
To FG

1
00:00:19,730 --> 00:00:18,410
it's all about fluids flames a materials

2
00:00:22,279 --> 00:00:19,740
research aboard the International Space

3
00:00:25,370 --> 00:00:22,289
Station hi I'm NASA astronaut Tracy

4
00:00:29,210 --> 00:00:25,380
Dyson welcome to station life isn't a

5
00:00:31,580 --> 00:00:29,220
two-for of illogically is r35 at four

6
00:00:33,919 --> 00:00:31,590
six four right now

7
00:00:35,540 --> 00:00:33,929
Jeffery's thank you okay Tracy we copy

8
00:00:39,049 --> 00:00:35,550
and that the information we'll pass it

9
00:00:40,579 --> 00:00:39,059
along welcome back this month on station

10
00:00:42,860 --> 00:00:40,589
life we're going to take a look at how

11
00:00:44,719 --> 00:00:42,870
the unique environment of space affects

12
00:00:47,660 --> 00:00:44,729
physical science experiments aboard the

13
00:00:49,879 --> 00:00:47,670

International Space Station the ISS is a

14
00:00:52,219 --> 00:00:49,889
laboratory like no other here on earth

15
00:00:54,500 --> 00:00:52,229
because of the lack of gravity we can

16
00:00:57,049 --> 00:00:54,510
use it as a variable or we can remove it

17
00:00:59,180 --> 00:00:57,059
from the equation entirely it's this

18
00:01:00,859 --> 00:00:59,190
absence of gravity that allows us to

19
00:01:02,989 --> 00:01:00,869
observe the aspects of fundamental

20
00:01:05,630 --> 00:01:02,999
physics that we can't see here on earth

21
00:01:08,030 --> 00:01:05,640
gravity here on earth often masks or

22
00:01:11,510 --> 00:01:08,040
distorts subtle forces such as surface

23
00:01:13,490 --> 00:01:11,520
tension or diffusion on ISS these forces

24
00:01:16,040 --> 00:01:13,500
can be harnessed for a wide variety of

25
00:01:17,330 --> 00:01:16,050
physical science applications so in

26
00:01:19,550 --> 00:01:17,340
today's program we're going to take a

27
00:01:22,010 --> 00:01:19,560
look at how the lack of gravity affects

28
00:01:25,490 --> 00:01:22,020
the physical sciences of fluids flames

29
00:01:27,950 --> 00:01:25,500
and materials the ISS is an amazing

30
00:01:30,200 --> 00:01:27,960
place it has all these laboratories and

31
00:01:31,930 --> 00:01:30,210
science racks to do amazing experiments

32
00:01:38,230 --> 00:01:31,940
that are literally out of this world

33
00:01:43,459 --> 00:01:41,029
the International Space Station is the

34
00:01:45,919 --> 00:01:43,469
largest most complex object ever

35
00:01:47,599 --> 00:01:45,929
assembled in space and is clearly

36
00:01:51,679 --> 00:01:47,609
visible from Earth with nothing more

37
00:01:53,300 --> 00:01:51,689
than the naked eye from end to end the

38
00:01:56,600 --> 00:01:53,310

station is slightly longer than an

39
00:01:59,449 --> 00:01:56,610
American football field the biggest

40
00:02:03,020 --> 00:01:59,459
shock I would say the biggest impact

41
00:02:05,449 --> 00:02:03,030
that I had during my flight is the first

42
00:02:08,479 --> 00:02:05,459
time I looked out the window of the

43
00:02:11,559 --> 00:02:08,489
orbiter and saw the space station it was

44
00:02:14,120 --> 00:02:11,569
huge it was huge and shiny and beautiful

45
00:02:17,870 --> 00:02:14,130
looking at it and knowing that a

46
00:02:21,559 --> 00:02:17,880
man-made structure that big is actually

47
00:02:24,020 --> 00:02:21,569
up there the interior of this incredible

48
00:02:27,520 --> 00:02:24,030
structure is larger than a five bedroom

49
00:02:31,520 --> 00:02:27,530
house with two baths a gym and a

50
00:02:33,920 --> 00:02:31,530
360-degree bay window the station's mass

51
00:02:36,770 --> 00:02:33,930
is almost 1 million pounds and it

52
00:02:40,369 --> 00:02:36,780
contains about 32,000 cubic feet of

53
00:02:42,590 --> 00:02:40,379
living space the space station functions

54
00:02:44,930 --> 00:02:42,600
as a microgravity and life sciences

55
00:02:47,900 --> 00:02:44,940
laboratory a testbed for new

56
00:02:53,000 --> 00:02:47,910
technologies and as a platform for both

57
00:02:54,559 --> 00:02:53,010
Earth and celestial observations the

58
00:02:57,530 --> 00:02:54,569
complex is made up of multiple

59
00:03:00,640 --> 00:02:57,540
interconnected modules group together at

60
00:03:04,520 --> 00:03:00,650
the center point of a 357 footlong

61
00:03:06,530 --> 00:03:04,530
integrated truss structure power is

62
00:03:11,910 --> 00:03:06,540
generated through four giant solar

63
00:03:17,220 --> 00:03:14,580

the pressurized components include three

64
00:03:20,250 --> 00:03:17,230
laboratories the u.s. laboratory module

65
00:03:22,500 --> 00:03:20,260
destiny the European research laboratory

66
00:03:27,510 --> 00:03:22,510
Columbus and the Japanese experiment

67
00:03:29,820 --> 00:03:27,520
module Kibo the Russian service module

68
00:03:32,760 --> 00:03:29,830
is the structural and functional center

69
00:03:35,370 --> 00:03:32,770
of the Russian segment of the station it

70
00:03:38,400 --> 00:03:35,380
provides living quarters communication

71
00:03:42,030 --> 00:03:38,410
systems and exercise facility and flight

72
00:03:43,800 --> 00:03:42,040
propulsion systems other Russian

73
00:03:47,340 --> 00:03:43,810
segments include the functional cargo

