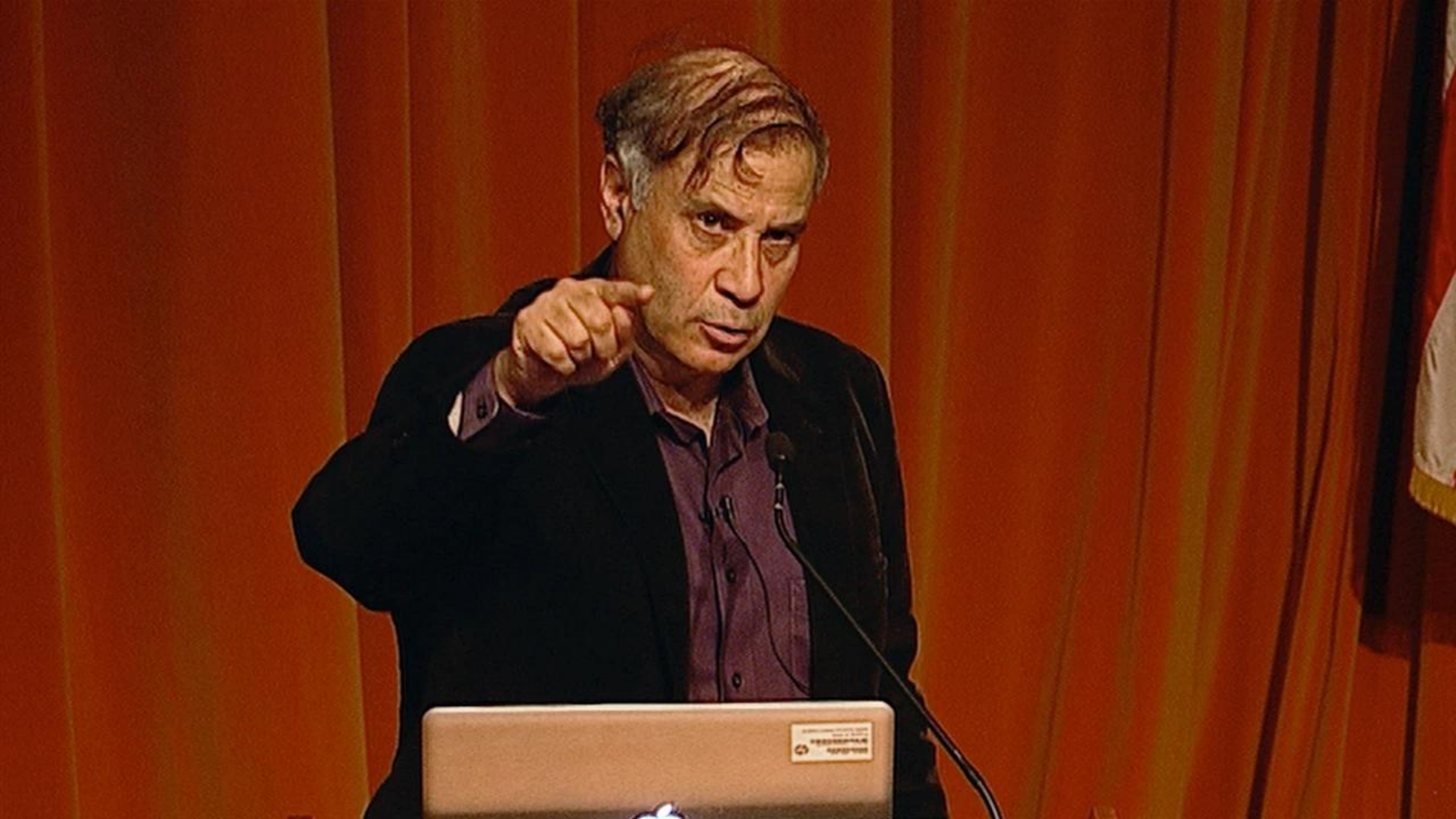

1
00:00:01,000 --> 00:00:07,000
[music playing]

2
00:00:17,433 --> 00:00:19,366
- WELCOME TO
THE 75TH ANNIVERSARY

3
00:00:19,366 --> 00:00:21,366
OF NASA AMES RESEARCH CENTER

4
00:00:21,366 --> 00:00:26,366
AND THE DIRECTOR'S
COLLOQUIUM SUMMER SERIES.

5
00:00:26,366 --> 00:00:29,766
WE FIRST ACHIEVED HUMAN LANDING

6
00:00:29,766 --> 00:00:34,300
ON THE MOON IN 1969.

7
00:00:34,300 --> 00:00:37,633
AT THE SAME TIME,
VON BRAUN AND OTHERS

8
00:00:37,633 --> 00:00:40,433
PITCHED THE IDEA
OF GOING TO MARS

9
00:00:40,433 --> 00:00:43,833
TO THE PRESIDENT
OF THE UNITED STATES.

10
00:00:43,833 --> 00:00:47,866
THE QUESTION IS: WHY MARS?

11
00:00:47,866 --> 00:00:51,133
FIRST, IT'S OUR NEAREST
NEIGHBOR, RIGHT?

12
00:00:51,133 --> 00:00:55,766
IT'S THE NEXT-PLANET NEIGHBOR,
VENUS AND MARS.

13
00:00:55,766 --> 00:01:01,733
SECOND, IT IS A WAY FOR US
TO UNDERSTAND OUR PAST

14
00:01:01,733 --> 00:01:06,066
BY STUDYING THE NEIGHBORS
THAT ARE NEXT TO US.

15
00:01:06,066 --> 00:01:11,733
IT'S ALSO POTENTIALLY A PLACE
TO COLONIZE IN THE FUTURE.

16
00:01:11,733 --> 00:01:15,900
BUT I ALWAYS SAY THAT
SCIENCE-FICTION DRIVES REALITY.

17
00:01:15,900 --> 00:01:18,500
WHEN WE FIRST STARTED
LOOKING AT MARS,

18
00:01:18,500 --> 00:01:21,833
WE SAW WHAT LOOKED
LIKE CANALS AND CHANNELS

19
00:01:21,833 --> 00:01:23,900
THAT ARE THERE CHANGING,

20
00:01:23,900 --> 00:01:25,400
AND WE ENVISIONED
THAT THERE ARE PEOPLE

21
00:01:25,400 --> 00:01:27,500
ON THAT PLANET.

22
00:01:27,500 --> 00:01:29,133

SOME EVEN ENVISIONED

23
00:01:29,133 --> 00:01:34,333
ATTACKS FROM MARS
ON OUR PLANET.

24
00:01:34,333 --> 00:01:38,666
SO FAR, WE HAVE HAD
MANY MISSIONS TO MARS,

25
00:01:38,666 --> 00:01:42,633
ROBOTIC MISSIONS
THAT ARE EXPLORING MARS.

26
00:01:42,633 --> 00:01:45,366
BUT I PERSONALLY,
AND MANY OTHERS,

27
00:01:45,366 --> 00:01:48,033
WANT TO SEE US THERE,

28
00:01:48,033 --> 00:01:52,633
SEE HUMANS GO TO MARS.

29
00:01:52,633 --> 00:01:55,533
WHEN DO WE DO THIS?

30
00:01:55,533 --> 00:01:59,833
DO WE WAIT UNTIL
WE'VE RESOLVED ALL ISSUES,

31
00:01:59,833 --> 00:02:03,733
UNTIL WE KNOW WE HAVE NO MORE
TECHNOLOGY DEVELOPMENT?

32
00:02:03,733 --> 00:02:08,600
OR DO WE DECIDE A CERTAIN DATE
BY WHICH WE STOP

33

00:02:08,600 --> 00:02:12,333
AND TAKE OUR TECHNOLOGY
THAT WE HAVE AND TAKE SOME RISKS

34
00:02:12,333 --> 00:02:16,900
AND GO TO MARS?

35
00:02:16,900 --> 00:02:19,933
WHEN YOU TAKE THOSE MISSIONS,
YOU WILL LEARN,

36
00:02:19,933 --> 00:02:21,466
AND AS YOU LEARN
FROM THOSE MISSIONS,

37
00:02:21,466 --> 00:02:24,266
YOU COULD HAVE
SAFER TRAVELS TO MARS

38
00:02:24,266 --> 00:02:28,533
AND POTENTIALLY OTHER PLANETS.

39
00:02:28,533 --> 00:02:31,366
TODAY'S TALK IS ENTITLED

40
00:02:31,366 --> 00:02:38,133
"MARS DIRECT: HUMANS TO
THE RED PLANET WITHIN A DECADE."

41
00:02:38,133 --> 00:02:42,433
IT WILL BE PRESENTED
BY DR. ROBERT ZUBRIN,

42
00:02:42,433 --> 00:02:47,033
WHO IS THE PRESIDENT
OF PIONEER ASTRONAUTICS

43
00:02:47,033 --> 00:02:50,633
AND ALSO THE SPIN-OFF
PIONEER ENERGY.

44
00:02:50,633 --> 00:02:54,800
HE IS A FELLOW OF THE BRITISH
INTERPLANETARY SOCIETY

45
00:02:54,800 --> 00:02:58,133
AND THE FOUNDER AND PRESIDENT
OF MARS SOCIETY.

46
00:03:00,933 --> 00:03:03,966
HE HAS INVENTED
SEVERAL UNIQUE CONCEPTS

47
00:03:03,966 --> 00:03:06,966
FOR SPACE PROPULSION
AND EXPLORATION,

48
00:03:06,966 --> 00:03:11,866
THE AUTHOR OF HUNDREDS
OF PUBLICATIONS,

49
00:03:11,866 --> 00:03:14,766
TECHNICAL PUBLICATIONS
AND NON-TECHNICAL PUBLICATIONS,

50
00:03:14,766 --> 00:03:19,733
INCLUDING NONFICTION
AND FICTION BOOKS.

51
00:03:19,733 --> 00:03:23,400
PLEASE JOIN ME
IN WELCOMING ROBERT ZUBRIN.

52
00:03:23,400 --> 00:03:26,966
[applause]

53
00:03:31,433 --> 00:03:32,966
- OKAY.

54

00:03:32,966 --> 00:03:35,366
SO, THANK YOU
FOR THAT KIND INTRODUCTION

55
00:03:35,366 --> 00:03:37,866
AND FOR INVITING ME
TO COME AND SPEAK HERE.

56
00:03:37,866 --> 00:03:39,500
AND THANKS TO ALL OF YOU
FOR COMING,

57
00:03:39,500 --> 00:03:41,000
LISTENING TO WHAT
I'VE GOT TO SAY,

58
00:03:41,000 --> 00:03:42,833
AND MORE IMPORTANTLY,
FOR WHAT YOU'RE DOING,

59
00:03:42,833 --> 00:03:46,566
BECAUSE I THINK THAT THIS TASK
OF OPENING SPACE,

60
00:03:46,566 --> 00:03:48,133
OPENING THE UNIVERSE
TO HUMANITY

61
00:03:48,133 --> 00:03:50,533
IS THE MOST IMPORTANT THING
GOING ON IN THE WORLD

62
00:03:50,533 --> 00:03:51,533
AT THIS TIME.

63
00:03:51,533 --> 00:03:54,000
THIS TIME WILL BE REMEMBERED

64
00:03:54,000 --> 00:03:56,033
BECAUSE THIS IS WHEN

WE FIRST SET SAIL

65
00:03:56,033 --> 00:03:57,700
FOR OTHER WORLDS.

66
00:03:57,700 --> 00:04:03,300
I'M GONNA TALK HUMANS TO MARS
WITHIN A DECADE, OKAY?

67
00:04:03,300 --> 00:04:08,866
AND I'M GONNA TALK
A LITTLE BIT

68
00:04:08,866 --> 00:04:11,966
ABOUT WHY I THINK
IT WOULD HAVE TO BE DONE

69
00:04:11,966 --> 00:04:14,300
IN THAT KIND OF TIME FRAME
IF YOU'RE GOING TO DO IT.

70
00:04:14,300 --> 00:04:15,800
I'M GONNA TALK AT SOME LENGTH

71
00:04:15,800 --> 00:04:17,466
AS TO HOW I THINK
IT COULD BE DONE.

72
00:04:17,466 --> 00:04:18,600
IN FACT, I'M GOING TO SHOW YOU

73
00:04:18,600 --> 00:04:19,966
TWO DIFFERENT WAYS
IT COULD BE DONE,

74
00:04:19,966 --> 00:04:21,300
A PREFERRED WAY

75
00:04:21,300 --> 00:04:24,900

AND ANOTHER WAY
THAT WOULD ALSO WORK,

76
00:04:24,900 --> 00:04:29,966
ALTHOUGH IT PUSHES THE LIMITS
OF MINIMALISM TO DO IT.

77
00:04:29,966 --> 00:04:33,800
AND FINALLY,
I'LL TALK A LITTLE BIT

78
00:04:33,800 --> 00:04:35,533
ABOUT WHY IT NEEDS
TO BE DONE AT ALL.

