



1
00:00:01,000 --> 00:00:16,216
[MUSIC]

2
00:00:25,000 --> 00:00:26,260
>> HOW DO YOU GET

3
00:00:26,500 --> 00:00:28,500
FROM HERE TO MARS?

4
00:00:28,600 --> 00:00:29,600
HOW DO YOU GET

5
00:00:29,700 --> 00:00:31,300
FROM HERE TO THE MOON?

6
00:00:31,800 --> 00:00:32,800
PROBABLY MORE IMPORTANT TO YOU,

7
00:00:33,000 --> 00:00:34,900
HOW DO YOU GET FROM HERE

8
00:00:35,000 --> 00:00:36,500
TO YOUR HOME?

9
00:00:36,560 --> 00:00:39,000
WELL TO START, THE ANSWER TO

10
00:00:39,100 --> 00:00:41,000
ALL THREE IS VERY SIMILAR:

11
00:00:41,100 --> 00:00:42,100
YOU NEED TO KNOW WHERE YOU ARE,

12
00:00:42,320 --> 00:00:43,500
YOU NEED TO KNOW WHERE YOU'RE

13
00:00:43,600 --> 00:00:45,000

GOING, AND YOU NEED A MAP

14

00:00:45,100 --> 00:00:47,100
THAT CAN CONNECT THE TWO.

15

00:00:47,200 --> 00:00:48,200
NOW IN THE CASE OF GOING HOME,

16

00:00:48,300 --> 00:00:49,800
YOUR MAP WILL HAVE ALL OF

17

00:00:50,000 --> 00:00:51,500
THE ROADS BETWEEN WHERE YOU ARE

18

00:00:51,680 --> 00:00:53,000
AND WHERE YOUR HOME IS,

19

00:00:53,100 --> 00:00:54,000
SO YOU CAN PICK YOUR PATH,

20

00:00:54,200 --> 00:00:55,200
OR YOUR TRAJECTORY,

21

00:00:55,700 --> 00:00:56,700
AND DRIVE YOUR WAY HOME.

22

00:00:57,100 --> 00:00:58,300
IN THE CASE OF GOING TO MARS,

23

00:00:58,500 --> 00:00:59,940
OR TO THE MOON, OR TO ANY OF

24

00:01:00,000 --> 00:01:02,420
THE PLANETS OR PLANETARY BODIES

25

00:01:02,720 --> 00:01:04,060
WHERE WE'VE SENT HUMANS

26
00:01:04,340 --> 00:01:05,680
OR ROBOTICS-- ROBOTIC SPACECRAFT

27
00:01:06,060 --> 00:01:08,000
TO OVER THE YEARS,

28
00:01:08,260 --> 00:01:09,800
FINDING THAT PATH,

29
00:01:10,060 --> 00:01:11,700
OR THAT TRAJECTORY, IS PROVED

30
00:01:11,860 --> 00:01:12,920
ALL THE MORE DIFFICULT,

31
00:01:13,140 --> 00:01:14,100
BECAUSE WHERE YOU ARE

32
00:01:14,300 --> 00:01:15,360
AND WHERE YOU'RE GOING

33
00:01:15,600 --> 00:01:17,180
ARE ALWAYS IN MOTION.

34
00:01:17,420 --> 00:01:19,260
WHICH LEADS ME TO ORBITS

35
00:01:19,420 --> 00:01:20,740
AND TRAJECTORIES AND NASA'S

36
00:01:20,940 --> 00:01:23,560
RETURN TO THE MOON.

37
00:01:24,180 --> 00:01:26,560
MERRIAM-WEBSTER DEFINES AN ORBIT

38
00:01:26,560 --> 00:01:28,140

AS THE PATH DESCRIBED BY ONE BODY IN ITS REVOLUTION

39

00:01:28,320 --> 00:01:29,720

ABOUT ANOTHER, LIKE THE EARTH

40

00:01:30,000 --> 00:01:31,520

GOING AROUND THE SUN.

41

00:01:32,260 --> 00:01:34,060

OR, IN THE CASE OF THIS TALK,

42

00:01:34,440 --> 00:01:35,780

A SPACECRAFT GOING AROUND

43

00:01:36,080 --> 00:01:38,680

A GRAVITATIONAL BODY OR TWO.

44

00:01:38,940 --> 00:01:40,180

NOW, WE ENTER THE WORLD

45

00:01:40,360 --> 00:01:42,340

OF ROCKET SCIENCE.

46

00:01:42,540 --> 00:01:44,580

JOHANNES KEPLER, WITH THE HELP

47

00:01:44,760 --> 00:01:46,620

FROM VOLUMES AND VOLUMES OF

48

00:01:46,820 --> 00:01:48,420

DATA ON PLANETARY MOTION,

49

00:01:48,600 --> 00:01:50,480

CAPTURED BY TYCHO BRAHE,

50

00:01:50,560 --> 00:01:53,040

CALCULATED THAT THE PATHS THESE

51
00:01:53,060 --> 00:01:54,660
ORBITS TOOK IN THE PRESENCE

52
00:01:54,880 --> 00:01:56,460
OF A GRAVITATIONAL FIELD

53
00:01:56,540 --> 00:01:58,040
FOLLOWED CONIC SHAPES,

54
00:01:58,140 --> 00:01:59,160
LIKE CIRCLES,

55
00:01:59,160 --> 00:02:01,840
OR NEARLY CIRCULAR ELLIPSES.

