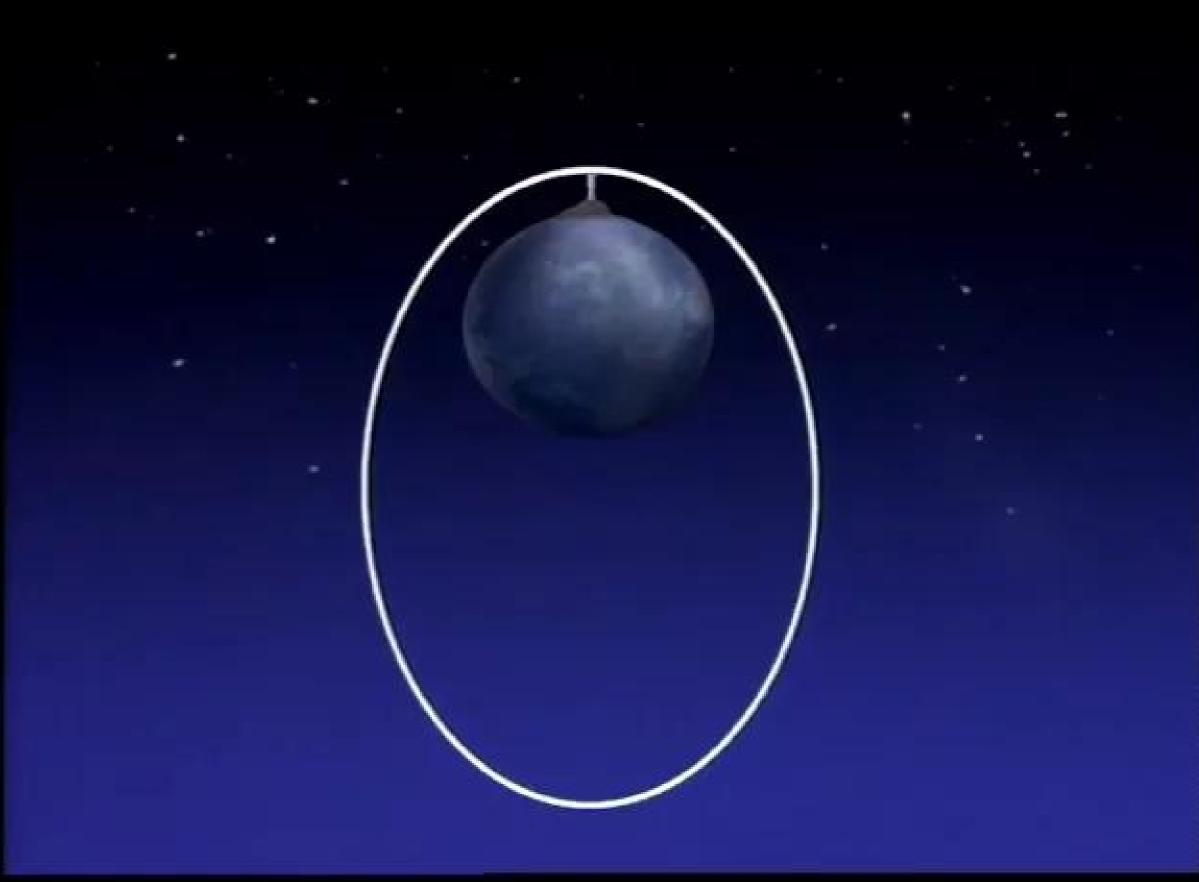

1
00:00:37,209 --> 00:00:35,110
when ancient man looked to the heavens

2
00:00:40,270 --> 00:00:37,219
for guidance from the gods

3
00:00:42,100 --> 00:00:40,280
he noticed star patterns and began to

4
00:00:44,950 --> 00:00:42,110
document their movement across the

5
00:00:48,340 --> 00:00:44,960
heavens the ancients believed that the

6
00:00:50,410 --> 00:00:48,350
earth was flat but around 350 BC

7
00:00:56,500 --> 00:00:50,420
Aristotle proved that the earth was

8
00:00:59,049 --> 00:00:56,510
round later about 150 AD Ptolemy

9
00:01:01,060 --> 00:00:59,059
presented the geocentric theory the

10
00:01:03,460 --> 00:01:01,070
belief that the earth is stationary at

11
00:01:06,550 --> 00:01:03,470
the center of the universe with the Sun

12
00:01:12,910 --> 00:01:06,560
Moon stars and planets revolving around

13
00:01:15,640 --> 00:01:12,920

it in complex orbits in the 1500s

14
00:01:18,160 --> 00:01:15,650
Nicholas Copernicus of Poland presented

15
00:01:21,100 --> 00:01:18,170
the heliocentric theory the belief that

16
00:01:24,460 --> 00:01:21,110
the Earth revolves around the Sun as it

17
00:01:26,649 --> 00:01:24,470
rotates on its axis this aspect of

18
00:01:29,350 --> 00:01:26,659
astronomy evolved into an intricate

19
00:01:33,760 --> 00:01:29,360
study of planetary motion known as

20
00:01:39,219 --> 00:01:36,789
today orbital mechanics is applied to

21
00:01:41,740 --> 00:01:39,229
spaceflight and satellites that orbit

22
00:02:05,260 --> 00:01:41,750
the Earth or travel beyond our solar

23
00:02:12,860 --> 00:02:10,130
in the early 1600s Johann Kepler a

24
00:02:15,170 --> 00:02:12,870
German mathematician using the data on

25
00:02:17,570 --> 00:02:15,180
planetary observations collected by the

26
00:02:22,040 --> 00:02:17,580
Danish scientist Tycho Brahe he

27
00:02:25,850 --> 00:02:22,050
developed three laws of planetary motion

28
00:02:28,820 --> 00:02:25,860
Kepler's first law states all planets

29
00:02:36,100 --> 00:02:28,830
move in ellipses or 'but there's a Sun

30
00:02:42,500 --> 00:02:39,290
applied to earth satellites the center

31
00:02:48,050 --> 00:02:42,510
of the earth becomes one focus with the

32
00:02:57,050 --> 00:02:48,060
other focus empty for circular orbits

33
00:03:00,440 --> 00:02:57,060
the two foci coincide Kepler's second

34
00:03:03,440 --> 00:03:00,450
law the law of areas states the line

35
00:03:08,160 --> 00:03:03,450
joining the planet to the Sun sweeps

36
00:03:11,490 --> 00:03:08,170
over equal areas in equal time intervals

37
00:03:14,460 --> 00:03:11,500
when a satellite orbits the line joining

38
00:03:18,510 --> 00:03:14,470

it to the earth sweeps over equal areas

39
00:03:22,260 --> 00:03:18,520
in equal periods of time if areas one

40
00:03:25,920 --> 00:03:22,270
two and three are equal times 1 2 & 3

41
00:03:28,260 --> 00:03:25,930
are also equal therefore the speed of

42
00:03:34,280 --> 00:03:28,270
the satellite changes depending on its

43
00:03:39,750 --> 00:03:37,530
speed is greatest at the point in the

44
00:03:42,990 --> 00:03:39,760
orbit closest to the earth called

45
00:03:51,610 --> 00:03:43,000
perigee and is slowest at the point

46
00:03:57,470 --> 00:03:54,920
it is important to note that the orbit

47
00:04:01,520 --> 00:03:57,480
followed by a satellite is not dependent

48
00:04:04,010 --> 00:04:01,530
on its mass a large heavy satellite

49
00:04:07,310 --> 00:04:04,020
could be in the same orbit with a small

50
00:04:12,050 --> 00:04:07,320
light one each sweeping out equal areas

51
00:04:15,230 --> 00:04:12,060
in equal periods of time Kepler's third

52
00:04:17,300 --> 00:04:15,240
law the law of periods relates the time

53
00:04:20,120 --> 00:04:17,310
required for a planet to make one

54
00:04:24,050 --> 00:04:20,130
complete trip around the Sun to its mean

55
00:04:26,720 --> 00:04:24,060
distance from the Sun for any planet the

56
00:04:29,750 --> 00:04:26,730
square of its period of revolution is

57
00:04:37,430 --> 00:04:29,760
directly proportional to the cube of its

58
00:04:39,410 --> 00:04:37,440
mean distance from the Sun applied to

59
00:04:42,560 --> 00:04:39,420
earth satellites Kepler's third law

60
00:04:44,660 --> 00:04:42,570
explains that the farther a satellite is

61
00:04:47,330 --> 00:04:44,670
from the earth the longer it will take

62
00:04:49,340 --> 00:04:47,340
to complete an orbit the greater the

63
00:04:52,040 --> 00:04:49,350

distance it will travel to complete an

64
00:04:59,409 --> 00:04:52,050
orbit and the slower its average speed

65
00:05:04,129 --> 00:05:02,299
Isaac Newton the father of classical

66
00:05:07,159 --> 00:05:04,139
mechanics laid the groundwork for

67
00:05:09,379 --> 00:05:07,169
orbital mechanics he combined the work

68
00:05:12,529 --> 00:05:09,389
of Kepler and others to formulate the

69
00:05:20,059 --> 00:05:12,539
law of universal gravitation and the

70
00:05:22,369 --> 00:05:20,069
three Newtonian laws of motion while

71
00:05:25,219 --> 00:05:22,379
Kepler's laws provided a conceptual

72
00:05:27,109 --> 00:05:25,229
model of orbital motion Newton's laws

73
00:05:29,929 --> 00:05:27,119
provided the foundation for the

74
00:05:37,359 --> 00:05:29,939
mathematical description of orbits they

75
00:05:43,519 --> 00:05:40,329
Newton's law of universal gravitation

76
00:05:45,949 --> 00:05:43,529
any two objects in the universe such as

77
00:05:48,379 --> 00:05:45,959
the earth and the moon attract each

78
00:05:50,359 --> 00:05:48,389
other with a force directly proportional

79
00:05:53,149 --> 00:05:50,369
to the product of their masses and

80
00:05:57,529 --> 00:05:53,159
inversely proportional to the square of

81