74
00:03:51,720 --> 00:03:47,350
block to many research modules and a

75
00:03:53,729 --> 00:03:51,730
docking compartment the Italian space

76
00:03:56,130 --> 00:03:53,739
agency provided a permanent

77
00:03:58,590 --> 00:03:56,140
multi-purpose module which can host up

78
00:04:03,270 --> 00:03:58,600
to 16 additional racks containing

79
00:04:05,970 --> 00:04:03,280
equipment experiments and supplies there

80
00:04:07,860 --> 00:04:05,980
are three modules called nodes that

81
00:04:11,130 --> 00:04:07,870
connect the elements of the station and

82
00:04:13,140 --> 00:04:11,140
provide berthing ports the primary

83
00:04:15,210 --> 00:04:13,150
residential areas include the Russian

84
00:04:17,789 --> 00:04:15,220
service module and node three

85
00:04:20,340 --> 00:04:17,799
tranquility which contains a bathroom

86
00:04:23,219 --> 00:04:20,350
for crew hygiene and exercise equipment

87
00:04:28,080 --> 00:04:23,229
a treadmill and a zero-g weightlifting

88
00:04:29,850 --> 00:04:28,090

device the quest airlock provides the

89
00:04:33,870 --> 00:04:29,860
capability for extra vehicular activity

90
00:04:36,600 --> 00:04:33,880
or EVs this is the module that provides

91
00:04:40,740 --> 00:04:36,610
the exit for spacewalking astronauts to

92
00:04:43,320 --> 00:04:40,750
go outside the station to work the

93
00:04:45,090 --> 00:04:43,330
cupola is a small module designed for

94
00:04:48,780 --> 00:04:45,100
the observation of operations outside

95
00:04:51,260 --> 00:04:48,790
the space station similar to a bay

96
00:04:54,510 --> 00:04:51,270
window in a home on earth but with a

97
00:04:56,159 --> 00:04:54,520
360-degree view the cupola allows crew

98
00:04:58,800 --> 00:04:56,169
members to observe the approach of

99
00:05:02,279 --> 00:04:58,810
vehicles as well as all robotic arm

100
00:05:04,529 --> 00:05:02,289
operations and spacewalks the

101
00:05:06,840 --> 00:05:04,539
canadian-built space station robotic arm

102
00:05:09,000 --> 00:05:06,850
is a larger version of the arm on the

103
00:05:10,980 --> 00:05:09,010
space shuttle and is used to move

104
00:05:13,180 --> 00:05:10,990
equipment and hardware around outside

105
00:05:15,890 --> 00:05:13,190
the station

106
00:05:18,469 --> 00:05:15,900
the space station is the home of six

107
00:05:20,749 --> 00:05:18,479
full-time crew members and is made up of

108
00:05:23,629 --> 00:05:20,759
astronauts and cosmonauts from nations

109
00:05:26,360 --> 00:05:23,639
around the world more than 200 people

110
00:05:36,640 --> 00:05:26,370
have visited so far and at least another

111
00:05:43,129 --> 00:05:39,020
we also just get my big brother on the

112
00:05:45,379 --> 00:05:43,139
other side of my ID back you coming here

113
00:05:50,899 --> 00:05:45,389

I'll be drilling without the floor

114
00:06:06,129 --> 00:05:50,909
dancing absolutely and it's just like in

115
00:06:12,589 --> 00:06:09,129
as the International Space Station flies

116
00:06:14,990 --> 00:06:12,599
257 statute miles over the coast of

117
00:06:22,370 --> 00:06:15,000
Chile terry virts and the initial

118
00:06:24,860 --> 00:06:22,380
moments of his first spacewalk hmm I

119
00:06:27,320 --> 00:06:24,870
don't know about you but I like to start

120
00:06:28,779 --> 00:06:27,330
my day with an awesome cup of coffee and

121
00:06:31,309 --> 00:06:28,789
onboard the International Space Station

122
00:06:33,920 --> 00:06:31,319
same thing no different

123
00:06:37,159 --> 00:06:33,930
the drinking coffee in space comes with

124
00:06:39,890 --> 00:06:37,169
its set of unique challenges without the

125
00:06:43,070 --> 00:06:39,900
pull of gravity liquid acts of really

126
00:06:44,960 --> 00:06:43,080
strange ways even some of the most basic

127
00:06:47,809 --> 00:06:44,970
maneuvers like drinking from a coffee

128
00:06:50,270 --> 00:06:47,819
cup are confounded by the absence of

129
00:06:52,070 --> 00:06:50,280
most fundamental forces we earthlings

130
00:06:54,260 --> 00:06:52,080
take for granted I mean last time I

131
00:06:55,700 --> 00:06:54,270
lived onboard the space station we had

132
00:07:01,460 --> 00:06:55,710
to drink coffee out of one of these a

133
00:07:04,790 --> 00:07:01,470
bag with a straw one problem there's no

134
00:07:07,909 --> 00:07:04,800
smell no I find half the joy of drinking

135
00:07:10,640 --> 00:07:07,919
coffee is the aromatic bouquet as you

136
00:07:12,589 --> 00:07:10,650
drink it so fellow astronaut Don Pettit

137
00:07:15,170 --> 00:07:12,599
came up with the solution and helped Co

138
00:07:17,810 --> 00:07:15,180

invent the first ever microgravity space

139
00:07:20,600 --> 00:07:17,820
coffee cup to enhance your coffee

140
00:07:23,600 --> 00:07:20,610
drinking experience on the ISS so here's

141
00:07:26,450 --> 00:07:23,610
my good buddy Don Pettit explaining his

142
00:07:29,540 --> 00:07:26,460
ingenious and that's more than genius

143
00:07:34,589 --> 00:07:29,550
solution to the ISS Coffee dilemma I

144
00:07:42,239 --> 00:07:40,230
a normal coffee cup or a normal open

145
00:07:43,589 --> 00:07:42,249
container just simply won't work in a

146