56
00:02:01,840 --> 00:02:03,580
AND WITH THIS INFORMATION,

57
00:02:03,580 --> 00:02:04,660
SCIENTISTS FIGURED OUT

58
00:02:04,660 --> 00:02:05,920
HOW TO MOVE AN OBJECT--

59
00:02:06,000 --> 00:02:07,140
A SPACECRAFT--

60
00:02:07,340 --> 00:02:09,540
FROM ONE ORBIT TO ANOTHER.

61
00:02:09,560 --> 00:02:10,720
ONE OF THE MOST FAMOUS OF

62
00:02:10,980 --> 00:02:12,200
THESE SCIENTISTS IN

63
00:02:12,220 --> 00:02:13,640

ORBITAL MECHANIC CIRCLES IS

64

00:02:13,680 --> 00:02:15,300

WALTER HOHMANN, WHO CREATED

65

00:02:15,320 --> 00:02:16,320

WHAT BECAME KNOWN AS

66

00:02:16,480 --> 00:02:18,020

THE HOHMANN TRANSFER.

67

00:02:18,060 --> 00:02:18,900

THE HOHMANN TRANSFER,

68

00:02:19,060 --> 00:02:20,100

SIMPLY PUT,

69

00:02:20,160 --> 00:02:21,560

IS AN ELLIPTICAL ORBIT

70

00:02:21,700 --> 00:02:23,200

THAT WILL ALLOW YOU TO TRANSFER

71

00:02:23,200 --> 00:02:24,900

BETWEEN TWO CIRCULAR ORBITS

72

00:02:24,920 --> 00:02:26,120

OF DIFFERENT RADII

73

00:02:26,260 --> 00:02:27,320

IN THE SAME PLANE,

74

00:02:27,340 --> 00:02:29,580

ABOUT THE SAME CENTRAL BODY.

75

00:02:29,760 --> 00:02:30,860

SO, REMEMBER WHEN I ASKED YOU

76

00:02:30,960 --> 00:02:31,800

HOW YOU WOULD GET

77

00:02:31,800 --> 00:02:33,200

FROM HERE TO MARS?

78

00:02:33,260 --> 00:02:34,320

WELL, THE HOHMANN TRANSFER

79

00:02:34,500 --> 00:02:35,700

FROM EARTH TO MARS,

80

00:02:35,720 --> 00:02:36,860

SHOWN IN THIS ANIMATION,

81

00:02:36,860 --> 00:02:38,360

WOULD TAKE YOU THERE.

82

00:02:38,360 --> 00:02:39,620

NASA SCIENTISTS AND ENGINEERS

83

00:02:39,620 --> 00:02:40,980

HAVE GOTTEN REALLY CREATIVE

84

00:02:41,080 --> 00:02:42,560

IN CREATING TRAJECTORIES TO

85

00:02:42,560 --> 00:02:43,660

SEND ROBOTIC SPACECRAFT

86

00:02:43,660 --> 00:02:45,220

AROUND AND BEYOND

87

00:02:45,320 --> 00:02:47,180

OUR SOLAR SYSTEM.

88

00:02:47,180 --> 00:02:48,980

BUT FOR HUMANS, THE FARTHEST

89

00:02:49,000 --> 00:02:51,680
THAT WE'VE GONE IS TO OUR MOON

90

00:02:51,680 --> 00:02:53,740
50 YEARS AGO.

91

00:02:53,740 --> 00:02:56,960
IN APOLLO 11, ON JULY 16TH,

92

00:02:56,960 --> 00:02:59,000
1969, THREE ASTRONAUTS WERE

93

00:02:59,000 --> 00:03:00,800
LAUNCHED ON A SATURN V ROCKET

94

00:03:01,020 --> 00:03:02,360
LEADING TO HUMANKIND'S

95

00:03:02,460 --> 00:03:04,420
FIRST GIANT LEAP.

96

00:03:04,840 --> 00:03:07,360
AFTER THE FIRST THREE SATURN,

97

00:03:07,360 --> 00:03:08,960
UM, ROCKETS--

98

00:03:09,160 --> 00:03:10,900
SATURN ENGINES BURNED,

99

00:03:10,900 --> 00:03:12,400
THE APOLLO SPACECRAFT WAS PLACED

100

00:03:12,580 --> 00:03:14,220
INTO A LOW CIRCULAR

101
00:03:14,380 --> 00:03:16,080
EARTH PARKING ORBIT,

102
00:03:16,160 --> 00:03:17,840
ROUGHLY 100 NAUTICAL MILES

103
00:03:17,840 --> 00:03:20,140
IN ALTITUDE, OR APPROXIMATELY

104
00:03:20,140 --> 00:03:21,280
THE DISTANCE BETWEEN

105
00:03:21,420 --> 00:03:23,960
CLEVELAND AND COLUMBUS.

