1
00:00:10,850 --> 00:00:05,170
well this is more of a technical talk

2
00:00:14,509 --> 00:00:10,860
but partly inspired by the fact that UFO

3
00:00:18,349 --> 00:00:14,519
reports frequently discuss impressive

4
00:00:20,480 --> 00:00:18,359
maneuverability at with usually no

5
00:00:25,490 --> 00:00:20,490
indication of conventionally known

6
00:00:28,480 --> 00:00:25,500
drives and to cut to the chase just in

7
00:00:31,130 --> 00:00:28,490
case I should run out of time a

8
00:00:32,930 --> 00:00:31,140
sufficiently advanced technology can use

9
00:00:35,450 --> 00:00:32,940
antimatter annihilation to power a

10
00:00:40,910 --> 00:00:35,460
reaction drive whose only exhaust is an

11
00:00:42,560 --> 00:00:40,920
intense beam of neutrinos this would not

12
00:00:45,290 --> 00:00:42,570
be visible it would be very hard to

13
00:00:48,490 --> 00:00:45,300

detect by any means but it is

14
00:00:51,920 --> 00:00:48,500
potentially a testable hypothesis from

15
00:00:55,850 --> 00:00:51,930
retrospective evidence that already

16
00:01:00,410 --> 00:00:55,860
exists just as a note by a sufficiently

17
00:01:03,709 --> 00:01:00,420
advanced technology I mean something

18
00:01:05,570 --> 00:01:03,719
that can accomplish anything that can be

19
00:01:08,179 --> 00:01:05,580
known that is known to be physically

20
00:01:13,130 --> 00:01:08,189
possible but that does not require any

21
00:01:17,330 --> 00:01:13,140
new physics simply on the grounds that I

22
00:01:19,490 --> 00:01:17,340
felt that a hypothesis is more credible

23
00:01:25,490 --> 00:01:19,500
if it sticks to things that we know are

24
00:01:28,569 --> 00:01:25,500
possible in principle now there's been a

25
00:01:31,940 --> 00:01:28,579
fair amount of discussion about

26
00:01:34,160 --> 00:01:31,950
theoretical space propulsion at the

27
00:01:37,190 --> 00:01:34,170
moment the only physics we know of

28
00:01:39,440 --> 00:01:37,200
relevant to space propulsion involves a

29
00:01:41,660 --> 00:01:39,450
law of equal action and reaction the

30
00:01:45,649 --> 00:01:41,670
only way you can move in one direction

31
00:01:49,030 --> 00:01:45,659
is to throw something else reaction mass

32
00:01:55,399 --> 00:01:49,040
as I call it in the other direction

33
00:01:58,130 --> 00:01:55,409
there are some variations that basically

34
00:02:00,920 --> 00:01:58,140
involve getting your reaction mass from

35
00:02:03,920 --> 00:02:00,930
outside the vehicle but they still

36
00:02:05,959 --> 00:02:03,930
adhere to Newton's third law and the

37
00:02:11,850 --> 00:02:05,969
most powerful known reaction drive is an

38
00:02:15,520 --> 00:02:14,230

i-i-i was told after i submitted my

39
00:02:18,340 --> 00:02:15,530
abstract that it would be good to

40
00:02:21,190 --> 00:02:18,350
provide a brief primer on on what

41
00:02:23,200 --> 00:02:21,200
antimatter is to begin with so every

42
00:02:28,810 --> 00:02:23,210
type of particle making up normal matter

43
00:02:30,820 --> 00:02:28,820
has a corresponding anti particle the

44
00:02:35,020 --> 00:02:30,830
relation between antimatter and normal

45
00:02:38,080 --> 00:02:35,030
matter is that every measurable property

46
00:02:40,930 --> 00:02:38,090
is either identical or exactly the

47
00:02:43,240 --> 00:02:40,940
opposite between the two mass is one of

48
00:02:45,760 --> 00:02:43,250
the identical properties antimatter

49
00:02:48,760 --> 00:02:45,770
particles have the same mass as matter

50
00:02:51,940 --> 00:02:48,770
particles electrical charge is one of

51
00:02:53,980 --> 00:02:51,950
the reversed properties the anti

52
00:02:56,860 --> 00:02:53,990
electron is also called the positron

53
00:03:00,730 --> 00:02:56,870
because it has a positive charge the

54
00:03:02,410 --> 00:03:00,740