79
00:04:35,533 --> 00:04:36,633
AND BY THE WAY,
IF YOU WANT TO HEAR MORE

80
00:04:36,633 --> 00:04:38,833
ON ESPECIALLY
THAT LATTER SUBJECT,

81
00:04:38,833 --> 00:04:41,733
THE MARS SOCIETY IS HAVING
ITS CONFERENCE IN HOUSTON

82
00:04:41,733 --> 00:04:43,366
AUGUST 7TH THROUGH 10TH.

83
00:04:43,366 --> 00:04:44,866
YOU'RE ALL INVITED TO COME.

84
00:04:44,866 --> 00:04:46,466
THERE'LL BE ALL KINDS
OF TALKS THERE

85
00:04:46,466 --> 00:04:49,800
ABOUT WHY AND HOW
WE CAN GO TO MARS.

86
00:04:49,800 --> 00:04:54,133
SO, HUMANS TO MARS
WITHIN A DECADE, OKAY?

87
00:04:54,133 --> 00:04:56,433
IS THAT REALLY POSSIBLE?

88
00:04:56,433 --> 00:04:58,866
NASA'S CURRENT, I MEAN, TIMELINE

89
00:04:58,866 --> 00:05:02,066
IS TO DO IT
AROUND THE YEAR 2047,

90
00:05:02,066 --> 00:05:03,733
MAYBE 3047.

91
00:05:03,733 --> 00:05:05,433
[laughter]

92
00:05:05,433 --> 00:05:11,166
THE QUESTION
OF WHETHER WE CAN DO

93
00:05:11,166 --> 00:05:12,666
HUMANS TO MARS IN TEN YEARS

94
00:05:12,666 --> 00:05:15,500
IS SOMEWHAT ANALOGOUS
TO THE QUESTION OF,

95
00:05:15,500 --> 00:05:17,866
"HOW MUCH ROPE DOES IT TAKE
TO CONNECT TWO POSTS

96
00:05:17,866 --> 00:05:20,366
SEPARATED BY A DISTANCE
OF 10 METERS?"

97
00:05:20,366 --> 00:05:23,333
IN PRINCIPLE, IT CAN BE DONE
WITH 10 METERS OF ROPE.

98
00:05:23,333 --> 00:05:24,633
ON THE OTHER HAND,
IF YOU LET THE ROPE

99
00:05:24,633 --> 00:05:26,033
BE TANGLED EVERY WHICH WAY,

100
00:05:26,033 --> 00:05:28,233
IT COULD TAKE AN INFINITE AMOUNT
OF ROPE, OKAY,

101
00:05:28,233 --> 00:05:32,500
AND SO THE ANSWER
TO THE QUESTION IS DEPENDENT

102
00:05:32,500 --> 00:05:34,500
UPON WHETHER YOU ACTUALLY WANT
TO CONNECT THE TWO POSTS

103
00:05:34,500 --> 00:05:37,733
OR WHETHER YOU'RE TRYING
TO SELL ROPE.

104
00:05:37,733 --> 00:05:40,566
AND "MARS DIRECT"
WAS ACTUALLY CONCEIVED

105
00:05:40,566 --> 00:05:42,600
BY A TEAM LED BY ME

106
00:05:42,600 --> 00:05:44,866
AND ANOTHER ENGINEER
NAMED DAVID BAKER

107

00:05:44,866 --> 00:05:47,633
AT MARTIN MARIETTA,
WHICH BECAME LOCKHEED MARTIN,

108
00:05:47,633 --> 00:05:50,400
IN 1990 IN RESPONSE
TO THE FAILURE,

109
00:05:50,400 --> 00:05:52,133
OR THE IMMINENT FAILURE--

110
00:05:52,133 --> 00:05:53,966
AT THAT TIME,
IT HADN'T QUITE FAILED YET--

111
00:05:53,966 --> 00:05:57,600
OF THE FIRST PRESIDENT BUSH'S
SPACE EXPLORATION INITIATIVE,

112
00:05:57,600 --> 00:06:00,200
WHICH WAS FOUNDERING
BASED ON STICKER SHOCK

113
00:06:00,200 --> 00:06:01,933
DUE TO THE 90-DAY REPORT

114
00:06:01,933 --> 00:06:04,066
WHICH HAD POSTULATED
A 30-YEAR PROGRAM

115
00:06:04,066 --> 00:06:05,466
COSTING $400 BILLION

116
00:06:05,466 --> 00:06:08,966
AND ALL SORTS OF EXERCISES
IN INFRASTRUCTURE

117
00:06:08,966 --> 00:06:11,933
AND TECHNOLOGY DEVELOPMENTS
BEFORE WE COULD GET TO MARS.

118
00:06:11,933 --> 00:06:15,633
AND IT WAS VERY CLEAR
TO US AT MARTIN

119
00:06:15,633 --> 00:06:18,666
THAT THE REASON
WHY THE 90-DAY REPORT

120
00:06:18,666 --> 00:06:21,133
WAS SO LONG AND COSTLY
AND COMPLEX

121
00:06:21,133 --> 00:06:24,133
WAS THAT IT WAS--
HAD BEEN DESIGNED

122
00:06:24,133 --> 00:06:28,600
WITH THE IDEA OF MAKING
A WHOLE BUNCH OF PEOPLE HAPPY,

123
00:06:28,600 --> 00:06:30,733
PEOPLE DEVELOPING THIS
TECHNOLOGY AND THAT TECHNOLOGY

124
00:06:30,733 --> 00:06:33,333
IN THIS CENTER AND THAT CENTER
OR THIS COMPANY OR THAT COMPANY

125
00:06:33,333 --> 00:06:35,100
OR HERE OR THERE OR EVERYWHERE.

126
00:06:35,100 --> 00:06:37,233
THEY HAD BASICALLY
NOT DESIGNED A MISSION

127
00:06:37,233 --> 00:06:38,333
BUT A CHRISTMAS TREE

128

00:06:38,333 --> 00:06:39,933
UPON WHICH TO HANG
ALL THE ORNAMENTS

129
00:06:39,933 --> 00:06:42,533
AND, YOU KNOW,
PROVIDE BUSINESS FOR EVERYONE.

130
00:06:42,533 --> 00:06:44,700
AND THAT'S THE EXACT OPPOSITE

131
00:06:44,700 --> 00:06:46,800
OF THE CORRECT WAY
TO DO ENGINEERING, OKAY?

132
00:06:46,800 --> 00:06:48,733
YOU DON'T DESIGN SOMETHING

133
00:06:48,733 --> 00:06:51,400
TO BE AS COMPLEX
AND COSTLY AS POSSIBLE

134
00:06:51,400 --> 00:06:53,200
IN ORDER TO PLEASE YOUR VENDORS.

135
00:06:53,200 --> 00:06:56,166
YOU DESIGN IT TO BE
AS SIMPLE AS POSSIBLE

136
00:06:56,166 --> 00:06:58,066
AND AS INEXPENSIVE
AS POSSIBLE

137
00:06:58,066 --> 00:07:01,933
IN ORDER TO DO THE JOB
MOST EFFICIENTLY.

138
00:07:01,933 --> 00:07:03,666
SO THE QUESTION
WE ASKED OURSELVES

139
00:07:03,666 --> 00:07:04,966
WHEN WE DESIGNED "MARS DIRECT"

140
00:07:04,966 --> 00:07:06,800
IS, IF YOU WANTED
TO DESIGN A MARS MISSION

141
00:07:06,800 --> 00:07:10,200
AND NOT PROVIDE EXCUSES
FOR PEOPLE WHO WANTED, YOU KNOW,

142
00:07:10,200 --> 00:07:11,366
TO USE THIS TECHNOLOGY,

143
00:07:11,366 --> 00:07:12,533
WANTED TO USE
ELECTRIC PROPULSION,

144
00:07:12,533 --> 00:07:14,033
WANTED TO USE
NUCLEAR PROPULSION,

145
00:07:14,033 --> 00:07:15,533
WANTED TO USE THIS,
WANTED TO USE THAT,

146
00:07:15,533 --> 00:07:16,900
WANTED TO USE
BIOREGENERATIVE LIFE SUPPORT

147
00:07:16,900 --> 00:07:18,666
AND PHYSICAL LIFE SUPPORT
AND THIS

148
00:07:18,666 --> 00:07:19,800
AND HAVE A LUNAR BASE

149
00:07:19,800 --> 00:07:21,166

AND HAVE A HANGAR
ON THE SPACE STATION

150
00:07:21,166 --> 00:07:25,333
AND, YOU KNOW, THE ABILITY
TO REUSE RL-10 ENGINES IN ORBIT,

151
00:07:25,333 --> 00:07:26,633
AND WHATEVER,

152
00:07:26,633 --> 00:07:27,966
HOW WOULD YOU DO IT

153
00:07:27,966 --> 00:07:31,033
IF YOU JUST WANTED
TO GET THE JOB DONE, OKAY?

154
00:07:31,033 --> 00:07:34,300
AND THAT IS THE QUESTION
WE ASKED OURSELVES.

155
00:07:34,300 --> 00:07:37,533
SO, FIRST, I'M GOING TO NOW
PRESENT THE DESIGN

156
00:07:37,533 --> 00:07:42,766
AS WE DEVELOPED IT
IN THE SPRING OF 1990.

157
00:07:42,766 --> 00:07:44,233
OKAY.

158
00:07:44,233 --> 00:07:46,733
THIS IS THE MISSION
SEQUENCE CHART

159
00:07:46,733 --> 00:07:49,033
FOR THE "MARS DIRECT" PLAN.

160

00:07:49,033 --> 00:07:51,033
YOU CAN LAUNCH TO MARS
EVERY TWO YEARS,

161
00:07:51,033 --> 00:07:52,600
SO WE'RE GOING TO BE LAUNCHING
TWO BOOSTERS

162
00:07:52,600 --> 00:07:57,933
EVERY TWO YEARS TO MARS
IN ORDER TO DO THIS.

163
00:07:57,933 --> 00:08:00,833
WELL, FIRST OF ALL,
ANY SPACE OPERATION

164
00:08:00,833 --> 00:08:02,700
REQUIRES AN APPROPRIATE
LAUNCH VEHICLE,

165
00:08:02,700 --> 00:08:05,900
AND WE SET OURSELVES THE TASK
OF DESIGNING ONE

166
00:08:05,900 --> 00:08:09,300
IN THE SATURN V CLASS
OUT OF AVAILABLE TECHNOLOGY,

167
00:08:09,300 --> 00:08:11,533
SHUTTLE TECHNOLOGY.

168
00:08:11,533 --> 00:08:13,933
AND ACTUALLY IT'S NOT
VERY DIFFERENT FROM THE SLS

169
00:08:13,933 --> 00:08:18,600
THAT IS CURRENTLY BEING
DEVELOPED BY NASA.

170
00:08:18,600 --> 00:08:20,300

I MEAN, WE'RE USING
SHUTTLE MAIN ENGINES

171
00:08:20,300 --> 00:08:22,066
INSTEAD OF SOME OTHER MAIN
ENGINES AT THE BOTTOM,

172
00:08:22,066 --> 00:08:23,500
AND THEY'RE OFFSET A LITTLE BIT

173
00:08:23,500 --> 00:08:25,333
BECAUSE THESE WERE
GOING TO BE LAUNCHED

174
00:08:25,333 --> 00:08:26,733
IN PARALLEL WITH THE SHUTTLE,

175
00:08:26,733 --> 00:08:29,400
WHICH HAS ITS FLAME TRENCHES
POSITIONED THUS.

176
00:08:29,400 --> 00:08:30,900
BUT, BASICALLY, HERE YOU GO.

177
00:08:30,900 --> 00:08:33,633
YOU HAVE FOUR SHUTTLE
MAIN ENGINES, A COUPLE SOLIDS,

178
00:08:33,633 --> 00:08:35,166
THE EXTERNAL TANK CORE,

179
00:08:35,166 --> 00:08:37,266
HYDROGEN-OXYGEN UPPER STAGE,

180
00:08:37,266 --> 00:08:38,600
AND A 10-METER FAIRING,

181
00:08:38,600 --> 00:08:42,600
OR 33 FEET IF YOU WORK

AT LOCKHEED MARTIN.

182
00:08:42,600 --> 00:08:46,500
AND THE--OKAY.

183
00:08:46,500 --> 00:08:50,033
AND THIS COULD LIFT 120 TONS
TO LOW EARTH ORBIT,

184
00:08:50,033 --> 00:08:51,566
BUT MORE IMPORTANTLY,

185
00:08:51,566 --> 00:08:57,266
IT COULD USE THIS UPPER STAGE
TO SEND 47 TONS

186
00:08:57,266 --> 00:08:59,000
ON DIRECT TRANS-MARS INJECTION

187
00:08:59,000 --> 00:09:01,600
OR 59 TONS
ON TRANS-LUNAR INJECTION.

