



1
00:00:30,460 --> 00:00:46,940
I go a lot further again

2
00:00:46,950 --> 00:01:01,030
hey babe

3
00:01:06,620 --> 00:01:03,980
welcome to this edition of NASA images

4
00:01:08,990 --> 00:01:06,630
i'm Lynn Bondurant during this show

5
00:01:11,900 --> 00:01:09,000
we're focusing on historic NASA film

6
00:01:13,850 --> 00:01:11,910
showing electric rockets and more recent

7
00:01:18,380 --> 00:01:13,860
videotape showing how we may someday

8
00:01:20,660 --> 00:01:18,390
explore Mars first let's go back to 1965

9
00:01:23,840 --> 00:01:20,670
to see most of the film electric

10
00:01:26,830 --> 00:01:23,850
propulsion though made in the mid 1960s

11
00:01:29,480 --> 00:01:26,840
much of the film is still current a

12
00:01:32,210 --> 00:01:29,490
concept showing how electric Rockets

13
00:01:45,770 --> 00:01:32,220

could be used to fly space travelers to

14

00:01:48,859 --> 00:01:45,780

Mars is included imagine for a moment

15

00:01:52,550 --> 00:01:48,869

that this is the period of the 1970s and

16

00:01:58,319 --> 00:01:52,560

1980s a period of amazing explorations

17

00:02:03,279 --> 00:02:00,999

imagine that the distant planet Jupiter

18

00:02:07,749 --> 00:02:03,289

is to be investigated scientifically by

19

00:02:09,820 --> 00:02:07,759

a spacecraft that will fly close by at

20

00:02:11,830 --> 00:02:09,830

the correct place in its orbit it's

21

00:02:14,050 --> 00:02:11,840

conventional chemical engines are fired

22

00:02:19,660 --> 00:02:14,060

to accelerate it to the velocity needed

23

00:02:22,210 --> 00:02:19,670

to get to Jupiter imagine also that nine

24

00:02:25,360 --> 00:02:22,220

and a half months later a craft with

25

00:02:27,280 --> 00:02:25,370

advanced engines is launched it slowly

26

00:02:30,550 --> 00:02:27,290

accelerates until it escapes Earth's

27

00:02:33,400 --> 00:02:30,560

gravity one year after the conventional

28

00:02:36,039 --> 00:02:33,410

craft started of course the first craft

29

00:02:38,410 --> 00:02:36,049

is well on its way since leaving Earth

30

00:02:44,140 --> 00:02:38,420

it has been coasting and it's velocity

31

00:02:45,910 --> 00:02:44,150

has continuously decreased but constant

32

00:02:48,819 --> 00:02:45,920

thrust is applied to the second craft

33

00:02:52,990 --> 00:02:48,829

for six months which continuously

34

00:02:53,860 --> 00:02:53,000

increases its velocity even though it

35

00:02:56,589 --> 00:02:53,870

escaped earth

36

00:02:59,020 --> 00:02:56,599

a year later it reaches Jupiter about

37

00:03:01,960 --> 00:02:59,030

eight months ahead of the conventional

38

00:03:06,520 --> 00:03:01,970

craft and carries three times the

39

00:03:14,710 --> 00:03:12,040

what could make this possible electric

40

00:03:18,160 --> 00:03:14,720

propulsion as used in the hypothetical

41

00:03:20,680 --> 00:03:18,170

second spacecraft and it is now under

42

00:03:23,020 --> 00:03:20,690

active research and development since

43

00:03:24,850 --> 00:03:23,030

the advent of the Space Age the roaring

44

00:03:26,440 --> 00:03:24,860

flaming spectacle of the chemically

45

00:03:29,110 --> 00:03:26,450

fueled rocket has become a common

46

00:03:34,630 --> 00:03:29,120

occurrence carrying space vehicles into

47

00:03:36,460 --> 00:03:34,640

Earth orbit and deep space the weight of

48

00:03:38,410 --> 00:03:36,470

such a payload is extremely small

49

00:03:41,080 --> 00:03:38,420

compared to the liftoff weight of the

50

00:03:43,690 --> 00:03:41,090

entire rocket because a chemical booster

51
00:03:46,660 --> 00:03:43,700
can put only 2 to 3% of its weight into

52
00:03:50,350 --> 00:03:46,670
orbit this lifting ratio cannot be

53
00:03:52,420 --> 00:03:50,360
improved significantly yet today the

54
00:03:57,340 --> 00:03:52,430
chemical rocket is the only means of

55
00:03:59,680 --> 00:03:57,350
launching a payload from Earth once the

56
00:04:02,110 --> 00:03:59,690
vehicle is in Earth orbit a chemical

57
00:04:04,150 --> 00:04:02,120
engine can send only about 1/3 of its

58
00:04:09,210 --> 00:04:04,160
orbital weight to the moon or the near

59
00:04:12,370 --> 00:04:09,220
planets two-thirds is fuel and engines

60
00:04:14,650 --> 00:04:12,380
the craft quickly burns the fuel of its

61
00:04:17,229 --> 00:04:14,660
final stage to accelerate the payload to

62
00:04:20,110 --> 00:04:17,239
a high velocity which then coasts the

63
00:04:22,090 --> 00:04:20,120

rest of the way this coasting flight

64

00:04:25,150 --> 00:04:22,100

takes considerable time to cover large

65

00:04:27,159 --> 00:04:25,160

distances but many deep space missions

66

00:04:29,800 --> 00:04:27,169

can be performed better by applying

67

00:04:33,660 --> 00:04:29,810

small amounts of thrust during most or

68

00:04:37,120 --> 00:04:35,740

over long distances

69

00:04:38,890 --> 00:04:37,130

this continuous thrusting will

70

00:04:41,770 --> 00:04:38,900