antiproton has a negative charge when

55
00:03:06,880 --> 00:03:02,420
matter and antimatter meet they

56
00:03:08,620 --> 00:03:06,890
annihilate releasing energy and just

57
00:03:10,390 --> 00:03:08,630
historically the first antiparticle

58
00:03:12,570 --> 00:03:10,400
discovered was the anti electron or

59
00:03:18,010 --> 00:03:16,330
okay now electron positron annihilation

60
00:03:20,800 --> 00:03:18,020
is nice and simple

61
00:03:22,930 --> 00:03:20,810
they simply meet each other and convert

62
00:03:26,680 --> 00:03:22,940
into a pair of gamma rays carrying all

63
00:03:28,780 --> 00:03:26,690

of the energy ah now in accelerators

64
00:03:31,660 --> 00:03:28,790
we've been studying anti protons for

65
00:03:34,510 --> 00:03:31,670
decades now their annihilation is more

66
00:03:36,699 --> 00:03:34,520
complicated partly because a proton is a

67
00:03:38,920 --> 00:03:36,709
composite object made of three quarks an

68
00:03:41,770 --> 00:03:38,930
antiproton of course is made of three

69
00:03:43,750 --> 00:03:41,780
anti quarks and partly because the

70
00:03:45,729 --> 00:03:43,760
energy release is so much bigger that

71
00:03:48,190 --> 00:03:45,739
completely new particles or rather

72
00:03:50,170 --> 00:03:48,200
particle-antiparticle pairs can be

73
00:03:52,930 --> 00:03:50,180
created out of the energy this is a

74
00:03:54,580 --> 00:03:52,940
reversible process but there is no

75
00:03:56,199 --> 00:03:54,590
material particle lighter than the

76
00:03:59,800 --> 00:03:56,209
electron so there's no alternative but

77
00:04:04,180 --> 00:03:59,810
photons here the primary annihilation

78
00:04:06,970 --> 00:04:04,190
gives you a mess of unstable reaction

79
00:04:10,030 --> 00:04:06,980
products that ultimately are all going

80
00:04:17,530 --> 00:04:10,040
to decay or mutually annihilate into

81
00:04:19,870 --> 00:04:17,540
photons and neutrinos the now if a

82
00:04:23,560 --> 00:04:19,880
single antiproton annihilates inside a

83
00:04:24,730 --> 00:04:23,570
large nucleus most of the intermediate

84
00:04:26,559 --> 00:04:24,740
products are strongly

85
00:04:28,900 --> 00:04:26,569
interacting maisons which are very

86
00:04:31,480 --> 00:04:28,910
efficient at transferring energy to the

87
00:04:33,629 --> 00:04:31,490
rest of the nucleus so most aside from

88
00:04:37,089 --> 00:04:33,639

photons most of the energy appears as

89
00:04:39,670 --> 00:04:37,099
thermal excitation in a nucleus that's

90
00:04:42,629 --> 00:04:39,680
literally been blown apart by the excess

91
00:04:47,670 --> 00:04:42,639
energy however if an antiproton

92
00:04:49,870 --> 00:04:47,680
annihilates an isolated proton the

93
00:04:51,999 --> 00:04:49,880
ultimate products all break down into

94
00:04:53,830 --> 00:04:52,009
photons and neutrinos and the neutrinos

95
00:04:58,210 --> 00:04:53,840
end up with the lion's share of the

96
00:05:01,060 --> 00:04:58,220
energy for technical reasons that I can

97
00:05:04,930 --> 00:05:01,070
get into later on if anybody is really

98
00:05:06,909 --> 00:05:04,940
interested now for a reaction Drive the

99
00:05:08,409 --> 00:05:06,919
faster you throw away your reaction mass

100
00:05:10,450 --> 00:05:08,419
the more efficient your drive is the

101
00:05:13,089 --> 00:05:10,460
more thrust you get per unit of fuel

102
00:05:16,060 --> 00:05:13,099
you're using up the ultimate reaction

103
00:05:17,290 --> 00:05:16,070
Drive would have an exhaust velocity

104
00:05:20,740 --> 00:05:17,300
equal to the speed of light

105
00:05:22,480 --> 00:05:20,750
now since which essentially amounts to

106
00:05:26,680 --> 00:05:22,490
turning your fuel mass into radiation

107
00:05:28,240 --> 00:05:26,690
and beaming it out the back you might

108
00:05:30,670 --> 00:05:28,250
