Moonbase: The Next Step

1
00:00:40,833 --> 00:00:44,100
In the unsettled, early days of our solar system,

2
00:00:44,100 --> 00:00:48,533
Earth is unrecognisable as the planet we now call the blue marble.

3
00:00:50,000 --> 00:00:55,600
And it’s on a collision course with the small planet Theia.

4
00:01:04,433 --> 00:01:09,100
Molten debris from this catastrophic
impact is caught in Earth's orbit,

5
00:01:09,100 --> 00:01:12,100
where gravity slowly gathers the pieces together.

6
00:01:12,966 --> 00:01:15,966
It is from these fragments of Earth
and Theia

7
00:01:16,200 --> 00:01:19,200
that the Moon is born.

8
00:01:19,700 --> 00:01:23,333
Heavily cratered by further impacts,
its surface is destined

9
00:01:23,333 --> 00:01:26,866
to remain dry and lifeless
for over 4 billion years.

10
00:01:29,700 --> 00:01:33,300

Until, one July day in 1969,

11
00:01:33,766 --> 00:01:36,800
a living creature stepped onto its barren landscape

12
00:01:37,200 --> 00:01:40,200
for the very first time.

13
00:01:41,533 --> 00:01:58,133
(NASA CAPCOM)

14
00:02:01,100 --> 00:02:03,966
Neil Armstrong's “small step”

15
00:02:03,966 --> 00:02:06,966
marks a new dawn for humankind.

16
00:02:07,600 --> 00:02:10,800
But the Apollo missions to the moon
are risky and expensive.

17
00:02:12,466 --> 00:02:14,433
Only 12 Apollo astronauts

18
00:02:14,433 --> 00:02:17,433
ever set foot on the lunar surface.

19
00:02:23,366 --> 00:02:24,366
After Apollo,

20
00:02:24,366 --> 00:02:27,366
we turn our focus to other objectives

21

00:02:27,766 --> 00:02:30,166
sending probes to distant worlds

22
00:02:30,166 --> 00:02:33,200
and ringing our planet
with thousands of satellites,

23
00:02:35,033 --> 00:02:38,033
including the largest satellite
of all time.

24
00:02:38,466 --> 00:02:41,466
The International Space Station.

25
00:02:42,233 --> 00:02:43,533
A living laboratory

26
00:02:43,533 --> 00:02:46,733
where astronauts
learn to live and work in space.

27
00:02:47,333 --> 00:02:51,000
Advancing new technologies
that have made human spaceflight

28
00:02:51,266 --> 00:02:54,266
safer than ever before.

29
00:03:08,266 --> 00:03:11,266
The moon, however, lost
none of its appeal.

30
00:03:11,600 --> 00:03:14,600
We just needed a good reason to go back.

31
00:03:14,666 --> 00:03:17,666
November 2009

32
00:03:17,766 --> 00:03:19,866
the Indian robotic spacecraft Chandrayaan 1

33
00:03:19,866 --> 00:03:22,866
scans the lunar surface,

34
00:03:23,100 --> 00:03:25,500
peering deep within a giant crater.

35
00:03:25,500 --> 00:03:31,166
It discovers a vital, life giving substance, later confirmed by other missions.

36
00:03:32,400 --> 00:03:33,600
Water.

37
00:03:33,600 --> 00:03:35,733
Frozen water.

38
00:03:35,733 --> 00:03:37,733
It's a game changer.

39
00:03:37,733 --> 00:03:40,733
Lunar ice is an extremely valuable commodity.

40
00:03:41,566 --> 00:03:43,800
There is enough ice here to spark

41
00:03:43,800 --> 00:03:46,800
a new space race.

42
00:03:47,100 --> 00:03:48,900
Now humanity is destined

43
00:03:48,900 --> 00:03:51,900
for the moon once more.

44
00:04:25,066 --> 00:04:27,100
Female Astronaut: Phoenix has landed.

45
00:04:27,100 --> 00:04:28,500
Suits pressurized.

46
00:04:28,500 --> 00:04:30,500
It's a go for depressurization.