accelerate spacecraft to very high

71

00:04:45,280 --> 00:04:41,780

velocities and shorten overall travel

72

00:04:47,590 --> 00:04:45,290

time when perfected electric propulsion

73

00:04:50,320 --> 00:04:47,600

will provide the continuous thrust

74

00:04:55,390 --> 00:04:50,330

needed to reduce travel time to distant

75

00:04:57,370 --> 00:04:55,400

points and will use fuel so effectively

76

00:04:59,530 --> 00:04:57,380

that a larger fraction of the Earth

77

00:05:02,770 --> 00:04:59,540

orbit weight will be delivered as useful

78

00:05:05,620 --> 00:05:02,780

payload if the goals for electric

79

00:05:07,840 --> 00:05:05,630

propulsion are achieved the entire solar

80

00:05:13,630 --> 00:05:07,850

system will be open to versatile

81

00:05:15,340 --> 00:05:13,640

exploration the most difficult space

82

00:05:17,290 --> 00:05:15,350

mission of this decade will be the

83

00:05:20,260 --> 00:05:17,300

landing of men on the moon and getting

84

00:05:21,790 --> 00:05:20,270

them back safely man in space must be

85

00:05:25,510 --> 00:05:21,800

transported in the shortest possible

86

00:05:27,400 --> 00:05:25,520

time today only an all chemical

87

00:05:34,240 --> 00:05:27,410

propulsion system can do this job of

88

00:05:36,370 --> 00:05:34,250

moon exploration but what lies beyond to

89

00:05:38,920 --> 00:05:36,380

establish and maintain a scientific base

90

00:05:40,570 --> 00:05:38,930

on the moon will require the delivery of

91

00:05:47,080 --> 00:05:40,580

large amounts of supplies and equipment

92

00:05:49,540 --> 00:05:47,090

a very expensive operation to send large

93

00:05:51,790 --> 00:05:49,550

manned spacecraft and unmanned probes to

94

00:05:53,860 --> 00:05:51,800

Mars and Beyond will require the

95

00:05:57,640 --> 00:05:53,870

propelling of very large payloads over

96

00:05:59,680 --> 00:05:57,650

great distances just to lift these

97

00:06:02,320 --> 00:05:59,690

heavier payloads into deep space with

98

00:06:04,000 --> 00:06:02,330

all chemical systems will require either

99

00:06:07,000 --> 00:06:04,010

building bigger and bigger launch

100

00:06:09,340 --> 00:06:07,010

vehicles or launching several vehicles

101
00:06:12,670 --> 00:06:09,350
into Earth orbit carrying engines and

102
00:06:15,760 --> 00:06:12,680
fuel and then assembling them to provide

103
00:06:19,510 --> 00:06:15,770
the propulsion needed both alternatives

104
00:06:22,420 --> 00:06:19,520
are extremely expensive so a propulsion

105
00:06:27,809 --> 00:06:22,430
system is needed that will use fuel more

106
00:06:33,159 --> 00:06:30,969
in a propulsion system fuel economy can

107
00:06:36,369 --> 00:06:33,169
be increased by speeding up the exhaust

108
00:06:38,709 --> 00:06:36,379
gases in chemical rockets the exhaust

109
00:06:48,980 --> 00:06:38,719
velocity is limited by the temperatures

110
00:07:03,450 --> 00:06:52,050
so methods other than combustion have to

111
00:07:08,740 --> 00:07:06,309
one way is to use the heat of a nuclear

112
00:07:12,159 --> 00:07:08,750
reactor to increase the exhaust velocity

113
00:07:15,159 --> 00:07:12,169

of a light gas such as hydrogen this

114

00:07:18,240 --> 00:07:15,169

velocity is about 2 and 1/2 times that

115

00:07:23,200 --> 00:07:20,980

therefore nuclear rockets will use fuel

116

00:07:29,200 --> 00:07:23,210

two and a half times as effectively as

117

00:07:31,990 --> 00:07:29,210

chemical rockets another way to increase

118

00:07:34,659 --> 00:07:32,000

exhaust velocity is to use electrical

119

00:07:37,119 --> 00:07:34,669

energy instead of heat to accelerate the

120

00:07:40,450 --> 00:07:37,129

propellant gas up to 20 times or more

121

00:07:42,279 --> 00:07:40,460

than in chemical rockets these high

122

00:07:44,619 --> 00:07:42,289

exhaust velocities in the electric

123

00:07:47,800 --> 00:07:44,629

engine increase the effectiveness of the

124

00:07:53,619 --> 00:07:47,810

fuel 20 times and more as well resulting

125

00:07:55,629 --> 00:07:53,629

in much more work per pound of fuel with

126

00:07:57,610 --> 00:07:55,639

this high fuel effectiveness and with

127

00:07:59,890 --> 00:07:57,620

the ability to apply continuous thrust

128

00:08:03,790 --> 00:07:59,900

the electric engine is a promising

129

00:08:06,249 --> 00:08:03,800

candidate for true space propulsion it

130

00:08:09,519 --> 00:08:06,259

cannot be used as a launch engine but

131

00:08:11,320 --> 00:08:09,529

once in space it can take over after the

132

00:08:13,390 --> 00:08:11,330

high thrust chemical booster has given

133

00:08:16,029 --> 00:08:13,400

the space vehicle sufficient velocity to

134

00:08:20,110 --> 00:08:16,039

overcome the main effects of gravity the

135

00:08:22,240 --> 00:08:20,120

electric engine is started this small

136

00:08:25,300 --> 00:08:22,250

thrust applied intermittently or

137

00:08:34,969 --> 00:08:25,310