think that you can do that with

109
00:05:33,279 --> 00:05:30,680
antimatter since it annihilates matter

110
00:05:35,560 --> 00:05:33,289
completely into energy except that the

111
00:05:36,939 --> 00:05:35,570
aforementioned neutrino problem the

112
00:05:39,640 --> 00:05:36,949
neutrinos fly off in all directions

113
00:05:42,700 --> 00:05:39,650

equally you can't direct them you can't

114
00:05:46,149 --> 00:05:42,710
manipulate them so much of the energy is

115
00:05:48,159 --> 00:05:46,159
lost in terms of neutrinos that a rich

116
00:05:52,180 --> 00:05:48,169
Mitch makes antimatter rocket would

117
00:05:54,459 --> 00:05:52,190
actually be terribly inefficient but

118
00:05:56,649 --> 00:05:54,469
that assumes you're just burning the

119
00:06:02,110 --> 00:05:56,659
matter antimatter makes in a reaction

120
00:06:04,480 --> 00:06:02,120
chamber ah the trick is to pre

121
00:06:08,050 --> 00:06:04,490
accelerate the particles you're going to

122
00:06:10,629 --> 00:06:08,060
annihilate as in a particle accelerator

123
00:06:13,510 --> 00:06:10,639
on earth you accelerate both the proton

124
00:06:16,330 --> 00:06:13,520
and the antiproton to high speed but in

125
00:06:18,100 --> 00:06:16,340
the same direction not ramming them into

126
00:06:21,909 --> 00:06:18,110
each other the way we do for experiments

127
00:06:25,600 --> 00:06:21,919
they annihilate in at high speed the

128
00:06:29,260 --> 00:06:25,610
reaction products inherit that center of

129
00:06:31,749 --> 00:06:29,270
mass motion and then you put in a

130
00:06:35,050 --> 00:06:31,759
retrieval stage the stuff that you can

131
00:06:38,559 --> 00:06:35,060
interact with you capture reprocess the

132
00:06:41,290 --> 00:06:38,569
energy use it to power the acceleration

133
00:06:44,290 --> 00:06:41,300
for the next particle pair meanwhile the

134
00:06:46,419 --> 00:06:44,300
neutrinos escape all of the momentum

135
00:06:48,609 --> 00:06:46,429
that has been put into them by the pre

136
00:06:56,049 --> 00:06:48,619
acceleration is just carried out of the

137
00:07:00,459 --> 00:06:56,059
chamber and you get a net thrust I'm

138
00:07:02,469 --> 00:07:00,469

going to skip quickly over the math here

139
00:07:05,980 --> 00:07:02,479
it we can refer to it in question two

140
00:07:10,570 --> 00:07:05,990
and answer if people really want but

141
00:07:13,899 --> 00:07:10,580
this graphic illustrates the drive

142
00:07:16,529 --> 00:07:13,909
attributes and a perhaps somewhat more

143
00:07:21,010 --> 00:07:16,539
accessible way down here at the bottom

144
00:07:25,420 --> 00:07:21,020
I've plotted the fraction of retrievable

145
00:07:28,389 --> 00:07:25,430
energy the amount of Annihilation energy

146
00:07:31,689 --> 00:07:28,399
that can be captured and used and that

147
00:07:34,629 --> 00:07:31,699
actually depends on how big your engine

148
00:07:36,669 --> 00:07:34,639
is and how much free path you have for

149
00:07:39,189 --> 00:07:36,679
intermediate reaction products to decay

150
00:07:42,459 --> 00:07:39,199
if something is still a Payan of some

151
00:07:45,219 --> 00:07:42,469
sort you can intercept it and use it it

152
00:07:49,179 --> 00:07:45,229
will decay naturally into neutrinos and

153
00:07:51,219 --> 00:07:49,189
photons and that that's that's where

154
00:07:57,159 --> 00:07:51,229
those neutrinos come from it's a process

155
00:08:02,129 --> 00:07:57,169
that takes time and requires a certain

156
00:08:04,689 --> 00:08:02,139
amount of free path to be completed now

157
00:08:08,079 --> 00:08:04,699
fortunately the math on the previous

158
00:08:11,859 --> 00:08:08,089
page indicates that the higher the mass

159
00:08:14,739 --> 00:08:11,869
retention that is the fewer neutrino

160
00:08:17,409 --> 00:08:14,749
