



1
00:00:07,430 --> 00:00:02,659
to fly your car from the moon to the

2
00:00:10,459 --> 00:00:07,440
earth if a vehicle had a one-to-one mass

3
00:00:14,240 --> 00:00:10,469
ratio meaning that the fuel tank holds

4
00:00:19,220 --> 00:00:14,250
as much as the payload it could thrust

5
00:00:21,349 --> 00:00:19,230
at 1g continuously for 245 days this is

6
00:00:23,390 --> 00:00:21,359
the kind of figure people are talking

7
00:00:26,679 --> 00:00:23,400
about for interstellar travel by

8
00:00:28,250 --> 00:00:26,689
conventional means through normal space

9
00:00:30,830 --> 00:00:28,260
whatever we might think about

10
00:00:33,920 --> 00:00:30,840
interstellar travel this obviously gives

11
00:00:41,630 --> 00:00:33,930
us ample power for maneuvering and

12
00:00:44,080 --> 00:00:41,640
travel within the solar system so in

13
00:00:46,340 --> 00:00:44,090

terms of empirical consequences

14

00:00:49,310 --> 00:00:46,350

detecting neutrinos is extremely

15

00:00:52,040 --> 00:00:49,320

difficult but there have been neutrino

16

00:00:53,360 --> 00:00:52,050

detectors in operation some of them are

17

00:00:55,430 --> 00:00:53,370

actually being called neutrino

18

00:00:59,959 --> 00:00:55,440

telescopes these days because they

19

00:01:02,750 --> 00:00:59,969

detect astronomical events literally for

20

00:01:08,740 --> 00:01:02,760

decades they had already established a

21

00:01:11,510 --> 00:01:08,750

solar neutrino problem in the late 1970s

22

00:01:14,539 --> 00:01:11,520

now most of the output of a neutrino

23

00:01:17,660 --> 00:01:14,549

drive will be muon neutrinos because

24

00:01:20,899 --> 00:01:17,670

those are produced by the first step in

25

00:01:22,940 --> 00:01:20,909

the decay cascade and we recall that you

26

00:01:24,950 --> 00:01:22,950

want to keep the decay cascade short

27

00:01:29,149 --> 00:01:24,960

because that's what makes the drive more

28

00:01:30,800 --> 00:01:29,159

efficient ah however the solution to the

29

00:01:32,960 --> 00:01:30,810

solar neutrino problem that I mentioned

30

00:01:37,160 --> 00:01:32,970

a moment ago is that neutrinos oscillate

31

00:01:39,200 --> 00:01:37,170

they change identity muon neutrinos will

32

00:01:41,030 --> 00:01:39,210

over a sufficiently long flight path

33

00:01:44,120 --> 00:01:41,040

some fraction of them will transform

34

00:01:47,440 --> 00:01:44,130

into electron neutrinos which can be

35

00:01:50,149 --> 00:01:47,450

picked up by the detectors so this

36

00:01:54,260 --> 00:01:50,159

postulates the possibility of a very

37

00:01:57,950 --> 00:01:54,270

simple retrospective test for whether

38

00:02:00,080 --> 00:01:57,960

vehicles that we see deut or that we

39

00:02:03,139 --> 00:02:00,090

think we see doing violent maneuvers in

40

00:02:06,260 --> 00:02:03,149

Earth's atmosphere are being powered by

41

00:02:07,850 --> 00:02:06,270

neutrino drives simply plot the

42

00:02:10,999 --> 00:02:07,860

direction of the maneuvers in

43

00:02:13,309 --> 00:02:11,009

three-dimensional space no note what

44

00:02:16,309 --> 00:02:13,319

direction they're accelerating in

45

00:02:18,259 --> 00:02:16,319

plot the opposite direction ignoring

46

00:02:20,959 --> 00:02:18,269

trivial obstacles like a few thousand

47

00:02:26,059 --> 00:02:20,969

miles of rock and see if they intersect

48

00:02:27,709 --> 00:02:26,069

a neutrino telescope if they do consult

49

00:02:29,750 --> 00:02:27,719

their records and find out if they got a

50

00:02:33,110 --> 00:02:29,760

blip of neutrino events at the

51
00:02:35,629 --> 00:02:33,120
appropriate time I have no idea how such