00:07:46,679 --> 00:07:43,599
weightless environment because the

147
00:07:49,260 --> 00:07:46,689
liquid will be in the bottom of the cup

148
00:07:50,820 --> 00:07:49,270
and you tip it up and it still stays in

149
00:07:53,159 --> 00:07:50,830
the bottom of the cup if you move it

150
00:07:56,070 --> 00:07:53,169
around too violently it'll all splash

151
00:07:58,079 --> 00:07:56,080
out make a big mess so we end up having

152
00:08:00,269 --> 00:07:58,089
to drink our beverages through a straw

153
00:08:02,369 --> 00:08:00,279
from a bag makes you feel like you're a

154
00:08:05,249 --> 00:08:02,379
big insect sucking the juices from

155
00:08:08,249 --> 00:08:05,259
another insect I wanted to see if I

156
00:08:10,109 --> 00:08:08,259
could figure out a way to have an open

157
00:08:11,850 --> 00:08:10,119
container Cup in a weightless

158
00:08:15,299 --> 00:08:11,860
environment which would allow you to

159
00:08:16,799 --> 00:08:15,309
drink your tea and your coffee in a

160
00:08:19,170 --> 00:08:16,809
manner that's commensurate with how

161
00:08:22,769 --> 00:08:19,180
people drink their beverages on earth

162
00:08:26,459 --> 00:08:22,779
taking some of my surface chemistry that

163
00:08:28,769 --> 00:08:26,469

I learned in college I devised a cup

164
00:08:30,179 --> 00:08:28,779
with a special shape the cross-section

165
00:08:33,809 --> 00:08:30,189
looks kind of like an airplane wing

166
00:08:36,990 --> 00:08:33,819
where it has a cusp and the cusps will

167
00:08:38,639 --> 00:08:37,000
allow channel flow so the liquid from

168
00:08:40,829 --> 00:08:38,649
the bottom of the cup will float up and

169
00:08:43,829 --> 00:08:40,839
just park itself right next to the rim

170
00:08:46,740 --> 00:08:43,839
and then you can drink it and it allows

171
00:08:49,110 --> 00:08:46,750
a crew to share a communal beverage you

172
00:08:50,970 --> 00:08:49,120
could share tea maybe you just come in

173
00:08:52,889 --> 00:08:50,980
from doing a spacewalk or something you

174
00:08:55,800 --> 00:08:52,899
want to celebrate a little bit if you

175
00:08:57,900 --> 00:08:55,810
have a real cup an open container it's

176
00:08:59,040 --> 00:08:57,910
so ingrained in human beings it's so

177
00:09:01,650 --> 00:08:59,050
ingrained in culture

178
00:09:04,079 --> 00:09:01,660
it adds back the dimension of what it's

179
00:09:05,630 --> 00:09:04,089
like to be a human being in a civilized

180
00:09:20,410 --> 00:09:05,640
way

181
00:09:25,690 --> 00:09:23,650
all kidding aside the solution of

182
00:09:27,610 --> 00:09:25,700
drinking coffee and space combined with

183
00:09:29,980 --> 00:09:27,620
the invention of the space coffee mug

184
00:09:32,380 --> 00:09:29,990
have helped us better understand fluid

185
00:09:34,420 --> 00:09:32,390
properties in microgravity so now let's

186
00:09:36,190 --> 00:09:34,430
take a look at how understanding the

187
00:09:39,010 --> 00:09:36,200
problems associated with drinking coffee

188
00:09:42,010 --> 00:09:39,020

and space relates to future space travel

189
00:09:43,900 --> 00:09:42,020
as well as life here on earth high above

190
00:09:46,570 --> 00:09:43,910
our planet in the realm of satellites

191
00:09:49,960 --> 00:09:46,580
and space stations the familiar rules of

192
00:09:50,980 --> 00:09:49,970
Earth do not apply the mid day sky is as

193
00:09:54,580 --> 00:09:50,990
black as night

194
00:09:56,770 --> 00:09:54,590
there is no up and no down dropped

195
00:09:59,890 --> 00:09:56,780
objects don't fall and hot air doesn't

196
00:10:01,930 --> 00:09:59,900
rise of all the strange things that

197
00:10:05,500 --> 00:10:01,940
happen up there however it is possible

198
00:10:07,780 --> 00:10:05,510
that the strangest happens to coffee in

199
00:10:10,710 --> 00:10:07,790
microgravity a simple morning cuppa Joe

200
00:10:13,210 --> 00:10:10,720
can be an out-of-this-world experience

201
00:10:15,220 --> 00:10:13,220
physics professor Mark Weiss logo of

202
00:10:16,960 --> 00:10:15,230
Portland State University has given a

203
00:10:19,540 --> 00:10:16,970
lot of thought to coffee and other

204
00:10:22,990 --> 00:10:19,550
fluids in space and he describes what

205
00:10:24,790 --> 00:10:23,000
happens for starters he says it would be

206
00:10:27,760 --> 00:10:24,800
a chore just getting the coffee into the

207
00:10:30,520 --> 00:10:27,770
cup absent the pull of gravity pouring

208
00:10:32,110 --> 00:10:30,530
liquids can be very tricky but for the

209
00:10:34,180 --> 00:10:32,120
sake of argument let's suppose you are

210
00:10:36,640 --> 00:10:34,190
on the space station and you have a cup

211
00:10:38,140 --> 00:10:36,650
of coffee in your hand the most natural

212
00:10:40,930 --> 00:10:38,150
thing would be to tip the cup toward

213
00:10:43,780 --> 00:10:40,940

your lips but when you do the coffee

214
00:10:46,360 --> 00:10:43,790
would be very hard to control in fact it

215
00:10:48,310 --> 00:10:46,370
probably wouldn't move you'd have to

216
00:10:49,960 --> 00:10:48,320
shake the cup toward your face and hope

217
00:10:52,570 --> 00:10:49,970
that some of the hot liquid breaks loose

218
00:10:54,550 --> 00:10:52,580