decays you allow the higher your

161
00:08:22,600 --> 00:08:17,419
effective exhaust velocity the amount of

162
00:08:24,519 --> 00:08:22,610
thrust you get per unit of fuel that

163
00:08:26,409 --> 00:08:24,529

this is a good thing because that means

164
00:08:30,909 --> 00:08:26,419
that the smaller your engine the more

165
00:08:34,779 --> 00:08:30,919
powerful and efficient it can be just

166
00:08:38,969 --> 00:08:34,789
for comparison a allene mix antimatter

167
00:08:42,100 --> 00:08:38,979
rocket where you're doing simple a

168
00:08:44,980 --> 00:08:42,110
burning like effect and have perhaps 5%

169
00:08:48,309 --> 00:08:44,990
antimatter would have about this thrust

170
00:08:51,280 --> 00:08:48,319
to mass ratio an ideal fusion rocket

171
00:08:52,180 --> 00:08:51,290
would be down here an ideal fission

172
00:08:54,280 --> 00:08:52,190
rocket would be

173
00:08:56,500 --> 00:08:54,290
down here and the chemical rockets that

174
00:08:58,480 --> 00:08:56,510
were actually building nowadays would be

175
00:09:05,230 --> 00:08:58,490
so far down into the corner that there's

176
00:09:07,870 --> 00:09:05,240
no room for the font now what that means

177
00:09:15,400 --> 00:09:07,880
in terms of the performance of such a

178
00:09:19,560 --> 00:09:15,410
drive system if oh sorry I overshot this

179
00:09:23,560 --> 00:09:19,570
shaded area here shows the approximate

180
00:09:26,530 --> 00:09:23,570
regime for an engine of reasonable size

181
00:09:28,960 --> 00:09:26,540
a few meters across and you can see that

182
00:09:31,120 --> 00:09:28,970
our effective exhaust velocity is indeed

183
00:09:35,890 --> 00:09:31,130
very close to the ultimate possible

184
00:09:39,460 --> 00:09:35,900
limit a vehicle with a drive of this

185
00:09:42,580 --> 00:09:39,470
type if it made a constant 1g thrust

186
00:09:46,720 --> 00:09:42,590
trip from the moon to the earth it would

187
00:09:49,450 --> 00:09:46,730
use up 0.42 kilograms of fuel mass for

188
00:09:52,480 --> 00:09:49,460

each metric tonne a vehicle mass that's

189
00:09:55,600 --> 00:09:52,490
about 1 pound of fuel on eighth of a

190
00:09:59,980 --> 00:09:55,610
gallon to fly your car from the moon to

191
00:10:02,740 --> 00:09:59,990
the earth if a vehicle had a one to one

192
00:10:06,970 --> 00:10:02,750
mass ratio meaning that the fuel tank

193
00:10:10,980 --> 00:10:06,980
holds as much as the payload it could

194
00:10:13,720 --> 00:10:10,990
thrust at 1g continuously for 245 days

195
00:10:16,330 --> 00:10:13,730
this is the kind of figure people are

196
00:10:19,620 --> 00:10:16,340
talking about for interstellar travel by

197
00:10:21,220 --> 00:10:19,630
conventional means through normal space

198
00:10:23,800 --> 00:10:21,230
whatever we might think about

199
00:10:26,860 --> 00:10:23,810
interstellar travel this obviously gives

200
00:10:33,340 --> 00:10:26,870
us ample power for maneuvering and

201
00:10:39,290 --> 00:10:36,999
so in terms of empirical consequences

202
00:10:42,259 --> 00:10:39,300
detecting neutrinos is extremely

203
00:10:45,019 --> 00:10:42,269
difficult but there have been neutrino

204
00:10:46,309 --> 00:10:45,029
detectors in operation some of them are

205
00:10:48,379 --> 00:10:46,319
actually being called neutrino

206
00:10:52,910 --> 00:10:48,389
telescopes these days because they

207
00:10:55,730 --> 00:10:52,920
detect astronomical events literally for

208
00:11:01,720 --> 00:10:55,740
decades they had already established a

209
00:11:04,460 --> 00:11:01,730
solar neutrino problem in the late 1970s

210
00:11:07,489 --> 00:11:04,470
now most of the output of a neutrino

211
00:11:10,639 --> 00:11:07,499
drive will be muon neutrinos because

212
00:11:13,850 --> 00:11:10,649