52
00:02:40,280 --> 00:02:35,639
a test would come out but at least it's

53
00:02:44,800 --> 00:02:40,290
a test that's doable there are also some

54
00:02:47,990 --> 00:02:44,810
more practical consequences um

55
00:02:50,509 --> 00:02:48,000
antimatter is a tremendously rich energy

56
00:02:53,420 --> 00:02:50,519
storage system there is a lot of storage

57
00:02:56,929 --> 00:02:53,430
stored energy in such a drive equals

58
00:02:58,849 --> 00:02:56,939
mc-squared a vehicle that crashes or

59
00:03:04,039 --> 00:02:58,859
even just loses whatever its containment

60
00:03:08,569 --> 00:03:04,049
system is is going to explode with a

61
00:03:11,899 --> 00:03:08,579
great deal of power even a kilogram of

62
00:03:14,959 --> 00:03:11,909
so or or so of antimatter is going to be

63
00:03:16,429 --> 00:03:14,969

a multi Megaton blast on other things

64

00:03:18,559 --> 00:03:16,439

this means that shooting them down

65

00:03:24,050 --> 00:03:18,569

doesn't sound like a very good idea if

66

00:03:26,749 --> 00:03:24,060

they're using this drive off hand the

67

00:03:30,199 --> 00:03:26,759

only way I can think of to avoid a

68

00:03:32,990 --> 00:03:30,209

tremendous explosion on upon crash

69

00:03:35,599 --> 00:03:33,000

landing is if the vehicle has already

70

00:03:37,460 --> 00:03:35,609

run out of fuel which when you think

71

00:03:43,939 --> 00:03:37,470

about it is a pretty good reason for a

72

00:03:46,939 --> 00:03:43,949

crash landing to happen just as a note

73

00:03:49,219 --> 00:03:46,949

for possible implications there's still

74

00:03:53,659 --> 00:03:49,229

speculation about what the Tunguska

75

00:03:55,309 --> 00:03:53,669

explosion in 1908 was but the estimated

76

00:03:56,869 --> 00:03:55,319

power of the blast court would

77

00:03:59,749 --> 00:03:56,879

correspond to the amount of antimatter

78

00:04:05,679 --> 00:03:59,759

it would power a small vehicle for a few

79

00:04:08,420 --> 00:04:05,689

hours of Hygiene maneuvering ah so if a

80

00:04:10,039 --> 00:04:08,430

one one can only imagine what a large

81

00:04:12,740 --> 00:04:10,049

vehicle powered for more than a few

82

00:04:17,990 --> 00:04:12,750

hours of maneuvers would what would

83

00:04:20,470 --> 00:04:18,000

produce if something bad happened um so

84

00:04:35,210 --> 00:04:23,300

brings me to the end of my talk and I'm

85

00:04:38,510 --> 00:04:35,220

happy to answer questions a couple of

86

00:04:40,670 --> 00:04:38,520

questions so just a detail first you

87

00:04:43,070 --> 00:04:40,680

talked about efficiency improvement from

88

00:04:46,120 --> 00:04:43,080

the thirty percent to more by pre

89

00:04:48,920 --> 00:04:46,130

accelerating the matter-antimatter mix

90

00:04:51,230 --> 00:04:48,930

but from conservation of momentum it

91

00:04:55,100 --> 00:04:51,240

would seem that whatever you gain from

92

00:04:58,400 --> 00:04:55,110

the increase by pre accelerating you've

93

00:05:00,770 --> 00:04:58,410

lost by doing the pre accelerating let

94

00:05:03,200 --> 00:05:00,780

me let me just ask add something to this

95

00:05:07,490 --> 00:05:03,210

and then I'll get off the microphone a

96

00:05:09,890 --> 00:05:07,500

second thing related is that if we are

97

00:05:13,310 --> 00:05:09,900

to believe the UFO sightings these

98

00:05:16,150 --> 00:05:13,320

spaceships can make right angle turns

99

00:05:19,600 --> 00:05:16,160

and so on so any sort of immense

100

00:05:23,140 --> 00:05:19,610

acceleration from any sort of inertial

101
00:05:25,880 --> 00:05:23,150
accelerator would slam the poor

102
00:05:29,330 --> 00:05:25,890