47
00:04:30,500 --> 00:04:36,200
Male Astronaut: Depressurisation complete. Opening airlock.

48
00:04:40,833 --> 00:04:44,000
Narrator: When astronauts set foot on the moon
once again,

49
00:04:44,533 --> 00:04:47,800
they will be taking the first steps
toward a permanent

50
00:04:47,800 --> 00:04:50,800
habitable settlement.

51
00:04:51,800 --> 00:04:54,800
Female Astronaut: The next step for humankind.

52

00:05:08,700 --> 00:05:10,033
Narrator: We've already proved that

53
00:05:10,033 --> 00:05:13,333
we can build space stations
and live in them for long periods.

54
00:05:14,033 --> 00:05:18,433
But a moon base is a much more difficult
and dangerous proposition.

55
00:05:19,500 --> 00:05:22,333
The moon is a long way from home.

56
00:05:22,333 --> 00:05:24,866
The journey takes three days and crosses

57
00:05:24,866 --> 00:05:28,533
nearly 250,000 miles of open space.

58
00:05:30,800 --> 00:05:31,833
And moon missions

59
00:05:31,833 --> 00:05:34,900
confront astronauts
with many critical dangers.

60
00:05:38,900 --> 00:05:41,900
As they leave the safety of Earth's
magnetic shield,

61
00:05:42,200 --> 00:05:46,633
they're exposed to harmful space
radiation, including cosmic rays.

62
00:05:46,966 --> 00:05:51,133
The solar wind and bursts of high energy
particles from the sun.

63
00:05:52,033 --> 00:05:55,233
There are also high speed projectiles
to contend with.

64
00:05:56,733 --> 00:06:00,233
Large space rocks are rare,
but at these speeds,

65
00:06:00,233 --> 00:06:04,133
even tiny micrometeorites
can rip through metal and spacesuits.

66
00:06:05,466 --> 00:06:07,400
The lunar surface is scarred

67
00:06:07,400 --> 00:06:10,500
by 4.5 billion years of bombardment.

68
00:06:11,000 --> 00:06:15,433
It is blanketed by a deep layer of glassy
shards and jagged dust.

69
00:06:16,133 --> 00:06:19,733
This loose rock and grit is called regolith.

70
00:06:22,900 --> 00:06:28,666
Regolith’s sharp and toxic dust is electrostatic,
charged by the solar wind,

71
00:06:29,433 --> 00:06:32,433

making it cling to surfaces.

72
00:06:32,433 --> 00:06:35,433
It finds its way into mechanisms
and bodies,

73
00:06:35,766 --> 00:06:38,766
harming both equipment and astronauts.

74
00:06:48,600 --> 00:06:53,633
An early priority for the first lunar
scouts is to establish a source of power.

75
00:06:54,666 --> 00:06:56,400
Here at the South Pole

76
00:06:56,400 --> 00:07:00,000
near-constant sunshine
provides the opportunity for year round

77
00:07:00,000 --> 00:07:03,000
solar generation.

78
00:07:03,266 --> 00:07:04,633
Female Astronaut: Okay, Ryan.

79
00:07:04,633 --> 00:07:06,700
Solar panels connected.

80
00:07:06,700 --> 00:07:09,700
Male Astronaut: Primary power is live.

81
00:07:09,866 --> 00:07:11,700
Narrator: With the power switched on.

82
00:07:11,700 --> 00:07:15,500
The astronauts can turn their attention
to building their base.

83
00:07:16,033 --> 00:07:17,100
Male Astronaut: Moving to HAB 01

84
00:07:17,100 --> 00:07:20,100
Now to initiate startup.

85
00:07:20,400 --> 00:07:22,500
Narrator: It's time to open up their Moonbase

86
00:07:22,500 --> 00:07:25,500
Habitation modules.

87
00:07:26,366 --> 00:07:27,933
These ‘habs’ were delivered

88
00:07:27,933 --> 00:07:31,200
by uncrewed missions in the months
leading up to their arrival.