those are produced by the first step in

213
00:11:15,889 --> 00:11:13,860

the decay cascade and we recall that you

214
00:11:17,869 --> 00:11:15,899
want to keep the decay cascade short

215
00:11:22,100 --> 00:11:17,879
because that's what makes the drive more

216
00:11:23,900 --> 00:11:22,110
efficient however the solution to the

217
00:11:25,910 --> 00:11:23,910
solar neutrino problem that I mentioned

218
00:11:30,110 --> 00:11:25,920
a moment ago is that neutrinos oscillate

219
00:11:32,150 --> 00:11:30,120
they change identity muon neutrinos will

220
00:11:33,949 --> 00:11:32,160
over a sufficiently long flight path

221
00:11:37,040 --> 00:11:33,959
some fraction of them will transform

222
00:11:40,389 --> 00:11:37,050
into electron neutrinos which can be

223
00:11:43,100 --> 00:11:40,399
picked up by the detectors so this

224
00:11:47,210 --> 00:11:43,110
postulates the possibility of a very

225
00:11:50,929 --> 00:11:47,220
simple retrospective test for whether

226
00:11:53,030 --> 00:11:50,939
vehicles that we see do or that we think

227
00:11:56,090 --> 00:11:53,040
we see doing violent maneuvers in

228
00:11:59,210 --> 00:11:56,100
Earth's atmosphere are being powered by

229
00:12:00,829 --> 00:11:59,220
neutrino drives simply plot the

230
00:12:03,949 --> 00:12:00,839
direction of the maneuvers in

231
00:12:07,009 --> 00:12:03,959
three-dimensional space no note what

232
00:12:09,769 --> 00:12:07,019
direction they're accelerating in plot

233
00:12:11,629 --> 00:12:09,779
the opposite direction ignoring trivial

234
00:12:14,150 --> 00:12:11,639
obstacles like a few thousand miles of

235
00:12:19,009 --> 00:12:14,160
rock and see if they intersect a

236
00:12:20,660 --> 00:12:19,019
neutrino telescope if they do consult

237
00:12:22,699 --> 00:12:20,670
their records and find out if they got a

238
00:12:26,059 --> 00:12:22,709

blip of neutrino events at the

239
00:12:28,579 --> 00:12:26,069
appropriate time I have no idea how such

240
00:12:33,259 --> 00:12:28,589
a test would come out but at least it's

241
00:12:38,749 --> 00:12:33,269
a test that's doable there are also some

242
00:12:41,389 --> 00:12:38,759
more practical consequences antimatter

243
00:12:44,059 --> 00:12:41,399
is a tremendously rich energy storage

244
00:12:46,420 --> 00:12:44,069
system there is a lot of storage that

245
00:12:49,930 --> 00:12:46,430
stored energy in such a drive equal

246
00:12:51,970 --> 00:12:49,940
mc-squared a vehicle that crashes or

247
00:12:56,860 --> 00:12:51,980
even just loses whatever its containment

248
00:13:01,510 --> 00:12:56,870
system is is going to explode with a

249
00:13:04,840 --> 00:13:01,520
great deal of power even a kilogram of

250
00:13:07,690 --> 00:13:04,850
so or or so of antimatter is going to be

251
00:13:09,550 --> 00:13:07,700
a multi Megaton blast among other things

252
00:13:11,889 --> 00:13:09,560
this means that shooting them down

253
00:13:16,990 --> 00:13:11,899
doesn't sound like a very good idea if

254
00:13:19,720 --> 00:13:17,000
they're using this drive off hand the

255
00:13:23,139 --> 00:13:19,730
only way I can think of to avoid a

256
00:13:25,900 --> 00:13:23,149
tremendous explosion on upon crash

257
00:13:28,750 --> 00:13:25,910
landing is if the vehicle has already

258
00:13:30,400 --> 00:13:28,760
run out of fuel which when you think

259
00:13:37,120 --> 00:13:30,410
about it is a pretty good reason for a

260
00:13:39,880 --> 00:13:37,130
crash landing to happen just as a note

261
00:13:42,160 --> 00:13:39,890
for possible implications there's still

262
00:13:46,630 --> 00:13:42,170
speculation about what the Tunguska

263
00:13:48,280 --> 00:13:46,640

explosion in 1908 was but the estimated

264
00:13:49,990 --> 00:13:48,290
power of the blast court would

265