inhabitants of the the spaceship against

103
00:05:32,270 --> 00:05:29,340
the wall at with tremendous velocity

104
00:05:34,700 --> 00:05:32,280
therefore it seems like some sort of

105
00:05:37,430 --> 00:05:34,710
drive would have to turn off inertia

106
00:05:40,160 --> 00:05:37,440
rather than use it and then finally

107
00:05:42,830 --> 00:05:40,170
given what you've talked about with this

108
00:05:47,540 --> 00:05:42,840
very efficient drive how about looking

109
00:05:50,060 --> 00:05:47,550
for a new green technology okay to

110
00:05:52,790 --> 00:05:50,070
address those points one after another

111
00:05:56,260 --> 00:05:52,800
what happens with the pre acceleration

112
00:06:00,010 --> 00:05:56,270
is that because the neutrinos escape the

113
00:06:02,180 --> 00:06:00,020

portion of the imparted momentum that

114

00:06:04,730 --> 00:06:02,190

corresponds to their share of the total

115

00:06:07,430 --> 00:06:04,740

mass energy just leaves the system

116

00:06:10,630 --> 00:06:07,440

that's how you get thrust in terms of

117

00:06:12,830 --> 00:06:10,640

protection against high-gee maneuvers up

118

00:06:14,840 --> 00:06:12,840

okay geometrically there's no such thing

119

00:06:18,470 --> 00:06:14,850

as a right angle turn it may require

120

00:06:23,290 --> 00:06:18,480

enormous acceleration but there is going

121

00:06:30,170 --> 00:06:27,320

writing about ways to protect against

122

00:06:32,839 --> 00:06:30,180

high accelerations is another issue but

123

00:06:35,629 --> 00:06:32,849

in principle

124

00:06:38,299 --> 00:06:35,639

we we think we can already imagine ways

125

00:06:41,809 --> 00:06:38,309

to shield human astronauts from

126

00:06:44,389 --> 00:06:41,819

accelerations up to 100 g or so we don't

127

00:06:47,119 --> 00:06:44,399

we are missing some of the chemical and

128

00:06:50,959 --> 00:06:47,129

biochemical technology for that but it's

129

00:06:53,899 --> 00:06:50,969

it seems to be a solvable problem and I

130

00:06:56,540 --> 00:06:53,909

did not want to try to branch into too

131

00:06:59,149 --> 00:06:56,550

many areas of Technology in terms of a

132

00:07:02,959 --> 00:06:59,159

green technology antimatter has the

133

00:07:05,059 --> 00:07:02,969

drawback that it is a secondary a fuel

134

00:07:07,969 --> 00:07:05,069

source it is a storage system rather

135

00:07:10,100 --> 00:07:07,979

than a power generation system okay

136

00:07:12,709 --> 00:07:10,110

Bernie and then we'll go to that side of

137

00:07:16,669 --> 00:07:12,719

the room I'm little surprised to hear

138

00:07:17,839 --> 00:07:16,679

you say that the most efficient form of

139

00:07:20,540 --> 00:07:17,849

propulsion is by having very high

140

00:07:22,730 --> 00:07:20,550

exhaust velocity but the ratio of the

141

00:07:24,739 --> 00:07:22,740

momentum to the energy it has the

142

00:07:27,679 --> 00:07:24,749

inverse of the velocity which is the

143

00:07:30,489 --> 00:07:27,689

opposite what you what you want ah the

144

00:07:33,499 --> 00:07:30,499

most efficient okay here i am turn

145

00:07:35,540 --> 00:07:33,509

casting efficiency in terms of how much

146

00:07:39,589 --> 00:07:35,550

delta v can you get for a certain mass

147

00:07:42,649 --> 00:07:39,599

of fuel the higher the higher your

148

00:07:45,290 --> 00:07:42,659

exhaust velocity the less mass you use

149

00:07:47,929 --> 00:07:45,300

up but the more energy you expend and

150

00:07:50,540 --> 00:07:47,939

this is simply a fact of life about the

151
00:07:52,489 --> 00:07:50,550
way reaction drives work and the second

152
00:07:54,439 --> 00:07:52,499