00:06:00,290 --> 00:05:57,539
the distance between them stated more

82
00:06:03,169 --> 00:06:00,300
simply the more massive the objects are

83
00:06:08,479 --> 00:06:03,179
or the closer they are the greater the

84
00:06:12,049 --> 00:06:08,489
gravitational pull between them Newton's

85
00:06:14,449 --> 00:06:12,059
first law of motion a body in motion

86
00:06:16,699 --> 00:06:14,459
will keep moving in the same speed and

87
00:06:21,330 --> 00:06:16,709
in the same direction and let's exit

88
00:06:27,290 --> 00:06:24,660

a satellite moves in a curved path

89
00:06:28,950 --> 00:06:27,300
around the earth because the Earth's

90
00:06:38,270 --> 00:06:28,960
gravitational pull

91
00:06:44,870 --> 00:06:42,230
Newton's second law of motion if the sum

92
00:06:47,330 --> 00:06:44,880
of the forces acting on an object is not

93
00:06:49,490 --> 00:06:47,340
zero the object will have an

94
00:06:52,070 --> 00:06:49,500
acceleration proportional to the

95
00:06:55,670 --> 00:06:52,080
magnitude and in the direction of the

96
00:06:58,129 --> 00:06:55,680
net force newton's second law states

97
00:07:01,370 --> 00:06:58,139
that force equals mass times

98
00:07:04,040 --> 00:07:01,380
acceleration it is this mathematical

99
00:07:06,620 --> 00:07:04,050
equation and the equation for universal

100
00:07:12,740 --> 00:07:06,630
gravitation that forms the basis for

101
00:07:15,710 --> 00:07:12,750
calculating orbits Newton's third law of

102
00:07:19,430 --> 00:07:15,720
motion explains how a satellite gets

103
00:07:22,490 --> 00:07:19,440
into orbit for every action there is an

104
00:07:25,850 --> 00:07:22,500
equal and opposite reaction

105
00:07:28,010 --> 00:07:25,860
if you blow up a balloon and let it go

106
00:07:31,780 --> 00:07:28,020
the balloon is pushed forward by the

107
00:07:34,850 --> 00:07:31,790
action of the air rushing out of it a

108
00:07:40,969 --> 00:07:34,860
Rockets exhaust gases are like the air

109
00:07:43,219 --> 00:07:40,979
rushing out of the balloon the following

110
00:07:48,230 --> 00:07:43,229
illustrates how a satellite stays in

111
00:07:51,830 --> 00:07:48,240
orbit if a man stands on a mountain and

112
00:07:53,900 --> 00:07:51,840
fires a projectile horizontally gravity

113
00:07:56,060 --> 00:07:53,910

will cause the path of the projectile to

114
00:08:00,100 --> 00:07:56,070
curve downward and it will strike the

115
00:08:06,219 --> 00:08:03,129
however if the man fires the projectile

116
00:08:08,350 --> 00:08:06,229
fast enough at a specific speed the

117
00:08:10,089 --> 00:08:08,360
curvature of its path due to gravity

118
00:08:13,570 --> 00:08:10,099
will match the curvature of the earth

119
00:08:15,820 --> 00:08:13,580
under it the projectile will then fall

120
00:08:19,360 --> 00:08:15,830
around the earth becoming an earth

121
00:08:21,879 --> 00:08:19,370
orbiting satellite a projectile fired

122
00:08:24,429 --> 00:08:21,889
even faster will have a flight path away

123
00:08:26,770 --> 00:08:24,439
from the earth but gravity will act to

124
00:08:29,320 --> 00:08:26,780
slow the projectile down change its

125
00:08:34,000 --> 00:08:29,330
flight path and pull it back toward

126
00:08:36,880 --> 00:08:34,010
Earth if the projectiles velocity

127
00:08:39,130 --> 00:08:36,890
increased enough a velocity sufficient

128
00:08:43,089 --> 00:08:39,140
to escape the Earth's gravitational pull

129
00:08:46,060 --> 00:08:43,099
will be reached this velocity is known

130
00:08:48,460 --> 00:08:46,070
as the escape velocity it is equal to

131
00:08:51,370 --> 00:08:48,470
about seven miles per second at the

132
00:08:53,710 --> 00:08:51,380
Earth's surface the preceding

133
00:08:56,560 --> 00:08:53,720
description did not consider atmospheric

134
00:08:58,509 --> 00:08:56,570
drag and the Earth's rotation both of

135
00:09:01,210 --> 00:08:58,519
which will affect the trajectory of the

136
00:09:07,139 --> 00:09:01,220
projectile it Illustrated the principles

137
00:09:13,509 --> 00:09:10,420
there are six numbers called the orbital

138
00:09:16,930 --> 00:09:13,519

elements which specify the size shape

139
00:09:19,090 --> 00:09:16,940
and orientation of an orbit in space as

140
00:09:22,900 --> 00:09:19,100
well as the location of the spacecraft

141
00:09:27,000 --> 00:09:22,910
in the orbit based on an orbit which is

142
00:09:31,710 --> 00:09:27,010
an ellipse the six orbital elements are

143
00:09:43,780 --> 00:09:39,250
eccentricity inclination right ascension

144
00:09:50,019 --> 00:09:43,790
of the ascending node argument of

145
00:09:52,600 --> 00:09:50,029
perigee time of perigee passage the

146
00:09:57,220 --> 00:09:52,610
major axis of an elliptical orbit is the

147
00:09:59,980 --> 00:09:57,230
line joining the perigee and Apogee this

148
00:10:05,380 --> 00:09:59,990
line is also referred to as the line of

149
00:10:08,290 --> 00:10:05,390
APSA DS the first orbital element is the

150
00:10:12,100 --> 00:10:08,300
semi-major axis it is simply one-half

151
00:10:14,500 --> 00:10:12,110
the major axis circular orbits have no

152
00:10:17,380 --> 00:10:14,510
Apogee or perigee therefore the

153
00:10:21,310 --> 00:10:17,390
semi-major axis is simply 1/2 the

154
00:10:24,069 --> 00:10:21,320
diameter of the orbit the semi-major

155
00:10:27,250 --> 00:10:24,079
axis is used to define the size of the

156
00:10:29,380 --> 00:10:27,260
orbit from this the orbital period or

157
00:10:34,890 --> 00:10:29,390
time that it takes for the satellite to

158
00:10:39,910 --> 00:10:38,140
the shape of an orbit is defined by the

159
00:10:44,830 --> 00:10:39,920
second orbital element called

160
00:10:47,080 --> 00:10:44,840
eccentricity for all ellipses the value

161