188
00:09:01,600 --> 00:09:03,866
AND THAT IS HOW
WE WANTED TO DO THE MISSION,

189
00:09:03,866 --> 00:09:05,366
JUST LIFT AND THROW
AND LET IT GO,

190
00:09:05,366 --> 00:09:06,866
SEND THE PAYLOAD TO THE PLANET,

191
00:09:06,866 --> 00:09:10,400
THE SAME BOOSTER THAT
LAUNCHED IT IN THE FIRST PLACE.

192
00:09:10,400 --> 00:09:11,500

THAT'S HOW WE'VE DONE

193
00:09:11,500 --> 00:09:13,333
EVERY REAL, UNMANNED
PLANETARY MISSION,

194
00:09:13,333 --> 00:09:15,800
THAT'S HOW WE DID THE REAL
APOLLO MISSIONS TO THE MOON.

195
00:09:15,800 --> 00:09:17,800
NO ONE'S EVER DONE
A MISSION TO ANYWHERE

196
00:09:17,800 --> 00:09:19,600
BY LIFTING THINGS
TO THE SPACE STATION

197
00:09:19,600 --> 00:09:21,233
AND WAITING
FOR THE INTERPLANETARY CRUISER

198
00:09:21,233 --> 00:09:22,566
TO RETURN FROM SATURN

199
00:09:22,566 --> 00:09:24,400
AND BE REFITTED
TO LOAD THE PAYLOAD ON IT

200
00:09:24,400 --> 00:09:25,666
AND THEN GO BACK OUT.

201
00:09:25,666 --> 00:09:27,866
NO, JUST LIFT AND THROW
AND LET IT GO.

202
00:09:27,866 --> 00:09:30,100
AND RIGHT THERE, IF YOU CAN
DO THE MISSION THAT WAY,

203
00:09:30,100 --> 00:09:32,833
YOU'VE GONE 90% OF THE WAY
TOWARDS TAKING THE MARS MISSION

204
00:09:32,833 --> 00:09:34,500
OUT OF THE SCIENCE-FICTION
FUTURE

205
00:09:34,500 --> 00:09:37,633
AND PUTTING IT IN OUR WORLD
OF REAL ENGINEERING.

206
00:09:37,633 --> 00:09:39,566
BUT HOW CAN YOU DO THAT?

207
00:09:39,566 --> 00:09:44,000
THE TYPICAL MARS MISSION
DESIGNS THAT WERE AROUND

208
00:09:44,000 --> 00:09:48,066
WERE 700 TO 1,000 TONS IN LEO.

209
00:09:48,066 --> 00:09:49,833
THIS IS 120 TONS IN LEO,

210
00:09:49,833 --> 00:09:51,800
WHICH, BY THE WAY, IS A LITTLE
LESS THAN A SATURN V,

211
00:09:51,800 --> 00:09:54,966
WHICH COULD DO 140.

212
00:09:54,966 --> 00:09:56,533
YOU KNOW, A BOOSTER
THAT COULD LAUNCH

213
00:09:56,533 --> 00:10:00,066
ONE OF THESE DEATH STAR
SPACESHIP CONCEPTS,

214
00:10:00,066 --> 00:10:02,133
YOU'D BLOW AWAY ORLANDO
WHEN YOU TOOK OFF.

215
00:10:02,133 --> 00:10:05,233
SO HOW COULD YOU
DO THIS MISSION

216
00:10:05,233 --> 00:10:07,500
WITH A SATURN V CLASS BOOSTER?

217
00:10:07,500 --> 00:10:10,166
WELL, IF YOU LOOKED
AT THESE OTHER MISSION PLANS,

218
00:10:10,166 --> 00:10:11,900
WHAT YOU SAW WAS THAT
THE MAJORITY OF THE MASS

219
00:10:11,900 --> 00:10:13,266
THAT THEY WERE SENDING TO MARS

220
00:10:13,266 --> 00:10:15,800
WAS THE PROPELLANT
TO COME BACK.

221
00:10:15,800 --> 00:10:17,933
WELL, THAT MAY
SEEM PRUDENT, OKAY?

222
00:10:17,933 --> 00:10:19,166
SHOULDN'T YOU GO TO MARS

223
00:10:19,166 --> 00:10:21,900
AND HAVE THE PROPELLANT
TO COME BACK?

224
00:10:21,900 --> 00:10:24,466

WELL, IS THAT HOW
WE'VE EXPLORED ON EARTH?

225
00:10:24,466 --> 00:10:27,700
DID LEWIS AND CLARK
CROSS THE AMERICAN CONTINENT

226
00:10:27,700 --> 00:10:29,866
BRINGING WITH THEM ALL
THE FOOD, WATER, AND AIR

227
00:10:29,866 --> 00:10:32,100
THEY WOULD NEED FOR THEMSELVES
AND THEIR HORSES

228
00:10:32,100 --> 00:10:33,333
FOR A THREE-YEAR
TRANSCONTINENTAL

229
00:10:33,333 --> 00:10:34,333
TRIP OF EXPLORATION?

230
00:10:34,333 --> 00:10:35,333
NO.

231
00:10:35,333 --> 00:10:36,600
IF THEY HAD DONE THAT,

232
00:10:36,600 --> 00:10:38,266
THEY WOULD HAVE NEEDED
A WAGON TRAIN OF SUPPLIES

233
00:10:38,266 --> 00:10:39,266
FOR EVERY MAN

234
00:10:39,266 --> 00:10:41,166
AND ANOTHER WAGON TRAIN
FOR EVERY HORSE,

235

00:10:41,166 --> 00:10:43,233
AND THEN, OF COURSE,
THE WAGON TRAIN MEN AND HORSES

236
00:10:43,233 --> 00:10:44,833
WOULD HAVE NEEDED
FURTHER WAGON TRAINS,

237
00:10:44,833 --> 00:10:46,400
AND IT WOULD HAVE
GONE EXPONENTIAL.

238
00:10:46,400 --> 00:10:47,966
AND NOT ONLY WOULD IT HAVE
BLOWN THE BUDGET

239
00:10:47,966 --> 00:10:49,633
OF THOMAS JEFFERSON'S AMERICA,

240
00:10:49,633 --> 00:10:52,900
IT WOULD HAVE EXCEEDED
THE MASS OF THE EARTH.

241
00:10:52,900 --> 00:10:57,266
OKAY, NOW, THE--BUT NO,
THAT'S NOT WHAT THEY DID.

242
00:10:57,266 --> 00:10:59,266
THEY HUNTED THEIR WAY ACROSS,

243
00:10:59,266 --> 00:11:02,733
AND IN CERTAIN WAYS THEY TRADED
WITH NATIVE AMERICANS

244
00:11:02,733 --> 00:11:04,433
TO OBTAIN NECESSARY SUPPLIES.

245
00:11:04,433 --> 00:11:06,166
BUT IN EITHER CASE,
THEY WERE MAKING USE

246
00:11:06,166 --> 00:11:08,166
OF THE RESOURCES
THAT WERE AVAILABLE

247
00:11:08,166 --> 00:11:10,966
IN THE ENVIRONMENT
THEY INTENDED TO OPERATE IN.

248
00:11:10,966 --> 00:11:12,366
WELL, WHY ARE WE GOING TO MARS?

249
00:11:12,366 --> 00:11:14,100
WE'RE GOING TO MARS
BECAUSE MARS IS THE PLANET

250
00:11:14,100 --> 00:11:16,433
THAT HAS THE RESOURCES
THAT CAN SUPPORT LIFE

251
00:11:16,433 --> 00:11:19,633
AND, THEREFORE, POTENTIALLY
TECHNOLOGICAL CIVILIZATION.

252
00:11:19,633 --> 00:11:23,100
WELL, THE SAME RESOURCES
THAT MAKE MARS INTERESTING,

253
00:11:23,100 --> 00:11:25,733
IF YOU MAKE USE OF THEM,
CAN ALSO MAKE IT ATTAINABLE.

254
00:11:25,733 --> 00:11:28,566
SO THAT IS THE ORIENTATION
WE TOOK HERE.

255
00:11:28,566 --> 00:11:31,033
WHAT IS THE TRAVEL-LIGHT,
LIVE-OFF-THE-LAND APPROACH

256
00:11:31,033 --> 00:11:33,600
TO MARS EXPLORATION?

257
00:11:33,600 --> 00:11:38,700
SO THE FIRST THING
THAT WE SEND TO MARS,

258
00:11:38,700 --> 00:11:41,166
THE FIRST LAUNCH, HERE,

259
00:11:41,166 --> 00:11:43,966
SENDS OUT
ON A MINIMUM-ENERGY TRAJECTORY

260
00:11:43,966 --> 00:11:46,966
A EARTH RETURN VEHICLE, ERV.

261
00:11:46,966 --> 00:11:48,833
AND WHAT THIS IS,
THIS IS A LITTLE ROCKET SHIP

262
00:11:48,833 --> 00:11:50,433
FOR RETURNING FROM MARS TO EARTH

263
00:11:50,433 --> 00:11:51,966
IN THE TERMINAL STAGE
OF THE MISSION.

264
00:11:51,966 --> 00:11:54,233
BUT NO ONE'S IN IT
WHEN IT GOES OUT THE FIRST TIME.

265
00:11:54,233 --> 00:11:56,133
SO IT IS UNMANNED.

266
00:11:56,133 --> 00:11:58,900
IT'S GOT A LITTLE CABIN HERE,
15 FEET IN DIAMETER,

267
00:11:58,900 --> 00:12:03,000
WITH SPARTAN QUARTERS
FOR A CREW OF FOUR

268
00:12:03,000 --> 00:12:05,233
FOR A SIX-MONTH VOYAGE
FROM MARS BACK TO EARTH.

269
00:12:05,233 --> 00:12:07,100
THEN IT'S GOT TWO
METHANE OXYGEN

270
00:12:07,100 --> 00:12:10,900
CHEMICAL PROPULSION STAGES HERE
WHICH ARE UNFUELED.

271
00:12:10,900 --> 00:12:12,300
THEY HAVE TO BE UNFUELED,

272
00:12:12,300 --> 00:12:13,566
OR THIS WILL WEIGH
MUCH TOO HEAVY

273
00:12:13,566 --> 00:12:16,966
FOR SOMETHING LIKE
A SATURN V CLASS BOOSTER

274
00:12:16,966 --> 00:12:18,333
TO THROW TO MARS.

275
00:12:18,333 --> 00:12:19,833
HOWEVER, IN SOME
OF THE LOWER STAGE TANKS

276
00:12:19,833 --> 00:12:21,933
THAT ARE LATER
GOING TO CONTAIN METHANE,

277
00:12:21,933 --> 00:12:23,833

WE'VE GOT ABOUT 6 TONS
OF LIQUID HYDROGEN

278
00:12:23,833 --> 00:12:25,300
PROBABLY IN GEL FORM,

279
00:12:25,300 --> 00:12:26,600
AND THEN SLUNG
BELOW THE VEHICLE,

280
00:12:26,600 --> 00:12:28,100
NOT SHOWN IN THIS DIAGRAM,

281
00:12:28,100 --> 00:12:29,300
IS A LITTLE TRUCK,
A LIGHT TRUCK,

282
00:12:29,300 --> 00:12:30,666
LIKE A LITTLE PICKUP TRUCK.

283
00:12:30,666 --> 00:12:34,133
IN THE BACK OF THAT TRUCK
IS A LITTLE NUCLEAR REACTOR

284
00:12:34,133 --> 00:12:36,166
WITH A POWER
OF 100 KILOWATTS.

285
00:12:36,166 --> 00:12:38,666
OKAY, 100 KILOWATTS
IS LIKE 130 HORSEPOWER,

286
00:12:38,666 --> 00:12:41,166
SAME AMOUNT OF POWER
THAT POWERS A MEDIUM-SIZE CAR.

287
00:12:41,166 --> 00:12:43,400
OKAY, SO IT'S NOT A GIANT
NUCLEAR POWER PLANT

288
00:12:43,400 --> 00:12:44,500
THAT POWERS A CITY.

289
00:12:44,500 --> 00:12:45,900
IT'S JUST A NICE LITTLE
PUTT-PUTT NUKE

290
00:12:45,900 --> 00:12:47,500
SITTING IN THE BACK OF A TRUCK.

291
00:12:47,500 --> 00:12:50,266
NOW, AFTER YOU'VE LANDED,

292
00:12:50,266 --> 00:12:51,966
THE TRUCK IS
TELEROBOTICALLY DRIVEN

293
00:12:51,966 --> 00:12:53,466
A FEW HUNDRED METERS AWAY,

294
00:12:53,466 --> 00:12:55,666
UNWINDING A CABLE
OFF THE BACK OF IT AS IT GOES,

295
00:12:55,666 --> 00:12:57,300
AND THEN THE REACTOR'S
PUT ON THE GROUND,

296
00:12:57,300 --> 00:12:58,900
PREFERABLY IN A DITCH
OR A CRATER

297
00:12:58,900 --> 00:13:00,266
ON THE REVERSE SIDE
OF THE HILL,

298
00:13:00,266 --> 00:13:01,833
ANYTHING TO PUT A NICE-SIZE
CHUNK OF DIRT

299
00:13:01,833 --> 00:13:03,833
BETWEEN THE REACTOR
AND THE MAIN LANDING AREA.