106
00:03:23,960 --> 00:03:25,880
AFTER FINAL CHECKOUTS, THE, UH--

107
00:03:25,880 --> 00:03:27,140
SATURN V BURNED WHAT'S CALLED

108
00:03:27,300 --> 00:03:29,340
A TRANS-LUNAR INJECTION BURN,

109
00:03:29,340 --> 00:03:31,060
OR TLI, THAT PLACED THEM ON

110
00:03:31,280 --> 00:03:32,420
THE TRAJECTORY THAT WOULD

111
00:03:32,460 --> 00:03:34,020
TAKE THEM TO THE MOON.

112
00:03:34,060 --> 00:03:35,060
THERE THEY WOULD COAST

113
00:03:35,160 --> 00:03:36,260

FOR THREE DAYS BEFORE BEING

114

00:03:36,580 --> 00:03:37,780

CAPTURED BY THE MOON'S GRAVITY

115

00:03:37,960 --> 00:03:39,360

INTO A LOW LUNAR ORBIT.

116

00:03:39,360 --> 00:03:40,520

NOW AFTER THEY COMPLETED

117

00:03:40,520 --> 00:03:41,820

THEIR SURFACE MISSION,

118

00:03:41,920 --> 00:03:43,080

THE ASTRONAUTS RETURNED TO

119

00:03:43,160 --> 00:03:44,300

THE WAITING COMMAND MODULE,

120

00:03:44,520 --> 00:03:45,780

COLUMBIA, TO START THEIR

121

00:03:46,160 --> 00:03:47,600

TRIP HOME.

122

00:03:47,960 --> 00:03:49,160

THE COLUMBIA, LIKE

123

00:03:49,420 --> 00:03:51,840

THE TRANS-LUNAR INJECTION BURN,

124

00:03:51,840 --> 00:03:53,380

BURNED A TRANS EARTH

125

00:03:53,380 --> 00:03:54,780

INJECTION BURN TO PLACE THEM ON

126
00:03:55,040 --> 00:03:57,160
THE TRAJECTORY BACK TO EARTH.

127
00:03:57,160 --> 00:03:58,720
NOW, HAVING TRAVELED AN AVERAGE

128
00:03:58,740 --> 00:04:00,840
DISTANCE OF 240,000 MILES

129
00:04:00,840 --> 00:04:02,220
FROM THE EARTH TO THE MOON,

130
00:04:02,220 --> 00:04:03,440
THESE APOLLO MISSIONS STILL

131
00:04:03,600 --> 00:04:04,740
STAND AS THE FARTHEST THAT

132
00:04:04,940 --> 00:04:06,080
HUMANS HAVE EVER GONE FROM

133
00:04:06,140 --> 00:04:07,700
THE SURFACE OF THE EARTH.

134
00:04:07,780 --> 00:04:08,580
AND THIS IS

135
00:04:08,580 --> 00:04:10,120
A SIGNIFICANT DISTANCE.

136
00:04:10,120 --> 00:04:12,160
GIVEN THE DIAMETER OF THE EARTH,

137
00:04:12,160 --> 00:04:13,940
ROUGHLY 30 EARTH-SIZED PLANETS

138
00:04:13,940 --> 00:04:15,180

CAN FIT BETWEEN THE EARTH

139

00:04:15,200 --> 00:04:18,420

AND THE MOON.

140

00:04:18,420 --> 00:04:20,260

NOW SINCE APOLLO, THE FARTHEST

141

00:04:20,260 --> 00:04:21,720

WE'VE SENT HUMANS IS TO

142

00:04:21,900 --> 00:04:23,980

THE INTERNATIONAL SPACE STATION,

143

00:04:23,980 --> 00:04:25,780

LOCATED IN A LOW EARTH ORBIT

144

00:04:25,820 --> 00:04:27,200

ROUGHLY 400 KILOMETERS FROM

145

00:04:27,200 --> 00:04:28,540

THE SURFACE OF THE EARTH,

146

00:04:28,540 --> 00:04:31,180

OR ABOUT 250 MILES,

147

00:04:31,440 --> 00:04:33,220

OR APPROXIMATELY

148

00:04:33,220 --> 00:04:34,380

THE DISTANCE BETWEEN

149

00:04:34,440 --> 00:04:37,660

CLEVELAND AND CINCINNATI.

150

00:04:37,820 --> 00:04:39,400

NOW BECAUSE THE

151
00:04:39,460 --> 00:04:40,940
INTERNATIONAL SPACE STATION

152
00:04:40,940 --> 00:04:43,100
ORBITS SO CLOSE TO THE EARTH,

153
00:04:43,100 --> 00:04:44,960
THE COMBINED GRAVITATIONAL PULL

154
00:04:44,980 --> 00:04:46,680
OF THE EARTH, AS WELL AS

155
00:04:46,860 --> 00:04:48,300
THE ATMOSPHERIC DRAG ON

156
00:04:48,300 --> 00:04:49,340
THE STATION, MEANS IT'S IN

157
00:04:49,420 --> 00:04:50,480
A CONSTANT STATE OF

158
00:04:50,540 --> 00:04:52,240
FREE FALL AND REENTRY.