and floats towards your mouth on the

219
00:10:56,840 --> 00:10:54,560
bright side you will probably be wide

220
00:10:58,759 --> 00:10:56,850
awake by the time the cup is empty

221
00:11:01,340 --> 00:10:58,769
Coffee is not the only liquid that

222
00:11:04,099 --> 00:11:01,350
misbehaves in space cryogenic fuels

223
00:11:07,369 --> 00:11:04,109
thermal coolants potable water and urine

224
00:11:09,409 --> 00:11:07,379
do it to the behavior of fluids is one

225
00:11:12,439 --> 00:11:09,419
of the most unintuitive things in all of

226
00:11:13,969 --> 00:11:12,449
spaceflight this poses an extreme

227
00:11:17,299 --> 00:11:13,979
challenge for engineers designing

228
00:11:19,329 --> 00:11:17,309
spacecraft systems that use fluids our

229
00:11:21,650 --> 00:11:19,339
intuition is all wrong laments wise logo

230
00:11:23,749 --> 00:11:21,660
when it comes to guessing what fluids

231
00:11:26,269 --> 00:11:23,759
will do in new systems were often in the

232
00:11:29,269 --> 00:11:26,279
dark to develop a better understanding

233
00:11:31,039 --> 00:11:29,279
of fluids in microgravity wise local and

234
00:11:32,479 --> 00:11:31,049
colleagues are conducting the capillary

235
00:11:35,210 --> 00:11:32,489
flow experiment onboard the

236
00:11:36,979 --> 00:11:35,220
International Space Station for instance

237
00:11:40,069 --> 00:11:36,989
one of the devices in their experiment

238
00:11:42,109 --> 00:11:40,079

suite looks at interior corners if two

239
00:11:44,809 --> 00:11:42,119
solid surfaces meet at a narrow enough

240
00:11:47,590 --> 00:11:44,819
angle fluids in microgravity naturally

241
00:11:50,569 --> 00:11:47,600
flow along the joint no pumping required

242
00:11:52,099 --> 00:11:50,579
this capillary effect could be used to

243
00:11:54,739 --> 00:11:52,109
guide all kinds of fluids through

244
00:11:57,229 --> 00:11:54,749
spacecraft from cryogenic fuel to

245
00:11:59,029 --> 00:11:57,239
recycled wastewater capillary driven

246
00:12:01,609 --> 00:11:59,039
flow is difficult to study on earth

247
00:12:03,710 --> 00:12:01,619
where it is dampened by gravity yet on

248
00:12:06,429 --> 00:12:03,720
the space station large-scale corner

249
00:12:08,749 --> 00:12:06,439
flows are easy to create and observe

250
00:12:10,789 --> 00:12:08,759
wise local and colleagues have already

251
00:12:13,639 --> 00:12:10,799
been granted three patents for devices

252
00:12:15,499 --> 00:12:13,649
invented as a result of their work one

253
00:12:18,619 --> 00:12:15,509
is for a microgravity condensing heat

254
00:12:20,840 --> 00:12:18,629
exchanger another describes a device

255
00:12:24,349 --> 00:12:20,850
that separates and controls multi-phase

256
00:12:27,129 --> 00:12:24,359
fluids the third patent is for you

257
00:12:29,539 --> 00:12:27,139
guessed it a low gravity coffee cup

258
00:12:31,219 --> 00:12:29,549
astronaut Don Pettit who worked with the

259
00:12:32,569 --> 00:12:31,229
capillary flow experiment during his

260
00:12:34,909 --> 00:12:32,579
time onboard the space station

261
00:12:36,259 --> 00:12:34,919
helped invent the cup and he shares the

262
00:12:38,599 --> 00:12:36,269
patent with wise local and two

263
00:12:40,909 --> 00:12:38,609

mathematicians Paul Conchas and Robert

264
00:12:42,940 --> 00:12:40,919
Finn who performed the first theoretical

265
00:12:45,280 --> 00:12:42,950
analysis of the phenomenon

266
00:12:47,500 --> 00:12:45,290
basically one side of the cup has a

267
00:12:49,090 --> 00:12:47,510
sharp interior corner in the

268
00:12:51,490 --> 00:12:49,100
microgravity environment of the space

269
00:12:53,530 --> 00:12:51,500
station capillary forces send fluid

270
00:12:56,470 --> 00:12:53,540
flowing along the channel right into the

271
00:12:58,540 --> 00:12:56,480
lips of the drinker as you sip more

272
00:12:59,880 --> 00:12:58,550
fluid keeps coming and you can enjoy

273
00:13:02,820 --> 00:12:59,890
your coffee in a weightless environment

274
00:13:05,200 --> 00:13:02,830
clear down to the last drops as padded

275
00:13:06,700 --> 00:13:05,210
this may well be what future space

276
00:13:09,220 --> 00:13:06,710
colonists use when they want to have a

277
00:13:10,810 --> 00:13:09,230
celebration indeed the patent

278
00:13:12,760 --> 00:13:10,820
application specifically mentions

279
00:13:15,670 --> 00:13:12,770
toasting as one of the uses of the

280
00:13:18,070 --> 00:13:15,680
device it's easy to imagine what they

281
00:13:19,810 --> 00:13:18,080
might be toasting toilets and air

282
00:13:22,090 --> 00:13:19,820
conditioners and fuel tanks and

283
00:13:24,220 --> 00:13:22,100
recycling systems all working better

284
00:16:07,610 --> 00:13:24,230
thanks to capillary flow experiments on

285
00:16:14,190 --> 00:16:11,970
as you can see the study of how the

286
00:16:16,260 --> 00:16:14,200
microgravity of space affects fluid

287
00:16:18,930 --> 00:16:16,270
physics is fundamental to the future of

288
00:16:21,000 --> 00:16:18,940

space travel things get even a little

289
00:16:23,070 --> 00:16:21,010
more crazy when we start to look at how

290
00:16:24,870 --> 00:16:23,080
