1
00:00:02,490 --> 00:00:32,940
[MUSIC]

2
00:00:32,940 --> 00:00:34,330
>> WE'RE GOING TO THE MOON.

3
00:00:34,330 --> 00:00:36,590
THIS TIME,
WE'RE GOING TO STAY.

4
00:00:36,590 --> 00:00:38,910
WE'RE GOING TO THE MOON AS
A PROVING GROUND FOR LEARNING

5
00:00:38,910 --> 00:00:41,880
HOW TO LIVE AND THRIVE
ON ANOTHER PLANETARY BODY

6
00:00:41,880 --> 00:00:45,680
IN PREPARATION FOR FUTURE
MISSIONS TO MARS.

7
00:00:45,680 --> 00:00:48,410
NASA ADMINISTRATOR
JIM BRIDENSTINE USES ONE WORD

8
00:00:48,410 --> 00:00:51,590
REPEATEDLY WHEN DESCRIBING HOW
THE ARTEMIS PROGRAM DIFFERS

9
00:00:51,590 --> 00:00:53,550
FROM THE APOLLO PROGRAM.

10
00:00:53,550 --> 00:00:55,940
>> THE PRESIDENT'S FIRST SPACE
POLICY DIRECTIVE SAYS TO GO TO

11
00:00:55,940 --> 00:00:58,730
THE MOON, GO SUSTAINABLY,

AND HAVE THE UNITED STATES OF

12
00:00:58,730 --> 00:01:02,720
AMERICA LEAD A COALITION OF
NATIONS FOR A SUSTAINABLE

13
00:01:02,720 --> 00:01:04,150
RETURN TO THE MOON.

14
00:01:04,150 --> 00:01:07,580
BY 2028, WE NEED SUSTAINABILITY.

15
00:01:07,580 --> 00:01:09,820
WE'RE GOING TO THE MOON,
WE'RE GOING SUSTAINABLY,

16
00:01:09,820 --> 00:01:12,399
WE'RE MOVING FAST.

17
00:01:12,399 --> 00:01:13,399
>> "SUSTAINABLE."

18
00:01:13,399 --> 00:01:15,869
WE ALSO HEAR OR SEE
THIS OR SIMILAR WORDS

19
00:01:15,869 --> 00:01:18,850
IN MEDIA POSTINGS FROM
SPACE ENTREPRENEURS AND

20
00:01:18,850 --> 00:01:21,210
INTERNATIONAL SPACE AGENCIES.

21
00:01:21,210 --> 00:01:25,189
SUSTAINABLE, REUSABLE,
RESOURCES.

22
00:01:25,189 --> 00:01:26,960
WHAT DOES ALL THIS MEAN?

23
00:01:26,960 --> 00:01:29,799
BEFORE I ANSWER THAT,
LET'S TALK ABOUT

24
00:01:29,799 --> 00:01:32,030
WHAT IT DOESN'T MEAN.

25
00:01:32,030 --> 00:01:34,869
SO FAR, IN OUR FIFTY YEAR
HISTORY OF SENDING HUMANS

26
00:01:34,869 --> 00:01:37,571
BEYOND EARTH ORBIT, WE HAVE
BROUGHT EVERYTHING WE NEED

27
00:01:37,571 --> 00:01:39,579
FOR THE TRIP FROM HOME.

28
00:01:39,579 --> 00:01:42,540
AND THE BULKIEST AND HEAVIEST
THING WE NEED IS THE ROCKET

29
00:01:42,540 --> 00:01:46,829
PROPELLANT THAT GETS US OFF
EARTH AND SAFELY BACK.

30
00:01:46,829 --> 00:01:50,420
WHEN THE SATURN V WAS SITTING
ON THE LAUNCH PAD, WE HAD BIG,

31
00:01:50,420 --> 00:01:53,299
POWERFUL ROCKET ENGINES AT
THE BOTTOM AND A TINY HUMAN

32
00:01:53,299 --> 00:01:56,229
SPACE CAPSULE AND LUNAR MODULE
AT THE TOP.

33

00:01:56,229 --> 00:01:58,979
IN BETWEEN IS MOSTLY PROPELLANT.

