 --> 00:02:58,862

BECOMES STRUCTURALLY

114
00:02:58,862 --> 00:03:00,196
VERY DIFFICULT.

115
00:03:00,196 --> 00:03:01,497
I THINK RIGHT NOW WE'RE STILL

116
00:03:01,497 --> 00:03:03,933
IN, UH, THE R&D PHASE.

117
00:03:03,933 --> 00:03:04,868
WE'VE COME OUT WITH

118
00:03:04,868 --> 00:03:07,303
OUR FIRST WORKING ASSEMBLIES.

119
00:03:07,303 --> 00:03:09,105
UH, THESE ARE FULLY PRINTED,

120
00:03:09,105 --> 00:03:11,741
FULLY AUTOMATED, UM,

121
00:03:11,741 --> 00:03:13,076
ASSEMBLED AND THEN TAKEN OVER

122
00:03:13,076 --> 00:03:15,044
TO A SOLAR SIMULATOR, TESTED,

123
00:03:15,044 --> 00:03:16,446
CONFIRMED WORKING.

124
00:03:16,446 --> 00:03:18,414
WE FOLDED 'EM UP, UNFOLDED 'EM,

125
00:03:18,414 --> 00:03:20,116
TESTED 'EM AGAIN, UH,

126
00:03:20,116 --> 00:03:21,851
WITHOUT ANY DEGRADATION.

127
00:03:21,851 --> 00:03:23,152
AND WE'VE STARTED PUTTING 'EM

128
00:03:23,152 --> 00:03:24,954
INTO SOME THERMAL SHOCK.

129
00:03:24,954 --> 00:03:25,989
UH, WITH ALL THESE MATERIALS

130
00:03:25,989 --> 00:03:27,090
LAID UP ON EACH OTHER,

131
00:03:27,090 --> 00:03:28,258
WE WANNA MAKE SURE THAT

132
00:03:28,258 --> 00:03:29,292
COEFFICIENT OF THERMAL

133
00:03:29,292 --> 00:03:30,426
EXPANSION-- THAT THERE'S

134
00:03:30,426 --> 00:03:31,828
NOTHING, UH, THAT'S GONNA

135
00:03:31,828 --> 00:03:34,631
DELAMINATE, PEEL, CRACK, BREAK.

136
00:03:34,631 --> 00:03:35,965
UM, AND THEY SURVIVED

137
00:03:35,965 --> 00:03:37,667
THROUGH THAT THERMAL SHOCK.

138
00:03:37,667 --> 00:03:39,335

WE CURRENTLY HAVE SAMPLES

139
00:03:39,335 --> 00:03:40,470
GOING UP TO THE INTERNATIONAL

140
00:03:40,470 --> 00:03:42,505
SPACE STATION, UH, WHICH

141
00:03:42,505 --> 00:03:44,741
WILL ESSENTIALLY BE PUT

142
00:03:44,741 --> 00:03:45,675
OUTSIDE OF THE INTERNATIONAL

143
00:03:45,675 --> 00:03:47,644
SPACE STATION FOR A YEAR,

144
00:03:47,644 --> 00:03:48,912
EXPOSED TO THE ENVIRONMENT.

145
00:03:48,912 --> 00:03:49,846
THEY'LL COME BACK DOWN

146
00:03:49,846 --> 00:03:50,880
AND WE'LL STUDY HOW DID THEY

147
00:03:50,880 --> 00:03:52,081
DEGRADE, AND DID THEY ACT

148
00:03:52,081 --> 00:03:53,583
AS WE THOUGHT THEY WOULD?

149
00:03:53,583 --> 00:03:54,350
I THINK THIS LAYS

150
00:03:54,350 --> 00:03:55,919
THE GROUNDWORK, UH, FOR WHAT

151
00:03:55,919 --> 00:03:57,587
COULD BE REALLY REVOLUTIONARY,

152
00:03:57,587 --> 00:03:58,488
AND THAT'S IN-SPACE

153
00:03:58,488 --> 00:04:01,024
MANUFACTURING OF SOLAR PANELS.