continuously for months or years will

138

00:08:41,639 --> 00:08:37,860

the effect of a very small thrust

139

00:08:44,400 --> 00:08:41,649

applied over a long time is the same as

140

00:08:48,120 --> 00:08:44,410

a very large thrust applied for a very

141

00:08:54,139 --> 00:08:48,130

short time thrust multiplied by the time

142

00:08:56,970 --> 00:08:54,149

it is applied is called total impulse a

143

00:08:59,759 --> 00:08:56,980

million pounds of thrust applied for 30

144

00:09:03,030 --> 00:08:59,769

seconds will deliver 30 million pound

145

00:09:05,100 --> 00:09:03,040

seconds of total impulse the same as a

146

00:09:11,880 --> 00:09:05,110

pound of thrust applied for 30 million

147

00:09:14,190 --> 00:09:11,890

seconds which is roughly a year each

148

00:09:16,560 --> 00:09:14,200

flight in space requires a certain total

149

00:09:18,930 --> 00:09:16,570

impulse the goal of deep space

150

00:09:22,350 --> 00:09:18,940

propulsion is to use the least amount of

151
00:09:24,990 --> 00:09:22,360
fuel for a given total impulse in space

152
00:09:27,900 --> 00:09:25,000
propulsion fuel economy of a rocket

153
00:09:30,690 --> 00:09:27,910
engine is discussed in terms of specific

154
00:09:35,780 --> 00:09:30,700
impulse which is defined as the total

155
00:09:41,970 --> 00:09:38,819
the higher the specific impulse the

156
00:09:45,870 --> 00:09:41,980
longer in seconds one pound of fuel will

157
00:09:47,850 --> 00:09:45,880
deliver one pound of thrust for

158
00:09:50,819 --> 00:09:47,860
convenience specific impulse is

159
00:09:52,650 --> 00:09:50,829
expressed in seconds chemical rockets

160
00:09:56,040 --> 00:09:52,660
are limited to specific impulses of

161
00:10:00,509 --> 00:09:56,050
about 450 seconds and relatively little

162
00:10:02,880 --> 00:10:00,519
improvement can be expected solid fuel

163
00:10:05,250 --> 00:10:02,890

nuclear rockets are expected to deliver

164

00:10:08,639 --> 00:10:05,260

up to about 1000 seconds of specific

165

00:10:10,439 --> 00:10:08,649

impulse electric engines however are now

166

00:10:13,350 --> 00:10:10,449

operating at specific impulses from

167

00:10:17,900 --> 00:10:13,360

around 800 to 10,000 seconds and higher

168

00:10:23,010 --> 00:10:20,370

the higher the specific impulse

169

00:10:24,900 --> 00:10:23,020

the higher the fuel economy but

170

00:10:27,630 --> 00:10:24,910

unfortunately as specific impulse

171

00:10:29,810 --> 00:10:27,640

increases for the same thrust the

172

00:10:31,020 --> 00:10:29,820

electric power needs increase and

173

00:10:34,440 --> 00:10:31,030

powerplant

174

00:10:41,790 --> 00:10:34,450

weight goes up even more so an optimum

175

00:10:43,890 --> 00:10:41,800

value must be bound for each mission but

176

00:10:45,720 --> 00:10:43,900

even with this compromise for many

177

00:10:48,090 --> 00:10:45,730

manned and unmanned interplanetary

178

00:10:50,070 --> 00:10:48,100

missions the electric engine appears to

179

00:10:52,590 --> 00:10:50,080

be the propulsion system to deliver

180

00:10:58,170 --> 00:10:52,600

significant payloads within a reasonable

181

00:11:00,060 --> 00:10:58,180

time for missions to Pluto for example

182

00:11:06,960 --> 00:11:00,070

the electric engine is the only device

183

00:11:09,240 --> 00:11:06,970

that can deliver any payload at all the

184

00:11:11,670 --> 00:11:09,250

power source for electric engines will

185

00:11:14,700 --> 00:11:11,680

be either a nuclear reactor or solar

186

00:11:17,940 --> 00:11:14,710

cells or heat concentrators depending

187

00:11:21,750 --> 00:11:17,950

upon how much power is needed waste heat

188

00:11:23,700 --> 00:11:21,760

is rejected to space by a radiator heat

189

00:11:26,460 --> 00:11:23,710
from the power source drives an

190

00:11:28,740 --> 00:11:26,470
electrical generator the electrical

191

00:11:30,870 --> 00:11:28,750
power is conditioned and controlled to

192

00:11:33,810 --> 00:11:30,880
provide the necessary voltages and

193

00:11:35,940 --> 00:11:33,820
currents the typical propulsion system

194

00:11:38,520 --> 00:11:35,950
also includes propellant storage and

195

00:11:41,850 --> 00:11:38,530
feed devices which lead to the engine

196

00:11:43,950 --> 00:11:41,860
itself three types of electric engines

197

00:11:46,110 --> 00:11:43,960
are under development they differ

198

00:11:50,460 --> 00:11:46,120
primarily in the way the propellant is

199

00:11:53,100 --> 00:11:50,470
accelerated the electro thermal engine

200

00:11:55,050 --> 00:11:53,110
uses an electric arc or resistance

201
00:11:57,180 --> 00:11:55,060
element to heat a propellant gas to a

202
00:12:00,810 --> 00:11:57,190
very high temperature which produces a

203
00:12:04,950 --> 00:12:00,820
high exhaust velocity specific impulses

204
00:12:08,940 --> 00:12:04,960
from 802 in excess of 2,500 seconds are

205
00:12:10,620 --> 00:12:08,950