159
00:04:52,240 --> 00:04:53,240
AND PERIODICALLY,

160
00:04:53,240 --> 00:04:54,380
VISITING VEHICLES WITH

161
00:04:54,500 --> 00:04:55,660
PROPULSION SYSTEMS,

162
00:04:55,740 --> 00:04:57,540
WILL GIVE THE ISS A BOOST

163
00:04:57,580 --> 00:05:00,720

TO KEEP IT IN ITS ORBIT.

164

00:05:00,980 --> 00:05:02,800

NOW, WITH THIS BRINGS

165

00:05:03,060 --> 00:05:05,300

ARTEMIS ANNOUNCEMENT.

166

00:05:05,500 --> 00:05:06,800

NASA HAS ANNOUNCED PLANS

167

00:05:06,940 --> 00:05:08,000

TO RETURN HUMANS TO

168

00:05:08,080 --> 00:05:09,440

THE SURFACE OF THE MOON,

169

00:05:09,740 --> 00:05:10,960

LANDING THE FIRST WOMAN

170

00:05:11,020 --> 00:05:12,420

AND THE NEXT MAN ON ITS SURFACE

171

00:05:12,420 --> 00:05:13,900

BY 2024.

172

00:05:13,900 --> 00:05:15,360

THE CURRENT ARTEMIS PLANS ARE

173

00:05:15,580 --> 00:05:16,940

A BLEND OF THOSE APOLLO

174

00:05:17,000 --> 00:05:18,200

LUNAR SORTIE CAMPAIGNS

175

00:05:18,280 --> 00:05:20,000

AS WELL AS THE ISS

176
00:05:20,000 --> 00:05:21,640
SUSTAINABILITY ELEMENTS.

177
00:05:21,640 --> 00:05:23,280
AND THE FIRST KEY SUSTAINING

178
00:05:23,320 --> 00:05:24,680
PIECE OF THIS

179
00:05:24,680 --> 00:05:26,020
ARTEMIS PROGRAM PLAN IS

180
00:05:26,120 --> 00:05:27,580
THE GATEWAY TO BE ASSEMBLED

181
00:05:27,580 --> 00:05:29,740
IN ORBIT NEAR THE MOON.

182
00:05:29,740 --> 00:05:31,640
THE GATEWAY IS A MOBILE COMMAND

183
00:05:31,640 --> 00:05:32,940
AND SERVICE MODULE,

184
00:05:33,100 --> 00:05:34,160
AND IT WILL PROVIDE US WITH

185
00:05:34,340 --> 00:05:35,900
A PLACE TO AGGREGATE

186
00:05:36,060 --> 00:05:37,360
AND ASSEMBLE THE SPACECRAFT

187
00:05:37,400 --> 00:05:38,820
THAT WILL LAND ONTO THE MOON,

188
00:05:38,820 --> 00:05:40,220

AS WELL AS PROVIDE US WITH

189

00:05:40,240 --> 00:05:42,280

A COMMUNICATIONS RELAY TO

190

00:05:42,280 --> 00:05:43,860

SUPPORT ROBOTIC AND HUMAN

191

00:05:43,860 --> 00:05:44,860

MISSIONS ANYWHERE ON

192

00:05:44,920 --> 00:05:46,260

THE MOON'S SURFACE,

193

00:05:46,260 --> 00:05:47,260

BUT STARTING AT THE MOON'S

194

00:05:47,480 --> 00:05:49,260

SOUTH POLE.

195

00:05:49,260 --> 00:05:50,520

THE FIRST ELEMENT OF

196

00:05:50,700 --> 00:05:52,160

THE GATEWAY IS THE POWER

197

00:05:52,160 --> 00:05:53,500

AND PROPULSION ELEMENT MANAGED

198

00:05:53,500 --> 00:05:55,140

HERE IN CLEVELAND AT

199

00:05:55,140 --> 00:05:56,820

NASA GLENN RESEARCH CENTER,

200

00:05:56,820 --> 00:05:57,920

AND BUILT IN A PUBLIC

201
00:05:57,940 --> 00:05:59,240
PRIVATE PARTNERSHIP

202
00:05:59,260 --> 00:06:01,560
WITH MAXAR TECHNOLOGIES.

203
00:06:01,560 --> 00:06:03,180
NOW, SAID OUR ADMINISTRATOR,

204
00:06:03,280 --> 00:06:05,000
JIM BRIDENSTINE, OF THE PPE,

205
00:06:05,000 --> 00:06:06,640
"IT WILL BE THE KEY COMPONENT

206
00:06:06,820 --> 00:06:08,080
UPON WHICH WE WILL BUILD OUR

207
00:06:08,080 --> 00:06:09,640
LUNAR GATEWAY OUTPOST,

208
00:06:09,880 --> 00:06:11,240
THE CORNERSTONE OF NASA'S

209
00:06:11,400 --> 00:06:12,740
SUSTAINABLE AND REUSABLE

210
00:06:12,760 --> 00:06:14,320
ARTEMIS EXPLORATION ARCHITECTURE

211
00:06:14,320 --> 00:06:16,080
ON AND AROUND THE MOON."