question is back to what Garrett alluded

153
00:07:55,609 --> 00:07:54,449
to that the reason you gave you a

154
00:07:57,829 --> 00:07:55,619
neutrino is to go out in one direction

155
00:08:00,379 --> 00:07:57,839
the direction that you want is because

156
00:08:01,609 --> 00:08:00,389
your pre accelerating the antimatter and

157
00:08:04,040 --> 00:08:01,619
so you've just transferred the

158
00:08:05,929 --> 00:08:04,050
acceleration process to the antimatter

159
00:08:09,079 --> 00:08:05,939
acceleration so there you have the same

160
00:08:11,889 --> 00:08:09,089
problem the same problem of not being

161
00:08:15,850 --> 00:08:11,899
able to get around Newton's third law

162
00:08:21,079 --> 00:08:15,860
the the whole point here is to work with

163
00:08:23,149 --> 00:08:21,089

Newton's third law um if you had a fuel

164

00:08:25,069 --> 00:08:23,159

lump and you simply shook it back and

165

00:08:27,730 --> 00:08:25,079

forth accelerated it and then caught it

166

00:08:31,029 --> 00:08:27,740

and stopped it you would get nowhere

167

00:08:33,199 --> 00:08:31,039

because you can use this annihilation

168

00:08:36,050 --> 00:08:33,209

transformation to convert part of it

169

00:08:40,579 --> 00:08:36,060

into a form that simply escapes out the

170

00:08:43,939 --> 00:08:40,589

back the amount of thrust you produce in

171

00:08:46,460 --> 00:08:43,949

the acceleration phase is not completely

172

00:08:48,980 --> 00:08:46,470

neutralized by the catching process

173

00:08:51,170 --> 00:08:48,990

square you intercept the portion of the

174

00:08:53,720 --> 00:08:51,180

inter of the energy that still interacts

175

00:08:56,690 --> 00:08:53,730

with normal matter then you're using

176
00:08:59,210 --> 00:08:56,700
that energy to accelerate the next lump

177
00:09:01,070 --> 00:08:59,220
in the train in a realistic system this

178
00:09:04,040 --> 00:09:01,080
would be a continuous process but

179
00:09:07,670 --> 00:09:04,050
thinking of it as a sequence I may makes

180
00:09:10,100 --> 00:09:07,680
the concepts a bit easier to follow okay

181
00:09:14,500 --> 00:09:10,110
if stones argh is in the room can you

182
00:09:17,120 --> 00:09:14,510
start coming up okay and Dale graph oh

183
00:09:18,710 --> 00:09:17,130
yes sir question I think this summer

184
00:09:21,200 --> 00:09:18,720
will learn a little bit more about what

185
00:09:24,050 --> 00:09:21,210
went on at Tunguska when the italian

186
00:09:26,690 --> 00:09:24,060
team digs down into that Lake to find

187
00:09:28,400 --> 00:09:26,700
out whether or not it was from a comment

188
00:09:31,340 --> 00:09:28,410

I'd hit or not so I look forward to

189

00:09:34,640 --> 00:09:31,350

seeing that result I have a comment on

190

00:09:36,950 --> 00:09:34,650

the as a compulsion thing here neutrinos

191

00:09:38,870 --> 00:09:36,960

are really tough to detect and these

192

00:09:41,000 --> 00:09:38,880

detectors I'm aware of that are deep in

193

00:09:43,010 --> 00:09:41,010

mountains only catch a few hits a year

194

00:09:45,410 --> 00:09:43,020

so maybe there's going to be a change in

195

00:09:46,940 --> 00:09:45,420

the technology that might help increase

196

00:09:49,010 --> 00:09:46,950

that hit right now you might want to

197

00:09:51,410 --> 00:09:49,020

comment on that the third comment I like

198

00:09:53,930 --> 00:09:51,420

to make is cosmologists do a lot of talk

199

00:09:55,310 --> 00:09:53,940

about eight years so ninety percent of

200

00:09:56,780 --> 00:09:55,320

the universe i think is ninety-six

201

00:09:59,600 --> 00:09:56,790

percent of the universe being dark