the microgravity of space affects the

291
00:16:27,930 --> 00:16:24,880
fundamental properties of the very fire

292
00:16:29,460 --> 00:16:27,940
we use to heat our coffee here on earth

293
00:16:32,010 --> 00:16:29,470
and in our everyday lives

294
00:16:34,140 --> 00:16:32,020
we understand how fire behaves there's

295
00:16:37,380 --> 00:16:34,150
very few surprises but in space

296
00:16:39,240 --> 00:16:37,390
completely different story on ISS we can

297
00:16:41,370 --> 00:16:39,250
use it as an opportunity to study the

298
00:16:43,530 --> 00:16:41,380
fundamentals of fire so we can better

299
00:16:46,620 --> 00:16:43,540
understand it so let's take a closer

300
00:16:48,870 --> 00:16:46,630
look at this phenomenon fire it is often

301
00:16:51,270 --> 00:16:48,880
said is mankind's oldest chemistry

302
00:16:53,730 --> 00:16:51,280
experiment for thousands of years people

303
00:16:55,980 --> 00:16:53,740
have been mixing the oxygen-rich air of

304
00:16:57,960 --> 00:16:55,990
the earth with an almost endless variety

305
00:17:00,060 --> 00:16:57,970
of fuels to produce a hot luminous flame

306
00:17:01,440 --> 00:17:00,070
there's an arc of learning about

307
00:17:03,330 --> 00:17:01,450
combustion that stretches from the

308
00:17:05,760 --> 00:17:03,340
earliest campfires of primitive humans

309
00:17:07,410 --> 00:17:05,770
to the most advanced automobiles racing

310
00:17:08,870 --> 00:17:07,420
down the super highways of the 21st

311
00:17:11,100 --> 00:17:08,880
century

312
00:17:12,980 --> 00:17:11,110
engineers studying burning to produce

313
00:17:15,210 --> 00:17:12,990

better internal combustion engines

314
00:17:18,570 --> 00:17:15,220
chemists peer into flames looking for

315
00:17:21,120 --> 00:17:18,580
exotic reactions chef's experiment with

316
00:17:23,550 --> 00:17:21,130
fire to cook better food you would think

317
00:17:25,680 --> 00:17:23,560
there's not much more to learn when it

318
00:17:27,420 --> 00:17:25,690
comes to fire flames are hard to

319
00:17:30,360 --> 00:17:27,430
understand because they're complicated

320
00:17:31,850 --> 00:17:30,370
in an ordinary candle flame thousands of

321
00:17:34,080 --> 00:17:31,860
chemical reactions take place

322
00:17:36,750 --> 00:17:34,090
hydrocarbon molecules from the wick are

323
00:17:38,820 --> 00:17:36,760
vaporized and cracked apart by heat they

324
00:17:43,050 --> 00:17:38,830
combine with oxygen to produce light

325
00:17:44,910 --> 00:17:43,060
heat carbon dioxide and water some of

326
00:17:46,950 --> 00:17:44,920
the hydrocarbon fragments form ring

327
00:17:49,800 --> 00:17:46,960
shaped molecules called polycyclic

328
00:17:53,310 --> 00:17:49,810
aromatic hydrocarbons and eventually

329
00:17:56,280 --> 00:17:53,320
soot set particles can themselves burn

330
00:17:58,230 --> 00:17:56,290
or simply drift away as smoke the

331
00:18:01,110 --> 00:17:58,240
familiar teardrop shape of the flame is

332
00:18:03,690 --> 00:18:01,120
an effect caused by gravity hot air

333
00:18:06,180 --> 00:18:03,700
rises and draws fresh cool air behind it

334
00:18:09,540 --> 00:18:06,190
this is called buoyancy and is what

335
00:18:11,430 --> 00:18:09,550
makes the flame shoot up and flicker but

336
00:18:13,970 --> 00:18:11,440
what happens when you light a candle say

337
00:18:16,880 --> 00:18:13,980
on the International Space Station in

338
00:18:20,880 --> 00:18:16,890

microgravity flames burn differently

339
00:18:22,830 --> 00:18:20,890
they form little spheres Space Station

340
00:18:24,950 --> 00:18:22,840
flame balls turn out to be wonderful

341
00:18:27,570 --> 00:18:24,960
mini labs for combustion research

342
00:18:30,030 --> 00:18:27,580
unlike flames on earth which expand

343
00:18:33,060 --> 00:18:30,040
greedily when they need more fuel flame

344
00:18:35,460 --> 00:18:33,070
balls let the oxygen come to them oxygen

345
00:18:37,920 --> 00:18:35,470
fuel combined in a narrow zone at the

346
00:18:40,290 --> 00:18:37,930
surface of the sphere not here and there

347
00:18:43,140 --> 00:18:40,300
throughout the flame it's a much simpler

348
00:18:45,960 --> 00:18:43,150
system recently on a space station

349
00:18:47,310 --> 00:18:45,970
experiment called flex where scientists

350
00:18:50,190 --> 00:18:47,320
learn how to put out fires in

351
00:18:52,230 --> 00:18:50,200
microgravity they noticed small droplets

352
00:18:54,300 --> 00:18:52,240
of heptane we're burning inside the Flex

353
00:18:57,510 --> 00:18:54,310
combustion chamber

354
00:18:59,610 --> 00:18:57,520
as planned the flames went out but

355
00:19:02,730 --> 00:18:59,620
unexpectedly the droplets of fuel

356
00:19:06,780 --> 00:19:02,740
continued burning the flames are they're

357
00:19:11,370 --> 00:19:06,790
just too faint to see these are cool

358
00:19:13,730 --> 00:19:11,380
flames ordinarily visible fires burn at

359
00:19:17,250 --> 00:19:13,740
a high temperature between 2200 and

360
00:19:19,080 --> 00:19:17,260
3,100 degrees Fahrenheit heptane flame

361
00:19:21,750 --> 00:19:19,090
balls on the space station started out

362
00:19:23,940 --> 00:19:21,760
in this hot fire regime but as the flame

363