00:13:52,690 --> 00:13:50,000
correspond to the amount of antimatter

266
00:13:59,620 --> 00:13:52,700
it would power a small vehicle for a few

267
00:14:01,360 --> 00:13:59,630
hours of haiji maneuvering so if a what

268
00:14:03,160 --> 00:14:01,370
one can only imagine what a large

269
00:14:05,829 --> 00:14:03,170
vehicle powered for more than a few

270
00:14:10,960 --> 00:14:05,839
hours of maneuvers would what would

271
00:14:15,730 --> 00:14:10,970
produce if something bad happened so

272
00:14:21,010 --> 00:14:15,740
that brings me to the end of my talk and

273
00:14:32,830 --> 00:14:30,820
a couple of questions so just a detail

274
00:14:36,010 --> 00:14:32,840
first you talked about efficiency

275
00:14:39,090 --> 00:14:36,020
improvement from the 30% to more by pre

276
00:14:41,890 --> 00:14:39,100
accelerating the matter/antimatter mix

277
00:14:44,590 --> 00:14:41,900
but from conservation of momentum it

278
00:14:48,040 --> 00:14:44,600
would seem that whatever you gained from

279
00:14:51,340 --> 00:14:48,050
the increase by pre accelerating you've

280
00:14:53,740 --> 00:14:51,350
lost by doing the pre accelerating let

281
00:14:56,140 --> 00:14:53,750
me let me just ask add something to this

282
00:15:00,460 --> 00:14:56,150
and then I'll get off the microphone a

283
00:15:02,890 --> 00:15:00,470
second thing related is that if we are

284
00:15:06,250 --> 00:15:02,900
to believe the UFO sightings these

285
00:15:09,090 --> 00:15:06,260
spaceships can make right angle turns

286
00:15:12,540 --> 00:15:09,100
and so on so any sort of immense

287
00:15:16,080 --> 00:15:12,550
acceleration from any sort of inertial

288
00:15:18,400 --> 00:15:16,090

accelerator would slam the poor

289
00:15:21,270 --> 00:15:18,410
inhabitants of the of the spaceship

290
00:15:24,730 --> 00:15:21,280
against the wall at with tremendous

291
00:15:27,250 --> 00:15:24,740
velocity therefore it seems like some

292
00:15:30,100 --> 00:15:27,260
sort of drive would have to turn off

293
00:15:32,470 --> 00:15:30,110
inertia rather than use it and then

294
00:15:35,440 --> 00:15:32,480
finally given what you've talked about

295
00:15:40,420 --> 00:15:35,450
with this very efficient drive how about

296
00:15:43,000 --> 00:15:40,430
looking for a new green technology okay

297
00:15:44,770 --> 00:15:43,010
to address those points one after

298
00:15:46,930 --> 00:15:44,780
another what happens with the pre

299
00:15:50,860 --> 00:15:46,940
acceleration is that because the

300
00:15:54,010 --> 00:15:50,870
neutrinos escape the portion of the

301
00:15:55,690 --> 00:15:54,020
imparted momentum that corresponds to

302
00:15:58,330 --> 00:15:55,700
their share of the total mass energy

303
00:16:01,090 --> 00:15:58,340
just leaves the system that's how you

304
00:16:03,580 --> 00:16:01,100
get thrust in terms of protection

305
00:16:06,010 --> 00:16:03,590
against high G maneuvers

306
00:16:07,780 --> 00:16:06,020
okay geometrically there's no such thing

307
00:16:11,410 --> 00:16:07,790
as a right angle turn it may require

308
00:16:16,230 --> 00:16:11,420
enormous acceleration but there is going

309
00:16:23,280 --> 00:16:20,260
writing about ways to protect against

310
00:16:27,520 --> 00:16:23,290
high accelerations is another issue but

311
00:16:30,820 --> 00:16:27,530
in principle we we think we can already

312
00:16:34,510 --> 00:16:30,830
imagine ways to shield human astronauts

313
00:16:36,550 --> 00:16:34,520

from accelerations up to 100 g or so

314
00:16:39,520 --> 00:16:36,560
we don't we are missing some of the

315
00:16:41,710 --> 00:16:39,530
chemical and biochemical technology for

316
00:16:46,180 --> 00:16:41,720
that but it's it seems to be a solvable

317
00:16:48,280 --> 00:16:46,190
problem and I did not want to try to

