
TBM

1
00:00:00,000 --> 00:00:10,408
Music

2
00:00:10,443 --> 00:00:11,592
How does the atomic

3
00:00:11,627 --> 00:00:13,401
clock play a role for deep space

4
00:00:13,436 --> 00:00:14,457
navigation? Well today atomic

5
00:00:14,492 --> 00:00:16,409
clocks are central to deep

6
00:00:16,444 --> 00:00:18,297
space navigation it's just

7
00:00:18,332 --> 00:00:19,386
that those clocks are on the

8
00:00:19,421 --> 00:00:22,728
ground. And so an atomic clock

9
00:00:22,763 --> 00:00:25,033
generates a signal and it is sent

10
00:00:25,068 --> 00:00:26,937
through the antennae on the

11
00:00:26,972 --> 00:00:28,952
ground to a spacecraft in deep

12
00:00:28,987 --> 00:00:30,361
space. And that signal is

13
00:00:30,396 --> 00:00:32,201

turned around and received back

14
00:00:32,236 --> 00:00:34,522
at the transmitting. And

15
00:00:34,557 --> 00:00:36,056
with that transmission of the

16
00:00:36,091 --> 00:00:37,418
signal we can do measurements

17
00:00:37,453 --> 00:00:38,680
of that signal. You know how the

18
00:00:38,715 --> 00:00:41,176
doppler shift on the signal

19
00:00:41,211 --> 00:00:43,304
is how we can know how fast

20
00:00:43,339 --> 00:00:45,145
the spacecraft is moving and

21
00:00:45,180 --> 00:00:46,809
how long that signal takes is a

22
00:00:46,844 --> 00:00:48,489
measure of how far that spacecraft

23
00:00:48,524 --> 00:00:51,881
is. So the deep space atomic

24
00:00:51,916 --> 00:00:53,545
clock can change that paradigm.

25
00:00:53,580 --> 00:00:55,289
It can originate the signal

26
00:00:55,324 --> 00:00:57,017
at the earth and it can end

27
00:00:57,052 --> 00:00:58,777
at the spacecraft. Its good

28
00:00:58,812 --> 00:01:00,328
enough, that small clock that

29
00:01:00,363 --> 00:01:02,537
we are building is as stable and

30
00:01:02,572 --> 00:01:04,616
accurate as the ground clock

31
00:01:04,651 --> 00:01:07,321
that originated the signal.

32
00:01:07,356 --> 00:01:08,810
We get to utilize some of the

33
00:01:08,845 --> 00:01:10,313
effiences that the deep space

34
00:01:10,348 --> 00:01:11,769
tracking network has to offer

35
00:01:11,804 --> 00:01:13,481
today. The DSN supports more

36
00:01:13,516 --> 00:01:16,168
downlinks than it does uplink

37
00:01:16,203 --> 00:01:18,328
and so at places like Mars

38
00:01:18,363 --> 00:01:19,769

where we have a number of

39
00:01:19,804 --> 00:01:21,448
spacecraft that are competing for

40
00:01:21,483 --> 00:01:23,304
two-way tracking time... you

41
00:01:23,339 --> 00:01:24,857
don't have to do that anymore.

42
00:01:24,892 --> 00:01:26,713
What does that do for us? well

43
00:01:26,748 --> 00:01:28,425
what we have found with a 2

44
00:01:28,460 --> 00:01:29,961
times increase in our

45
00:01:29,996 --> 00:01:31,369
tracking data for a Mars orbiter,

46
00:01:31,404 --> 00:01:33,544
the orbit information that

47
00:01:33,579 --> 00:01:35,912
we get is improved upon by a

48
00:01:35,947 --> 00:01:38,568
factor of five. One of the things

49
00:01:38,603 --> 00:01:39,768
we are envisioning at Mars is

50
00:01:39,803 --> 00:01:41,977
landing a pin-point lander,

51
00:01:42,012 --> 00:01:43,961
one that can land to a very

52
00:01:43,996 --> 00:01:45,865
precise location (beep sounds)

53
00:01:45,900 --> 00:01:47,081
on the surface of Mars. there's

54
00:01:47,116 --> 00:01:48,392
a lot of steps into making

55
00:01:48,427 --> 00:01:49,657
that happen. One of which is

56
00:01:49,692 --> 00:01:51,800
entering the top of the atomosphere

57
00:01:51,835 --> 00:01:54,360
and taking your entry state

58
00:01:54,395 --> 00:01:55,944
knowledge and onboard flying

59
00:01:55,979 --> 00:01:57,833
a trajectory with that entry

60
00:01:57,868 --> 00:01:59,209
state knowledge. We way in

61
00:01:59,244 --> 00:02:00,842
which we upload that navigation

62
00:02:00,877 --> 00:02:02,298
state today is that we do all

63
00:02:02,333 --> 00:02:03,545

the processing on the ground

64
00:02:03,580 --> 00:02:05,432
in about six or so hours and

65
00:02:05,467 --> 00:02:07,160
before entry we upload a final

66
00:02:07,195 --> 00:02:09,656
nav state to the vehicle. Well

67
00:02:09,691 --> 00:02:11,000
you can imagine after six hours

68
00:02:11,035 --> 00:02:13,240
of flight that solutions is little

69
00:02:13,275 --> 00:02:14,937
stale when you get to the top

70
00:02:14,972 --> 00:02:16,393
of the atmosphere. Well with DSAC

71
00:02:16,428 --> 00:02:18,121
with the measurement happening

72
00:02:18,156 --> 00:02:19,385
onboard you don't have to suffer

73
00:02:19,420 --> 00:02:22,537
that six hour delay. You can be

74
00:02:22,572 --> 00:02:23,752
computing onboard in real time.