possible with these engines the electro

206
00:12:12,630 --> 00:12:10,630
thermal engines have demonstrated good

207
00:12:15,420 --> 00:12:12,640
performance in vacuum chamber tests

208
00:12:15,810 --> 00:12:15,430
however laboratory work must continue in

209
00:12:19,640 --> 00:12:15,820
order

210
00:12:25,320 --> 00:12:22,530
electromagnetic engines a fast-moving

211
00:12:28,920 --> 00:12:25,330
ionized gas is generated and used as the

212
00:12:31,560 --> 00:12:28,930
propellant this gas is a plasma of ions

213
00:12:33,810 --> 00:12:31,570

and electrons electric and magnetic

214

00:12:35,580 --> 00:12:33,820

fields then speed up the charged

215

00:12:38,730 --> 00:12:35,590

particles to much higher exhaust

216

00:12:41,850 --> 00:12:38,740

velocities a specific impulse range of

217

00:12:47,280 --> 00:12:41,860

800 to an excess of 10,000 seconds

218

00:12:49,200 --> 00:12:47,290

appears to be possible these

219

00:12:51,540 --> 00:12:49,210

electromagnetic devices are the least

220

00:12:53,570 --> 00:12:51,550

developed at this time however there are

221

00:12:58,400 --> 00:12:53,580

many promising designs under laboratory

222

00:13:02,310 --> 00:12:58,410

investigation in the third type the

223

00:13:05,130 --> 00:13:02,320

electrostatic or ion engine cesium or

224

00:13:08,160 --> 00:13:05,140

mercury fuel is ionized and the

225

00:13:11,250 --> 00:13:08,170

resulting electrons removed the ions

226

00:13:13,080 --> 00:13:11,260

being positively charged are accelerated

227

00:13:16,380 --> 00:13:13,090

to very high velocities by a high

228

00:13:18,800 --> 00:13:16,390

negative voltage electrode these engines

229

00:13:25,070 --> 00:13:18,810

will operate at specific impulses from

230

00:13:29,730 --> 00:13:27,240

electrostatic ion engines are the most

231

00:13:32,130 --> 00:13:29,740

advanced electric type but much work

232

00:13:53,120 --> 00:13:32,140

remains to develop larger more efficient

233

00:13:59,010 --> 00:13:55,950

though work on electric engines has been

234

00:14:00,330 --> 00:13:59,020

underway only since 1959 great progress

235

00:14:03,300 --> 00:14:00,340

has been made in government and

236

00:14:05,010 --> 00:14:03,310

contractor laboratories thrust levels

237

00:14:07,890 --> 00:14:05,020

approaching a pound have already been

238

00:14:10,110 --> 00:14:07,900

obtained yet enormous strides must still

239

00:14:13,170 --> 00:14:10,120

be taken before larger reliable engines

240

00:14:15,510 --> 00:14:13,180

are available goals for electric systems

241

00:14:18,390 --> 00:14:15,520

include achieving power supply weights

242

00:14:21,270 --> 00:14:18,400

of less than 40 and an ultimate goal of

243

00:14:24,630 --> 00:14:21,280

20 pounds per kilowatt with lifetimes of

244

00:14:26,850 --> 00:14:24,640

more than 10,000 hours development of

245

00:14:29,370 --> 00:14:26,860

the engines themselves strives for

246

00:14:32,000 --> 00:14:29,380

smaller weight and size per unit thrust

247

00:14:34,890 --> 00:14:32,010

and higher overall effectiveness

248

00:14:36,780 --> 00:14:34,900

eventually the entire engine system must

249

00:14:40,230 --> 00:14:36,790

operate continuously for up to four

250

00:14:43,350 --> 00:14:40,240

years by grouping engines together as

251
00:14:46,650 --> 00:14:43,360
building blocks power levels up to 40

252
00:14:53,640 --> 00:14:46,660
megawatts and total thrusts of over 450

253
00:14:55,680 --> 00:14:53,650
pounds may be obtained in addition to

254
00:14:58,320 --> 00:14:55,690
this laboratory work electric engines

255
00:15:00,570 --> 00:14:58,330
must be flight tested space conditions

256
00:15:03,240 --> 00:15:00,580
cannot be totally simulated even in

257
00:15:05,190 --> 00:15:03,250
these advanced vacuum chambers and there

258
00:15:08,970 --> 00:15:05,200
may be influential environmental factors

259
00:15:10,800 --> 00:15:08,980
in space unknown at this time small

260
00:15:14,880 --> 00:15:10,810
electric engines already being developed

261
00:15:16,920 --> 00:15:14,890
may perform early missions the first

262
00:15:20,240 --> 00:15:16,930
application may be to control a

263
00:15:23,370 --> 00:15:20,250

synchronous communication satellite

264

00:15:26,130 --> 00:15:23,380

these engines can deliver small accurate

265

00:15:29,040 --> 00:15:26,140

bits of thrust for months or years using

266

00:15:32,760 --> 00:15:29,050

only small amounts of fuel solar cells

267

00:15:34,620 --> 00:15:32,770

will furnish the power another solar

268

00:15:36,630 --> 00:15:34,630

powered application could be the raising

269

00:15:39,260 --> 00:15:36,640

of an advanced communication satellite

270

00:15:44,340 --> 00:15:39,270

from a low Earth orbit to its final

271

00:15:48,820 --> 00:15:46,840

solar-powered electric engines may also

272

00:15:50,890 --> 00:15:48,830

be used to slowly spiral out a

273