318
00:16:50,610 --> 00:16:48,290
branch into too many areas of technology

319
00:16:53,640 --> 00:16:50,620
in terms of a green technology

320
00:16:56,530 --> 00:16:53,650
antimatter has the drawback that it is a

321
00:16:58,330 --> 00:16:56,540
secondary fuel source

322
00:17:02,050 --> 00:16:58,340
it is a storage system rather than a

323
00:17:03,870 --> 00:17:02,060
power generation system okay Bernie and

324
00:17:06,340 --> 00:17:03,880
then we'll go to that side of the room

325
00:17:10,360 --> 00:17:06,350
I'm not surprised to hear you say that

326
00:17:12,400 --> 00:17:10,370
the most efficient form of caution is by

327
00:17:14,650 --> 00:17:12,410
having very high exhaust velocity but

328
00:17:16,630 --> 00:17:14,660
the ratio of the momentum to the energy

329
00:17:18,610 --> 00:17:16,640
go that's the inverse of the velocity

330
00:17:19,210 --> 00:17:18,620
which is the opposite of what you what

331
00:17:22,840 --> 00:17:19,220
you want

332
00:17:26,290 --> 00:17:22,850
ah the most efficient okay here I am

333
00:17:28,270 --> 00:17:26,300
turn casting efficiency in terms of how

334
00:17:32,590 --> 00:17:28,280
much Delta V can you get for a certain

335
00:17:35,620 --> 00:17:32,600
mass of fuel the higher the higher your

336
00:17:38,200 --> 00:17:35,630
exhaust velocity the less mass you use

337
00:17:40,870 --> 00:17:38,210
up but the more energy you expend and

338
00:17:43,480 --> 00:17:40,880

this is simply a fact of life about the

339
00:17:45,430 --> 00:17:43,490
way reaction drives work and the second

340
00:17:47,380 --> 00:17:45,440
question is back to what garrett alluded

341
00:17:49,450 --> 00:17:47,390
to that the reason you gave me the

342
00:17:50,770 --> 00:17:49,460
neutrinos to go out in one direction the

343
00:17:52,330 --> 00:17:50,780
direction that you want is because

344
00:17:54,040 --> 00:17:52,340
you're pre accelerating the the

345
00:17:56,350 --> 00:17:54,050
antimatter and so you've just

346
00:17:58,420 --> 00:17:56,360
transferred the acceleration process to

347
00:18:00,880 --> 00:17:58,430
the antimatter acceleration so there you

348
00:18:03,790 --> 00:18:00,890
have the same problem the same problem

349
00:18:07,480 --> 00:18:03,800
of not being able to get around Newton's

350
00:18:13,240 --> 00:18:07,490
third law uh the the whole point here is

351
00:18:15,670 --> 00:18:13,250
to work with Newton's third law if you

352
00:18:17,650 --> 00:18:15,680
had a fuel lump and you simply shook it

353
00:18:20,200 --> 00:18:17,660
back and forth accelerated it and then

354
00:18:23,410 --> 00:18:20,210
caught it and stopped it you would get

355
00:18:25,570 --> 00:18:23,420
nowhere because you can use this

356
00:18:27,670 --> 00:18:25,580
annihilation transformation to convert

357
00:18:31,450 --> 00:18:27,680
part of it into a form that simply

358
00:18:34,510 --> 00:18:31,460
escapes out the back the amount of

359
00:18:38,200 --> 00:18:34,520
thrust you produce in the acceleration

360
00:18:41,020 --> 00:18:38,210
phase is not completely neutralized by

361
00:18:43,150 --> 00:18:41,030
the catching process where you intercept

362
00:18:45,030 --> 00:18:43,160
the portion of the entry of the energy

363
00:18:48,250 --> 00:18:45,040

that still interacts with normal matter

364
00:18:51,010 --> 00:18:48,260
then you're using that energy to

365
00:18:52,450 --> 00:18:51,020
accelerate the next lump in the train in

366
00:18:54,790 --> 00:18:52,460
a realistic system this would be a

367
00:18:58,090 --> 00:18:54,800
continuous process but thinking of it as

368
00:19:02,380 --> 00:18:58,100
a sequence make makes the concepts a bit

369
00:19:04,690 --> 00:19:02,390
easier to follow okay if stoian zarg is

370
00:19:09,490 --> 00:19:04,700