89
00:07:32,700 --> 00:07:35,933
Inside the airlock, astronauts
carefully clean regolith

90
00:07:35,933 --> 00:07:39,233
from their spacesuits
to avoid contaminating the living space.

91
00:07:41,600 --> 00:07:43,200
But solar radiation

92
00:07:43,200 --> 00:07:47,366
isn't so easily kept at bay
during dangerous solar storms.

93
00:07:47,833 --> 00:07:52,433
Astronauts will need to use equipment
and water supplies as extra shielding.

94
00:07:53,400 --> 00:07:56,066
Early warning of such storms
will be confirmed

95
00:07:56,066 --> 00:07:59,066
by an orbiting lunar outpost.

96
00:08:00,633 --> 00:08:01,500
It's called

97
00:08:01,500 --> 00:08:04,500
“The Gateway”,
the liaison point for spacecraft,

98
00:08:05,133 --> 00:08:09,100
a remote operational control
hub and communications relay.

99
00:08:21,233 --> 00:08:24,400
With their have established,
the lunar astronauts can move to

100
00:08:24,400 --> 00:08:28,933
the next stage of their mission, exploring
the cratered landscape around them.

101
00:08:30,200 --> 00:08:32,900
Apollo
era moon buggies could barely survive

102
00:08:32,900 --> 00:08:35,900
one mission in the moon's
harsh environment.

103
00:08:36,266 --> 00:08:38,466
These new vehicles are tough enough

104
00:08:38,466 --> 00:08:41,466
to survive many years.

105
00:08:42,233 --> 00:08:44,633
With powerful batteries and motors.

106
00:08:44,633 --> 00:08:47,633
Astronauts
can travel further than ever before.

107
00:08:51,600 --> 00:08:55,266
Control: EV1 comms test complete. You are clear to proceed.

108
00:08:56,266 --> 00:08:56,800
Astronaut: Roger that Control,

109
00:08:56,800 --> 00:09:00,200
current heading 205 at 12

110
00:09:05,800 --> 00:09:07,500
Male Astronaut: We're really doing this to Sofia!

111

00:09:07,500 --> 00:09:10,500
just incredible.

112
00:09:15,300 --> 00:09:18,300
Beautiful day for a drive.

113
00:09:26,133 --> 00:09:28,500
Take a heading up towards the rim.

114
00:09:28,500 --> 00:09:31,500
Right up here.

115
00:09:42,366 --> 00:09:45,633
This is it!

116
00:09:45,633 --> 00:09:48,633
This is what we came for.

117
00:09:48,933 --> 00:09:51,933
Female Astronaut: Impressionante!

118
00:09:52,500 --> 00:09:55,000
Control: Control to EV1

119
00:09:55,000 --> 00:09:56,233
A solar storm just got picked up

120
00:09:56,233 --> 00:09:58,100
SEP coming this way

121
00:09:58,100 --> 00:10:00,300
We need you back in the HAB in 15 minutes.

122

00:10:03,500 --> 00:10:04,900
Astronaut: Roger that, Control

123
00:10:04,900 --> 00:10:06,966
 Heading back to buggy now.

124
00:10:07,400 --> 00:10:09,433
Just keep following our tracks back.

125
00:10:09,433 --> 00:10:11,100
Nice driving, Ryan.

126
00:10:18,266 --> 00:10:20,133
Male Astronaut: Okay, nearly there.

127
00:10:20,133 --> 00:10:21,900
Prepare to release your seatbelt.

128
00:10:22,566 --> 00:10:23,400
Female Astronaut: Roger that

129
00:10:23,400 --> 00:10:25,666
I'm ready to move.

130
00:10:28,066 --> 00:10:31,066
Sofia to Control, we are back at the HAB

131
00:10:32,300 --> 00:10:35,300
Entering airlock now.

132
00:10:37,033 --> 00:10:37,900
We're taking cover

133

00:10:37,900 --> 00:10:40,900
under the water canisters.

134
00:10:41,100 --> 00:10:44,100
Control: Great job

135
00:10:55,600 --> 00:10:56,933
Narrator: To avoid unnecessary

136
00:10:56,933 --> 00:11:00,300
outings, much of the outdoor work is done
by robots.