34
00:01:58,979 --> 00:02:01,630
OXYGEN AND KEROSENE
TO GET US OFF EARTH,

35
00:02:01,630 --> 00:02:04,110
OXYGEN AND HYDROGEN TO
PUSH 'EM TO THE MOON,

36
00:02:04,110 --> 00:02:07,590
AND STORABLE PROPELLANTS TO GET
DOWN TO THE LUNAR SURFACE,

37
00:02:07,590 --> 00:02:10,570
BACK UP TO ORBIT, AND BACK HOME.

38
00:02:10,570 --> 00:02:12,940
AND WHILE THE PROPELLANTS FOR
THE RETURN TRIP SEEMS

39
00:02:12,940 --> 00:02:15,190
SMALL WHEN COMPARED TO
THE OTHER STAGES.

40
00:02:15,190 --> 00:02:19,080
IT CAN HAVE A HUGE IMPACT
ON THE ENTIRE VEHICLE.

41
00:02:19,080 --> 00:02:21,440
THINK OF WHAT HAPPENS TO
THE GAS MILEAGE IN THE FAMILY

42
00:02:21,440 --> 00:02:25,380
MINIVAN ON A ROAD TRIP WHEN WE
START CLIMBING THE MOUNTAINS.

43
00:02:25,380 --> 00:02:27,960
OR WORSE, WHEN WE START

CLIMBING THE MOUNTAINS,

44
00:02:27,960 --> 00:02:30,690
CARRYING PRECIOUS VACATION GEAR.

45
00:02:30,690 --> 00:02:32,830
IMAGINE WHAT WOULD HAPPEN IF
THE FAMILY MINIVAN HAD A PULL

46
00:02:32,830 --> 00:02:35,220
OF TANKER OF GAS OVER THOSE
MOUNTAINS IN ORDER TO

47
00:02:35,220 --> 00:02:37,620
REFUEL FOR THE TRIP HOME.

48
00:02:37,620 --> 00:02:40,790
AS AMUSING AS THIS IMAGE IS,
BECAUSE WE ALL REALIZE HOW

49
00:02:40,790 --> 00:02:43,940
UNSUSTAINABLE THIS METHOD OF
VACATIONING WOULD BE,

50
00:02:43,940 --> 00:02:48,880
THIS IS EXACTLY HOW WE HAVE
EXPLORED SPACE, UNTIL NOW.

51
00:02:48,880 --> 00:02:51,590
SO HOW ARE WE GOING TO
CHANGE THIS PARADIGM?

52
00:02:51,590 --> 00:02:53,840
WE'RE GOING TO BUILD
A GAS STATION ON THE MOON

53
00:02:53,840 --> 00:02:56,870
FOR THE ASTRONAUTS TO REFUEL
THEIR VEHICLE FOR THE TRIP HOME.

54
00:02:56,870 --> 00:03:00,690
OF COURSE, GAS STATIONS ONLY
DISPENSE THE GAS, SO WE WILL

55
00:03:00,690 --> 00:03:03,790
ALSO NEED THE EQUIPMENT TO
GATHER THE RAW RESOURCES,

56
00:03:03,790 --> 00:03:06,180
AND A REFINERY TO PROCESS
THOSE RESOURCES INTO

57
00:03:06,180 --> 00:03:07,840
ROCKET PROPELLANT.

58
00:03:07,840 --> 00:03:10,700
WE CALL THIS
"IN SITU RESOURCE UTILIZATION,"

59
00:03:10,700 --> 00:03:13,820
OR ISOU FOR SHORT.

60
00:03:13,820 --> 00:03:17,430
OUR ANCESTORS CALLED IT
"LIVING OFF THE LAND."

61
00:03:17,430 --> 00:03:20,940
WE ESTIMATE THAT WE WILL NEED
APPROXIMATELY TWELVE TONS OF

62
00:03:20,940 --> 00:03:24,430
OXYGEN AND HYDROGEN PROPELLANT
TO REFUEL THE LANDER,

63
00:03:24,430 --> 00:03:26,550
GET IT BACK UP TO LUNAR ORBIT
SO WE CAN USE IT AGAIN

64
00:03:26,550 --> 00:03:28,600

ON THE NEXT TRIP.