00:10:49,630 --> 00:10:47,090
of eccentricity lies between zero and

162
00:10:53,020 --> 00:10:49,640
one the larger the value the more

163
00:10:55,330 --> 00:10:53,030

elliptical the orbit a spacecraft in

164
00:10:58,390 --> 00:10:55,340
Earth orbit with an eccentricity equal

165
00:11:04,420 --> 00:10:58,400
to or greater than one will escape the

166
00:11:06,910 --> 00:11:04,430
Earth's gravitational field when

167
00:11:09,100 --> 00:11:06,920
orienting an orbit in space a three

168
00:11:12,670 --> 00:11:09,110
dimensional coordinate system must be

169
00:11:15,490 --> 00:11:12,680
defined the coordinate system commonly

170
00:11:18,070 --> 00:11:15,500
used is the geocentric equatorial

171
00:11:20,710 --> 00:11:18,080
coordinate system which has its origin

172
00:11:23,440 --> 00:11:20,720
at the Earth's center

173
00:11:26,200 --> 00:11:23,450
this coordinate system is a non-rotating

174
00:11:29,020 --> 00:11:26,210
reference system in which a satellites

175
00:11:31,390 --> 00:11:29,030
orbital plane tends to remain fixed

176
00:11:36,220 --> 00:11:31,400
relative to the stars while the Earth

177
00:11:38,860 --> 00:11:36,230
turns beneath it the XY plane is the

178
00:11:43,540 --> 00:11:38,870
Earth's equatorial plane the positive

179
00:11:45,370 --> 00:11:43,550
x-axis points to the vernal equinox this

180
00:11:47,560 --> 00:11:45,380
is the point where the Sun appears to

181
00:11:49,900 --> 00:11:47,570
cross the earth's equator on its way

182
00:11:54,160 --> 00:11:49,910
north on the first day of spring each

183
00:12:00,040 --> 00:11:54,170
year the z axis is along the Earth's

184
00:12:02,500 --> 00:12:00,050
spin axis toward the North Pole nodes

185
00:12:05,730 --> 00:12:02,510
are points in a satellites orbit which

186
00:12:08,860 --> 00:12:05,740
intersect the Earth's equatorial plane

187
00:12:11,740 --> 00:12:08,870
the ascending node is the point at which

188
00:12:15,970 --> 00:12:11,750

the spacecraft crosses the equator going

189
00:12:18,070 --> 00:12:15,980
from south to north the descending node

190
00:12:22,180 --> 00:12:18,080
is where the spacecraft crosses the

191
00:12:24,430 --> 00:12:22,190
equator going from north to south the

192
00:12:28,780 --> 00:12:24,440
line joining the two nodes is called the

193
00:12:31,240 --> 00:12:28,790
line of nodes the orientation of an

194
00:12:35,920 --> 00:12:31,250
orbit is determined by three orbital

195
00:12:38,110 --> 00:12:35,930
element angles the right ascension of

196
00:12:41,260 --> 00:12:38,120
the ascending node is the angle between

197
00:12:43,660 --> 00:12:41,270
the x-axis and the ascending node it is

198
00:12:45,820 --> 00:12:43,670
always measured eastward from the

199
00:12:52,850 --> 00:12:45,830
direction away from the vernal equinox

200
00:12:58,100 --> 00:12:55,880
the argument of perigee is the angle

201
00:13:00,950 --> 00:12:58,110
between the ascending node and the point

202
00:13:02,930 --> 00:13:00,960
of perigee it is measured in the orbital

203
00:13:07,970 --> 00:13:02,940
plane in the direction of spacecraft

204
00:13:10,640 --> 00:13:07,980
motion inclination is the angle between

205
00:13:15,470 --> 00:13:10,650
the equatorial plane and the orbital

206
00:13:18,020 --> 00:13:15,480
plane a satellite which has an eastward

207
00:13:20,900 --> 00:13:18,030
velocity component at the ascending node

208
00:13:24,620 --> 00:13:20,910
as an orbital inclination lying between

209
00:13:32,140 --> 00:13:24,630
0 and 90 degrees such an orbit is called

210
00:13:38,290 --> 00:13:34,990
a satellite which moves due north at the

211
00:13:40,510 --> 00:13:38,300
ascending node is in a polar orbit polar

212
00:13:45,250 --> 00:13:40,520
orbits have an orbital inclination of

213
00:13:47,290 --> 00:13:45,260

exactly 90 degrees a satellite with a

214
00:13:49,930 --> 00:13:47,300
westward velocity component at the

215
00:13:52,060 --> 00:13:49,940
ascending node is in a retrograde orbit

216
00:13:55,670 --> 00:13:52,070
and has an orbital inclination between

217
00:13:58,730 --> 00:13:55,680
90 and 180 degrees

218
00:14:01,400 --> 00:13:58,740
the five orbital elements explained thus

219
00:14:04,730 --> 00:14:01,410
far described the size shape and

220
00:14:07,189 --> 00:14:04,740
orientation of the orbit in space the

221
00:14:09,730 --> 00:14:07,199
final element is a time value used to

222
00:14:12,739 --> 00:14:09,740
locate the satellite in its orbit a

223
00:14:13,280 --> 00:14:12,749
satellite moves in a very predictable

224
00:14:16,249 --> 00:14:13,290
manner

225
00:14:18,350 --> 00:14:16,259
it stays on schedule thus if the time at

226
00:14:20,660 --> 00:14:18,360
which a satellite passes a particular

227
00:14:23,679 --> 00:14:20,670
point is known the time when it will

228
00:14:26,989 --> 00:14:23,689
pass any other point can be determined

229
00:14:29,540 --> 00:14:26,999
the particular point chosen is perigee

230
00:14:35,720 --> 00:14:29,550
and the time of perigee passage is the

231
00:14:38,150 --> 00:14:35,730
last of the six orbital elements the six

232
00:14:41,869 --> 00:14:38,160
orbital elements depict a spacecrafts

233
00:14:43,999 --> 00:14:41,879
orbit in non rotating coordinates to

234
00:14:46,759 --> 00:14:44,009
visualize an orbit relative to the

235
00:14:48,769 --> 00:14:46,769
rotating earth a projection traces the

236
00:14:53,090 --> 00:14:48,779
spacecraft's position on the Earth's

237
00:14:58,220 --> 00:14:53,100
surface the projected path is called the

238
00:15:00,970 --> 00:14:58,230

ground track as a satellite orbits the

239
00:15:04,669 --> 00:15:00,980
earth the ground track shifts westward

240
00:15:06,439 --> 00:15:04,679
there are two causes for this first the