300
00:13:03,833 --> 00:13:05,100
AND THEN YOU GOT POWER
AT THE SHIP.

301
00:13:05,100 --> 00:13:07,766
YOU TURN IT ON, OKAY,
AND WHAT YOU DO THEN IS,

302
00:13:07,766 --> 00:13:10,500
YOU RUN A PUMP, AND YOU SUCK IN
THE MARTIAN AIR,

303
00:13:10,500 --> 00:13:13,033
WHICH IS 95% CARBON DIOXIDE,

304
00:13:13,033 --> 00:13:14,300
AND YOU REACT THAT

305
00:13:14,300 --> 00:13:16,400
WITH THE HYDROGEN
THAT YOU BROUGHT FROM EARTH,

306
00:13:16,400 --> 00:13:20,100
AND HYDROGEN CAN BE REACTED
WITH CARBON DIOXIDE

307
00:13:20,100 --> 00:13:22,500
IN THE PRESENCE OF EITHER
RUTHENIUM OR NICKEL

308
00:13:22,500 --> 00:13:25,633
ON ALUMINA CATALYST
TO PRODUCE METHANE AND WATER.

309

00:13:25,633 --> 00:13:27,100
THAT'S KNOWN
AS SABATIER REACTION.

310
00:13:27,100 --> 00:13:28,733
METHANE'S GOOD ROCKET FUEL.
YOU STORE THAT.

311
00:13:28,733 --> 00:13:30,433
YOU TAKE THE WATER,
YOU ELECTROLYZE IT,

312
00:13:30,433 --> 00:13:32,766
SPLIT IT INTO HYDROGEN
AND OXYGEN.

313
00:13:32,766 --> 00:13:35,900
OH, HERE'S THE WHOLE DIAGRAM.

314
00:13:35,900 --> 00:13:39,300
AND SO THIS MAKES
METHANE AND WATER.

315
00:13:39,300 --> 00:13:41,466
THE WATER IS ELECTROLYZED,
GIVES YOU OXYGEN.

316
00:13:41,466 --> 00:13:42,733
HYDROGEN IS RECYCLED.

317
00:13:42,733 --> 00:13:45,733
THEN, TO MAKE ADDITIONAL OXYGEN,
YOU HAVE A THIRD REACTOR

318
00:13:45,733 --> 00:13:47,833
IN WHICH YOU SPLIT
CARBON DIOXIDE

319
00:13:47,833 --> 00:13:49,366
INTO CARBON MONOXIDE

AND OXYGEN,

320
00:13:49,366 --> 00:13:51,366
KEEP THE OXYGEN,
DUMP THE CARBON MONOXIDE.

321
00:13:51,366 --> 00:13:52,600
YOU CAN DO THAT ON MARS.

322
00:13:52,600 --> 00:13:54,900
THERE'S NO EPA THERE,

323
00:13:54,900 --> 00:13:58,533
WHICH IS A SUBSTANTIAL
GOOD REASON TO GO TO MARS.

324
00:13:58,533 --> 00:14:01,466
[laughter]

325
00:14:01,466 --> 00:14:03,500
AND NOW YOU'VE GOT A FULLY
FUELED EARTH RETURN VEHICLE

326
00:14:03,500 --> 00:14:05,366
SITTING, WAITING FOR YOU
ON THE SURFACE OF MARS.

327
00:14:05,366 --> 00:14:07,000
AND, IN FACT, WE MAKE
EXTRA PROPELLANT

328
00:14:07,000 --> 00:14:08,966
BEYOND WHAT THE EARTH RETURN
VEHICLE NEEDS

329
00:14:08,966 --> 00:14:12,333
SO THAT WE CAN OPERATE
CHEMICAL-POWERED VEHICLES

330

00:14:12,333 --> 00:14:14,600
ON THE SURFACE OF MARS
FOR EXPLORATION PURPOSES.

331
00:14:14,600 --> 00:14:15,800
AND WHY DO WE WANT TO DO THAT?

332
00:14:15,800 --> 00:14:17,333
BECAUSE WE'RE GOING TO MARS
TO EXPLORE,

333
00:14:17,333 --> 00:14:20,900
AND CHEMICAL-REACTION VEHICLES

334
00:14:20,900 --> 00:14:23,300
HAVE A MUCH HIGHER
POWER-TO-MASS RATIO

335
00:14:23,300 --> 00:14:25,600
THAN YOU CAN GET WITH ELECTRIC
VEHICLES OR R.T.G. VEHICLES

336
00:14:25,600 --> 00:14:27,100
OR ANYTHING OF THAT SORT,

337
00:14:27,100 --> 00:14:30,466
WHICH IS WHY THEY'RE SO MUCH
MORE POPULAR HERE ON EARTH.

338
00:14:30,466 --> 00:14:32,200
AND IN A FRONTIER ENVIRONMENT
LIKE MARS,

339
00:14:32,200 --> 00:14:34,333
WHERE YOU REALLY WANT THE SPEED,
THE LONG RANGE, THE TORQUE,

340
00:14:34,333 --> 00:14:35,666
THE HAULING CAPABILITY,

341
00:14:35,666 --> 00:14:38,033
AND ALL-AROUND MUSCLE YOU GET
FROM HAVING A REAL CAR

342
00:14:38,033 --> 00:14:39,200
INSTEAD OF A GOLF CART,

343
00:14:39,200 --> 00:14:40,333
YOU REALLY WANT TO HAVE ONE.

344
00:14:40,333 --> 00:14:41,600
BUT IT WOULDN'T BE PRACTICAL

345
00:14:41,600 --> 00:14:43,233
IF YOU HAD TO BRING THE FUEL
FROM EARTH.

346
00:14:43,233 --> 00:14:44,866
BUT BECAUSE YOU CAN MAKE
THE FUEL ON MARS,

347
00:14:44,866 --> 00:14:46,966
THEN YOU HAVE THIS
ADDITIONAL CAPABILITY.

348
00:14:46,966 --> 00:14:48,666
SO THE POINT HERE
IS THAT THE ABILITY

349
00:14:48,666 --> 00:14:50,266
TO MAKE USE OF LOCAL RESOURCES

350
00:14:50,266 --> 00:14:52,500
IS NOT JUST THE KEY
TO MAKING THE MISSION CHEAP.

351
00:14:52,500 --> 00:14:54,333
IT'S ALSO THE KEY
TO MAKING THE MISSION EFFECTIVE,

352
00:14:54,333 --> 00:14:56,233
WHICH IS EVEN
MORE IMPORTANT, ACTUALLY,

353
00:14:56,233 --> 00:14:57,733
BECAUSE THERE'S NO POINT
GOING TO MARS

354
00:14:57,733 --> 00:15:01,666
UNLESS YOU CAN DO SOMETHING
USEFUL ONCE YOU GET THERE.

355
00:15:01,666 --> 00:15:04,066
SO, OKAY, THE NEXT--

356
00:15:04,066 --> 00:15:05,933
THIS BEING DONE,

357
00:15:05,933 --> 00:15:07,933
AT THE NEXT LAUNCH OPPORTUNITY,
TWO YEARS LATER,

358
00:15:07,933 --> 00:15:09,766
WE LAUNCH TWO MORE BOOSTERS
OFF THE CAPE.

359
00:15:09,766 --> 00:15:11,666
ONE SENDS OUT
ANOTHER EARTH RETURN VEHICLE.

360
00:15:11,666 --> 00:15:13,000
THE OTHER SHOOTS OUT A HAB

361
00:15:13,000 --> 00:15:15,500
WITH A CREW
OF FOUR ASTRONAUTS IN IT.

362
00:15:15,500 --> 00:15:17,633

NOW, BECAUSE OUR RETURN RIDE

363
00:15:17,633 --> 00:15:19,400
IS WAITING FOR US
ON THE SURFACE OF MARS,

364
00:15:19,400 --> 00:15:20,566
WE DON'T NEED TO FLY TO MARS

365
00:15:20,566 --> 00:15:22,933
IN A GIGANTIC
DEATH STAR SPACESHIP, OKAY?

366
00:15:22,933 --> 00:15:24,233
WE DON'T EVEN HAVE TO FLY OUT

367
00:15:24,233 --> 00:15:26,733
IN A COMPARATIVELY MODEST
"MILLENNIUM FALCON."

368
00:15:26,733 --> 00:15:29,600
WE CAN FLY TO MARS
IN A TUNA CAN.

369
00:15:29,600 --> 00:15:32,766
AND THAT'S A VERY GOOD THING,

370
00:15:32,766 --> 00:15:34,500
BECAUSE WE KNOW
HOW TO BUILD THEM

371
00:15:34,500 --> 00:15:36,366
AND THEY'VE BEEN PROVEN
IN INDUSTRY

372
00:15:36,366 --> 00:15:38,700
TO BE A VERY EFFECTIVE FORM
OF PACKAGING.

373

00:15:38,700 --> 00:15:41,066
NOW, OURS IS SOMEWHAT LARGER

374
00:15:41,066 --> 00:15:43,633
THAN THE CHICKEN
OF THE SEA UNIT.

375
00:15:43,633 --> 00:15:47,466
OKAY, THIS IS 8 1/2 METERS,
27 FEET IN DIAMETER.

376
00:15:47,466 --> 00:15:50,700
TWO DECKS,
EACH WITH 8 FEET OF HEADROOM.

377
00:15:50,700 --> 00:15:52,233
UPPER DECK IS WHERE THEY LIVE.

378
00:15:52,233 --> 00:15:54,366
LOWER DECK IS MORE
OF A CARGO HOLD,

379
00:15:54,366 --> 00:15:56,233
WORKSHOP KIND OF PLACE.

380
00:15:56,233 --> 00:15:59,866
HERE'S ONE POTENTIAL LAYOUT
OF THE UPPER DECK.

381
00:15:59,866 --> 00:16:01,433
FOUR LITTLE STATEROOMS.

382
00:16:01,433 --> 00:16:04,566
THERE'S A CREW OF FOUR IN HERE,
IF I DIDN'T MENTION THAT.

383
00:16:04,566 --> 00:16:06,900
SCIENCE AREA, GALLEY,
EXERCISE AREA,

384
00:16:06,900 --> 00:16:10,133
AND IN THE CENTER IS
A SOLAR FLARE STORM SHELTER.

385
00:16:10,133 --> 00:16:12,233
OKAY, THERE'S TWO KINDS
OF RADIATION

386
00:16:12,233 --> 00:16:13,833
THAT CAN GET YOU IN SPACE:

387
00:16:13,833 --> 00:16:15,700
SOLAR FLARES, COSMIC RAYS.

388
00:16:15,700 --> 00:16:17,333
SOLAR FLARES COME FROM THE SUN,

389
00:16:17,333 --> 00:16:20,266
BIG PULSES OF RADIATION
IN AN UNPREDICTABLE WAY.

390
00:16:20,266 --> 00:16:23,366
THAT IS, YOU DON'T KNOW
WHEN IT'S GONNA HAPPEN,

391
00:16:23,366 --> 00:16:25,033
MAYBE ONE BIG ONE A YEAR.

392
00:16:25,033 --> 00:16:27,000
BUT THEY'RE BASICALLY PROTONS

393
00:16:27,000 --> 00:16:28,766
WITH ENERGIES
OF ABOUT A MEGAVOLT

394
00:16:28,766 --> 00:16:31,066
THAT CAN BE STOPPED
BY 5 INCHES OF WATER.

395
00:16:31,066 --> 00:16:34,000
AND WE HAVE ENOUGH PROVISIONS
ON THE SHIP TO MASS THAT OUT.

396
00:16:34,000 --> 00:16:36,300
SO THAT'S HOW YOU'RE SAFE
AGAINST THE SOLAR FLARES.

397
00:16:36,300 --> 00:16:39,566
THE COSMIC RAYS, WHICH ARE A
LITTLE PITTER-PATTER CONSTANTLY

398
00:16:39,566 --> 00:16:41,033
OF HIGH-ENERGY RADIATION

399
00:16:41,033 --> 00:16:42,733
COMING IN FROM
INTERSTELLAR SPACE,

400
00:16:42,733 --> 00:16:45,033
THAT CANNOT BE STOPPED
WITH 5 INCHES OF WATER,

401
00:16:45,033 --> 00:16:47,033
BUT THE DOSE FOR THAT
IS MODERATE,

402
00:16:47,033 --> 00:16:48,633
AS I WILL SHOW YOU LATER,

403
00:16:48,633 --> 00:16:49,900
THAT THIS IS--

404
00:16:49,900 --> 00:16:52,200
YOU'RE GONNA TAKE THIS
WHEN YOU GO TO MARS

405
00:16:52,200 --> 00:16:54,200
NO MATTER WHAT YOU DO,

406
00:16:54,200 --> 00:16:55,933
BUT IT REPRESENTS
A MODEST PORTION

407
00:16:55,933 --> 00:16:59,100
OF OVERALL MISSION RISK.