65
00:03:28,600 --> 00:03:31,410
IF WE CAN MAKE THAT TWELVE TONS
ON THE LUNAR SURFACE,

66
00:03:31,410 --> 00:03:33,840
WE WOULDN'T NEED TO
BRING IT FROM EARTH.

67
00:03:33,840 --> 00:03:36,870
WHILE THIS SOUNDS LIKE A HUGE
SAVINGS ON ITS OWN,

68
00:03:36,870 --> 00:03:40,340
BECAUSE LUNAR ASCENT IS
THE LAST PHASE OF THE MISSION,

69
00:03:40,340 --> 00:03:43,310
ANY SAVINGS ARE LIKE
COMPOUNDED INTEREST,

70
00:03:43,310 --> 00:03:46,060
AND THAT 12 TONS NEEDED
AT THE END OF OUR TRIP CAN

71
00:03:46,060 --> 00:03:49,120
ADD UP TO MUCH LARGER SAVINGS.

72
00:03:49,120 --> 00:03:51,330
IN THE PREVIOUS TALK,
YOU HEARD ABOUT SOME OF

73
00:03:51,330 --> 00:03:53,650
THE DIFFERENT PARTS OF
THE TRIP TO THE MOON.

74
00:03:53,650 --> 00:03:55,700
LET'S FOLLOW THAT
TRIP BACKWARDS.

75
00:03:55,700 --> 00:03:58,420
ASSUMING WE MAKE JUST
ONE KILOGRAM OF PROPELLANT

76
00:03:58,420 --> 00:04:00,290
ON THE LUNAR SURFACE.

77
00:04:00,290 --> 00:04:03,070
IN ORDER TO LAND THAT ONE
KILOGRAM FROM LOW LUNAR ORBIT,

78
00:04:03,070 --> 00:04:05,890
WE NEED ANOTHER ONE KILOGRAM
OF PROPELLANT IN TANKS,

79
00:04:05,890 --> 00:04:08,250
WHICH WE ALSO DON'T NEED TO
BRING FROM EARTH WHEN MAKING

80
00:04:08,250 --> 00:04:10,350
THE ONE KILOGRAM ON THE SURFACE.

81
00:04:10,350 --> 00:04:13,670
OUR SAVINGS ARE AT TWO AND A--
K-- TWO KILOGRAMS.

82
00:04:13,670 --> 00:04:15,680
CONTINUING BACKWARDS,
WE WOULD NEED ANOTHER

83
00:04:15,680 --> 00:04:19,289
HALF KILOGRAM TO GET THAT
TWO KILOGRAMS FROM GATEWAY

84
00:04:19,289 --> 00:04:20,669
DOWN TO LOW LUNAR ORBIT.

85
00:04:20,669 --> 00:04:24,460

SO NOW WE HAVE SAVED
TWO AND A HALF KILOGRAMS.

86
00:04:24,460 --> 00:04:27,780
AND EVEN WITH THE VERY EFFICIENT
SLOW ROAD TRIP THAT IS PLANNED

87
00:04:27,780 --> 00:04:30,939
TO GET THE UNCREWED ELEMENTS
OUT TO GATEWAY, WE WOULD STILL

88
00:04:30,939 --> 00:04:33,940
NEED MORE THAN SIX KILOGRAMS
OF PROPELLANT TO GET THAT

89
00:04:33,940 --> 00:04:36,439
TWO AND A HALF KILOGRAMS
FROM LOW EARTH ORBIT

90
00:04:36,439 --> 00:04:38,300
UP TO GATEWAY.

91
00:04:38,300 --> 00:04:40,630
ADD IT ALL TOGETHER,
THAT ONE KILOGRAM WE MADE

92
00:04:40,630 --> 00:04:43,949
ON THE LUNAR SURFACE HAS REDUCED
OUR MASS IN LOW EARTH ORBIT

93
00:04:43,949 --> 00:04:47,080
BY ALMOST NINE KILOGRAMS,
WHICH MEANS THE ABILITY TO

94
00:04:47,080 --> 00:04:50,080
MAKE TWELVE TONS ON
THE LUNAR SURFACE CAN REDUCE

95
00:04:50,080 --> 00:04:53,509
OUR MASS IN LOW EARTH ORBIT

BY OVER ONE HUNDRED TONS.