212
00:06:16,480 --> 00:06:17,940
THIS POWER AND PROPULSION

213
00:06:18,180 --> 00:06:20,740

ELEMENT IS A HIGH POWER,

214

00:06:20,980 --> 00:06:22,540

50 KILOWATT CLASS

215

00:06:22,560 --> 00:06:23,620

SOLAR ELECTRIC

216

00:06:23,820 --> 00:06:25,920

PROPULSION SPACECRAFT.

217

00:06:26,120 --> 00:06:27,060

AND AT THAT,

218

00:06:27,220 --> 00:06:28,180

IT'S ROUGHLY THREE TIMES

219

00:06:28,180 --> 00:06:29,320

MORE POWERFUL THAN CURRENT

220

00:06:29,320 --> 00:06:31,780

STATE OF THE ART TECHNOLOGIES.

221

00:06:31,840 --> 00:06:33,920

NOW, THE GATEWAY WITH THIS PPE,

222

00:06:33,920 --> 00:06:35,520

WITH BOTH POWER AND PROPULSION,

223

00:06:35,720 --> 00:06:37,620

IS CAPABLE OF NOT ONLY HOLDING

224

00:06:37,800 --> 00:06:39,640

PLACE IN ONE ORBIT, BUT OF

225

00:06:39,640 --> 00:06:41,080

TRANSFERRING BETWEEN ORBITS,

226
00:06:41,280 --> 00:06:42,540
IN SUPPORT OF THIS SUSTAINABLE

227
00:06:42,600 --> 00:06:44,520
LUNAR ARCHITECTURE.

228
00:06:44,560 --> 00:06:46,020
FLYING THE PPE WILL

229
00:06:46,100 --> 00:06:47,340
PROVIDE US WITH

230
00:06:47,340 --> 00:06:49,040
INVALUABLE EXPERIENCE FOR

231
00:06:49,040 --> 00:06:50,760
FUTURE MISSIONS TO MARS,

232
00:06:50,940 --> 00:06:52,180
AND THE CURRENT PLAN

233
00:06:52,180 --> 00:06:53,080
IS TO LAUNCH

234
00:06:53,180 --> 00:06:54,800
THE POWER AND PROPULSION ELEMENT

235
00:06:55,060 --> 00:06:56,860
IN 2022.

236
00:06:59,580 --> 00:07:01,300
THE GATEWAY WILL BE ASSEMBLED

237
00:07:01,540 --> 00:07:03,180
IN A NEW TYPE OF ORBIT,

238
00:07:03,380 --> 00:07:04,340

PERFECTLY BALANCED BY

239

00:07:04,560 --> 00:07:05,800

THE GRAVITATIONAL PULLS OF

240

00:07:05,980 --> 00:07:07,440

THE EARTH AND THE MOON, CALLED

241

00:07:07,700 --> 00:07:10,240

A NEAR RECTILINEAR HALO ORBIT,

242

00:07:10,240 --> 00:07:12,760

OR NRHO, A FAMILY OF WHICH

243

00:07:12,760 --> 00:07:15,560

YOU CAN SEE IN THIS ANIMATION.

244

00:07:15,620 --> 00:07:16,920

NOW WHEN APOLLO

245

00:07:17,060 --> 00:07:18,820

WENT TO THE MOON,

246

00:07:18,820 --> 00:07:20,940

THE LOW LUNAR ORBIT IN WHICH

247

00:07:20,940 --> 00:07:22,480

THE COMMAND MODULE WAITED,

248

00:07:22,480 --> 00:07:23,880

WAS SO PULLED BY THE MOON'S

249

00:07:23,880 --> 00:07:25,220

GRAVITY, THAT WOULD--

250

00:07:25,280 --> 00:07:26,440

IT WAS NOT STABLE AND WOULD

251
00:07:26,720 --> 00:07:27,680
NOT HAVE ALLOWED FOR

252
00:07:27,840 --> 00:07:29,600
THE SPACECRAFT TO STAY FOR LONG.

253
00:07:29,780 --> 00:07:30,920
BUT THE NEAR RECTILINEAR

254
00:07:31,060 --> 00:07:33,340
HALO ORBIT, BALANCING AS IT DOES

255
00:07:33,600 --> 00:07:35,060
BETWEEN THE EARTH AND THE MOON

256
00:07:35,220 --> 00:07:36,820
IN GLOWING YELLOW HERE,

257
00:07:36,960 --> 00:07:37,860
MEANS THAT THE POWER

258
00:07:38,220 --> 00:07:39,120
AND PROPULSION ELEMENT

259
00:07:39,300 --> 00:07:40,960
ONLY NEED TO PERFORM SMALL

260
00:07:41,080 --> 00:07:42,500
ORBIT MAINTENANCE MANEUVERS

261
00:07:42,640 --> 00:07:44,380
TO STAY PERMANENTLY.

262
00:07:44,400 --> 00:07:45,560
THE GRAVITY WILL BALANCE--

263
00:07:45,720 --> 00:07:46,620

OKAY.

264

00:07:46,620 --> 00:07:47,260

UM.

