1
00:00:01,200 --> 00:00:03,503
Here on Earth we all
know about gravity.

2
00:00:04,336 --> 00:00:05,805
But what you might
not realize

3
00:00:05,838 --> 00:00:07,707
is that, depending where
you are on the planet,

4
00:00:07,740 --> 00:00:09,976
the strength of gravity
is different.

5
00:00:11,677 --> 00:00:13,646
For example, up here
on a mountain

6
00:00:13,679 --> 00:00:15,048
with all this mass underneath,

7
00:00:15,081 --> 00:00:17,483
gravity is stronger.

8
00:00:18,818 --> 00:00:20,853
Water also has mass.

9
00:00:21,821 --> 00:00:22,922
And the Earth has a
whole lot of water.

10
00:00:22,955 --> 00:00:25,358
It's moving around.
It's changing phases.

11
00:00:25,391 --> 00:00:27,627
If you can track the

change in gravity,

12
00:00:27,660 --> 00:00:28,961
you can track the
change in mass.

13
00:00:28,994 --> 00:00:30,196
And that means you're
understanding

14
00:00:30,229 --> 00:00:31,931
the movement of water.

15
00:00:31,964 --> 00:00:34,000
NASA's about to send the
GRACE Follow-On mission

16
00:00:34,033 --> 00:00:36,102
which will continue
to do just that.

17
00:00:36,135 --> 00:00:39,539
Let's learn about it on this
episode of Crazy Engineering.

18
00:00:39,572 --> 00:00:40,306
[chomp]

19
00:00:40,339 --> 00:00:42,308
[■]

20
00:00:48,314 --> 00:00:49,415
[whoosh]

21
00:00:49,449 --> 00:00:50,983
OK, everybody. We're here
with Neil, he's one of the

22
00:00:51,016 --> 00:00:54,087

key engineers on the
GRACE Follow-On mission.

23
00:00:54,120 --> 00:00:55,521
Neil, thank you so
much for joiining us

24
00:00:55,554 --> 00:00:56,856
and answering our questions.

25
00:00:56,889 --> 00:00:58,257
Why do we call it
"GRACE Follow-On"?

26
00:00:58,290 --> 00:01:01,694
So, GRACE stands for Gravity
Recovery and Climate Experiment.

27
00:01:01,727 --> 00:01:04,831
And we're using gravity to track
water motion around the planet.

28
00:01:04,864 --> 00:01:06,799
And the "Follow-On" because
we've done this before--

29
00:01:06,832 --> 00:01:08,468
and we're doing it again
with two new satellites.

30
00:01:08,501 --> 00:01:11,003
The original GRACE mission
was launched in 2002.

31
00:01:11,036 --> 00:01:13,806
They lasted for 15 years and
provided amazing science

32
00:01:13,839 --> 00:01:15,108
for the scientists.

33
00:01:15,141 --> 00:01:18,311
Both of these missions
have two satellites.

34
00:01:18,344 --> 00:01:20,179
Can you explain to us why
we need two satellites

35
00:01:20,212 --> 00:01:21,314
instead of just one?

36
00:01:21,347 --> 00:01:23,049
So, we need two satellites
because we're trying to

37
00:01:23,082 --> 00:01:25,885
measure very precise, small
amounts of gravity changes

38
00:01:25,918 --> 00:01:27,386
in the Earth.

39
00:01:27,419 --> 00:01:29,655
The Earth is actually lumpy,
when it comes to gravity.

40
00:01:29,688 --> 00:01:31,958
Far away from Earth, gravity's
just a single number.

41
00:01:31,991 --> 00:01:34,861
But as you get closer to
the Earth the gravity changes

42
00:01:34,894 --> 00:01:37,196
because the Himalayas have a
little bit more mass...

43

00:01:37,229 --> 00:01:39,065
certain areas have less mass.

44
00:01:39,098 --> 00:01:41,167
So as the satellite is
orbiting the planet,

45
00:01:41,200 --> 00:01:43,703
as it comes towards a
large mass like a mountain

46
00:01:43,736 --> 00:01:45,171
it actually will speed up.

47
00:01:45,204 --> 00:01:47,340
And then as it leaves
it will slow down.

48
00:01:47,373 --> 00:01:49,408
And so with two satellites,
we're able to measure

49
00:01:49,441 --> 00:01:51,144
the distance between the two.