00:15:55,630 --> 00:15:50,900

scientific satellite to make a detailed

274

00:15:57,460 --> 00:15:55,640

study of the Van Allen belt flight tests

275

00:15:59,290 --> 00:15:57,470

and early missions will provide data

276

00:16:01,329 --> 00:15:59,300

that will help perfect the larger

277

00:16:05,410 --> 00:16:01,339

electric engines needed for more

278

00:16:06,579 --> 00:16:05,420

ambitious projects large electric

279

00:16:08,860 --> 00:16:06,589

propulsion systems

280

00:16:11,079 --> 00:16:08,870

when perfected they take large amounts

281

00:16:14,440 --> 00:16:11,089

of supplies and equipment to the moon

282

00:16:18,460 --> 00:16:14,450

and do it much cheaper than all chemical

283

00:16:20,370 --> 00:16:18,470

systems chemically propelled boosters

284

00:16:23,350 --> 00:16:20,380

will place the freight into Earth orbit

285

00:16:26,019 --> 00:16:23,360

the spacecraft may incorporate a small

286

00:16:28,150 --> 00:16:26,029

chemical engine and electrically

287

00:16:30,700 --> 00:16:28,160

propelled lunar freighter will

288

00:16:33,640 --> 00:16:30,710

rendezvous with the craft take it to the

289

00:16:38,800 --> 00:16:33,650

vicinity of the moon and place it in a

290

00:16:42,950 --> 00:16:41,360

the chemical stage will lower the

291

00:16:48,430 --> 00:16:42,960

freight loaded craft to the lunar

292

00:16:53,590 --> 00:16:50,960

while the electrically driven freighter

293

00:16:55,970 --> 00:16:53,600

returns to Earth orbit for another load

294

00:16:58,670 --> 00:16:55,980

it will continue to shuttle back and

295

00:17:04,160 --> 00:16:58,680

forth with periodic fuel replacement as

296

00:17:05,840 --> 00:17:04,170

long as its power supply lasts of course

297

00:17:08,120 --> 00:17:05,850

the electric freighter will take longer

298

00:17:10,310 --> 00:17:08,130

to get to the moon but for most Freight

299

00:17:20,810 --> 00:17:10,320

the longer travel time is not an

300

00:17:22,850 --> 00:17:20,820

important consideration for the same

301
00:17:25,250 --> 00:17:22,860
amount of freight this system will need

302
00:17:28,670 --> 00:17:25,260
far fewer expensive earth launch

303
00:17:32,010 --> 00:17:28,680
boosters than all chemical system would

304
00:17:38,260 --> 00:17:34,870
on small vehicle missions to the near

305
00:17:40,810 --> 00:17:38,270
planets Mars and Venus electric engines

306
00:17:44,080 --> 00:17:40,820
can deliver much more payload by taking

307
00:17:46,659 --> 00:17:44,090
a slightly longer time a three-stage

308
00:17:49,270 --> 00:17:46,669
chemical rocket now being studied could

309
00:17:53,140 --> 00:17:49,280
get a 2,500 pound payload into an orbit

310
00:17:55,140 --> 00:17:53,150
around Mars in about 210 days and

311
00:17:58,030 --> 00:17:55,150
electrically propel spacecraft

312
00:18:01,480 --> 00:17:58,040
substituted for the third stage could do

313
00:18:03,640 --> 00:18:01,490

as well in the same time but by using a

314

00:18:07,419 --> 00:18:03,650

higher specific impulse engine and

315

00:18:12,460 --> 00:18:07,429

taking only 40 more days it can deliver

316

00:18:14,799 --> 00:18:12,470

twice the payload to those planets

317

00:18:16,450 --> 00:18:14,809

beyond Mars and Venus electric

318

00:18:19,240 --> 00:18:16,460

propulsion gives both the payload and

319

00:18:21,280 --> 00:18:19,250

time advantage it appears to be the most

320

00:18:23,260 --> 00:18:21,290

promising means of sending scientific

321

00:18:26,770 --> 00:18:23,270

probes from Earth orbit into the

322

00:18:29,620 --> 00:18:26,780

asteroid belt beyond Mars to Jupiter and

323

00:18:31,870 --> 00:18:29,630

farther a greater the distance the

324

00:18:35,770 --> 00:18:31,880

greater the advantages of electric

325

00:18:38,289 --> 00:18:35,780

propulsion looking toward the day when

326

00:18:40,570 --> 00:18:38,299

large power supplies from 20 to 40

327

00:18:43,240 --> 00:18:40,580

megawatts and large engines of proven

328

00:18:45,280 --> 00:18:43,250

reliability are available scientists

329

00:18:47,560 --> 00:18:45,290

have developed a concept for a manned

330

00:18:50,289 --> 00:18:47,570

Mars expedition with electrically

331

00:18:52,419 --> 00:18:50,299

propelled vehicles the concept suggests

332

00:18:55,180 --> 00:18:52,429

the expedition will consist of five

333

00:19:00,220 --> 00:18:55,190

spaceships which will be assembled in a

334

00:19:06,310 --> 00:19:03,649

the completed ships will each weigh 360

335

00:19:08,659 --> 00:19:06,320

tons and will carry a payload of 40 tons

336

00:19:10,490 --> 00:19:08,669

at one end of the vehicle

337

00:19:13,879 --> 00:19:10,500

there will be a 40 megawatt nuclear

338

00:19:16,879 --> 00:19:13,889

power supply next will be power

339

00:19:19,539 --> 00:19:16,889

converter equipment there also will be

340

00:19:25,190 --> 00:19:19,549

radiators to give off waste heat and

341

00:19:27,740 --> 00:19:25,200