00:19:27,150 --> 00:19:23,950

balls cooled and began to go out a

364
00:19:28,980 --> 00:19:27,160
different kind of burning took over cool

365
00:19:32,040 --> 00:19:28,990
flames burn at the relatively low

366
00:19:33,900 --> 00:19:32,050
temperature of 400 to 1000 degrees

367
00:19:35,390 --> 00:19:33,910
Fahrenheit and their chemistry is

368
00:19:38,010 --> 00:19:35,400
completely different

369
00:19:40,500 --> 00:19:38,020
normal flames produce soot carbon

370
00:19:43,380 --> 00:19:40,510
dioxide and water cool flames produce

371
00:19:44,850 --> 00:19:43,390
carbon monoxide and formaldehyde similar

372
00:19:47,130 --> 00:19:44,860
cool flames have been produced on earth

373
00:19:50,130 --> 00:19:47,140
but they flicker out almost immediately

374
00:19:53,130 --> 00:19:50,140
on the space station however cool flames

375
00:19:55,020 --> 00:19:53,140
can burn for nearly a minute there are

376
00:19:57,180 --> 00:19:55,030
practical implications of these results

377
00:19:59,970 --> 00:19:57,190
for instance they could lead to cleaner

378
00:20:01,650 --> 00:19:59,980
Auto ignitions one of the ideas that

379
00:20:05,520 --> 00:20:01,660
auto companies have worked on for years

380
00:20:08,310 --> 00:20:05,530
is H CCI short for homogeneous charge

381
00:20:10,470 --> 00:20:08,320
compression ignition an automobile

382
00:20:12,600 --> 00:20:10,480
cylinder instead of a spark there would

383
00:20:14,310 --> 00:20:12,610
be a gentler less polluting combustion

384
00:20:17,220 --> 00:20:14,320
process throughout the entire chamber

385
00:20:20,970 --> 00:20:17,230
the chemistry of H CCI involves cool

386
00:20:22,380 --> 00:20:20,980
flame chemistry the extra control we get

387
00:20:24,270 --> 00:20:22,390
from the steady-state burning on the

388
00:20:25,860 --> 00:20:24,280

space station will give us more accurate

389
00:20:29,370 --> 00:20:25,870
chemistry values for this type of

390
00:20:32,670 --> 00:20:29,380
research a combustion integrated rack or

391
00:20:34,830 --> 00:20:32,680
Cir in the Destiny laboratory makes it

392
00:20:37,140 --> 00:20:34,840
possible to perform a wide variety of

393
00:20:40,470 --> 00:20:37,150
experiments that teach us how fire

394
00:20:43,350 --> 00:20:40,480
behaves in microgravity in the center of

395
00:20:45,360 --> 00:20:43,360
the Cir is a large round chamber called

396
00:20:48,450 --> 00:20:45,370
the multi-user droplet combustion

397
00:20:50,850 --> 00:20:48,460
apparatus the 100 liter chamber has

398
00:20:52,950 --> 00:20:50,860
eight windows and five cameras that

399
00:20:55,470 --> 00:20:52,960
allow scientists to observe patterns

400
00:20:56,850 --> 00:20:55,480
made when burning fuels under different

401
00:20:58,919 --> 00:20:56,860
conditions

402
00:21:01,320 --> 00:20:58,929
the five cameras are capable of

403
00:21:04,049 --> 00:21:01,330
photographing high resolution high frame

404
00:21:07,139 --> 00:21:04,059
rate images in ultraviolet low light and

405
00:21:09,899 --> 00:21:07,149
in multiple spectrums that are specific

406
00:21:12,090 --> 00:21:09,909
to combustion events several additional

407
00:21:14,490 --> 00:21:12,100
hardware components can be added to the

408
00:21:17,370 --> 00:21:14,500
sir to customize its chamber for

409
00:21:20,100 --> 00:21:17,380
specific experiments flex is the flame

410
00:21:22,799 --> 00:21:20,110
extinguishment experiment that utilizes

411
00:21:25,889 --> 00:21:22,809
the sir to conduct various burn tests on

412
00:21:27,810 --> 00:21:25,899
gas and liquid fuel it also tests the

413
00:21:30,500 --> 00:21:27,820

effectiveness of different methods for

414
00:21:33,360 --> 00:21:30,510
extinguishing the flames from the test

415
00:21:35,669 --> 00:21:33,370
ISS provides a sustained microgravity

416
00:21:38,419 --> 00:21:35,679
environment which allows scientists to

417
00:21:40,769 --> 00:21:38,429
observe the geometric chemical and

418
00:21:43,740 --> 00:21:40,779
thermodynamic properties of both the

419
00:21:46,529 --> 00:21:43,750
flame and the fuel droplet inside the

420
00:21:48,000 --> 00:21:46,539
burn chamber under these conditions we

421
00:21:50,879 --> 00:21:48,010
can advance our fundamental

422
00:21:53,310 --> 00:21:50,889
understanding about how fuels burn in

423
00:21:55,560 --> 00:21:53,320
microgravity as well as on earth this

424
00:21:58,620 --> 00:21:55,570
research will be used to better address

425
00:22:01,019 --> 00:21:58,630
fire hazards associated with liquid

426
00:22:03,810 --> 00:22:01,029
combustibles the wealth of information

427
00:22:06,090 --> 00:22:03,820
obtained from the test in Flex will also

428
00:22:08,190 --> 00:22:06,100
help scientists on earth solve problems

429
00:22:10,620 --> 00:22:08,200
with pollution that are generated by

430
00:22:12,779 --> 00:22:10,630
combustion the many different

431
00:22:15,360 --> 00:22:12,789
experiments in the combustion integrated

432
00:22:17,430 --> 00:22:15,370
rack will help engineers increase the

433
00:22:19,980 --> 00:22:17,440
efficiency of gasoline and diesel

434
00:22:21,629 --> 00:22:19,990
engines here on earth and will help us

435
00:22:44,690 --> 00:22:21,639