241
00:15:09,110 --> 00:15:06,449
primary contributor is the Earth's

242
00:15:12,679 --> 00:15:09,120
rotation toward the east under the

243
00:15:15,199 --> 00:15:12,689
orbital plane second because the earth

244
00:15:18,049 --> 00:15:15,209
is not a uniform sphere and bulges at

245
00:15:18,889 --> 00:15:18,059
the equator its gravity is greatest at

246
00:15:21,889 --> 00:15:18,899
the equator

247
00:15:24,769 --> 00:15:21,899
this causes the orbital plane to rotate

248
00:15:29,840 --> 00:15:24,779
slowly around the Earth's polar axis in

249
00:15:32,090 --> 00:15:29,850
a motion called precession precession is

250
00:15:34,009 --> 00:15:32,100
toward the west where pro-grade orbits

251
00:15:36,009 --> 00:15:34,019
and toward the east for retrograde

252
00:15:41,420 --> 00:15:36,019
orbits

253
00:15:44,119 --> 00:15:41,430
the space shuttle at 150 miles altitude

254
00:15:47,240 --> 00:15:44,129
the westward shift of the ground track

255
00:15:49,639 --> 00:15:47,250
due to the Earth's rotation is about 22

256
00:15:51,889 --> 00:15:49,649
and a half degrees while the shift due

257
00:15:57,290 --> 00:15:51,899
to precession is only about a half

258
00:15:59,449 --> 00:15:57,300
degree the inclination of a satellite

259
00:16:03,410 --> 00:15:59,459
orbit determines the north and south

260
00:16:06,110 --> 00:16:03,420
latitude limits of its ground track the

261
00:16:08,569 --> 00:16:06,120
minimum orbital inclination is equal to

262
00:16:13,189 --> 00:16:08,579
the latitude of the launch site and is

263
00:16:15,679 --> 00:16:13,199

achieved by launching due east for

264
00:16:17,360 --> 00:16:15,689
example if a satellite is launched due

265
00:16:20,030 --> 00:16:17,370
east out of the Kennedy Space Center

266
00:16:22,910 --> 00:16:20,040
which is located at 28 and a half

267
00:16:25,160 --> 00:16:22,920
degrees north latitude its orbital

268
00:16:28,100 --> 00:16:25,170
inclination will be 28 and 1/2 degrees

269
00:16:30,679 --> 00:16:28,110
and the limits of its ground track will

270
00:16:33,650 --> 00:16:30,689
vary between 28 and 1/2 degrees north

271
00:16:37,819 --> 00:16:33,660
latitude and 28 and 1/2 degrees south

272
00:16:40,069 --> 00:16:37,829
latitude if launch azimuth or direction

273
00:16:43,009 --> 00:16:40,079
of flight at launch measured eastward

274
00:16:43,639 --> 00:16:43,019
from due north is increased from due

275
00:16:46,490 --> 00:16:43,649
east

276
00:16:49,069 --> 00:16:46,500
the orbital inclination angle increases

277
00:16:53,600 --> 00:16:49,079
as well as the maximum latitude of the

278
00:16:55,579 --> 00:16:53,610
north-south ground track therefore the

279
00:16:59,199 --> 00:16:55,589
latitude limits of the ground track

280
00:17:01,850 --> 00:16:59,209
equal the new launch inclination

281
00:17:04,549 --> 00:17:01,860
similarly if launched azimuth is

282
00:17:07,789 --> 00:17:04,559
decreased from due east orbital

283
00:17:09,740 --> 00:17:07,799
inclination once again increases as well

284
00:17:12,299 --> 00:17:09,750
as the latitude limits of the ground

285
00:17:18,039 --> 00:17:15,490
the maximum practical inclination from a

286
00:17:21,189 --> 00:17:18,049
Kennedy Space Center launch is 57

287
00:17:23,379 --> 00:17:21,199
degrees this limit is imposed for safety

288
00:17:25,870 --> 00:17:23,389

considerations in order to keep the

289
00:17:27,970 --> 00:17:25,880
spacecraft and its booster system from

290
00:17:32,560 --> 00:17:27,980
flying over land masses during the

291
00:17:35,590 --> 00:17:32,570
ascent phase to obtain an orbit with an

292
00:17:37,180 --> 00:17:35,600
inclination greater than 57 degrees the

293
00:17:40,049 --> 00:17:37,190
spacecraft is launched from Vandenberg

294
00:17:42,490 --> 00:17:40,059
Air Force Base in California

295
00:17:44,560 --> 00:17:42,500
Vandenberg offers the opportunity for

296
00:17:47,230 --> 00:17:44,570
southerly launches with orbit

297
00:17:50,049 --> 00:17:47,240
inclinations between approximately 70

298
00:17:54,129 --> 00:17:50,059
degrees pro-grade through 138 degrees

299
00:17:56,019 --> 00:17:54,139
retrograde a significant advantage of

300
00:17:58,629 --> 00:17:56,029
launching from Vandenberg is the

301
00:18:01,119 --> 00:17:58,639
capability to economically achieve polar

302
00:18:03,460 --> 00:18:01,129
orbits with ground tracks covering all

303
00:18:07,119 --> 00:18:03,470
latitudes from the North Pole to the

304
00:18:09,730 --> 00:18:07,129
South Pole the earth is constantly

305
00:18:11,769 --> 00:18:09,740
turning and all points on its surface

306
00:18:13,779 --> 00:18:11,779
have an eastward velocity with the

307
00:18:17,289 --> 00:18:13,789
greatest velocity occurring at the

308
00:18:20,169 --> 00:18:17,299
equator the farther the launch site is

309
00:18:22,389 --> 00:18:20,179
from the equator or as launch azimuth is

310
00:18:25,149 --> 00:18:22,399
increased or decreased from due east

311
00:18:27,749 --> 00:18:25,159
less of the Earth's rotational velocity

312
00:18:30,730 --> 00:18:27,759
will be imparted to the launch vehicle

313
00:18:33,100 --> 00:18:30,740

this requires more fuel to get into

314
00:18:37,869 --> 00:18:33,110
orbit or payload weight will have to be

315
00:18:40,330 --> 00:18:37,879
decreased launches due east from a

316
00:18:42,249 --> 00:18:40,340
position on or near the equator such as

317
00:18:45,100 --> 00:18:42,259
the kuru launch site in French Guiana

318
00:18:47,980 --> 00:18:45,110
used by the European Space Agency

319
00:18:52,150 --> 00:18:47,990
acquire the advantage of a free velocity

320
00:18:55,640 --> 00:18:52,160
gain of about 1500 feet per second

321
00:18:58,070 --> 00:18:55,650
this compares to the approximate 1,300