cesium fuel tanks at the other end will

342

00:19:30,259 --> 00:19:27,750

be a three-man crew compartment there

343

00:19:32,509 --> 00:19:30,269

will be a total of 15 men to perform all

344

00:19:34,850 --> 00:19:32,519

the mission objectives three of the

345

00:19:37,310 --> 00:19:34,860

ships will carry piggyback Mars landing

346

00:19:42,619 --> 00:19:37,320

vehicles while the other two will carry

347

00:19:44,389 --> 00:19:42,629

extra fuel for the return to earth five

348

00:19:47,509 --> 00:19:44,399

vehicles will be used for safety

349

00:19:49,100 --> 00:19:47,519

purposes if one or more failed the men

350

00:19:51,169 --> 00:19:49,110

would be transferred to the other ships

351
00:19:53,869 --> 00:19:51,179
to continue the flight or return to

352
00:19:56,240 --> 00:19:53,879
Earth after checkout and placing the

353
00:19:58,700 --> 00:19:56,250
flight crew aboard the electric engines

354
00:20:00,950 --> 00:19:58,710
would spiral them continuously for 56

355
00:20:05,210 --> 00:20:00,960
days until they escape the Earth's

356
00:20:07,399 --> 00:20:05,220
gravity then they would enter a transfer

357
00:20:11,810 --> 00:20:07,409
orbit around the Sun traveling toward

358
00:20:13,369 --> 00:20:11,820
Mars the ships would take 148 days to

359
00:20:19,020 --> 00:20:13,379
make the trip to the vicinity of the

360
00:20:24,610 --> 00:20:22,270
once near Mars they would spiral into a

361
00:20:29,680 --> 00:20:24,620
low orbit this would take an additional

362
00:20:31,510 --> 00:20:29,690
21 days once in this orbit one of the

363
00:20:33,880 --> 00:20:31,520

piggyback chemical vehicles would go

364

00:20:38,980 --> 00:20:33,890

down to the surface without men to land

365

00:20:42,850 --> 00:20:38,990

equipment then one manned craft would

366

00:20:44,890 --> 00:20:42,860

land to explore the surface after 29

367

00:20:47,380 --> 00:20:44,900

days the party would board the landing

368

00:20:49,690 --> 00:20:47,390

craft and rejoin the ships then the

369

00:20:52,210 --> 00:20:49,700

landing craft would be abandoned and the

370

00:20:57,850 --> 00:20:52,220

fuel equalized between ships for the

371

00:21:00,250 --> 00:20:57,860

return trip they would reverse their

372

00:21:02,890 --> 00:21:00,260

original flight path and head back to a

373

00:21:06,280 --> 00:21:02,900

low Earth orbit this would take another

374

00:21:09,400 --> 00:21:06,290

318 days making a total of five hundred

375

00:21:12,190 --> 00:21:09,410

seventy-two days for the round-trip by

376
00:21:14,920 --> 00:21:12,200
applying thrust continuously over vast

377
00:21:23,390 --> 00:21:14,930
distances travel time will be greatly

378
00:21:28,140 --> 00:21:26,190
he will will be used so effectively that

379
00:21:30,390 --> 00:21:28,150
a much bigger weight fraction of the

380
00:21:36,720 --> 00:21:30,400
space vehicle will be devoted to useful

381
00:21:42,350 --> 00:21:36,730
payload reduce travel time to the

382
00:21:44,970 --> 00:21:42,360
distant planets larger useful payloads

383
00:21:48,150 --> 00:21:44,980
these are the goals of electric

384
00:21:49,860 --> 00:21:48,160
propulsion which will allow numerous

385
00:21:53,750 --> 00:21:49,870
missions to be carried out that would

386
00:21:57,780 --> 00:21:53,760
otherwise be impractical or impossible

387
00:22:03,480 --> 00:21:57,790
our next film is more recent from 1987

388
00:22:05,640 --> 00:22:03,490

it's also about exploring Mars Mars

389

00:22:08,250 --> 00:22:05,650

commonly referred to as the red planet

390

00:22:11,010 --> 00:22:08,260

is one of our closest neighbors beyond

391

00:22:14,370 --> 00:22:11,020

the moon it has qualities that make it a

392

00:22:16,490 --> 00:22:14,380

potentially habitable outpost before all

393

00:22:20,310 --> 00:22:16,500

Martian exploration ended in November

394

00:22:24,300 --> 00:22:20,320

1982 a handful of probes had made the

395

00:22:26,790 --> 00:22:24,310

year-long journey Viking ones orbiter

396

00:22:29,139 --> 00:22:26,800

completed nearly 1500 picture-taking

397

00:22:31,329 --> 00:22:29,149

trips around the planet

398

00:22:33,789 --> 00:22:31,339

while it's Lander studied samples and

399

00:22:36,279 --> 00:22:33,799

returned to views from the surface as a

400

00:22:38,739 --> 00:22:36,289

result Mars is well met but many

401
00:22:40,989 --> 00:22:38,749
questions remain so researchers are

402
00:22:43,810 --> 00:22:40,999
designing systems to explore the varied

403
00:22:47,349 --> 00:22:43,820
Martian geography in anticipation of a

404
00:22:49,659 --> 00:22:47,359
return mission on calm sunny mornings

405
00:22:51,519 --> 00:22:49,669
Jim Burke can often be found flying this

406
00:22:52,930 --> 00:22:51,529
lightweight solar balloon in the

407
00:22:56,440 --> 00:22:52,940
courtyard at NASA's Jet Propulsion

408
00:22:58,329 --> 00:22:56,450
Laboratory in Pasadena California mr.