408
00:16:59,100 --> 00:17:01,933
NOW, LET ME JUST SAY THIS,
BY THE WAY.

409
00:17:01,933 --> 00:17:04,366
THE TRAJECTORY THAT WE'RE
GOING OUT TO MARS ON

410
00:17:04,366 --> 00:17:06,566
IS A SIX-MONTH TRAJECTORY.

411
00:17:06,566 --> 00:17:08,900
AND THIS IS
THE CORRECT TRAJECTORY

412
00:17:08,900 --> 00:17:10,400
TO SEND PEOPLE TO MARS ON

413
00:17:10,400 --> 00:17:13,433
REGARDLESS OF THE PROPULSION
SYSTEM THAT YOU HAVE.

414
00:17:13,433 --> 00:17:15,466
THAT IS, THERE'S PEOPLE
GOING AROUND SAYING,

415
00:17:15,466 --> 00:17:17,533
"WE'VE GOT TO GO TO MARS FASTER.
WE'VE GOT TO GO TO MARS FASTER.

416
00:17:17,533 --> 00:17:19,766

"IF WE HAD
NUCLEAR THERMAL ROCKETS,

417
00:17:19,766 --> 00:17:21,266
WE COULD GET TO MARS
IN FOUR MONTHS."

418
00:17:21,266 --> 00:17:25,133
WELL, YOU COULD,
BUT YOU SHOULDN'T.

419
00:17:25,133 --> 00:17:26,633
IF YOU HAD
NUCLEAR THERMAL ROCKETS,

420
00:17:26,633 --> 00:17:28,033
YOU SHOULD GET TO MARS
IN SIX MONTHS

421
00:17:28,033 --> 00:17:29,866
AND USE THE SUPERIOR
PROPULSION CAPABILITY

422
00:17:29,866 --> 00:17:31,866
TO DOUBLE YOUR PAYLOAD, OKAY?

423
00:17:31,866 --> 00:17:32,866
WHY?

424
00:17:32,866 --> 00:17:33,900
WELL, THERE'S TWO REASONS.

425
00:17:33,900 --> 00:17:35,400
ONE IS, DOUBLING THE PAYLOAD

426
00:17:35,400 --> 00:17:37,500
WILL DO FAR MORE
FOR MISSION SAFETY

427

00:17:37,500 --> 00:17:40,766
THAN REDUCING THE TRANSIT TIME
BY TWO MONTHS, OKAY.

428
00:17:40,766 --> 00:17:43,000
IN TERMS OF MORE REDUNDANCY,

429
00:17:43,000 --> 00:17:45,866
OF CRITICAL SYSTEMS
AND SO FORTH, THAT'S POSSIBLE.

430
00:17:45,866 --> 00:17:47,766
BUT THE OTHER IS THIS.

431
00:17:47,766 --> 00:17:49,800
SIX MONTHS OUTBOUND TRANSIT

432
00:17:49,800 --> 00:17:52,800
IS THE TWO-YEAR FREE RETURN
TRAJECTORY TO EARTH.

433
00:17:52,800 --> 00:17:54,400
SO IF YOU HAVE TO
ABORT THE MISSION,

434
00:17:54,400 --> 00:17:55,666
YOU CAN FLY BY MARS, COME BACK,

435
00:17:55,666 --> 00:17:56,766
YOU GET BACK TO EARTH'S ORBIT

436
00:17:56,766 --> 00:17:58,866
EXACTLY TWO YEARS
AFTER YOU LEFT IT,

437
00:17:58,866 --> 00:18:00,266
AND EARTH WILL BE THERE.

438
00:18:00,266 --> 00:18:02,166

IF YOU TRY TO GO TO MARS FASTER,

439
00:18:02,166 --> 00:18:04,566
YOU NECESSARILY GO OUT FURTHER
ON A FREE RETURN.

440
00:18:04,566 --> 00:18:06,433
YOU COME BACK
IN MORE THAN TWO YEARS,

441
00:18:06,433 --> 00:18:08,300
AND EARTH IS NOT THERE, OKAY?

442
00:18:08,300 --> 00:18:13,033
SO, BY TRYING TO GO TO MARS
FASTER THAN SIX MONTHS,

443
00:18:13,033 --> 00:18:16,900
YOU LOSE ROBUSTNESS
AND YOU LOSE THE FREE RETURN,

444
00:18:16,900 --> 00:18:18,866
SO YOU SHOULDN'T DO IT, OKAY?

445
00:18:18,866 --> 00:18:20,266
BETTER PROPULSION IS BETTER,

446
00:18:20,266 --> 00:18:22,300
BUT USE IT TO INCREASE
THE PAYLOAD.

447
00:18:22,300 --> 00:18:24,033
OKAY.

448
00:18:24,033 --> 00:18:28,000
NOW, THE ONE HEALTH EFFECT THAT
WE REALLY HAVE SEEN IN SPACE

449
00:18:28,000 --> 00:18:29,266

HAS NOT BEEN FROM RADIATION.

450
00:18:29,266 --> 00:18:31,333
IT'S BEEN FROM ZERO GRAVITY.

451
00:18:31,333 --> 00:18:36,200
OKAY, AND SO WE MAKE
ARTIFICIAL GRAVITY ON THE SHIP

452
00:18:36,200 --> 00:18:38,333
BY TETHERING OFF
THE BURNT-OUT UPPER STAGE.

453
00:18:38,333 --> 00:18:40,533
THIS IS THE BURNT-OUT
UPPER STAGE OF THE ARES BOOSTER.

454
00:18:40,533 --> 00:18:41,800
IT THREW US TO MARS.

455
00:18:41,800 --> 00:18:43,066
IT'S COASTING TO MARS TOO.

456
00:18:43,066 --> 00:18:44,133
IT CAN BE USED
AS A COUNTERWEIGHT

457
00:18:44,133 --> 00:18:45,300
ON THE END OF A TETHER.

458
00:18:45,300 --> 00:18:47,900
THIS THING IS ABOUT A MILE LONG,
1,500 METERS.

459
00:18:47,900 --> 00:18:51,333
SPIN THIS AT 1 RPM,
YOU GET MARS GRAVITY IN THE HAB.

460
00:18:51,333 --> 00:18:53,433

IF YOU SPUN IT AT
A LITTLE LESS THAN 2 RPM,

461
00:18:53,433 --> 00:18:54,933
YOU'D HAVE EARTH GRAVITY
IN THE HAB

462
00:18:54,933 --> 00:18:58,466
AND AVOID THE DECONDITIONING
ASSOCIATED WITH ZERO GRAVITY

463
00:18:58,466 --> 00:19:02,366
AND OTHER HEALTH EFFECTS,
EYE EFFECTS AND SO FORTH,

464
00:19:02,366 --> 00:19:03,700
THAT HAVE BEEN IDENTIFIED.

465
00:19:03,700 --> 00:19:05,900
THOSE ARE THE SERIOUS
HEALTH EFFECTS OF SPACE FLIGHT,

466
00:19:05,900 --> 00:19:09,500
AND THEY CAN BE AMELIORATED
THIS WAY.

467
00:19:09,500 --> 00:19:13,466
OKAY, SO--
I DON'T KNOW WHY THAT'S THERE.

468
00:19:13,466 --> 00:19:15,466
OH, I KNOW WHY IT'S THERE.

469
00:19:15,466 --> 00:19:17,966
OKAY, SO THEY FLY OUT TO MARS,
TAKE SIX MONTHS.

470
00:19:17,966 --> 00:19:20,400
THEY FIRE PYRO, CUT THE CABLE,
AERO-BRAKE,

471
00:19:20,400 --> 00:19:22,266
AND GO AND LAND
AT LANDING SITE NUMBER ONE,

472
00:19:22,266 --> 00:19:24,000
WHERE THE FULLY FUELED
EARTH RETURN VEHICLE

473
00:19:24,000 --> 00:19:25,333
IS WAITING FOR THEM.

474
00:19:25,333 --> 00:19:26,966
OKAY.

475
00:19:26,966 --> 00:19:28,466
IF THEY LAND OFF-COURSE,

476
00:19:28,466 --> 00:19:30,933
THEY'VE GOT A PRESSURIZED ROVER
IN THE LOWER DECK OF THE HAB.

477
00:19:30,933 --> 00:19:32,900
IT HAS A ONE-WAY RANGE
OF 600 MILES,

478
00:19:32,900 --> 00:19:34,666
SO THEY REALLY SHOULD
BE ABLE TO ACHIEVE

479
00:19:34,666 --> 00:19:36,133
THIS SURFACE RENDEZVOUS.

480
00:19:36,133 --> 00:19:37,866
IF THEY CAN'T,
THEY HAVE A REAL PROBLEM

481
00:19:37,866 --> 00:19:40,500
WITH THE PILOT

SELECTION PROCESS.

482
00:19:40,500 --> 00:19:43,366
AND IF THAT'S THE CASE,
WE CAN STILL SAVE THE MISSION

483
00:19:43,366 --> 00:19:45,033
BY TAKING THE SECOND
EARTH RETURN VEHICLE

484
00:19:45,033 --> 00:19:46,733
AND LANDING IT NEAR THEM.

485
00:19:46,733 --> 00:19:50,433
BUT, ASSUMING THAT
THEY DO LAND CORRECTLY,

486
00:19:50,433 --> 00:19:53,366
THE SECOND EARTH RETURN VEHICLE
CAN BE LANDED ANYWHERE ELSE,

487
00:19:53,366 --> 00:19:54,866
COULD BE LANDED CLOSE BY,

488
00:19:54,866 --> 00:19:56,166
COULD BE ON THE OTHER SIDE
OF THE PLANET,

489
00:19:56,166 --> 00:19:58,833
BUT I WOULD LAND IT
A FEW HUNDRED MILES AWAY,

490
00:19:58,833 --> 00:20:00,000
BECAUSE IT WILL DEFINE

491
00:20:00,000 --> 00:20:02,166
WHERE THE NEXT
EXPLORATION MISSION GOES.

492

00:20:02,166 --> 00:20:04,133
BUT I WOULD STILL LIKE IT TO BE

493
00:20:04,133 --> 00:20:05,633
WITHIN AT LEAST
ONE-WAY DRIVING RANGE

494
00:20:05,633 --> 00:20:07,800
OF THE AVAILABLE
GROUND TRANSPORTATION.

495
00:20:07,800 --> 00:20:10,133
SO THE CREW HAS TWO COMPLETE
EARTH RETURN VEHICLES,

496
00:20:10,133 --> 00:20:11,800
EITHER ONE OF WHICH
COULD TAKE THEM HOME.

497
00:20:11,800 --> 00:20:13,766
AND THEY HAVE THREE
HABITABLE VOLUMES,

498
00:20:13,766 --> 00:20:14,900
THE BIG ONE IN THE HAB

499
00:20:14,900 --> 00:20:16,666
AND THE CABINS
OF THE TWO ERVs.

500
00:20:16,666 --> 00:20:18,866
SO THEY'RE MULTIPLY
BACKED UP IN THAT WAY.

501
00:20:18,866 --> 00:20:22,133
BUT THE REAL PURPOSE
OF THIS ERV IS NOT FOR THEM.

502
00:20:22,133 --> 00:20:24,566
IT'S TO START MAKING PROPELLANT

TO SUPPORT THE NEXT MISSION,

503
00:20:24,566 --> 00:20:26,266
WHICH FLIES OUT TWO YEARS LATER,

504
00:20:26,266 --> 00:20:28,200
ALONG WITH ANOTHER ERV,
WHICH IS THEIR BACKUP,

505
00:20:28,200 --> 00:20:32,900
BUT WHICH OTHERWISE OPENS UP
LANDING SITE NUMBER THREE.

506
00:20:32,900 --> 00:20:35,500
SO THIS IS AN ACTUAL PHOTOGRAPH
OF THE BASE.

507
00:20:35,500 --> 00:20:37,900
[laughter]

508
00:20:37,900 --> 00:20:41,833
WHAT YOU SEE HERE, HERE IS
THE EARTH RETURN VEHICLE.

509
00:20:41,833 --> 00:20:43,800
THERE'S THE CABIN,
THE TWO PROPULSION STAGES,

510
00:20:43,800 --> 00:20:47,566
THE INTAKES FOR THE CHEMICAL
PROCESSING UNIT,

511
00:20:47,566 --> 00:20:49,200
WHICH IS BUILT
INTO THE LANDING STAGE

512
00:20:49,200 --> 00:20:51,366
THAT ACTS AS THE TAKEOFF PAD
FOR THE REST OF IT.

513
00:20:51,366 --> 00:20:53,366
HERE'S THE REACTOR AND THE
CRATER IN THE BACKGROUND,

514
00:20:53,366 --> 00:20:55,366
THE HABITAT,
UPPER STAGE WHERE THEY LIVE,

515
00:20:55,366 --> 00:20:57,266
UPPER DECK WHERE THEY LIVE.