322
00:19:00,170 --> 00:18:58,080
feet per second gain available at the

323
00:19:05,450 --> 00:19:00,180
further north latitude of the Kennedy

324
00:19:08,120 --> 00:19:05,460
Space Center launching from an

325
00:19:10,370 --> 00:19:08,130
equatorial site offers a significant

326
00:19:12,650 --> 00:19:10,380
advantage in payload weight capability

327
00:19:17,750 --> 00:19:12,660
and minimizes the amount of fuel needed

328
00:19:20,240 --> 00:19:17,760
to achieve an equatorial orbit since

329
00:19:22,220 --> 00:19:20,250
many satellites operate in equatorial

330
00:19:29,780 --> 00:19:22,230
orbits these are important

331
00:19:32,000 --> 00:19:29,790
considerations spacecraft are launched

332
00:19:35,180 --> 00:19:32,010
within a specified time interval called

333
00:19:37,790 --> 00:19:35,190
the launch window some of the factors

334
00:19:43,990 --> 00:19:37,800
affecting the launch window are launched

335
00:19:49,010 --> 00:19:44,000
in orbit lighting conditions Sun angles

336
00:19:51,820 --> 00:19:49,020
payload orbit requirements rendezvous

337
00:19:54,500 --> 00:19:51,830
phasing if a rendezvous is planned

338
00:19:58,220 --> 00:19:54,510

tracking and communication requirements

339
00:20:01,420 --> 00:19:58,230
and collision avoidance with other

340
00:20:03,700 --> 00:20:01,430
orbiting objects to name a few

341
00:20:06,190 --> 00:20:03,710
one of the factors defining the launch

342
00:20:08,050 --> 00:20:06,200
window for the Space Shuttle is launched

343
00:20:10,810 --> 00:20:08,060
lighting conditions which can be

344
00:20:16,420 --> 00:20:10,820
illustrated by plotting time versus day

345
00:20:17,950 --> 00:20:16,430
of year on this plot we see daylight and

346
00:20:20,290 --> 00:20:17,960
darkness at the launch site

347
00:20:24,780 --> 00:20:20,300
the longer daylight hours occur in the

348
00:20:30,340 --> 00:20:27,940
if daylight conditions are required for

349
00:20:32,200 --> 00:20:30,350
a convenient emergency landing site for

350
00:20:36,790 --> 00:20:32,210
the space shuttle the launch window

351
00:20:37,600 --> 00:20:36,800
would now look like this during the

352
00:20:39,430 --> 00:20:37,610
winter months

353
00:20:41,920 --> 00:20:39,440
the available launch window for lighting

354
00:20:44,620 --> 00:20:41,930
conditions alone can be as little as

355
00:20:47,080 --> 00:20:44,630
three hours per day when combined with

356
00:20:52,690 --> 00:20:47,090
the many other launch factors the launch

357
00:20:54,760 --> 00:20:52,700
window becomes even more constrained the

358
00:20:56,560 --> 00:20:54,770
choice of a particular launch vehicle

359
00:20:59,380 --> 00:20:56,570
for a mission depends upon the weight

360
00:21:04,270 --> 00:20:59,390
and size of the payload and the desired

361
00:21:06,880 --> 00:21:04,280
orbit expendable rockets used to place

362
00:21:09,520 --> 00:21:06,890
spacecraft in orbit usually consist of

363
00:21:11,410 --> 00:21:09,530

several stages that may incorporate both

364
00:21:14,260 --> 00:21:11,420
solid and liquid propellants for

365
00:21:16,450 --> 00:21:14,270
propulsion when the fuel in each stage

366
00:21:22,360 --> 00:21:16,460
is depleted the spent stage is

367
00:21:24,549 --> 00:21:22,370
jettisoned staging offers the advantage

368
00:21:28,630 --> 00:21:24,559
of discarding weight when it is no

369
00:21:31,810 --> 00:21:28,640
longer needed the Space Shuttle is a

370
00:21:34,150 --> 00:21:31,820
two-stage system at liftoff the two

371
00:21:36,850 --> 00:21:34,160
solid rocket boosters and three Space

372
00:21:40,570 --> 00:21:36,860
Shuttle main engines are all producing

373
00:21:44,650 --> 00:21:40,580
thrust after approximately two minutes

374
00:21:46,750 --> 00:21:44,660
of flight at an altitude of 25 miles the

375
00:21:49,230 --> 00:21:46,760
fuel and the solid rocket boosters is

376
00:21:52,120 --> 00:21:49,240
depleted and they are jettisoned the

377
00:21:54,460 --> 00:21:52,130
three main engines fueled by liquid

378
00:21:57,220 --> 00:21:54,470
oxygen and liquid hydrogen carried in

379
00:21:58,720 --> 00:21:57,230
the external tank continue to burn for

380
00:22:01,570 --> 00:21:58,730
several minutes until the shuttle

381
00:22:04,180 --> 00:22:01,580
reaches its cutoff velocity at this time

382
00:22:08,470 --> 00:22:04,190
the main engines are shut down and the

383
00:22:10,840 --> 00:22:08,480
external tank is jettisoned to

384
00:22:13,240 --> 00:22:10,850
additional burns using the orbiters

385
00:22:16,240 --> 00:22:13,250
maneuvering system referred to as ohm's

386
00:22:19,419 --> 00:22:16,250
are required to place the orbiter in its

387
00:22:21,640 --> 00:22:19,429
final orbit the ohm's one burn occurs

388
00:22:24,100 --> 00:22:21,650

about two minutes after main engine

389
00:22:27,340 --> 00:22:24,110
shutdown and establishes the orbital

390
00:22:29,880 --> 00:22:27,350
Apogee point the ohms to burn takes

391
00:22:36,010 --> 00:22:29,890
place approximately 30 minutes later and

392
00:22:37,840 --> 00:22:36,020
circular eise's the orbit once

393
00:22:38,380 --> 00:22:37,850
satellites are launched and put into

394
00:22:40,450 --> 00:22:38,390
orbit

395
00:22:44,380 --> 00:22:40,460
it is often necessary to change the

396
00:22:46,720 --> 00:22:44,390
orbit with an on-orbit burn the common

397
00:22:51,250 --> 00:22:46,730
term used in describing on-orbit burns

398
00:22:53,020 --> 00:22:51,260
or engine firings is Delta V Delta V is

399
00:22:55,810 --> 00:22:53,030
the incremental change in spacecraft

400
00:22:59,170 --> 00:22:55,820
velocity measured in feet per second

401
00:23:01,810 --> 00:22:59,180
resulting from the burn the amount of

402
00:23:04,570 --> 00:23:01,820