265

00:07:47,480 --> 00:07:49,120

THE NEAR RECTILINEAR HALO

266

00:07:49,140 --> 00:07:50,520

ORBIT IS DIFFERENT THAN THOSE

267

00:07:50,600 --> 00:07:52,160

CIRCULAR ORBITS THAT I MENTIONED

268

00:07:52,260 --> 00:07:53,460

THAT KEPLER DISCOVERED,

269

00:07:53,600 --> 00:07:54,560

LIKE THE ORBIT THAT THE MOON

270

00:07:54,600 --> 00:07:55,840

TAKES AROUND THE EARTH.

271

00:07:56,000 --> 00:07:57,140

THESE THREE VIEWS HERE

272

00:07:57,140 --> 00:07:58,100

SHOW YOU THAT THE NEAR

273

00:07:58,200 --> 00:07:59,260

RECTILINEAR HALO ORBIT

274

00:07:59,380 --> 00:08:01,060

IS AN ORBIT ABOUT THE EARTH,

275

00:08:01,220 --> 00:08:02,640

BUT AT THE DISTANCE OF THE MOON,

276

00:08:02,640 --> 00:08:04,240

SO IT'S TUGGED BY THE MOON,

277

00:08:04,340 --> 00:08:05,500

AND THESE EARTH-MOON

278

00:08:05,700 --> 00:08:06,960

INTERACTIONS MEAN THAT FOR

279

00:08:07,300 --> 00:08:08,640

EVERY TWO ORBITS THAT

280

00:08:08,640 --> 00:08:10,200

THE MOON MAKES ABOUT THE EARTH,

281

00:08:10,240 --> 00:08:11,240

THE SPACECRAFT,

282

00:08:11,440 --> 00:08:12,440

THE GATEWAY IN THIS

283

00:08:12,560 --> 00:08:14,060

NEAR RECTILINEAR HALO ORBIT,

284

00:08:14,200 --> 00:08:15,100

WILL MAKE NINE OF THESE

285

00:08:15,300 --> 00:08:16,660

LEAPFROGS OVER AND UNDER

286

00:08:16,780 --> 00:08:17,660

THE MOON.

287

00:08:17,820 --> 00:08:19,080

AND THE PERIOD OF THIS NEAR

288

00:08:19,320 --> 00:08:20,720

RECTILINEAR HALO ORBIT, OR

289

00:08:20,940 --> 00:08:22,360

THE PERIOD BETWEEN THESE LEAPS,

290

00:08:22,480 --> 00:08:24,360

IS ROUGHLY SIX AND A HALF DAYS,

291

00:08:24,680 --> 00:08:26,100

WITH ONLY FOUR HOURS OUT OF THAT

292

00:08:26,280 --> 00:08:28,020

ALMOST WEEK SPENT OUT OF VIEW

293

00:08:28,300 --> 00:08:29,720

OF THE MOON'S SOUTH POLE.

294

00:08:29,880 --> 00:08:30,940

NOW, IF YOU VIEW IT FROM

295

00:08:31,100 --> 00:08:32,760

THE EARTH, THE NEAR RECTILINEAR

296

00:08:32,920 --> 00:08:34,320

HALO ORBIT LOOKS LIKE A LONG

297

00:08:34,620 --> 00:08:35,920

ELLIPTICAL ORBIT ABOUT

298

00:08:36,020 --> 00:08:37,620

THE MOON, OR A HALO,

299

00:08:37,620 --> 00:08:38,920

THUS THE NAME.

300

00:08:38,980 --> 00:08:40,780

AND THIS ONE HAS ITS CLOSEST

301
00:08:40,980 --> 00:08:41,980
APPROACH TO THE MOON AT

302
00:08:42,000 --> 00:08:43,300
THE MOON'S NORTH POLE,

303
00:08:43,500 --> 00:08:44,440
AND IT'S FARTHEST APPROACH

304
00:08:44,520 --> 00:08:46,020
AT THE MOON'S SOUTH POLE.

305
00:08:46,200 --> 00:08:46,960
AND AS I SAID,

306
00:08:47,200 --> 00:08:48,440
THIS NEAR RECTILINEAR HALO ORBIT

307
00:08:48,520 --> 00:08:49,800
IS ONE OF-OF LARGE FAMILY,

308
00:08:49,860 --> 00:08:51,280
AND IT WAS DESIGNED SPECIFICALLY

309
00:08:51,400 --> 00:08:52,760
TO PROVIDE FOR MAXIMUM LUNAR

310
00:08:52,860 --> 00:08:54,320
COVERAGE OF THE SOUTH POLE,

311
00:08:54,460 --> 00:08:55,660
AS WELL AS TO PROVIDE THAT

312
00:08:55,700 --> 00:08:57,000
A SPACECRAFT IN THIS ORBIT,

313
00:08:57,060 --> 00:08:58,720

THE GATEWAY, STAYS IN AS MUCH

314

00:08:58,820 --> 00:09:01,820

DIRECT SUNLIGHT AS POSSIBLE.

315

00:09:01,820 --> 00:09:03,820

NOW, NEAR RECTILINEAR HALO

316

00:09:03,980 --> 00:09:06,220

ORBITS ARE VERY FAVORABLE FOR

317

00:09:06,420 --> 00:09:08,320

TRANSFERRING INTO AND OUT OF,

318

00:09:08,400 --> 00:09:09,300

WHICH IS NICE WHEN YOUR

319

00:09:09,460 --> 00:09:10,520

SPACECRAFT IS MEANT TO BE

320

00:09:10,580 --> 00:09:12,400

A STAGING AREA FOR EXPLORATION,

321

00:09:12,500 --> 00:09:13,220

WITH OTHER SHIPS

322

00:09:13,220 --> 00:09:14,520

COMING AND GOING.