516
00:20:57,266 --> 00:20:58,433
LOWER DECK IS THE GARAGE

517
00:20:58,433 --> 00:21:00,166
FOR THE LITTLE
PRESSURIZED ROVER,

518
00:21:00,166 --> 00:21:02,033
COUPLE OF SOLAR PANELS
USED AS BACKUP POWER

519
00:21:02,033 --> 00:21:03,400
IF YOU HAVE TO TURN
THE REACTOR OFF.

520
00:21:03,400 --> 00:21:04,433
YOU ALSO HAVE BACKUP POWER

521
00:21:04,433 --> 00:21:05,966
BY RUNNING THE ENGINE
OF THE ROVER

522
00:21:05,966 --> 00:21:07,500
OR THE LIGHT TRUCK,

523
00:21:07,500 --> 00:21:09,466
WHICH MAY BE HARD TO SEE,
BUT IT'S SITTING OVER HERE.

524
00:21:09,466 --> 00:21:10,733
IT'S AN UNPRESSURIZED VEHICLE

525
00:21:10,733 --> 00:21:12,366
WHICH IS ALSO THE BACKUP
FOR THIS ONE.

526
00:21:12,366 --> 00:21:15,166
AND THEN THIS THING HERE
IS AN INFLATABLE GREENHOUSE.

527
00:21:15,166 --> 00:21:16,900
THIS IS NOT
A MISSION-CRITICAL ELEMENT.

528
00:21:16,900 --> 00:21:19,766
IT'S AN EXPERIMENT IN LEARNING
HOW TO GROW CROPS ON MARS

529
00:21:19,766 --> 00:21:21,666
IN MARTIAN SOIL,
MARTIAN SUNLIGHT,

530
00:21:21,666 --> 00:21:23,566
MARTIAN GRAVITY, MARTIAN WATER,

531
00:21:23,566 --> 00:21:27,900
FOR THE BENEFIT OF FUTURE
MISSIONS AND FUTURE BASES.

532
00:21:27,900 --> 00:21:30,900
NOW, AFTER A NUMBER OF THESE
MISSIONS HAVE OCCURRED

533
00:21:30,900 --> 00:21:32,200
IN DIFFERENT PLACES,

534
00:21:32,200 --> 00:21:35,466

YOU'LL KNOW WHERE YOU WANT
TO DEVELOP A MAJOR BASE,

535
00:21:35,466 --> 00:21:38,800
AND YOU COULD DO THAT
BY LANDING A LOT OF THE HABS

536
00:21:38,800 --> 00:21:41,566
IN THE SAME PLACE
AND MATING THEM UP.

537
00:21:41,566 --> 00:21:43,166
THESE ARE
SECOND-GENERATION HABS HERE

538
00:21:43,166 --> 00:21:46,300
WHOSE LANDING LEGS
CAN ARTICULATE

539
00:21:46,300 --> 00:21:49,800
NOT ONLY UP AND DOWN
BUT ALSO SIDE-TO-SIDE,

540
00:21:49,800 --> 00:21:52,233
THUS ALLOWING THEM TO WALK
MUCH IN THE MANNER

541
00:21:52,233 --> 00:21:55,833
THAT THE MARTIANS DID
IN "THE WAR OF THE WORLDS."

542
00:21:55,833 --> 00:21:58,000
SO THIS HAS HERITAGE.

543
00:21:58,000 --> 00:22:00,133
[laughter]

544
00:22:00,133 --> 00:22:02,200
AND THERE IT IS.

545
00:22:02,200 --> 00:22:04,533
AND I DON'T HAVE TIME
TO GO INTO IT,

546
00:22:04,533 --> 00:22:05,800
BUT I'LL ASSERT WITHOUT PROOF

547
00:22:05,800 --> 00:22:07,433
THAT WE COULD USE
THE SAME FLIGHT ELEMENTS

548
00:22:07,433 --> 00:22:09,166
TO BUILD A LUNAR BASE TOO,

549
00:22:09,166 --> 00:22:11,700
SO WE COULD DO THESE THINGS
IN PARALLEL, OKAY.

550
00:22:11,700 --> 00:22:13,966
WE DON'T BUILD A LUNAR BASE
IN ORDER TO GO TO MARS.

551
00:22:13,966 --> 00:22:15,933
YOU DON'T NEED A LUNAR BASE
TO GO TO MARS.

552
00:22:15,933 --> 00:22:18,700
BUT, IN FACT, IF YOU WANTED
TO MAINTAIN THE FLIGHT RATE

553
00:22:18,700 --> 00:22:21,833
ASSOCIATED WITH HAVING
AN ACTIVE BOOSTER PROGRAM,

554
00:22:21,833 --> 00:22:24,133
YOU DON'T WANT TO BE LAUNCHING
TWO EVERY TWO YEARS.

555
00:22:24,133 --> 00:22:26,600

YOU NEED TO LAUNCH
MORE FREQUENTLY THAN THAT,

556
00:22:26,600 --> 00:22:28,633
OR, FRANKLY, YOU'RE WASTING
A LOT OF MONEY

557
00:22:28,633 --> 00:22:30,866
BY HAVING A STANDING ARMY
SITTING AROUND DOING NOTHING

558
00:22:30,866 --> 00:22:32,733
AND, IN FACT,
GETTING OUT OF PRACTICE.

559
00:22:32,733 --> 00:22:34,466
SO YOU WOULD PROBABLY ACTUALLY
DO THESE THINGS

560
00:22:34,466 --> 00:22:37,133
AT THE SAME TIME.

561
00:22:37,133 --> 00:22:40,366
AND SO THIS IS THE HARDWARE SET
THAT WE NEED

562
00:22:40,366 --> 00:22:42,866
TO OPEN UP TWO NEW WORLDS.

563
00:22:42,866 --> 00:22:46,133
NOW, OKAY, THAT'S HOW
I'D LIKE TO DO MARS,

564
00:22:46,133 --> 00:22:47,533
AND I THINK WE CAN DO THAT.

565
00:22:47,533 --> 00:22:54,866
HOWEVER, RECENTLY, YOU KNOW,

566

00:22:54,866 --> 00:22:56,433
SPACEX HAS COME ALONG,

567
00:22:56,433 --> 00:22:58,500
AND THEY ARE DEVELOPING HARDWARE

568
00:22:58,500 --> 00:23:01,500
THAT'S GOING TO BE DEVELOPED
RELATIVELY SOON,

569
00:23:01,500 --> 00:23:02,966
OR SO IT WOULD SEEM,

570
00:23:02,966 --> 00:23:05,566
INCLUDING FALCON HEAVY CAPABLE
OF LAUNCHING 50 TONS

571
00:23:05,566 --> 00:23:07,866
TO LOW EARTH ORBIT.

572
00:23:07,866 --> 00:23:12,066
NOW, 50 TONS IS NOT 120.
IT'S LESS.

573
00:23:12,066 --> 00:23:14,733
IT IS.

574
00:23:14,733 --> 00:23:17,966
AND--BUT, YOU KNOW,
I SET MYSELF THE TASK OF SAYING,

575
00:23:17,966 --> 00:23:20,233
"WELL, LOOK, WHAT IF I DIDN'T
HAVE WHAT I WANT?

576
00:23:20,233 --> 00:23:22,866
"WHAT IF I HAVE THAT?

577
00:23:22,866 --> 00:23:25,300

"OKAY, CAN WE STILL
DO HUMANS TO MARS?

578
00:23:25,300 --> 00:23:27,700
IS THERE A WAY THAT,
YOU KNOW--"

579
00:23:27,700 --> 00:23:29,033
IN OTHER WORDS,
THIS IS NOT AN IDEAL WORLD.

580
00:23:29,033 --> 00:23:30,100
YOU'VE GOT TO, YOU KNOW--

581
00:23:30,100 --> 00:23:31,366
AS DONALD RUMSFELD SAID,

582
00:23:31,366 --> 00:23:32,833
"YOU GO TO WAR
WITH THE FORCES YOU GOT."

583
00:23:32,833 --> 00:23:36,233
OKAY, HE'S AN AUTHORITY.

584
00:23:36,233 --> 00:23:40,900
AND, ANYWAY, YOU GO TO MARS
WITH THE FORCES YOU GOT.

585
00:23:40,900 --> 00:23:42,333
SO HOW WOULD I DO IT?

586
00:23:42,333 --> 00:23:45,966
WELL, FIRST OF ALL, I WOULD TAKE
AN ALTERATION OF THIS PLAN

587
00:23:45,966 --> 00:23:48,233
WHICH I CALL THE
"MARS SEMI-DIRECT" PLAN.

588

00:23:48,233 --> 00:23:50,533
AND THIS, BY THE WAY,
IS THE MISSION ARCHITECTURE

589
00:23:50,533 --> 00:23:53,066
THAT WAS ADOPTED
BY NASA JOHNSON SPACE CENTER

590
00:23:53,066 --> 00:23:56,100
AND WAS D.R.,
DESIGN REFERENCE, MISSION 3.

591
00:23:56,100 --> 00:23:59,033
OKAY, THIS IS A THREE-LAUNCH
MISSION ARCHITECTURE, OKAY,

592
00:23:59,033 --> 00:24:01,533
IN WHICH ONE LAUNCH
SENDS TO MARS

593
00:24:01,533 --> 00:24:09,033
THE EARTH-MARS ASCENT VEHICLE,

594
00:24:09,033 --> 00:24:10,233
WHICH GOES TO THE SURFACE

595
00:24:10,233 --> 00:24:12,066
AND MAKES PROPELLANT
ON THE SURFACE.

596
00:24:12,066 --> 00:24:17,100
ONE SENDS THE HAB OUT
WITH A CREW,

597
00:24:17,100 --> 00:24:19,600
AND ONE SENDS
AN EARTH RETURN VEHICLE

598
00:24:19,600 --> 00:24:24,766
TO A HIGHLY ELLIPTICAL,

LOOSELY BOUND MARS ORBIT,

599
00:24:24,766 --> 00:24:27,166
AND SO THAT THE MISSION PLAN IS,

600
00:24:27,166 --> 00:24:29,500
FIRST, YOU SEND
AN ASCENT VEHICLE

601
00:24:29,500 --> 00:24:31,600
WHICH FUELS ITSELF
ON THE SURFACE,

602
00:24:31,600 --> 00:24:33,766
WHOSE PROCESS IS SIMILAR
TO "MARS DIRECT."

603
00:24:33,766 --> 00:24:35,900
OKAY, AND THEN, IN THE NEXT
LAUNCH OPPORTUNITY,

604
00:24:35,900 --> 00:24:39,833
YOU SEND OUT AN EARTH RETURN
VEHICLE AND A HAB.

605
00:24:39,833 --> 00:24:44,333
NOW, IN FACT, THIS WOULD REQUIRE
THREE FALCON HEAVIES,

606
00:24:44,333 --> 00:24:46,333
SO IT'S THREE LAUNCHES, OKAY.

607
00:24:46,333 --> 00:24:47,933
AND WHAT WE DID HERE WAS,

608
00:24:47,933 --> 00:24:50,300
THE FIRST TIME, I WOULD SEND
ALL THESE ELEMENTS OUT,

609

00:24:50,300 --> 00:24:51,933
BUT WITH NO ONE
IN ANY OF THEM,

610
00:24:51,933 --> 00:24:53,433
AND THEN AT
THE SECOND OPPORTUNITY,

611
00:24:53,433 --> 00:24:57,866
YOU SEND OUT THE CREW IN A HAB
THAT RENDEZVOUS ON THE SURFACE

612
00:24:57,866 --> 00:25:00,233
WITH THE ASCENT VEHICLE

613
00:25:00,233 --> 00:25:03,133
AND ANOTHER EARTH RETURN VEHICLE
TO POSITION IN MARS ORBIT

614
00:25:03,133 --> 00:25:04,966
AND ANOTHER ASCENT VEHICLE.

615
00:25:04,966 --> 00:25:09,133
SO THE--AND THEN THE CREW
ASCENDS TO ORBIT

616
00:25:09,133 --> 00:25:11,566
AT THE END OF A YEAR AND A HALF
ON THE MARTIAN SURFACE

617
00:25:11,566 --> 00:25:13,733
IN THE PRE-POSITIONED
ASCENT VEHICLE.

618
00:25:13,733 --> 00:25:15,800
AND WHILE THE OTHER ONE
IS THERE MAKING PROPELLANT,

619
00:25:15,800 --> 00:25:17,400
THEN, IN FACT,

IT'S A BACKUP FOR THEM.

620
00:25:17,400 --> 00:25:19,666
AND THE PRE-POSITIONED HAB
IS THERE

621
00:25:19,666 --> 00:25:21,533
SO THAT WHEN THEY LAND
IN THEIR HAB,

622
00:25:21,533 --> 00:25:23,266
THERE'S ACTUALLY TWO HABS.