96
00:04:53,509 --> 00:04:56,879
ALSO, BECAUSE WE CAN
NOW REUSE THE LANDER,

97
00:04:56,879 --> 00:05:00,580
WE REALIZE AN ADDITIONAL 18 TON
SAVINGS IN LOW EARTH ORBIT

98
00:05:00,580 --> 00:05:02,630
BECAUSE OF ALL THE PROPELLANT
WE DON'T NEED TO PUSH

99
00:05:02,630 --> 00:05:05,560
A NEW LANDER OUT
TO GATEWAY ON EVERY TRIP.

100
00:05:05,560 --> 00:05:07,690
ALL TOGETHER,
PRODUCTION OF PROPELLANT

101
00:05:07,690 --> 00:05:11,949
ENABLE REUSABLE LANDER COULD
RESULT IN 120 TONS LESS

102
00:05:11,949 --> 00:05:15,189
AT THE START OF OUR TRIP,
A SUBSTANTIAL REDUCTION FROM

103
00:05:15,189 --> 00:05:17,960
THE OLD WAY OF EXPLORING SPACE.

104
00:05:17,960 --> 00:05:20,400
THIS SAVES SIGNIFICANT
LAUNCH COSTS, AND BRINGS

105
00:05:20,400 --> 00:05:23,150
THE VISION OF SUSTAINED PRESENCE
ON THE LUNAR SURFACE

106
00:05:23,150 --> 00:05:25,509
WITHIN OUR GRASP.

107
00:05:25,509 --> 00:05:28,029
SO LET'S TALK NOW ABOUT SOME
OF THE TECHNOLOGY NEEDED

108
00:05:28,029 --> 00:05:30,960
TO MAKE ISOU A REALITY.

109
00:05:30,960 --> 00:05:33,819
NASA PLANS TO LAND
NEAR THE SOUTH POLE,

110
00:05:33,819 --> 00:05:36,430
WHERE ORBITAL MISSIONS,
SUCH AS CLEMENTINE AND THE

111
00:05:36,430 --> 00:05:40,090
LUNAR RECONNAISSANCE ORBITER
DETECTED WATER SIGNATURES IN

112
00:05:40,090 --> 00:05:43,080
AND NEAR THE PERMANENTLY
SHADOWED REGIONS.

113
00:05:43,080 --> 00:05:45,860
AND THE PLUME CREATED WHEN
THE L-CROSS SPACECRAFT WAS

114
00:05:45,860 --> 00:05:49,000
PURPOSEFULLY CRASHED INTO
CABEUS CRATER CONTAINED

115
00:05:49,000 --> 00:05:53,210
HYDROGEN COMPONENTS EQUIVALENT
TO 5% WATER BY WEIGHT.

116

00:05:53,210 --> 00:05:56,710
THIS DATA COMBINED HAS PAINTED
A PICTURE OF SIGNIFICANT WATER

117
00:05:56,710 --> 00:05:58,129
RESOURCES, SHOWN HERE IN BLUE.

118
00:05:58,129 --> 00:06:01,449
IF IT CAN BE HARVESTED FOR
LIFE SUSTAINING WATER AND AIR

119
00:06:01,449 --> 00:06:04,370
FOR THE ASTRONAUTS, AS WELL
AS THE TONS OF PROPELLANT

120
00:06:04,370 --> 00:06:06,409
FOR THE TRIP HOME.

121
00:06:06,409 --> 00:06:09,729
THE FIRST STEP IS TO DIG UP
THE ICY REGOLITH AND DELIVER

122
00:06:09,729 --> 00:06:11,930
IT TO A PROCESSING PLANT.

123
00:06:11,930 --> 00:06:14,880
BUT NEWTON'S THIRD LAW OF MOTION
SAYS THAT FOR EVERY ACTION

124
00:06:14,880 --> 00:06:18,129
THERE IS AN EQUAL AND OPPOSITE
REACTION, AND THE 1/6 GRAVITY

125
00:06:18,129 --> 00:06:20,780
ON THE MOON MAKES IT DIFFICULT
TO FIND THE REACTION FORCE

126
00:06:20,780 --> 00:06:23,820
NECESSARY FOR DIGGING
AND DRIVING.