fuel used during a burn depends on the

403
00:23:06,880 --> 00:23:04,580
desired Delta V change and the mass of

404
00:23:09,730 --> 00:23:06,890
the spacecraft because the amount of

405
00:23:11,920 --> 00:23:09,740
fuel carried is limited fuel consumption

406
00:23:14,500 --> 00:23:11,930
is one of the primary considerations in

407
00:23:19,810 --> 00:23:14,510
spacecraft mission planning and is

408
00:23:22,330 --> 00:23:19,820
critical to orbit lifetime on orbit a

409
00:23:25,120 --> 00:23:22,340
spacecraft can thrust in any direction

410
00:23:28,540 --> 00:23:25,130
burns along the flight path forward and

411
00:23:31,090 --> 00:23:28,550
backward are the most common a unique

412
00:23:33,970 --> 00:23:31,100
feature of any orbital burn is that if

413
00:23:36,340 --> 00:23:33,980

no other burns occur the spacecraft will

414
00:23:40,750 --> 00:23:36,350
later always pass again through the

415
00:23:43,090 --> 00:23:40,760
point of burn forward burns increase the

416
00:23:47,500 --> 00:23:43,100
spacecraft's velocity and are known as

417
00:23:49,600 --> 00:23:47,510
paws agreed burns with paws agreed burns

418
00:23:52,210 --> 00:23:49,610
the flight path of the vehicle will be

419
00:23:56,260 --> 00:23:52,220
raised at all points except the burn

420
00:23:58,270 --> 00:23:56,270
point burns opposite the direction of

421
00:24:02,140 --> 00:23:58,280
flight which slow the spacecraft down

422
00:24:04,150 --> 00:24:02,150
are called retrograde burns for

423
00:24:06,340 --> 00:24:04,160
retrograde burns the orbit will be

424
00:24:09,490 --> 00:24:06,350
lowered at all points except the burn

425
00:24:11,320 --> 00:24:09,500
point the greater the Delta V the

426
00:24:16,130 --> 00:24:11,330
greater the difference between the pre

427
00:24:21,820 --> 00:24:18,770
burns can be combined into maneuver

428
00:24:24,740 --> 00:24:21,830
sequences to change orbits size shape or

429
00:24:26,960 --> 00:24:24,750
orientation one of the most common

430
00:24:29,750 --> 00:24:26,970
maneuver sequences is made up of two

431
00:24:32,660 --> 00:24:29,760
burns and is used to accomplish an orbit

432
00:24:36,380 --> 00:24:32,670
transfer between two circular orbits in

433
00:24:38,960 --> 00:24:36,390
the same orbital plane the most energy

434
00:24:43,250 --> 00:24:38,970
efficient transfer between two orbits of

435
00:24:45,830 --> 00:24:43,260
this type is the Hohmann transfer the

436
00:24:48,260 --> 00:24:45,840
Hohmann transfer is actually one half of

437
00:24:50,900 --> 00:24:48,270
an elliptical orbit with its perigee in

438
00:24:54,020 --> 00:24:50,910

one of the orbits at its Apogee in the

439
00:24:58,190 --> 00:24:54,030
other the burns occur at the perigee and

440
00:25:00,530 --> 00:24:58,200
Apogee of the transfer orbit the use of

441
00:25:03,140 --> 00:25:00,540
the Hohmann transfer minimizes the Delta

442
00:25:06,560 --> 00:25:03,150
V required thus having the advantage of

443
00:25:08,600 --> 00:25:06,570
using minimum fuel the disadvantage of

444
00:25:12,409 --> 00:25:08,610
the Hohmann transfer is that it takes

445
00:25:14,750 --> 00:25:12,419
longer than most other transfers the

446
00:25:16,520 --> 00:25:14,760
type of the transfer sequence depends on

447
00:25:20,480 --> 00:25:16,530
the mission and the amount of fuel

448
00:25:23,210 --> 00:25:20,490
available for example a space rescue

449
00:25:25,640 --> 00:25:23,220
where time is critical might use a fast

450
00:25:28,010 --> 00:25:25,650
transfer while a routine satellite

451
00:25:30,620 --> 00:25:28,020
deployment where fuel saved for later

452
00:25:35,299 --> 00:25:30,630
use is important would most likely use a

453
00:25:37,250 --> 00:25:35,309
Hohmann transfer the burns discussed so

454
00:25:39,770 --> 00:25:37,260
far have all been maneuvering in the

455
00:25:43,620 --> 00:25:39,780
original orbital plane and do not affect

456
00:25:46,529 --> 00:25:43,630
orbit inclination or node position

457
00:25:49,049 --> 00:25:46,539
there are situations which require an

458
00:25:51,480 --> 00:25:49,059
orbital plane change such as setting up

459
00:25:54,900 --> 00:25:51,490
a rendezvous or placing a satellite in

460
00:25:57,270 --> 00:25:54,910
an equatorial orbit to change the

461
00:25:59,430 --> 00:25:57,280
inclination the thrust vector must be

462
00:26:03,360 --> 00:25:59,440
directed at an angle to the orbital

463
00:26:05,640 --> 00:26:03,370

plane a thrust with a component that is

464
00:26:08,370 --> 00:26:05,650
perpendicular to the orbital plane at

465
00:26:11,190 --> 00:26:08,380
either the ascending or descending node

466
00:26:12,620 --> 00:26:11,200
will rotate the orbital plane about the

467
00:26:15,029 --> 00:26:12,630
line of nodes

468
00:26:17,190 --> 00:26:15,039
Northerly out of plane thrust at the

469
00:26:19,710 --> 00:26:17,200
ascending node will increase the

470
00:26:24,180 --> 00:26:19,720
inclination of a pro-grade orbit while a

471
00:26:26,370 --> 00:26:24,190
southerly thrust will decrease it out of

472
00:26:28,590 --> 00:26:26,380
plane thrusts require considerable

473
00:26:35,700 --> 00:26:28,600
amounts of fuel and are performed only

474
00:26:37,680 --> 00:26:35,710
when absolutely required the Space

475
00:26:40,289 --> 00:26:37,690
Shuttle for example using all of its

476
00:26:43,080 --> 00:26:40,299
onboard propellant is capable of an

477
00:26:47,850 --> 00:26:43,090
on-orbit plane change of less than three

478
00:26:53,049 --> 00:26:50,680
satellite orbital planes and altitudes

479
00:26:55,540 --> 00:26:53,059
are determined by their design mission

480
00:26:57,640 --> 00:26:55,550
which very often includes a field of

481
00:27:00,790 --> 00:26:57,650