50
00:01:51,177 --> 00:01:53,079
How far apart are
these satellites?

51
00:01:53,112 --> 00:01:55,281
And just how precise? Do they
have to have knowledge

52
00:01:55,314 --> 00:01:56,482
of each other's position?

53
00:01:56,515 --> 00:01:58,484
We have the satellites at
200 kilometers apart,

54
00:01:58,517 --> 00:02:00,887
but we're measuring down to an
accuracy of a micron level,

55
00:02:00,920 --> 00:02:02,788
which is about a tenth
of a human hair.

56
00:02:02,821 --> 00:02:04,690
That is extremely precise!

57
00:02:04,723 --> 00:02:07,059
It sounds like a very hard
engineering problem.

58
00:02:07,092 --> 00:02:09,228
What's the technology
that lets us do this?

59
00:02:09,261 --> 00:02:12,465
We're using microwave
technologies at about 30 GHz.

60
00:02:12,498 --> 00:02:14,066
Here you see one
of the satellites.

61
00:02:14,099 --> 00:02:16,636
And 200 kilometers away
is the other satellite.

62
00:02:16,669 --> 00:02:18,838
And what we're doing is
we're firing our signal

63
00:02:18,871 --> 00:02:20,173
to the other satellite,

64
00:02:20,206 --> 00:02:21,674

and the other satellite's
measuring that.

65
00:02:21,707 --> 00:02:23,576
And as you move
backwards and forwards

66
00:02:23,609 --> 00:02:24,810
relative to this sine wave,

67
00:02:24,844 --> 00:02:27,847
you can measure the distance
changes to the levels we need.

68
00:02:27,880 --> 00:02:29,649
Neil, it's been well
more than a decade

69
00:02:29,682 --> 00:02:30,983
since the original
GRACE mission.

70
00:02:31,016 --> 00:02:33,486
I assume we're upgrading some
of these technologies.

71
00:02:33,519 --> 00:02:34,787
Can you describe some of those?

72
00:02:34,820 --> 00:02:37,423
Sure. Like technology
advances in general,

73
00:02:37,456 --> 00:02:39,192
we have upgraded
computer systems.

74
00:02:39,225 --> 00:02:41,060
We have more efficient
solar cells.

75
00:02:41,093 --> 00:02:42,528
We have better star cameras.

76
00:02:42,561 --> 00:02:43,930
And, like everything else
in the future,

77
00:02:43,963 --> 00:02:45,298
we now have lasers!

78
00:02:45,331 --> 00:02:46,933
Lasers! Yes!

79
00:02:46,966 --> 00:02:48,901
What do lasers
actually get for us?

80
00:02:48,934 --> 00:02:51,604
So, we're actually using the
lasers to do the measurement

81
00:02:51,637 --> 00:02:52,905
between the two satellites.

82
00:02:52,938 --> 00:02:55,241
We're using RF systems from
the previous missions.

83
00:02:55,274 --> 00:02:57,810
On top of that, we have this new
technology demonstrator

84
00:02:57,843 --> 00:03:00,046
where we're going to fire
laser beams between each other

85
00:03:00,079 --> 00:03:01,547
to make a more accurate

measurement

86
00:03:01,580 --> 00:03:02,982
between the two satellites.

87
00:03:03,015 --> 00:03:04,450
Neil, this is without a doubt

88
00:03:04,483 --> 00:03:06,219
one of the coolest
missions we've seen!

89
00:03:06,252 --> 00:03:08,621
Thank you so much for
answering our questions.

90
00:03:08,654 --> 00:03:10,756
When can we hope to
see this launch?

91
00:03:10,789 --> 00:03:12,892
So we're hoping to hitch a ride
with a SpaceX rocket

92
00:03:12,925 --> 00:03:14,860
later this year and we should
be collecting science data

93
00:03:14,893 --> 00:03:15,995
shortly after that.

94
00:03:16,028 --> 00:03:17,697
All right. Well, we'll
certainly check that out.

95
00:03:17,730 --> 00:03:19,966
And, everyone out there, check
back soon for some more

96

00:03:19,999 --> 00:03:21,200
Crazy Engineering!

97
00:03:21,233 --> 00:03:23,202
[■]

98
00:03:29,375 --> 00:03:31,844
NASA Jet Propulsion Laboratory