127
00:06:23,820 --> 00:06:26,389
SO WE ARE WORKING ON NEW WAYS
OF DIGGING IN COMPACT TO

128
00:06:26,389 --> 00:06:29,870
GRANULAR REGOLITH AND IN
HARD MATERIALS, WHERE WE

129
00:06:29,870 --> 00:06:33,789
MAY TAKE MANY SMALL SCOOPS
INSTEAD OF BIG SCOOPS,

130
00:06:33,789 --> 00:06:36,479
PUSH SIDEWAYS AGAINST THE WHEELS
OF THE EXCAVATOR INSTEAD OF

131
00:06:36,479 --> 00:06:39,490
IN LINE WITH THEM,
OR POSSIBLY DIG AT BOTH ENDS

132
00:06:39,490 --> 00:06:42,169
TO PROVIDE THE REACTION FOR US.

133
00:06:42,169 --> 00:06:45,289
WE ARE WORKING ON LIGHTWEIGHT
COMPLIANT WHEELS MADE OF WIRES

134
00:06:45,289 --> 00:06:48,400
THAT REMEMBER THEIR ORIGINAL
SHAPE TO PROVIDE TRACTION

135
00:06:48,400 --> 00:06:49,400
FOR OUR EXCAVATORS.

136
00:06:49,400 --> 00:06:52,789
AND WE ARE DESIGNING
MOBILITY PLATFORMS WITH

137

00:06:52,789 --> 00:06:56,530
EASILY-REPLACEABLE COMPONENTS
FOR PROLONGED LIFE WHEN

138
00:06:56,530 --> 00:07:00,349
WE ARE SO FAR AWAY FROM
OUR FAVORITE MECHANIC.

139
00:07:00,349 --> 00:07:02,689
ONCE WE HAVE GATHERED
THE RESOURCE, WE WILL BAKE IT

140
00:07:02,689 --> 00:07:05,509
TO EXTRACT THE WATER,
POSSIBLY IN SOMETHING SIMILAR

141
00:07:05,509 --> 00:07:09,300
TO A TERRESTRIAL SOIL DRYER,
EXCEPT ON EARTH, THEY ARE

142
00:07:09,300 --> 00:07:12,930
INTERESTED IN THE DRY DIRT,
AND ON THE MOON AND MARS,

143
00:07:12,930 --> 00:07:16,699
WE ARE INTERESTED IN
THE WATER THAT COMES OUT.

144
00:07:16,699 --> 00:07:20,409
SO WHILE ALL OF THIS SOUNDS
SIMPLE ENOUGH-- KIND OF--

145
00:07:20,409 --> 00:07:22,449
THERE'S STILL MANY CHALLENGES
TO GETTING TO THIS

146
00:07:22,449 --> 00:07:25,240
EXCITING NATURAL RESOURCE
AND EXTRACTING THE WATER

147

00:07:25,240 --> 00:07:26,659
FOR USE.

148
00:07:26,659 --> 00:07:30,460
FIRST, THE WATER IS IN
PERMANENTLY SHADOWED REGIONS,

149
00:07:30,460 --> 00:07:32,039
WHICH ARE
SURROUNDED BY SUNLIGHT,

150
00:07:32,039 --> 00:07:35,029
BUT REMAIN IN PERMANENT SHADOW,
BECAUSE THEY ARE LOWER THAN

151
00:07:35,029 --> 00:07:37,280
THE SURROUNDING TERRAIN.

152
00:07:37,280 --> 00:07:40,759
TERRAIN MAPS OF THE AREA SAY
THAT THE PATH INTO THESE REGIONS

153
00:07:40,759 --> 00:07:44,229
CAN BE LONG AND STEEP,
WITH MOST SLOPES GREATER THAN

154
00:07:44,229 --> 00:07:47,860
FIFTEEN DEGREES,
SHOWN HERE IN GREEN,

155
00:07:47,860 --> 00:07:49,810
PRESENTING SIGNIFICANT
CHALLENGES IF WE WANNA

156
00:07:49,810 --> 00:07:52,349
CONTINUALLY DRIVE IN
TO GATHER THE RESOURCE

157
00:07:52,349 --> 00:07:55,759
AND DRIVE BACK OUT TO DELIVER IT

TO THE PROCESSING PLANT.