154
00:04:01,024 --> 00:04:02,525
AND SO RIGHT NOW, WE'RE USING

155
00:04:02,525 --> 00:04:03,793
COTS, OR COMMERCIAL

156
00:04:03,793 --> 00:04:05,595
OFF THE SHELF, THIN FILM

157
00:04:05,595 --> 00:04:07,096
SOLAR CELLS IN OUR PROCESS.

158
00:04:07,096 --> 00:04:08,231
SO WE BUY THE SOLAR CELLS

159
00:04:08,231 --> 00:04:10,266
FROM A-A TERRESTRIAL COMPANY,

160
00:04:10,266 --> 00:04:11,634
AND WE'RE ACTUALLY USING

161
00:04:11,634 --> 00:04:13,136
A ROBOTIC ARM TO INCORPORATE

162
00:04:13,136 --> 00:04:15,204
THEM INTO OUR PROCESS.

163
00:04:15,204 --> 00:04:17,707

UM, WHAT WOULD BE VERY POWERFUL

164
00:04:17,707 --> 00:04:19,208
IS IF WE COULD THEN

165
00:04:19,208 --> 00:04:20,410
GO AND ACTUALLY PRINT

166
00:04:20,410 --> 00:04:21,411
THAT SOLAR CELL.

167
00:04:21,411 --> 00:04:22,412
SO RIGHT NOW, WE'RE PRINTING

168
00:04:22,412 --> 00:04:24,047
ALL THE STUFF AROUND A COTS

169
00:04:24,047 --> 00:04:24,814
SOLAR CELL.

170
00:04:24,814 --> 00:04:25,615
IF WE COULD ACTUALLY PRINT

171
00:04:25,615 --> 00:04:27,717
THAT SOLAR CELL ITSELF, THEN

172
00:04:27,717 --> 00:04:29,018
WE HAVE A FULLY PRINTED

173
00:04:29,018 --> 00:04:31,154
SOLAR PANEL THAT WE COULD,

174
00:04:31,154 --> 00:04:33,790
SAY, IF WE'RE ON A LUNAR BASE,

175
00:04:33,790 --> 00:04:35,692
OR WE HAVE OUR MISSION TO MARS,

176
00:04:35,692 --> 00:04:38,094
OR EVENTUALLY DEEPER INTO SPACE,

177
00:04:38,094 --> 00:04:39,495
WE CAN PRINT STUFF ON DEMAND.

178
00:04:39,495 --> 00:04:40,463
YOU KNOW, IF WE HAVE A SOLAR

179
00:04:40,463 --> 00:04:41,965
PANEL THAT GETS DAMAGED,

180
00:04:41,965 --> 00:04:43,032
UH, WE NEED MORE POWER

181
00:04:43,032 --> 00:04:45,335
FOR-FOR SOME OTHER EXPERIMENT,

182
00:04:45,335 --> 00:04:46,302
UH, OR JUST SIMPLY PUT,

183
00:04:46,302 --> 00:04:47,337
WE'RE JUST UP THERE LONG ENOUGH

184
00:04:47,337 --> 00:04:48,705
WHERE WE'RE STARTING TO DEGRADE

185
00:04:48,705 --> 00:04:50,073
IN A SPACE ENVIRONMENT.

186
00:04:50,073 --> 00:04:51,174
WE COULD ON DEMAND, THEN,

187
00:04:51,174 --> 00:04:53,109
PRINT, UH, A NEW SOLAR PANEL

188
00:04:53,109 --> 00:04:54,610

TO-TO ACCOMMODATE

189
00:04:54,610 --> 00:04:56,312
THOSE EXTRA POWER NEEDS.

190
00:04:56,312 --> 00:04:57,714
UM, AND I THINK THAT COULD BE