623
00:25:23,266 --> 00:25:28,466
NOW, WHAT WE-- WHAT I ASSUMED
FOR THIS

624
00:25:28,466 --> 00:25:31,233
IS THAT WE HAD, ALSO,
THE DRAGON

625
00:25:31,233 --> 00:25:32,966
WITH A LONG-DURATION
LIFE SUPPORT SYSTEM

626
00:25:32,966 --> 00:25:35,866
INSTALLED IN IT.

627
00:25:35,866 --> 00:25:38,100
NOW, THE DRAGON
IS KIND OF SMALL

628
00:25:38,100 --> 00:25:43,166
FOR LONG-DURATION HABITATION,

629
00:25:43,166 --> 00:25:47,700
SO THE NOTION HERE WAS THAT
AN INFLATABLE EXTENSION

630

00:25:47,700 --> 00:25:49,700
FOR THE DRAGON COULD BE MADE
THAT WOULD--

631
00:25:49,700 --> 00:25:53,200
IN OTHER WORDS, THE CREW COULD
LAUNCH TO ORBIT IN A DRAGON,

632
00:25:53,200 --> 00:25:55,966
AND THEN HERE IT IS.

633
00:25:55,966 --> 00:25:58,366
IT TURNS AROUND,
DOES THE APOLLO MANEUVER,

634
00:25:58,366 --> 00:26:03,433
AND PULLS OUT OF HERE,
OR THE INFLATABLE,

635
00:26:03,433 --> 00:26:05,733
AND ALSO A TETHER THAT GOES
TO THE UPPER STAGE

636
00:26:05,733 --> 00:26:11,333
AND CAN GIVE THIS
ARTIFICIAL GRAVITY

637
00:26:11,333 --> 00:26:13,800
OFF THE TRANS-MARS
INJECTION STAGE.

638
00:26:13,800 --> 00:26:17,366
NOW, I SAID I'D MENTION THIS
BUSINESS ABOUT RADIATION,

639
00:26:17,366 --> 00:26:20,266
BECAUSE, ONCE AGAIN,
THIS HAS REALLY BEEN USED

640
00:26:20,266 --> 00:26:25,200

AS A KIND OF SNOW DAY
BY THOSE IN AUTHORITY

641
00:26:25,200 --> 00:26:26,800
WHO DON'T WANT TO GO TO MARS.

642
00:26:26,800 --> 00:26:29,166
IN OTHER WORDS, YOU KNOW,
WE RECENTLY HAD

643
00:26:29,166 --> 00:26:32,033
RADIATION RESULTS
FROM "CURIOSITY" IN TRANSIT

644
00:26:32,033 --> 00:26:36,333
WHICH WERE THE SAME AS THOSE
FROM "MARIE" IN TRANSIT IN 2001.

645
00:26:36,333 --> 00:26:39,266
THE DATA WAS THE SAME,
BUT IN 2001 THEY SAID,

646
00:26:39,266 --> 00:26:42,000
"THIS SHOWS THAT THE RADIATION
DOSE OF GOING TO MARS

647
00:26:42,000 --> 00:26:43,900
IS A MODEST PORTION
OF TOTAL MISSION RISK."

648
00:26:43,900 --> 00:26:46,166
THEN IN 2013, THEY SAID,

649
00:26:46,166 --> 00:26:52,500
"THIS SHOWS THAT WE CAN'T
GO TO MARS--HA-HA, SNOW DAY."

650
00:26:52,500 --> 00:26:54,300
BUT, IN FACT,

651
00:26:54,300 --> 00:26:56,666
THE COSMIC RAY
RADIATION DOSE RATES

652
00:26:56,666 --> 00:26:58,366
IN LOW EARTH ORBIT

653
00:26:58,366 --> 00:27:01,633
ARE HALF OF THOSE
OF INTERPLANETARY SPACE.

654
00:27:01,633 --> 00:27:03,833
AND THIS IS BECAUSE
THE EARTH'S MAGNETIC FIELD

655
00:27:03,833 --> 00:27:07,033
DOES NOT BLOCK
AGAINST G-E-V COSMIC RAYS.

656
00:27:07,033 --> 00:27:09,500
THE EARTH BLOCKS OUT
HALF THE SKY,

657
00:27:09,500 --> 00:27:11,366
AND THAT'S WHY
IT'S A FACTOR OF TWO LESS.

658
00:27:11,366 --> 00:27:12,633
BUT IT'S THE SAME STUFF,

659
00:27:12,633 --> 00:27:13,800
AND IT'S JUST HALF
THE DOSE RATE.

660
00:27:13,800 --> 00:27:15,066
AND, AS YOU CAN SEE,

661
00:27:15,066 --> 00:27:17,066
THERE'S ABOUT TEN COSMONAUTS

AND ASTRONAUTS

662
00:27:17,066 --> 00:27:18,700
WHO HAVE RECEIVED,

663
00:27:18,700 --> 00:27:23,166
DUE TO LONG-DURATION ACTIVITY
ON THE MIR OR THE SPACE STATION,

664
00:27:23,166 --> 00:27:25,433
COSMIC RAY DOSES THAT ARE
QUITE COMPARABLE

665
00:27:25,433 --> 00:27:27,933
TO WHAT YOU WOULD GET
DOING A ROUNDTRIP TO MARS.

666
00:27:27,933 --> 00:27:30,133
AND THERE HAVE BEEN NO
RADIOLOGICAL CASUALTIES

667
00:27:30,133 --> 00:27:31,533
AMONG THIS GROUP.

668
00:27:31,533 --> 00:27:33,266
NOR WOULD WE EXPECT
THERE TO HAVE BEEN,

669
00:27:33,266 --> 00:27:36,700
BECAUSE THE RADIATION RISK
IS ABOUT 1%.

670
00:27:36,700 --> 00:27:42,133
AND SO THE IDEA
THAT WE CANNOT GO TO MARS

671
00:27:42,133 --> 00:27:44,100
UNTIL MUCH MORE ADVANCED
PROPULSION SYSTEMS

672
00:27:44,100 --> 00:27:46,300
THAT ARE AVAILABLE THAT CAN
GET US TO MARS IN 30 DAYS

673
00:27:46,300 --> 00:27:50,600
IS NOT A VALID ARGUMENT,

674
00:27:50,600 --> 00:27:55,100
AND I BELIEVE
IT'S DISINGENUOUS AS WELL.

675
00:27:55,100 --> 00:27:58,400
GIVEN THE FACT,
GIVEN THE FACT, FIGURE IT OUT.

676
00:27:58,400 --> 00:28:00,500
OVER THE NEXT TEN YEARS,

677
00:28:00,500 --> 00:28:02,900
SPACE STATION WILL BE
CONTINUALLY OCCUPIED,

678
00:28:02,900 --> 00:28:05,733
OKAY, WITH A CREW
ABOUT THE SAME SIZE

679
00:28:05,733 --> 00:28:08,700
AS A MARS MISSION CREW, OKAY,

680
00:28:08,700 --> 00:28:11,466
SO TEN YEARS
CONTINUAL OCCUPATION

681
00:28:11,466 --> 00:28:14,700
AT HALF THE DOSE RATE
OF HUMAN MARS MISSIONS

682
00:28:14,700 --> 00:28:18,433
WHICH SPEND 40% OF THEIR TIME

IN TRANSIT, OKAY.

683
00:28:18,433 --> 00:28:21,700
THE TOTAL NUMBER OF PERSON REMS
BOTH PROGRAMS WOULD RECEIVE,

684
00:28:21,700 --> 00:28:23,266
THE SPACE STATION
OVER THE NEXT TEN YEARS

685
00:28:23,266 --> 00:28:25,533
OR A PROGRAM OF SENDING
FIVE HUMAN MISSIONS TO MARS

686
00:28:25,533 --> 00:28:26,900
OVER TEN YEARS,

687
00:28:26,900 --> 00:28:28,666
USING EVERY OPPORTUNITY
FOR FLIGHT,

688
00:28:28,666 --> 00:28:30,433
IS THE SAME.

689
00:28:30,433 --> 00:28:32,033
SO RIGHT NOW, NASA,

690
00:28:32,033 --> 00:28:33,766
WHILE WAVING ITS HANDS
IN HORROR

691
00:28:33,766 --> 00:28:35,500
OVER THE RADIATION RISK
OF GOING TO MARS,

692
00:28:35,500 --> 00:28:37,733
IS ACTUALLY IMPOSING
THAT SAME RADIATION RISK

693

00:28:37,733 --> 00:28:43,566
ON THEIR CREWS
WITHOUT GOING ANYWHERE.

694
00:28:43,566 --> 00:28:47,700
NOW, ALL RIGHT.

695
00:28:47,700 --> 00:28:50,233
SO I WORKED OUT THE MASSES
ON THIS,

696
00:28:50,233 --> 00:28:52,633
AND THE MARGINS ARE TIGHT,
BUT THIS LOOKS DOABLE.

697
00:28:52,633 --> 00:28:56,100
ASSUMING 8 TONS, METRIC TONS,
FOR THE DRAGONS THEMSELVES,

698
00:28:56,100 --> 00:28:58,200
YOU GO THROUGH
THE VARIOUS CONSUMABLES.

699
00:28:58,200 --> 00:29:00,466
YOU HAVE TO HAVE
WATER RECYCLING.

700
00:29:00,466 --> 00:29:05,400
AND THAT, BY THE WAY,
IS KEY FOR ANY MARS MISSION,

701
00:29:05,400 --> 00:29:09,600
BECAUSE THE AMOUNT OF WATER
THAT YOU USE, OKAY,

702
00:29:09,600 --> 00:29:12,900
NASA--WELL, AT LEAST IN SOME
AMES DOCUMENTS

703
00:29:12,900 --> 00:29:14,533

THAT I SAW A DECADE AGO--

704
00:29:14,533 --> 00:29:18,400
THEY WERE SAYING 32 KILOGRAMS
PER DAY PER PERSON

705
00:29:18,400 --> 00:29:19,900
WITHOUT RECYCLING.

706
00:29:19,900 --> 00:29:23,266
IN OUR MARS--ARTIC AND MARS
DESERT RESEARCH STATIONS,

707
00:29:23,266 --> 00:29:25,500
WE'VE BEEN ABLE TO GET IT DOWN
TO 12 A DAY PER PERSON.

708
00:29:25,500 --> 00:29:30,033
BUT EVEN THERE,
IF YOU HAVE FOUR PEOPLE

709
00:29:30,033 --> 00:29:32,000
AND ROUND IT OFF
TO 1,000 DAYS,

710
00:29:32,000 --> 00:29:36,033
4,000 TIMES 12 WOULD BE
48 TONS OF WATER

711
00:29:36,033 --> 00:29:37,800
IF YOU HAD NO RECYCLING.

712
00:29:37,800 --> 00:29:40,933
IF YOU HAVE 90% RECYCLING,
IT'S 4.8 TONS OF WATER.

713
00:29:40,933 --> 00:29:42,200
SO THAT BECOMES DOABLE,

714

00:29:42,200 --> 00:29:43,866
BUT YOU'VE GOT TO DO THAT.

715
00:29:43,866 --> 00:29:47,400
THE KEY TECHNOLOGY HERE
IS WATER RECYCLING.

716
00:29:47,400 --> 00:29:50,233
IT'S NOT IMPORTANT
TO MAKE YOUR FOOD.

717
00:29:50,233 --> 00:29:51,966
YOU CAN BRING YOUR FOOD.

718
00:29:51,966 --> 00:29:54,766
THAT IS A MODEST MASS.

719
00:29:54,766 --> 00:29:58,133
IT'S WATER
THAT REALLY WEIGHS IT.

720
00:29:58,133 --> 00:30:00,400
AND, WELL, IT'S ALL HERE.

721
00:30:00,400 --> 00:30:05,766
NOW, THE CREW IS A CREW OF TWO.

722
00:30:05,766 --> 00:30:07,300
AND, BY THE WAY,
IN DOING THIS,

723
00:30:07,300 --> 00:30:12,900
I ASSUMED TWO AVERAGE PEOPLE
IN TERMS OF SIZE.

724
00:30:12,900 --> 00:30:17,233
NOW, THAT COULD BE ALTERED.

725
00:30:17,233 --> 00:30:19,866

WHY DO WE HAVE TO SEND
AVERAGE-SIZE PEOPLE TO MARS?

726
00:30:19,866 --> 00:30:21,766
WHY NOT SEND SMALL PEOPLE?

727
00:30:21,766 --> 00:30:25,133
WE TRY TO MAKE EVERYTHING ELSE
SMALL AND LIGHTWEIGHT

728
00:30:25,133 --> 00:30:26,433
ON THE MISSION,

729
00:30:26,433 --> 00:30:28,566
AND A 100-POUND PERSON
EATS HALF AS MUCH

730
00:30:28,566 --> 00:30:31,400
AS A 200-POUND PERSON.