understand fire prevention and

436
00:22:50,070 --> 00:22:48,419
now that was hot okay fluids and flames

437
00:22:52,289 --> 00:22:50,080
are acting a little differently but

438
00:22:54,570 --> 00:22:52,299

that's not all let's take a look now at

439
00:22:56,700 --> 00:22:54,580
colloids magnetic fluids and smart

440
00:23:00,029 --> 00:22:56,710
materials but first let me tell you what

441
00:23:02,580 --> 00:23:00,039
those are Colon's that contain suspended

442
00:23:04,380 --> 00:23:02,590
particles magnetic fluids are smart

443
00:23:05,880 --> 00:23:04,390
fluids that increase an apparent

444
00:23:08,730 --> 00:23:05,890
thickness when exposed to a magnetic

445
00:23:11,370 --> 00:23:08,740
field and smart materials are specially

446
00:23:13,020 --> 00:23:11,380
designed to significantly change in a

447
00:23:14,970 --> 00:23:13,030
controlled fashion when exposed to

448
00:23:17,159 --> 00:23:14,980
stress temperature or magnetic field

449
00:23:19,770 --> 00:23:17,169
colloids magnetic fluids and smart

450
00:23:22,710 --> 00:23:19,780
materials oh my now let's take a look at

451
00:23:25,020 --> 00:23:22,720
how these are studied on ISS if you have

452
00:23:27,419 --> 00:23:25,030
a smartphone take it out and run your

453
00:23:29,700 --> 00:23:27,429
fingers along the glass surface it's

454
00:23:32,070 --> 00:23:29,710
cool to the touch incredibly thin and

455
00:23:34,860 --> 00:23:32,080
strong and almost impervious to

456
00:23:38,700 --> 00:23:34,870
scratching you're now in contact with a

457
00:23:41,340 --> 00:23:38,710
smart material smart materials don't

458
00:23:42,930 --> 00:23:41,350
occur naturally instead they're designed

459
00:23:45,299 --> 00:23:42,940
by engineers working at the molecular

460
00:23:49,350 --> 00:23:45,309
level to produce substances made to

461
00:23:51,510 --> 00:23:49,360
order for futuristic applications the

462
00:23:53,580 --> 00:23:51,520
Corning Gorilla Glass that overlays the

463
00:23:56,370 --> 00:23:53,590

displays of many smartphones is a great

464
00:23:59,039 --> 00:23:56,380
example it gets its toughness in part

465
00:24:01,110 --> 00:23:59,049
from fat potassium ions stuffed into the

466
00:24:04,649 --> 00:24:01,120
empty spaces between old-fashioned glass

467
00:24:06,899 --> 00:24:04,659
molecules when the molten glass cools

468
00:24:09,149 --> 00:24:06,909
during manufacturing densed pack

469
00:24:10,919 --> 00:24:09,159
molecules solidify into a transparent

470
00:24:14,370 --> 00:24:10,929
armor that gives Gorilla Glass as

471
00:24:16,380 --> 00:24:14,380
extraordinary properties around the

472
00:24:18,899 --> 00:24:16,390
world designers are working on other

473
00:24:21,510 --> 00:24:18,909
smart materials such as alloys that can

474
00:24:24,149 --> 00:24:21,520
change shape on demand plastics that

475
00:24:26,430 --> 00:24:24,159
heal themselves when ruptured and fluids

476
00:24:29,669 --> 00:24:26,440
that obey magnetic commands to flow or

477
00:24:31,260 --> 00:24:29,679
stiffen under computer control one of

478
00:24:33,120 --> 00:24:31,270
the greatest challenges in creating a

479
00:24:36,750 --> 00:24:33,130
smart material is arranging the

480
00:24:38,820 --> 00:24:36,760
molecules they're so small we want to

481
00:24:42,450 --> 00:24:38,830
create a new class of materials beyond

482
00:24:44,860 --> 00:24:42,460
smart we need genius materials materials

483
00:24:47,260 --> 00:24:44,870
that arrange themselves

484
00:24:49,510 --> 00:24:47,270
the research to accomplish this is

485
00:24:50,289 --> 00:24:49,520
already underway on the International

486
00:24:52,690 --> 00:24:50,299
Space Station

487
00:24:56,830 --> 00:24:52,700
dr. first is the principal investigator

488
00:24:59,440 --> 00:24:56,840

of an experiment called inspace-3 in the

489
00:25:01,360 --> 00:24:59,450
microgravity of Earth orbit vials of

490
00:25:03,610 --> 00:25:01,370
fluid mixed with very small colloidal

491
00:25:05,649 --> 00:25:03,620
particles about a millionth of a meter

492
00:25:06,490 --> 00:25:05,659
in diameter are exposed to magnetic

493
00:25:08,919 --> 00:25:06,500
fields

494
00:25:11,680 --> 00:25:08,929
magnetism can be switched on and off

495
00:25:13,600 --> 00:25:11,690
again very rapidly this jostles the

496
00:25:15,580 --> 00:25:13,610
particles causing them to bump together

497
00:25:18,220 --> 00:25:15,590
and self-assemble into microscopic

498
00:25:20,080 --> 00:25:18,230
structures these structures can be very

499
00:25:21,490 --> 00:25:20,090
difficult to predict even using

500
00:25:24,310 --> 00:25:21,500
cutting-edge models running on

501
00:25:25,600 --> 00:25:24,320
supercomputers astronauts enjoy watching

502
00:25:27,850 --> 00:25:25,610
this process in action through

503
00:25:29,860 --> 00:25:27,860
microscopes because the samples are

504
00:25:34,060 --> 00:25:29,870
backlit by a green lamp they sometimes

505
00:25:36,220 --> 00:25:34,070
call it the green blob experiment first

506
00:25:38,799 --> 00:25:36,230
recently won an award from the American

507
00:25:41,860 --> 00:25:38,809
astronautical Society for his work on in

508