137
00:11:01,200 --> 00:11:04,200
Remote controlled diggers
heap regolith onto halves

138
00:11:04,333 --> 00:11:07,333
as additional radiation shielding.

139
00:11:08,300 --> 00:11:10,200
But these next generation robots

140
00:11:10,200 --> 00:11:13,200
do so much more than shoveling.

141
00:11:13,600 --> 00:11:16,466
Many use AI and machine learning.

142
00:11:16,466 --> 00:11:21,100
They are autonomous, able to run
independent experiments, and able

143
00:11:21,100 --> 00:11:25,100

to react to unexpected circumstances,
much like a human

144
00:11:25,100 --> 00:11:28,100
astronaut might.

145
00:11:30,833 --> 00:11:32,366
As the years go by,

146
00:11:32,366 --> 00:11:36,066
larger structures are built
by using the moon's own resources.

147
00:11:37,966 --> 00:11:39,800
Dangerous as it can be,

148
00:11:39,800 --> 00:11:42,566
regolith is also useful.

149
00:11:42,566 --> 00:11:45,566
It can be bound into kind of a moon cement

150
00:11:45,600 --> 00:11:50,100
to feed huge 3D printers, spinning
robotic arms,

151
00:11:50,466 --> 00:11:53,866
print large regolith structures
from the ground up.

152
00:12:18,533 --> 00:12:21,333
Alternatively, regolith can be superheated

153
00:12:21,333 --> 00:12:25,200

with focused sunbeams
fuzing it to form glass sheets.

154
00:12:25,466 --> 00:12:29,000
These can be used to build
lunar mirrors and solar panels.

155
00:12:29,466 --> 00:12:33,166
Crucial steps
to setting up an ice mine at the moon's

156
00:12:33,166 --> 00:12:36,166
southern pole.

157
00:12:52,933 --> 00:12:54,366
As the sun circles

158
00:12:54,366 --> 00:12:57,900
the polar horizon, deep craters like this

159
00:12:58,366 --> 00:13:01,366
have remained
beyond the reach of its warming rays

160
00:13:01,700 --> 00:13:04,433
for billions of years.

161
00:13:04,433 --> 00:13:07,866
To reach this precious ice,
robots must venture

162
00:13:07,866 --> 00:13:11,033
deep into a pitch black frozen crater.

163

00:13:12,033 --> 00:13:15,466
Its depths are one of the coldest places
in the solar System,

164
00:13:15,833 --> 00:13:18,833
with temperatures close to absolute zero.

165
00:13:19,000 --> 00:13:21,600
No human could hope to survive.

166
00:13:21,600 --> 00:13:26,466
Materials shatter and unprotected
electronics would grind to a halt.

167
00:13:32,400 --> 00:13:34,900
Water is vital for life.

168
00:13:34,900 --> 00:13:38,233
Its chemical properties
also make it uniquely valuable.

169
00:13:39,233 --> 00:13:41,566
Using solar energy.

170
00:13:41,566 --> 00:13:45,500
H2O molecules can be split into hydrogen
and oxygen.

171
00:13:46,166 --> 00:13:51,300
These can be stored then later explosively
recombined to release their energy.

172
00:13:51,666 --> 00:13:53,166
It's rocket fuel.

173
00:13:53,166 --> 00:13:57,000
This is why
water is known as the oil of space.

174
00:13:58,100 --> 00:14:00,800
The valuable ice is mixed up with regolith

175
00:14:00,800 --> 00:14:04,800
at the base of a frozen crater twice
as deep as the Grand Canyon.

176
00:14:05,200 --> 00:14:09,733
Mining it presents one of the greatest
engineering challenges ever faced.

177
00:14:10,333 --> 00:14:13,333
First, the ice must be warmed.

178
00:14:13,566 --> 00:14:16,533
Giant mirrors
positioned around the crater rim.

179
00:14:16,533 --> 00:14:19,533
Direct sunlight down into the darkness.