158
00:07:55,759 --> 00:07:59,740
AN ALTERNATIVE IS TO DO MORE
PROCESSING AT THE EXCAVATION

159
00:07:59,740 --> 00:08:04,159
SITE, BAKING THE WATER OUT ON
A HOT PLATE AS WE DIG IT UP.

160
00:08:04,159 --> 00:08:07,499
OF COURSE, THIS IS ALSO
NOT AS EASY AS IT SOUNDS.

161
00:08:07,499 --> 00:08:09,569
AS WE HAVE DISCOVERED,
THAT THE DIRT FLOWS OVER

162
00:08:09,569 --> 00:08:12,300
THE PLATE MUCH MORE QUICKLY
IN A VACUUM THAN IN OUR

163
00:08:12,300 --> 00:08:15,119
INITIAL OPEN AIR TESTS,
AND SOME OF THE SIMULANTS

164
00:08:15,119 --> 00:08:17,690
FALL OUT OF THE SCOOP
MORE EASILY THAN OTHERS,

165
00:08:17,690 --> 00:08:20,460
LEAVING BIG QUESTIONS ABOUT HE--
ANY OF THIS WILL WORK IN

166
00:08:20,460 --> 00:08:22,120
THE REAL LUNAR ENVIRONMENT.

167
00:08:22,120 --> 00:08:25,800
UH, TO AVOID HAVING TO DIG UP
THE DIRT ALTOGETHER,

168
00:08:25,800 --> 00:08:27,729
WE MAY TAKE INSPIRATION
FROM THE WORKINGS OF

169
00:08:27,729 --> 00:08:31,949
A TERRESTRIAL ZAMBONI AND CREATE
A LUNAR ZAMBONI THAT HEATS

170
00:08:31,949 --> 00:08:35,449
THE DIRT WITH MICROWAVES
AND COLLECTS THE EVOLVING WATER

171
00:08:35,449 --> 00:08:38,690
AS IT ROVES THROUGH THE SHADOWS.

172
00:08:38,690 --> 00:08:40,979
EXTRACTING THE WATER INSIDE
THE REGION AND STORING IT IN

173
00:08:40,979 --> 00:08:44,279
A TANKER MEANS FEWER TRIPS
OUTSIDE OF THE REGION,

174
00:08:44,279 --> 00:08:47,750
BUT MORE POWER INSIDE,
WHERE THAT SAME LACK OF SUNLIGHT

175
00:08:47,750 --> 00:08:50,770
THAT'S GOOD FOR PRESERVING
THE ICE IS BAD WHEN WANTING

176
00:08:50,770 --> 00:08:52,740
TO USE SOLAR ENERGY.

177
00:08:52,740 --> 00:08:56,130
THEREFORE, PROCESSING INSIDE
THE SHADOWED REGIONS WILL

178

00:08:56,130 --> 00:09:00,519
LIKELY REQUIRE SOME SORT OF
BEAMED ENERGY OR NUCLEAR POWER,

179
00:09:00,519 --> 00:09:02,790
ANOTHER TECHNOLOGY BEING
DEVELOPED HERE AT

180
00:09:02,790 --> 00:09:06,550
THE NASA GLENN RESEARCH CENTER.

181
00:09:06,550 --> 00:09:09,900
IN ORDER TO MOVE TOWARD OUR
SUSTAINABILITY GOAL FASTER,

182
00:09:09,900 --> 00:09:11,560
WE MAY START BY
PROCESSING THE REGOLITH

183
00:09:11,560 --> 00:09:14,060
OUTSIDE THE SHADOW REGIONS,
WHERE WE STILL HAVE PLENTY

184
00:09:14,060 --> 00:09:16,900
OF SUNLIGHT FOR SOLAR ENERGY.

185
00:09:16,900 --> 00:09:20,440
THE LUNAR REGOLITH
CONTAINS OVER 40% OXYGEN,

186
00:09:20,440 --> 00:09:23,620
BOUND UP IN A MIX OF MINERALS
COMPRISED OF METAL OXIDES,

187
00:09:23,620 --> 00:09:26,750
SUCH AS IRON OXIDE
AND SILICON OXIDE.