409
00:23:00,459 --> 00:22:58,339
Burke views his study as an important

410
00:23:02,529 --> 00:23:00,469
stepping stone to a larger goal in

411
00:23:05,379 --> 00:23:02,539
gathering more precise information about

412
00:23:09,489 --> 00:23:05,389
the red planet NOW the Martian

413
00:23:11,709 --> 00:23:09,499

atmosphere is carbon dioxide and if you

414

00:23:14,379 --> 00:23:11,719

put a black balloon that's light enough

415

00:23:17,320 --> 00:23:14,389

with a light enough payload into that

416

00:23:19,719 --> 00:23:17,330

atmosphere the sun shining on the black

417

00:23:21,700 --> 00:23:19,729

balloon will warm it up like the heat

418

00:23:25,329 --> 00:23:21,710

inside a parked car with the windows

419

00:23:29,560 --> 00:23:25,339

shut and it gets hot enough inside to

420

00:23:32,139 --> 00:23:29,570

become a hot air balloon scientists

421

00:23:34,450 --> 00:23:32,149

students and engineers from JPL and the

422

00:23:36,430 --> 00:23:34,460

California Institute of Technology have

423

00:23:38,769 --> 00:23:36,440

taken the concept a step further by

424

00:23:41,079 --> 00:23:38,779

testing the feasibility of this 30 foot

425

00:23:44,649 --> 00:23:41,089

diameter solar balloon that might be

426
00:23:46,690 --> 00:23:44,659
used to study Mars in theory the device

427
00:23:48,759 --> 00:23:46,700
could be blown around by local Martian

428
00:23:50,979 --> 00:23:48,769
winds during the day to collect data and

429
00:23:53,649 --> 00:23:50,989
take pictures at night it would cool

430
00:23:55,539 --> 00:23:53,659
down lose buoyancy and lower itself to

431
00:23:58,930 --> 00:23:55,549
the ground to survey the planet's

432
00:24:00,459 --> 00:23:58,940
surface the small clear balloon holds

433
00:24:01,959 --> 00:24:00,469
the larger one off the ground at night

434
00:24:04,119 --> 00:24:01,969
so it won't get damaged

435
00:24:06,010 --> 00:24:04,129
there are many regions of Mars that

436
00:24:09,450 --> 00:24:06,020
could be explored this way

437
00:24:13,180 --> 00:24:09,460
to Gymboree one very interesting

438
00:24:15,610 --> 00:24:13,190

possibility is to put the balloon in the

439

00:24:17,800 --> 00:24:15,620

atmosphere get it inflated operating up

440

00:24:21,550 --> 00:24:17,810

in the polar regions and let the

441

00:24:25,180 --> 00:24:21,560

circumpolar winds drift it down across

442

00:24:27,520 --> 00:24:25,190

the polar cap over the layered terrain

443

00:24:29,620 --> 00:24:27,530

which is in the canyons that spiral out

444

00:24:33,370 --> 00:24:29,630

from the polar cap then across the

445

00:24:35,770 --> 00:24:33,380

immense dune fields that surround the

446

00:24:38,860 --> 00:24:35,780

polar caps and on downward into

447

00:24:41,320 --> 00:24:38,870

temperate latitudes on Mars to remotely

448

00:24:43,480 --> 00:24:41,330

explore the surface of Mars a number of

449

00:24:46,060 --> 00:24:43,490

devices have been investigated they

450

00:24:48,490 --> 00:24:46,070

include early roving vehicle prototypes

451

00:24:51,730 --> 00:24:48,500

designed to crawl or wheel their way

452

00:24:53,980 --> 00:24:51,740

across alien terrain Rovers continue to

453

00:24:58,090 --> 00:24:53,990

be designed today based on some of these

454

00:25:00,400 --> 00:24:58,100

models University of Arizona's lunar and

455

00:25:02,170 --> 00:25:00,410

planetary labs graduate students and

456

00:25:05,260 --> 00:25:02,180

faculty have recently built this

457

00:25:06,060 --> 00:25:05,270

gigantic two-wheeled prototype Mars

458

00:25:08,470 --> 00:25:06,070

rover

459

00:25:10,840 --> 00:25:08,480

another vehicle being developed as this

460

00:25:13,450 --> 00:25:10,850

robotic six wheeled version which is

461

00:25:15,610 --> 00:25:13,460

JPL's latest testbed for understanding

462

00:25:18,010 --> 00:25:15,620

the control and vision systems needed

463

00:25:19,870 --> 00:25:18,020

for a Mars mission according to Brian

464

00:25:22,690 --> 00:25:19,880