view requirement for optical or

482
00:27:03,070 --> 00:27:00,800
communications purposes the field of

483
00:27:05,590 --> 00:27:03,080
view of a satellite is defined as the

484
00:27:07,660 --> 00:27:05,600
area of the Earth's surface that is in

485
00:27:11,200 --> 00:27:07,670
view from the satellite at any given

486
00:27:13,390 --> 00:27:11,210
time satellites in high orbits have

487
00:27:16,900 --> 00:27:13,400
greater fields of view than those in

488
00:27:19,570 --> 00:27:16,910

lower orbits for example a satellite at

489
00:27:21,760 --> 00:27:19,580
an altitude of 800 nautical miles has a

490
00:27:26,100 --> 00:27:21,770
circular field of view with a diameter

491
00:27:29,049 --> 00:27:26,110
of about 40 100 nautical miles a

492
00:27:31,240 --> 00:27:29,059
satellite at 200 nautical miles has a

493
00:27:35,290 --> 00:27:31,250
circular field of view with a diameter

494
00:27:37,150 --> 00:27:35,300
of about 2,000 nautical miles low orbit

495
00:27:39,370 --> 00:27:37,160
satellites are often used for

496
00:27:43,510 --> 00:27:39,380
photography and other types of Earth

497
00:27:45,580 --> 00:27:43,520
observation a satellite placed in a low

498
00:27:48,700 --> 00:27:45,590
inclination circular orbit at an

499
00:27:51,299 --> 00:27:48,710
altitude of about 19,000 300 nautical

500
00:27:55,720 --> 00:27:51,309
miles will have an angular velocity

501
00:27:57,250 --> 00:27:55,730
exactly equal to that of the earth the

502
00:27:59,919 --> 00:27:57,260
satellite would seem to remain

503
00:28:02,799 --> 00:27:59,929
stationary in longitude as viewed from

504
00:28:05,350 --> 00:28:02,809
the ground such orbits are called

505
00:28:07,690 --> 00:28:05,360
geosynchronous and are used to provide a

506
00:28:09,760 --> 00:28:07,700
continuous communications capability

507
00:28:12,850 --> 00:28:09,770
among any system of ground stations

508
00:28:15,190 --> 00:28:12,860
within their field of view the

509
00:28:17,530 --> 00:28:15,200
geosynchronous orbit field of view is

510
00:28:20,020 --> 00:28:17,540
constant and is limited to a latitude

511
00:28:23,560 --> 00:28:20,030
zone of about 70 degrees north and south

512
00:28:25,810 --> 00:28:23,570
of the equator effective satellite

513
00:28:29,500 --> 00:28:25,820

communications from geosynchronous orbit

514
00:28:32,080 --> 00:28:29,510
is not possible at either Pole however

515
00:28:34,890 --> 00:28:32,090
because of their altitude their field of

516
00:28:37,660 --> 00:28:34,900
view covers nearly half the globe a

517
00:28:40,090 --> 00:28:37,670
special type of geosynchronous orbit

518
00:28:45,790 --> 00:28:40,100
with an inclination of 0 degrees is

519
00:28:47,890 --> 00:28:45,800
called a geostationary orbit it appears

520
00:28:51,019 --> 00:28:47,900
to hover over a fixed point on the

521
00:28:54,060 --> 00:28:51,029
Earth's surface at the equator

522
00:28:56,700 --> 00:28:54,070
most us communication satellites are in

523
00:29:01,169 --> 00:28:56,710
geosynchronous orbits providing near

524
00:29:03,029 --> 00:29:01,179
worldwide communications coverage for

525
00:29:06,680 --> 00:29:03,039
effective communications at high

526
00:29:09,510 --> 00:29:06,690
latitudes the molniya orbit is used

527
00:29:12,330 --> 00:29:09,520
mahlia is the Russian word for lightning

528
00:29:14,639 --> 00:29:12,340
and is an orbit used extensively by the

529
00:29:18,060 --> 00:29:14,649
Soviet Union for its communication

530
00:29:20,490 --> 00:29:18,070
satellites pneumoniae orbit is highly

531
00:29:23,039 --> 00:29:20,500
eccentric with an Apogee that is near

532
00:29:28,560 --> 00:29:23,049
the geosynchronous altitude and an

533
00:29:30,810 --> 00:29:28,570
inclination of about 63 degrees the

534
00:29:32,760 --> 00:29:30,820
satellite slows down at Apogee in the

535
00:29:36,570 --> 00:29:32,770
northern hemisphere and whips through

536
00:29:38,580 --> 00:29:36,580
perigee in the southern hemisphere this

537
00:29:41,880 --> 00:29:38,590
provides communications in the northern

538
00:29:45,690 --> 00:29:41,890

hemisphere for up to 75% of its orbital

539
00:29:48,090 --> 00:29:45,700
period several satellites properly

540
00:29:50,610 --> 00:29:48,100
spaced in molniya orbits can provide

541
00:29:55,740 --> 00:29:50,620
constant communications at the northern

542
00:29:58,200 --> 00:29:55,750
latitudes navigation satellites such as

543
00:30:01,260 --> 00:29:58,210
the US Navy's transit system and the

544
00:30:04,200 --> 00:30:01,270
joint service Navstar GPS Global

545
00:30:06,450 --> 00:30:04,210
Positioning System use lower orbits so

546
00:30:10,130 --> 00:30:06,460
that a user can receive signals from

547
00:30:13,049 --> 00:30:10,140
more than one satellite at any time

548
00:30:16,769 --> 00:30:13,059
another frequently used orbit is known

549
00:30:18,389 --> 00:30:16,779
as a sun-synchronous orbit these take

550
00:30:21,000 --> 00:30:18,399
advantage of the precession of the

551
00:30:23,909 --> 00:30:21,010
orbital plane caused by the earth not

552
00:30:25,980 --> 00:30:23,919
being a perfect sphere all Sun

553
00:30:28,740 --> 00:30:25,990
synchronous orbits are highly inclined

554
00:30:30,990 --> 00:30:28,750
retrograde orbits which precess eastward

555
00:30:34,409 --> 00:30:31,000
around the Earth's polar axis at the

556
00:30:36,659 --> 00:30:34,419
rate of one revolution per year since

557
00:30:38,460 --> 00:30:36,669
the Earth's Sun line also revolves

558
00:30:40,680 --> 00:30:38,470
eastward of the rate of one revolution

559
00:30:43,500 --> 00:30:40,690
per year the orbital plane will maintain

560
00:30:48,389 --> 00:30:43,510
a constant orientation relative to the

561
00:30:50,610 --> 00:30:48,399
Earth's Sun line if the satellites