188
00:09:26,750 --> 00:09:29,430
BY PROCESSING THIS REGOLITH

AT HIGH TEMPERATURES

189
00:09:29,430 --> 00:09:33,060
AND ADDING IN HYDROGEN, WE CAN
BREAK THE IRON OXIDE BONDS

190
00:09:33,060 --> 00:09:36,149
AND EXTRACT THE OXYGEN
IN THE FORM OF WATER.

191
00:09:36,149 --> 00:09:38,959
BY GOING TO EVEN HIGHER
TEMPERATURES AND INTRODUCING

192
00:09:38,959 --> 00:09:41,990
CARBON IN THE FORM OF
METHANE GAS, MORE OF

193
00:09:41,990 --> 00:09:46,690
THE METAL OXIDE BONDS CAN BE
BROKEN TO EXTRACT THE OXYGEN.

194
00:09:46,690 --> 00:09:49,250
WHILE PRODUCTION OF OXYGEN ALONE
FROM THE REGOLITH

195
00:09:49,250 --> 00:09:52,050
OUTSIDE THE SHADOWED REGIONS
DOES NOT GET US ALL THE WAY

196
00:09:52,050 --> 00:09:55,150
TO OUR SUSTAINABILITY GOALS,
TEN OF THAT TWELVE TONS

197
00:09:55,150 --> 00:09:57,279
OF PROPELLANT I SAID
WE NEEDED FOR THE TRIP HOME

198
00:09:57,279 --> 00:09:58,490
IS OXYGEN.

199
00:09:58,490 --> 00:10:01,190
SO IT IS A GOOD START.

200
00:10:01,190 --> 00:10:03,970
AFTER ESTABLISHING A FOOTHOLD
ON THE EDGE OF THE COUNTRY,

201
00:10:03,970 --> 00:10:07,040
OUR PIONEER ANCESTORS
BEGAN PUSHING WESTWARD.

202
00:10:07,040 --> 00:10:09,639
WE CAN IMAGINE-- 'CAUSE WE'RE
A BUNCH OF ENGINEERS,

203
00:10:09,639 --> 00:10:12,630
WE ACTUALLY DID THE MATH--
WHAT WOULD'VE HAPPENED IF THEIR

204
00:10:12,630 --> 00:10:15,610
COVERED WAGONS FILLED WITH
THE POSSESSIONS AND TOOLS NEEDED

205
00:10:15,610 --> 00:10:18,670
TO SURVIVE IN THE WILDERNESS
INSTEAD NEEDED TO CARRY

206
00:10:18,670 --> 00:10:22,560
THE FOOD, WATER, AND AIR
FOR THE MULES PULLING THE WAGON?

207
00:10:22,560 --> 00:10:25,470
ASSUMING SIX MULES CAN
PULL A TWO THOUSAND POUND WAGON

208
00:10:25,470 --> 00:10:28,880
25 MILES A DAY,
AND THOSE SAME SIX MULES

209
00:10:28,880 --> 00:10:32,230
REQUIRE EIGHTY-FIVE POUNDS
A DAY OF FOOD, WATER, AND AIR,

210
00:10:32,230 --> 00:10:34,290
THEN OUR ANCESTORS
NEVER WOULD'VE MADE

211
00:10:34,290 --> 00:10:37,089
THE APPALACHIAN MOUNTAINS.

212
00:10:37,089 --> 00:10:39,569
THERE ARE MANY MORE PARTS WE'RE
WORKING ON TO COMPLETE OUR

213
00:10:39,569 --> 00:10:42,600
COMBINATION MINE REFINERY
AND GAS STATION FOR

214
00:10:42,600 --> 00:10:44,380
THE MOON AND MARS.

215
00:10:44,380 --> 00:10:47,529
WHEN WE ARE DONE,
WE WILL HAVE DISCOVERED,

216
00:10:47,529 --> 00:10:51,880
OR PERHAPS REDISCOVERED,
A NEW AND BETTER WAY

217
00:10:51,880 --> 00:10:54,480
OF EXPLORING BEYOND
THE BOUNDS OF EARTH.