75
00:02:23,787 --> 00:02:26,680
And what that does is where the

76
00:02:26,715 --> 00:02:29,417
six hour solution is in error by

77
00:02:29,452 --> 00:02:31,738
a few kilometers, this solution

78
00:02:31,773 --> 00:02:33,609
that's onboard is only off by a

79
00:02:33,644 --> 00:02:35,609
handful meters. that has a real

80
00:02:35,644 --> 00:02:37,993
benefit to decreasing the amount

81
00:02:38,028 --> 00:02:39,689
of propellant you have to carry to

82
00:02:39,724 --> 00:02:41,560
then later fly out the errors

83
00:02:41,595 --> 00:02:44,216
you had when you didn't know where

84
00:02:44,251 --> 00:02:45,528
you were at when you originally

85
00:02:45,563 --> 00:02:46,921
were at the top of the atmosphere.So

86
00:02:46,956 --> 00:02:48,264
that's gonna open up new ways,

87
00:02:48,299 --> 00:02:50,200
new science we are going to be

88
00:02:50,235 --> 00:02:51,480

able to do. In fact it's going

89
00:02:51,515 --> 00:02:52,777
to improve the gravity science we

90
00:02:52,812 --> 00:02:54,281
are going to be able to do at

91
00:02:54,316 --> 00:02:56,169
Mars today. An example of gravity

92
00:02:56,204 --> 00:02:58,216
science improvement that the clock

93
00:02:58,251 --> 00:03:00,042
enables further out is NASA is

94
00:03:00,077 --> 00:03:03,305
envisioning going to Europa, a

95
00:03:03,340 --> 00:03:05,449
moon around Jupiter, and one of the

96
00:03:05,484 --> 00:03:06,968
fundemental things we want to

97
00:03:07,003 --> 00:03:09,545
learn about Europa is if there is an

98
00:03:09,580 --> 00:03:11,450
ocean under the crustal ice that

99
00:03:11,485 --> 00:03:14,153
we see at Europa? Well gravity

100
00:03:14,188 --> 00:03:15,817
science is a way in which we can

101
00:03:15,852 --> 00:03:17,400
make that determination; if there

102
00:03:17,435 --> 00:03:19,177
is an ocean underneath. And to

103
00:03:19,212 --> 00:03:22,296
be able to do the measurement, the

104
00:03:22,331 --> 00:03:24,008
gravity science measurement that

105
00:03:24,043 --> 00:03:26,889
NASA is planning. They're going

106
00:03:26,924 --> 00:03:29,977
to do it, one approach is a

107
00:03:30,012 --> 00:03:31,369
flyby mission. So they will fly by

108
00:03:31,404 --> 00:03:33,561
Europa with a four hour tracking

109
00:03:33,596 --> 00:03:35,449
pass, and then have a thirty day

110
00:03:35,484 --> 00:03:37,944
orbit around Europa, and then

111
00:03:37,979 --> 00:03:39,352
come back again for another flyby.

112
00:03:39,387 --> 00:03:41,753
And do a sequence of thirty or so

113
00:03:41,788 --> 00:03:44,361

of these flybys. Well if we have

114
00:03:44,396 --> 00:03:46,809
the atomic clock on a downlink

115
00:03:46,844 --> 00:03:49,273
signal from that flyby and it's

116
00:03:49,308 --> 00:03:50,680
received at the earth we can do

117
00:03:50,715 --> 00:03:54,072
it at Ka band. and the benefit of

118
00:03:54,107 --> 00:03:55,800
going to Ka band isn't so much

119
00:03:55,835 --> 00:03:57,464
that it has to deal with we can

120
00:03:57,499 --> 00:03:58,873
increase the bandwidth but what

121
00:03:58,908 --> 00:04:01,529
it does do is that it improves the

122
00:04:01,564 --> 00:04:02,633
accuracy of the measurement that

123
00:04:02,668 --> 00:04:04,473
we are taking, and it improves it

124
00:04:04,508 --> 00:04:06,009
by an order of magnitude and that

125
00:04:06,044 --> 00:04:07,832
is fundemental. Its that improvement

126
00:04:07,867 --> 00:04:10,552
in the data quality that will

127
00:04:10,587 --> 00:04:12,313
allow us to determine the gravity