00:25:43,779 --> 00:25:41,870
space 3 just by toggling a magnetic

509
00:25:45,850 --> 00:25:43,789
field we're learning how to take many

510
00:25:47,860 --> 00:25:45,860
kinds of microscopic building blocks and

511
00:25:51,760 --> 00:25:47,870
get them to spontaneously form

512
00:25:53,440 --> 00:25:51,770
interesting structures recently

513
00:25:55,980 --> 00:25:53,450

observers have seen the colloidal

514
00:25:58,330 --> 00:25:55,990
particles forming long fibrous chains

515
00:25:59,889 --> 00:25:58,340
first speculates that these could lead

516
00:26:03,519 --> 00:25:59,899
to materials that conduct heat or

517
00:26:05,289 --> 00:26:03,529
electricity in only one direction the

518
00:26:06,909 --> 00:26:05,299
experiment has also yielded crystalline

519
00:26:09,820 --> 00:26:06,919
structures that the team is just

520
00:26:11,529 --> 00:26:09,830
beginning to investigate the fluids

521
00:26:13,899 --> 00:26:11,539
underlying these tests are themselves

522
00:26:16,899 --> 00:26:13,909
very smart they're called

523
00:26:19,060 --> 00:26:16,909
magnetorheological or mr fluids because

524
00:26:22,029 --> 00:26:19,070
they harden or change shape when they

525
00:26:24,549 --> 00:26:22,039
feel a magnetic field if you own a

526
00:26:26,680 --> 00:26:24,559
sports or luxury car you might have mr

527
00:26:28,659 --> 00:26:26,690
fluids in your shock absorbers the

528
00:26:30,610 --> 00:26:28,669
stiffness of magnetic shocks can be

529
00:26:32,830 --> 00:26:30,620
electronically adjusted thousands of

530
00:26:35,649 --> 00:26:32,840
times per second providing a remarkably

531
00:26:37,240 --> 00:26:35,659
smooth ride similar but more powerful

532
00:26:39,700 --> 00:26:37,250
devices have been installed at Japan's

533
00:26:43,180 --> 00:26:39,710
National Museum of emerging science and

534
00:26:45,220 --> 00:26:43,190
China's daunting Lake bridge they're

535
00:26:48,519 --> 00:26:45,230
there to counteract vibrations caused by

536
00:26:50,350 --> 00:26:48,529
earthquakes and gusts of wind some

537
00:26:52,210 --> 00:26:50,360
researchers have speculated that mr

538
00:26:54,190 --> 00:26:52,220

fluids might one day flow through the

539
00:26:55,240 --> 00:26:54,200
actuators and hydraulic dampers of

540
00:26:57,190 --> 00:26:55,250
robots

541
00:26:59,770 --> 00:26:57,200
moving artificial joints and limbs and

542
00:27:01,450 --> 00:26:59,780
lifelike fashion scientists and

543
00:27:03,899 --> 00:27:01,460
researchers are using these fluids as a

544
00:27:07,299 --> 00:27:03,909
laboratory for studying self-assembly

545
00:27:09,190 --> 00:27:07,309
EMR fluids are by definition responsive

546
00:27:11,770 --> 00:27:09,200
to the magnetic nudging that sets

547
00:27:14,140 --> 00:27:11,780
self-assembly in motion furthermore in

548
00:27:17,049 --> 00:27:14,150
space the particles don't sediment out

549
00:27:20,200 --> 00:27:17,059
due to gravity we can study the full 3d

550
00:27:22,480 --> 00:27:20,210
evolution of the material varying the

551
00:27:24,669 --> 00:27:22,490
shape of the colloidal particles the

552
00:27:26,260 --> 00:27:24,679
cadence of magnetic toggling the

553
00:27:28,000 --> 00:27:26,270
temperature of the fluid and other

554
00:27:29,680 --> 00:27:28,010
factors will allow researchers and

555
00:27:32,620 --> 00:27:29,690
astronauts to further explore the

556
00:27:34,779 --> 00:27:32,630
frontiers of self-assembly touch the

557
00:27:45,669 --> 00:27:34,789
surface of your smartphone again that's

558
00:27:47,169 --> 00:27:45,679
just the beginning the International

559
00:27:49,480 --> 00:27:47,179
Space Station is an unprecedented

560
00:27:51,159 --> 00:27:49,490
research platform in space allowing

561
00:27:53,200 --> 00:27:51,169
scientists and researchers from all over

562
00:27:55,659 --> 00:27:53,210
the world to conduct experiments that

563
00:27:57,130 --> 00:27:55,669

can't be done anywhere else this work

564
00:27:58,840 --> 00:27:57,140
off the earth will lead to a better

565
00:28:01,149 --> 00:27:58,850
understanding of the fundamentals of

566
00:28:03,669 --> 00:28:01,159
surface tension combustion and colloids

567
00:28:05,350 --> 00:28:03,679
in the absence of gravity benefiting us

568
00:28:07,450 --> 00:28:05,360
by helping to make more efficient

569
00:28:09,789 --> 00:28:07,460
combustion engines better portable

570
00:28:11,830 --> 00:28:09,799
medical diagnostics stronger lighter

571
00:28:13,750 --> 00:28:11,840
alloys medicines that have a longer

572
00:28:16,299 --> 00:28:13,760
shelf life and buildings that are more

573
00:28:18,340 --> 00:28:16,309
resistant to earthquakes research on the

574
00:28:21,159 --> 00:28:18,350
International Space Station continues to

575
00:28:22,990 --> 00:28:21,169
benefit us all here on earth be sure to

576
00:28:24,760 --> 00:28:23,000
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00:28:26,710 --> 00:28:24,770
and Twitter for the latest research news

578
00:28:27,970 --> 00:28:26,720
and don't forget to download our newest

579
00:28:30,370 --> 00:28:27,980
app on your mobile device

580
00:28:33,020 --> 00:28:30,380
until next time we're working off the