731
00:30:31,400 --> 00:30:34,266
AND SO, YOU KNOW,

732
00:30:34,266 --> 00:30:38,166
I UNDERSTAND THAT THERE
ARE CULTURAL ISSUES HERE,

733
00:30:38,166 --> 00:30:40,866
BUT IF ONE WANTED
TO BE PRACTICAL,

734
00:30:40,866 --> 00:30:43,833
YOU MIGHT START THINKING
IN THOSE DIRECTIONS.

735
00:30:43,833 --> 00:30:45,366
AND, IN FACT, THOUGH,

736
00:30:45,366 --> 00:30:50,300

IF WE DID USE SMALL PEOPLE,

737
00:30:50,300 --> 00:30:53,500
WE PROBABLY COULD HAVE
A CREW OF THREE.

738
00:30:56,300 --> 00:31:01,766
OKAY, AND THEN THIS IS JUST
AN ARTIST'S DEPICTION

739
00:31:01,766 --> 00:31:03,366
OF THESE THINGS LANDED ON MARS.

740
00:31:03,366 --> 00:31:06,100
THE NOTION HERE IS THESE HABS.

741
00:31:06,100 --> 00:31:08,766
YOU DON'T DO ENTRY AND LANDING
WITH THE HABS INFLATED.

742
00:31:08,766 --> 00:31:11,333
THEY WOULD BE DEFLATED,
STUFFED BACK INSIDE,

743
00:31:11,333 --> 00:31:14,866
AND THEN INFLATED AGAIN
ONCE THEY'RE ON THE SURFACE.

744
00:31:14,866 --> 00:31:16,666
AND THIS LOOKS VERY VULNERABLE

745
00:31:16,666 --> 00:31:18,466
TO BEING BLOWN OVER BY THE WIND
OR SOMETHING,

746
00:31:18,466 --> 00:31:21,666
BUT, IN FACT, THE DYNAMIC
PRESSURE OF WINDS

747

00:31:21,666 --> 00:31:25,766
ON THE SURFACE OF MARS
IS QUITE LOW.

748
00:31:25,766 --> 00:31:27,566
AND THESE THINGS HERE,
BY THE WAY,

749
00:31:27,566 --> 00:31:29,033
THE NOTION OF THIS ONE

750
00:31:29,033 --> 00:31:32,100
WAS THAT IT WOULDN'T TRANSPORT
HYDROGEN TO MARS.

751
00:31:32,100 --> 00:31:34,466
IT WOULD TRANSPORT
HYDROCARBON FUEL

752
00:31:34,466 --> 00:31:35,933
AND JUST MAKE THE OXYGEN,

753
00:31:35,933 --> 00:31:39,066
WHICH IS 3/4 OF THE PROPELLANT,

754
00:31:39,066 --> 00:31:42,833
BECAUSE THE SMALLER SIZE MAKES
IT HARDER TO TRANSPORT HYDROGEN.

755
00:31:42,833 --> 00:31:48,600
NOW, THIS MISSION...

756
00:31:48,600 --> 00:31:51,433
IS DESIGNED IN ACCORDANCE
WITH, YOU KNOW,

757
00:31:51,433 --> 00:31:55,066
JUST THREE FALCON HEAVY LAUNCHES
PER OPPORTUNITY.

758
00:31:55,066 --> 00:31:57,633
SLS, IN ITS EARLIEST
INCARNATION,

759
00:31:57,633 --> 00:31:59,400
IS 75 TONS TO ORBIT.

760
00:31:59,400 --> 00:32:02,433
THAT WOULD INCREASE
THE MASS MARGINS BY 50%.

761
00:32:02,433 --> 00:32:05,266
OR YOU COULD SAY, OKAY,
WE'LL DO TWO FALCON HEAVIES

762
00:32:05,266 --> 00:32:07,000
FOR EACH OF THESE
THREE PACKAGES,

763
00:32:07,000 --> 00:32:10,300
MATE AND DOCK,
AND THAT WOULD DOUBLE IT.

764
00:32:10,300 --> 00:32:13,300
WHAT I AM SAYING HERE

765
00:32:13,300 --> 00:32:17,333
IS NOT TO ADVOCATE
THIS DESIGN IN DETAIL,

766
00:32:17,333 --> 00:32:21,033
BUT TO SAY,
IF YOU WANT TO GET TO MARS,

767
00:32:21,033 --> 00:32:23,433
YOU WANT TO TRY TO APPROACH IT

768
00:32:23,433 --> 00:32:26,700
IN A SPIRIT

OF RUTHLESS MINIMALISM,

769
00:32:26,700 --> 00:32:29,466
TO SAY, "HOW COULD WE ACTUALLY
DO THIS WITH WHAT WE HAVE

770
00:32:29,466 --> 00:32:31,033
OR WHAT WE'RE LIKELY TO HAVE?"

771
00:32:31,033 --> 00:32:32,333
AS OPPOSED TO SAYING,

772
00:32:32,333 --> 00:32:34,533
"WELL, YOU KNOW,
WHEN I GO TO MARS,

773
00:32:34,533 --> 00:32:37,033
"I WANT TO HAVE THIS
NAUTILUS SPACESHIP

774
00:32:37,033 --> 00:32:41,333
"WITH A, YOU KNOW, SPA
AND A SAUNA AND THIS AND THAT,

775
00:32:41,333 --> 00:32:44,933
"AND A POOL ROOM, BECAUSE
REALLY, WITHOUT A POOL ROOM,

776
00:32:44,933 --> 00:32:48,900
ASTRONAUTS WON'T BE HAPPY."

777
00:32:48,900 --> 00:32:52,600
YOU WANT TO SAY, "HOW CAN WE
ACTUALLY GET THIS DONE

778
00:32:52,600 --> 00:32:53,900
"WITH THE SORT OF THING WE HAVE

779
00:32:53,900 --> 00:32:57,233

AND DESIGN THE MISSION
IN THAT WAY?"

780
00:32:57,233 --> 00:32:58,500
BUT THE BOTTOM LINE IS,

781
00:32:58,500 --> 00:33:01,933
WHETHER WE DO IT WITH
A TRUE HEAVY-LIFT BOOSTER

782
00:33:01,933 --> 00:33:03,400
LIKE "MARS DIRECT" IS,

783
00:33:03,400 --> 00:33:08,600
OR WE DO IT IN THIS SORT OF--
THIS FALCON DIRECT ARCHITECTURE

784
00:33:08,600 --> 00:33:10,733
WITH A SEMI-HEAVY BOOSTER,

785
00:33:10,733 --> 00:33:11,866
THERE'S WAYS TO DO THIS.

786
00:33:11,866 --> 00:33:14,300
WE DO NOT NEED
SCIENCE-FICTION SPACESHIPS

787
00:33:14,300 --> 00:33:16,400
TO GO TO MARS, OKAY?

788
00:33:16,400 --> 00:33:17,566
WE JUST DON'T.

789
00:33:17,566 --> 00:33:20,533
SO, OKAY.

790
00:33:25,933 --> 00:33:27,033
I'LL LEAVE IT THERE.

791
00:33:27,033 --> 00:33:28,466
THANKS.

792
00:33:28,466 --> 00:33:32,000
[applause]

793
00:33:38,700 --> 00:33:40,333
- SO WE HAVE TIME FOR QUESTIONS.

794
00:33:40,333 --> 00:33:41,666
WAIT FOR THE MICROPHONE,

795
00:33:41,666 --> 00:33:44,166
AND PLEASE STAND UP
WHEN YOU ASK A QUESTION.

796
00:33:46,966 --> 00:33:50,800
- SO, NASA LEADERSHIP NOW
SEEMS TO EMBRACE MARS

797
00:33:50,800 --> 00:33:54,500
AS THE PRIMARY DESTINATION.

798
00:33:54,500 --> 00:33:59,266
AND THEY CERTAINLY ARE AWARE
OF YOUR PLAN.

799
00:33:59,266 --> 00:34:01,433
SO, WHAT IS THEIR RESPONSE?

800
00:34:01,433 --> 00:34:04,800
WHY WOULD NOT THEY GET
INTERESTED IN THIS PLAN

801
00:34:04,800 --> 00:34:06,633
AND TRYING TO ADOPT IT?

802
00:34:06,633 --> 00:34:08,866

BECAUSE IT'S SO MUCH CHEAPER,
IT SEEMS TO ME.

803
00:34:08,866 --> 00:34:10,300
NOT ONLY FASTER, BUT CHEAPER.

804
00:34:10,300 --> 00:34:15,533
- OKAY, WELL, I UNDERSTAND WHY
YOU JUST SAID WHAT YOU SAID,

805
00:34:15,533 --> 00:34:17,266
BUT I DISAGREE WITH YOUR PREMISE

806
00:34:17,266 --> 00:34:21,066
THAT NASA HAS EMBRACED MARS
AS A DESTINATION.

807
00:34:21,066 --> 00:34:24,933
IF NASA HAD EMBRACED MARS
AS A DESTINATION,

808
00:34:24,933 --> 00:34:28,166
IT WOULDN'T BE PLANNING
AN ASTEROID-REDIRECT MISSION,

809
00:34:28,166 --> 00:34:30,900
BECAUSE THE ASTEROID-REDIRECT
MISSION HAS NOTHING TO DO

810
00:34:30,900 --> 00:34:32,700
WITH HUMANS TO MARS.

811
00:34:32,700 --> 00:34:39,033
OKAY, THE--THEY'VE CHOSEN
TO INVOKE HUMANS TO MARS

812
00:34:39,033 --> 00:34:42,066
AS SIZZLE BUT NOT THE STEAK,
OKAY?

813
00:34:42,066 --> 00:34:44,033
IN OTHER WORDS--

814
00:34:44,033 --> 00:34:47,766
AND THIS IS FUNDAMENTAL.

815
00:34:50,433 --> 00:34:54,733
YOU CAN'T GET TO MARS
WITH A PROGRAM

816
00:34:54,733 --> 00:34:59,766
THAT IS DESIGNED AROUND PLEASING
VARIOUS CONSTITUENCIES

817
00:34:59,766 --> 00:35:01,166
WITHIN THE ORGANIZATION.

818
00:35:01,166 --> 00:35:02,833
FOR INSTANCE,
THE ASTEROID-REDIRECT MISSION,

819
00:35:02,833 --> 00:35:05,766
THE PURPOSE OF IT
IS TO PROVIDE A MISSION

820
00:35:05,766 --> 00:35:08,266
FOR AN ELECTRIC PROPULSION
SYSTEM

821
00:35:08,266 --> 00:35:11,766
WHICH HAPPENS TO HAVE THE EAR
OF THE CURRENT ADMINISTRATOR.

822
00:35:11,766 --> 00:35:13,533
OKAY, IT IS--

823
00:35:13,533 --> 00:35:15,100
NO ONE IN THEIR WILDEST DREAMS

824
00:35:15,100 --> 00:35:18,300
EVER PUT REDIRECTING
A 500-TON BOULDER

825
00:35:18,300 --> 00:35:19,800
FROM THE NEAR-EARTH
ASTEROID BELT

826
00:35:19,800 --> 00:35:21,366
INTO A RETROGRADE LUNAR ORBIT

827
00:35:21,366 --> 00:35:23,700
ON THE CRITICAL PATH TO MARS.

828
00:35:23,700 --> 00:35:26,966
OKAY, I MEAN, YOU KNOW,

829
00:35:26,966 --> 00:35:29,133
THIS IS NEW.

830
00:35:29,133 --> 00:35:33,200
AND THE--NOW, SOME PEOPLE
HAVE ARGUED THAT A LUNAR BASE

831
00:35:33,200 --> 00:35:35,033
IS ON THE CRITICAL PATH
TO MARS,

832
00:35:35,033 --> 00:35:36,533
AND I DISAGREE,

833
00:35:36,533 --> 00:35:39,633
BUT AT LEAST THEIR ARGUMENT
HAS THE MERIT

834
00:35:39,633 --> 00:35:41,533
THAT A LUNAR BASE
IS ON THE CRITICAL PATH

835
00:35:41,533 --> 00:35:44,033
TO HAVING A LUNAR BASE.

836
00:35:44,033 --> 00:35:46,400
AND SO, IF YOU BUILD
A LUNAR BASE,

837
00:35:46,400 --> 00:35:48,100
YOU WILL AT LEAST
GET A LUNAR BASE.

838
00:35:48,100 --> 00:35:52,100
OKAY, SO, YOU CAN BE SANE
AND ARGUE THAT.

839
00:35:52,100 --> 00:35:56,333
BUT THE--

840
00:35:56,333 --> 00:35:57,900
BECAUSE, IN FACT,
THE PEOPLE WHO ARGUE

841
00:35:57,900 --> 00:35:59,766
THAT WE NEED TO BUILD THE LUNAR
BASE BEFORE WE GO TO MARS

842
00:35:59,766 --> 00:36:01,900
ARE PEOPLE WHO WANT
TO HAVE A LUNAR BASE.

843
00:36:01,900 --> 00:36:04,100
NOW, THE--

844
00:36:08,966 --> 00:36:12,366
THE PROBLEM HERE IS,
IT'S ENTROPY.