323

00:09:14,740 --> 00:09:16,280

IN THIS TRAJECTORY ANIMATION

324

00:09:16,460 --> 00:09:18,080

SHOWS THE PATH THAT THE ORION

325

00:09:18,240 --> 00:09:19,460

WITH THE CREW IN IT WOULD TAKE

326

00:09:19,500 --> 00:09:20,600

AS THEY DEPART EARTH,

327

00:09:20,660 --> 00:09:21,940

HEAD TOWARD A POWER LUNAR FLYBY

328

00:09:22,000 --> 00:09:23,280

TO PUT THEM INTO THE GATEWAY

329

00:09:23,420 --> 00:09:25,460

IN THE NRHO, STAY IN THE NRHO

330

00:09:25,460 --> 00:09:27,180

FOR ONE AND A HALF ORBITS

331

00:09:27,320 --> 00:09:28,840

BEFORE DEPARTING TO HEAD BACK

332

00:09:28,840 --> 00:09:30,720

TO ANOTHER POWERED LUNAR FLYBY

333

00:09:30,980 --> 00:09:32,320

TO PUT THEM ON THE TRAJECTORY

334

00:09:32,740 --> 00:09:34,080

THAT WOULD TAKE THEM BACK HOME.

335

00:09:38,500 --> 00:09:40,440

NOW, RECALL THAT THE GATEWAY,

336

00:09:40,720 --> 00:09:41,580

WITH THE POWER AND PROPULSION

337

00:09:41,940 --> 00:09:43,700

ELEMENT, IS CAPABLE NOT JUST

338

00:09:43,960 --> 00:09:45,660

OF HOLDING PLACE IN ONE ORBIT,

339

00:09:45,660 --> 00:09:46,620

BUT ALSO OF TRANSFERRING

340

00:09:46,620 --> 00:09:47,920

BETWEEN ORBITS.

341

00:09:47,920 --> 00:09:49,080

THE NASA GLENN RESEARCH CENTER

342

00:09:49,180 --> 00:09:50,380

POWER AND PROPULSION ELEMENT

343

00:09:50,460 --> 00:09:51,700

MISSION AND DESIGN TEAM HAS

344

00:09:51,920 --> 00:09:53,620

DESIGNED SEVERAL TRAJECTORIES,

345

00:09:53,620 --> 00:09:54,660

TAKING THE GATEWAY FARTHER

346

00:09:54,900 --> 00:09:56,460

AND FARTHER FROM EARTH TO OTHER

347

00:09:56,620 --> 00:09:57,820

ORBITS WHERE MISSION SCENARIOS

348

00:09:57,960 --> 00:09:59,580

AND SCIENCE CAN BE COMPLETED.

349

00:10:00,400 --> 00:10:01,760

FLYING THESE TRANSFERS

350

00:10:01,800 --> 00:10:03,200

WILL ALLOW US TO GAIN

351
00:10:03,200 --> 00:10:05,200
INVALUABLE EXPERIENCE OPERATING

352
00:10:05,200 --> 00:10:06,780
THESE TYPES OF LARGE,

353
00:10:06,780 --> 00:10:09,360
HUMAN TENDED SYSTEMS IN SPACE,

354
00:10:09,360 --> 00:10:10,920
AND ALONG THE LENGTHY TRANSFERS

355
00:10:10,980 --> 00:10:11,800
WE'RE GOING TO NEED TO

356
00:10:12,020 --> 00:10:13,320
ACCOMPLISH IF WE'RE GOING

357
00:10:13,480 --> 00:10:14,740
TO BE ABLE TO SEND HUMANS

358
00:10:14,960 --> 00:10:16,420
TO OUR CLOSEST NEIGHBOR,

359
00:10:16,420 --> 00:10:18,420
THE RED PLANET, MARS.

360
00:10:20,940 --> 00:10:23,100
NOW, THE CURRENT ARTEMIS PLANS

361
00:10:23,200 --> 00:10:24,260
WILL TAKE PLACE IN

362
00:10:24,560 --> 00:10:26,100
A TWO-PHASED APPROACH,

363
00:10:26,100 --> 00:10:28,120

WITH THE FIRST FOCUSED ON SPEED,

364

00:10:28,120 --> 00:10:29,020

LANDING ON THE MOON

365

00:10:29,060 --> 00:10:31,000

BY 2024 AS WE DISCUSSED,

366

00:10:31,060 --> 00:10:32,560

AND THE SECOND TO ESTABLISH

367

00:10:32,620 --> 00:10:34,520

A SUSTAINED LUNAR PRESENCE ON

368

00:10:34,520 --> 00:10:37,160

AND AROUND THE MOON BY 2028.