562
00:30:53,310 --> 00:30:50,620
period is then synchronized with the

563
00:30:55,470 --> 00:30:53,320

rotation of the earth it will pass over

564
00:30:58,169 --> 00:30:55,480
the same point on the Earth's surface at

565
00:31:01,550 --> 00:30:58,179
the same local time at a regular

566
00:31:06,920 --> 00:31:04,400
a sun-synchronous satellite ensures that

567
00:31:09,410 --> 00:31:06,930
a constant sun angle and uniform

568
00:31:13,760 --> 00:31:09,420
lighting exist for the same field of

569
00:31:16,010 --> 00:31:13,770
view from past to pass satellites such

570
00:31:18,980 --> 00:31:16,020
as those in the defense meteorological

571
00:31:21,680 --> 00:31:18,990
satellite program and Landsat our Sun

572
00:31:27,650 --> 00:31:21,690
synchronous imaging the entire Earth on

573
00:31:32,880 --> 00:31:30,390
the gravitational attraction of the

574
00:31:36,870 --> 00:31:32,890
earth on a spacecraft causes it to move

575
00:31:39,030 --> 00:31:36,880
in its orbit around the Earth there are

576
00:31:41,220 --> 00:31:39,040
other much smaller forces which will

577
00:31:44,400 --> 00:31:41,230
cause a spacecraft to deviate from its

578
00:31:47,780 --> 00:31:44,410
desired orbit these forces cause what

579
00:31:52,800 --> 00:31:50,280
orbital precession which is used to

580
00:31:54,480 --> 00:31:52,810
obtain Sun synchronous orbits results

581
00:31:58,110 --> 00:31:54,490
from the perturbing effects of the

582
00:32:01,020 --> 00:31:58,120
Earth's non spherical shape other

583
00:32:07,790 --> 00:32:01,030
perturbing forces are the gravitational

584
00:32:11,520 --> 00:32:07,800
pull of the Sun the moon and planets and

585
00:32:13,710 --> 00:32:11,530
solar winds which are charged streams of

586
00:32:15,450 --> 00:32:13,720
protons and electrons that heat the

587
00:32:20,490 --> 00:32:15,460
Earth's atmosphere and increase

588
00:32:22,830 --> 00:32:20,500

atmospheric drag in most cases

589
00:32:25,650 --> 00:32:22,840
perturbing forces can be compensated for

590
00:32:29,760 --> 00:32:25,660
in the spacecraft and orbit design and

591
00:32:32,520 --> 00:32:29,770
present no major problems if the forces

592
00:32:34,650 --> 00:32:32,530
disturb the orbit too much thrusters can

593
00:32:39,480 --> 00:32:34,660
be fired to re-establish its desired

594
00:32:41,550 --> 00:32:39,490
orbital orientation or altitude this is

595
00:32:44,190 --> 00:32:41,560
particularly true for spacecraft

596
00:32:46,560 --> 00:32:44,200
orbiting at very low altitudes where the

597
00:32:49,170 --> 00:32:46,570
effects of atmospheric drag are greater

598
00:32:51,000 --> 00:32:49,180
and if not compensated for will

599
00:32:54,750 --> 00:32:51,010
eventually cause the spacecraft to

600
00:32:57,090 --> 00:32:54,760
deorbit a spacecrafts operational

601
00:32:59,730 --> 00:32:57,100
lifetime is frequently limited only by

602
00:33:03,420 --> 00:32:59,740
the amount of fuel available to maintain

603
00:33:06,390 --> 00:33:03,430
its desired orbit when its useful life

604
00:33:08,940 --> 00:33:06,400
is complete a satellite is left in orbit

605
00:33:11,870 --> 00:33:08,950
or is deorbited burning up when

606
00:33:14,340 --> 00:33:11,880
re-entering the Earth's atmosphere

607
00:33:16,800 --> 00:33:14,350
when the Space Shuttle completes its

608
00:33:19,650 --> 00:33:16,810
orbital mission it executes a precise

609
00:33:22,650 --> 00:33:19,660
retrograde burn to initiate its

610
00:33:24,990 --> 00:33:22,660
controlled return to earth this burn

611
00:33:27,440 --> 00:33:25,000
occurs nearly halfway around the Earth

612
00:33:29,450 --> 00:33:27,450
from the landing site

613
00:33:32,150 --> 00:33:29,460

the new orbit established by the

614
00:33:34,730 --> 00:33:32,160
retrograde burn causes the orbiter to

615
00:33:36,560 --> 00:33:34,740
enter the Earth's atmosphere about four

616
00:33:39,320 --> 00:33:36,570
thousand miles from the landing site

617
00:33:41,600 --> 00:33:39,330
during the period the orbiter descends

618
00:33:44,600 --> 00:33:41,610
from its orbital altitude to atmospheric

619
00:33:47,510 --> 00:33:44,610
reentry its attitude is maintained by

620
00:33:51,980 --> 00:33:47,520
the use of reaction control jets located

621
00:33:53,270 --> 00:33:51,990
in the nose and tail of the orbiter once

622
00:33:56,150 --> 00:33:53,280
the orbiter enters the Earth's

623
00:33:58,670 --> 00:33:56,160
atmosphere its wing and tail arrow

624
00:34:01,460 --> 00:33:58,680
surfaces begin to become effective and

625
00:34:05,480 --> 00:34:01,470
gradually replace the Jets for attitude

626
00:34:08,330 --> 00:34:05,490
control as the orbiter nears the landing

627
00:34:13,360 --> 00:34:08,340
field it maneuvers to a long straight in

628
00:34:16,430 --> 00:34:13,370
approach at an angle of 17 to 19 degrees

629
00:34:18,680 --> 00:34:16,440
nearing the runway it executes a flare

630
00:34:21,260 --> 00:34:18,690
maneuver to reduce its sink rate and

631
00:34:25,669 --> 00:34:21,270
glides to a touchdown at approximately

632
00:34:28,610 --> 00:34:25,679
230 miles per hour as the orbiter rolls

633
00:34:31,220 --> 00:34:28,620
to a stop our journey into the world of

634
00:34:32,290 --> 00:34:31,230
orbital mechanics comes to an end for

635
00:34:35,000 --> 00:34:32,300
now

636
00:34:37,040 --> 00:34:35,010
this is only the basics of orbital

637
00:34:40,099 --> 00:34:37,050
mechanics an intricate study of

638
00:34:42,169 --> 00:34:40,109

planetary and satellite motion the next

639
00:34:44,200 --> 00:34:42,179
time you see a launch you will see it

640
00:34:47,569 --> 00:34:44,210
from a different somewhat knowledgeable

641
00:35:51,840 --> 00:34:47,579
perspective you will understand the