180
00:14:19,733 --> 00:14:24,566
The reflected energy warms
the ice and vaporize it into a gas,

181
00:14:25,166 --> 00:14:28,166
which is then captured into large barrels.

182
00:14:38,133 --> 00:14:41,133
Female Astronaut: You ready?

183
00:14:41,600 --> 00:14:43,233
Male Astronaut: I'm ready.

184
00:14:43,233 --> 00:14:43,933
Here we go.

185
00:14:45,100 --> 00:14:47,100
System live.

186
00:14:47,100 --> 00:14:50,100
Female Astronaut: Barrel robots are en route.

187
00:14:55,566 --> 00:14:56,466
Male Astronaut: Copy that.

188
00:14:56,466 --> 00:14:59,466
Tracking position.

189
00:15:11,900 --> 00:15:14,766
Female Astronaut: They're approaching the base
of the crater.

190
00:15:14,766 --> 00:15:17,766
Now.

191
00:15:18,066 --> 00:15:19,600
Attaching to the silver lining,

192
00:15:19,600 --> 00:15:22,600
trying to collect extracted water.

193
00:15:22,866 --> 00:15:23,833

Male Astronaut: Copy that.

194
00:15:23,833 --> 00:15:26,833
Initiate transfer to supertankers.

195
00:15:32,766 --> 00:15:34,266
Loading complete

196
00:15:34,266 --> 00:15:37,266
Tanker One starting journey out of the crater.

197
00:15:49,000 --> 00:15:53,566
Over time, the moonbase mine operation grows

198
00:15:53,566 --> 00:15:58,200
Abundant solar power converts the extracted water
into rocket fuel for export.

199
00:15:58,433 --> 00:16:00,933
But hydrogen isn't only for rockets.

200
00:16:00,933 --> 00:16:04,800
It is a clean fuel
that can be used back on Earth to power

201
00:16:04,800 --> 00:16:08,166
cars, heat homes,
or to generate electricity.

202
00:16:09,900 --> 00:16:12,966
The moon's weak
gravity makes launching this cargo

203
00:16:12,966 --> 00:16:17,100

to the orbiting gateway outpost
relatively easy and cost efficient,

204
00:16:17,666 --> 00:16:21,266
and sustaining the lunar expansion
long into the future.

205
00:16:23,100 --> 00:16:26,700
The Gateway becomes the first off
planet rocket refueling

206
00:16:26,700 --> 00:16:30,366
station that provides the key
to onward space travel.

207
00:16:30,900 --> 00:16:33,533
Mars ships will not only refuel here,

208
00:16:33,533 --> 00:16:37,833
but also take on water
for use as onboard radiation shielding.

209
00:16:40,133 --> 00:16:43,133
But mining water is just the beginning.

210
00:16:43,600 --> 00:16:46,666
Regolith is rich and valuable materials

211
00:16:47,133 --> 00:16:50,133
rare earth metals and helium three.

212
00:16:50,666 --> 00:16:51,133
Mining.

213

00:16:51,133 --> 00:16:56,100
These will further sustain the moon base
and help to secure our future

214
00:16:56,400 --> 00:16:59,400
as an interplanetary species.

215
00:17:30,066 --> 00:17:33,533
What might we have built
100 years from now?

216
00:17:41,966 --> 00:17:46,000
Could we create an aspirational place to live?

217
00:17:55,933 --> 00:17:58,933
A sustainable environment.

218
00:18:06,000 --> 00:18:09,000
With the familiarity of Earth.

219
00:18:16,633 --> 00:18:20,066
And a habitat rich in life.

220
00:18:29,900 --> 00:18:32,900
A place we could call home.

221
00:19:12,700 --> 00:19:16,200
Is it possible that we might one day
explore

222
00:19:16,433 --> 00:19:21,300
distant stars, or even build settlements
on other planets?

223

00:19:21,300 --> 00:19:24,300
And moons across the cosmos?

224
00:19:28,466 --> 00:19:31,733
To find out, we just need to take

225
00:19:32,933 --> 00:19:34,866
the next step.