369

00:10:37,160 --> 00:10:38,560

FLYING THE GATEWAY AND

370

00:10:38,700 --> 00:10:40,600

THE POWER AND PROPULSION ELEMENT

371

00:10:40,700 --> 00:10:41,900

WILL ALLOW US TO ACCOMPLISH

372

00:10:42,240 --> 00:10:43,840

BOTH THE FIRST, BY GIVING US

373

00:10:44,080 --> 00:10:45,200

A PLACE TO AGGREGATE

374

00:10:45,560 --> 00:10:47,000

AND ASSEMBLE THE SPACECRAFT

375

00:10:47,100 --> 00:10:48,500

THAT WILL LAND ON THE MOON,

376

00:10:48,500 --> 00:10:49,700

AS WELL AS THE SECOND BY

377

00:10:49,800 --> 00:10:50,800

PROVIDING US A PLACE TO

378

00:10:51,180 --> 00:10:52,480

REFURBISH AND REFUEL

379

00:10:52,680 --> 00:10:53,880

THE LUNAR ELEMENTS FOR

380

00:10:54,100 --> 00:10:55,240

SUBSEQUENT LUNAR MISSIONS

381

00:10:55,440 --> 00:10:57,340

OR REORIENT TO FOCUS ON OTHER

382

00:10:57,500 --> 00:10:59,700

AREAS ON AND AROUND THE MOON.

383

00:10:59,700 --> 00:11:01,040

THE CURRENT PLANS FOR ARTEMIS

384

00:11:01,220 --> 00:11:02,640

HAVE SEVERAL ELEMENTS

385

00:11:02,700 --> 00:11:03,720

THAT ARE SIMILAL--

386

00:11:03,820 --> 00:11:05,420

SIMILAR TO APOLLO.

387

00:11:05,640 --> 00:11:06,880

THE YEARS MAY CHANGE, BUT

388

00:11:06,880 --> 00:11:08,460

THE PHYSICS REMAINS THE SAME.

389

00:11:08,460 --> 00:11:10,220

FIRST, THE CREW IS LAUNCHED

390

00:11:10,260 --> 00:11:11,920

IN THE ORION SPACECRAFT ON

391

00:11:12,060 --> 00:11:13,520

A SPACE LAUNCH SYSTEM,

392

00:11:13,740 --> 00:11:16,080

OR SLS ROCKET, ON A TRAJECTORY

393

00:11:16,140 --> 00:11:16,980

THAT WILL TAKE THEM

394

00:11:17,200 --> 00:11:18,900

DIRECTLY TO THE NRHO,

395

00:11:18,960 --> 00:11:20,900

WHICH YOU'VE ALREADY SEEN.

396

00:11:20,900 --> 00:11:21,920

ONCE THE ORION DOCKS

397

00:11:22,100 --> 00:11:23,240

WITH THE GATEWAY,

398

00:11:23,280 --> 00:11:24,420

THE TWO CREW MEMBERS WHO WILL GO

399

00:11:24,440 --> 00:11:26,000

TO THE SURFACE TRANSFER FROM

400

00:11:26,080 --> 00:11:27,680

THE ORION INTO THE WAITING

401
00:11:27,760 --> 00:11:29,440
LUNAR LANDER SYSTEM.

402
00:11:29,680 --> 00:11:30,840
CURRENT CONCEPTS FOR

403
00:11:31,160 --> 00:11:32,620
THE LUNAR LANDER SYSTEM ARE

404
00:11:32,920 --> 00:11:34,980
COMPOSED OF THREE PARTS:

405
00:11:34,980 --> 00:11:36,620
FIRST A TRANSFER MODULE,

406
00:11:36,620 --> 00:11:38,280
THEN AN ASCENT MODULE,

407
00:11:38,440 --> 00:11:39,660
AND A DESCENT MODULE.

408
00:11:39,860 --> 00:11:40,960
THE TRANSFER MODULE WILL TAKE

409
00:11:41,160 --> 00:11:43,220
THE ENTIRE STACK AND THE CREW

410
00:11:43,460 --> 00:11:45,240
TO A LOW LUNAR PARKING ORBIT.

411
00:11:45,240 --> 00:11:47,080
FROM THERE, THE DESCENT MODULE

412
00:11:47,280 --> 00:11:48,680
WILL TAKE THE ASCENT MODULE

413
00:11:48,880 --> 00:11:49,740

WITH THE CREW

414

00:11:49,920 --> 00:11:51,360
DOWN TO THE SURFACE.

415

00:11:51,380 --> 00:11:52,440
WHEN THEY'VE COMPLETED

416

00:11:52,640 --> 00:11:53,940
THEIR MISSION, THE ASCENT MODULE

417

00:11:54,020 --> 00:11:55,260
WILL RETURN THE CREW

418

00:11:55,460 --> 00:11:56,740
BACK TO THE GATEWAY.

419

00:11:56,740 --> 00:11:58,200
CURRENT PLANS HAVE

420

00:11:58,220 --> 00:11:59,280
LUNAR SURFACE MISSIONS

421

00:11:59,280 --> 00:12:01,040
ROUGHLY THREE TO SEVEN DAYS,

422

00:12:01,080 --> 00:12:02,380
AFTER WHICH THE ASTRONAUTS

423

00:12:02,400 --> 00:12:03,400
WILL RETURN TO THE GATEWAY,