in the room can you start coming up okay

371
00:19:11,110 --> 00:19:09,500
and do grant oh yes sir question I think

372
00:19:13,510 --> 00:19:11,120
this summer we'll learn a little bit

373
00:19:15,520 --> 00:19:13,520
more about what went on in Cusco when

374
00:19:17,890 --> 00:19:15,530
the Italian team digs down into that

375
00:19:20,920 --> 00:19:17,900
lake to find out whether or not it was

376
00:19:23,380 --> 00:19:20,930
from a comet that hit or not so I look

377
00:19:26,380 --> 00:19:23,390
forward to seeing that result I have a

378
00:19:28,750 --> 00:19:26,390
comment on the as a compulsion thing

379
00:19:31,000 --> 00:19:28,760
here neutrinos are really tough to

380
00:19:32,980 --> 00:19:31,010
detect and these detectors I'm aware of

381
00:19:35,140 --> 00:19:32,990
that are deep in mountains only catch a

382
00:19:37,000 --> 00:19:35,150
few hits a year so maybe there's going

383
00:19:39,310 --> 00:19:37,010
to be a change in the technology that

384
00:19:40,990 --> 00:19:39,320
might help increase that hit right now

385
00:19:42,540 --> 00:19:41,000
you might want to comment on that and

386
00:19:44,590 --> 00:19:42,550
the third comment I like to make is

387
00:19:47,530 --> 00:19:44,600
cosmologists do a lot of talk about

388
00:19:49,420 --> 00:19:47,540

eight years so 90% of the universe I

389
00:19:52,300 --> 00:19:49,430
think it's 96% of the universe being

390
00:19:54,460 --> 00:19:52,310
dark matter is any theoretical work done

391
00:19:59,710 --> 00:19:54,470
and how we might be able to capture dark

392
00:20:05,020 --> 00:19:59,720
matter okay I love these multi-part

393
00:20:06,790 --> 00:20:05,030
questions I am NOT trying to make a case

394
00:20:09,610 --> 00:20:06,800
that the Tunguska blast was an

395
00:20:12,220 --> 00:20:09,620
antimatter explosion I simply wished to

396
00:20:14,680 --> 00:20:12,230
point to it as an example of the type of

397
00:20:17,560 --> 00:20:14,690
event we're looking at in terms of

398
00:20:20,740 --> 00:20:17,570
neutrino detection that is constrained

399
00:20:24,280 --> 00:20:20,750
by particle interaction cross-sections

400
00:20:26,590 --> 00:20:24,290
which at the moment we have no idea how

401
00:20:29,110 --> 00:20:26,600
to manipulate and there may in fact be

402
00:20:40,900 --> 00:20:29,120
no way even in principle to manipulate

403
00:20:43,750 --> 00:20:40,910
them Oh dark matter we don't know what

404
00:20:45,520 --> 00:20:43,760
dark matter is but whatever it is it

405
00:20:47,560 --> 00:20:45,530
presumably shares the properties of

406
00:20:51,250 --> 00:20:47,570
neutrinos and having very low

407
00:20:54,610 --> 00:20:51,260
interaction prosection z-- therefore

408
00:20:56,680 --> 00:20:54,620
being able to tap it for energy looks

409
00:20:59,110 --> 00:20:56,690
like an exceedingly remote prospect at

410
00:21:00,820 --> 00:20:59,120
this time I always bend the rules a

411
00:21:02,140 --> 00:21:00,830
little bit when younger people want to

412
00:21:10,330 --> 00:21:02,150
participate so we have one more

413
00:21:14,350 --> 00:21:10,340

question I was wondering how you would

414
00:21:19,030 --> 00:21:14,360
capture those particles to reuse them to

415
00:21:23,490 --> 00:21:19,040
get energy to use the other particles

416
00:21:29,620 --> 00:21:26,950
okay how do we have how do we actually

417
00:21:34,270 --> 00:21:29,630
do the capture and reprocessing that I

418
00:21:37,660 --> 00:21:34,280
refer to so glibly the the answer is

419
00:21:39,580 --> 00:21:37,670
that this is where I wave my hands with

420
00:21:42,700 --> 00:21:39,590
the phrase of sufficiently advanced

421
00:21:45,370 --> 00:21:42,710
technology we know that it's physically

422
00:21:47,020 --> 00:21:45,380
possible in principle we don't know how