Wilcox of the robotics and tella

465

00:25:24,610 --> 00:25:22,700

operators Research Group at JPL sending

466

00:25:27,070 --> 00:25:24,620

commands to a rover on Mars would be

467

00:25:29,500 --> 00:25:27,080

difficult because of the 10 to 40 minute

468

00:25:31,660 --> 00:25:29,510

round-trip delay you can't just sit

469

00:25:34,090 --> 00:25:31,670

there and steer in your armchair from a

470

00:25:36,190 --> 00:25:34,100

TV monitor and make the vehicle do

471

00:25:37,750 --> 00:25:36,200

useful things because of this long speed

472

00:25:40,870 --> 00:25:37,760

of light delay so we've identified

473

00:25:43,720 --> 00:25:40,880

several techniques to maneuver a vehicle

474

00:25:46,690 --> 00:25:43,730

on Mars in such a way that you can go

475

00:25:49,270 --> 00:25:46,700

useful distances in a day in spite of

476

00:25:51,490 --> 00:25:49,280

the fact that the humans are this long

477

00:26:09,550 --> 00:25:51,500

speed of light delay remove from the

478

00:26:14,930 --> 00:26:12,830

the rugged vehicle has two TV cameras

479

00:26:17,600 --> 00:26:14,940

for eyes and is capable of climbing

480

00:26:19,880 --> 00:26:17,610

objects 1/3 taller than its wheel height

481

00:26:22,310 --> 00:26:19,890

the proposed mission vehicle would have

482

00:26:30,430 --> 00:26:22,320

robotic arms to make measurements and

483

00:26:35,749 --> 00:26:33,289

using Rovers onboard vision system

484

00:26:37,580 --> 00:26:35,759

scientists can freeze three-dimensional

485

00:26:40,190 --> 00:26:37,590

images from its pair of television

486

00:26:42,499 --> 00:26:40,200

cameras they can then designate the

487

00:26:44,629 --> 00:26:42,509

pathway to follow continually updating

488

00:26:48,070 --> 00:26:44,639

commands from Earth so that the rover is

489

00:26:50,810 --> 00:26:48,080

able to avoid obstacles and hazards as

490

00:26:52,430 --> 00:26:50,820

more sophisticated visual systems are

491

00:26:54,560 --> 00:26:52,440

developed greater artificial

492

00:26:57,200 --> 00:26:54,570

intelligence can help the rover find its

493

00:26:59,539 --> 00:26:57,210

own way if given high-resolution imagery

494

00:27:01,700 --> 00:26:59,549

of the Martian surface and a list of

495

00:27:05,060 --> 00:27:01,710

targeted regions designated by

496

00:27:06,950 --> 00:27:05,070

earthbound scientists the hope is to

497

00:27:09,409 --> 00:27:06,960

someday send a manned mission to Mars

498

00:27:11,840 --> 00:27:09,419

but a more detailed study of the planet

499

00:27:14,269 --> 00:27:11,850

is necessary first and these pioneering

500

00:27:17,330 --> 00:27:14,279

steps can be made by roving vehicles and

501
00:27:20,299 --> 00:27:17,340
balloons again Brian Wilcox if you

502
00:27:22,629 --> 00:27:20,309
imagine an expedition Lewis and Clark

503
00:27:25,609 --> 00:27:22,639
trying to survey the Louisiana Purchase

504
00:27:27,289 --> 00:27:25,619
they've basically made one track across

505
00:27:30,379 --> 00:27:27,299
a very small fraction of the land

506
00:27:33,680 --> 00:27:30,389
surface of the earth took them years to

507
00:27:35,299 --> 00:27:33,690
do it and yet they found incredible

508
00:27:38,090 --> 00:27:35,309
things all along the way we could

509
00:27:41,930 --> 00:27:38,100
certainly have a dozen Rover missions

510
00:27:45,919 --> 00:27:41,940
which yielded equally interesting

511
00:27:48,950 --> 00:27:45,929
results the exploration of Mars sending

512
00:27:51,800 --> 00:27:48,960
unmanned vehicles as pathfinders for the

513
00:27:57,420 --> 00:27:54,270

that's all we have for this edition of

514

00:27:59,640 --> 00:27:57,430

NASA images but before we go let me

515

00:28:02,190 --> 00:27:59,650

remind you that you're cordially invited

516

00:28:04,380 --> 00:28:02,200

to see the displays here at the Visitor

517

00:28:07,080 --> 00:28:04,390

Center at the NASA Lewis Research Center

518

00:28:09,660 --> 00:28:07,090

we're located near Hopkins International