



1
00:00:00,100 --> 00:00:01,968
[Music]

2
00:00:01,968 --> 00:00:05,071
One of Earth's closest
neighbors is a dark, jumbled

3
00:00:05,071 --> 00:00:08,608
mass of rocks and boulders
known as asteroid Bennu.

4
00:00:09,342 --> 00:00:12,979
Bennu is ancient, a rugged
survivor of the solar system's

5
00:00:12,979 --> 00:00:16,616
chaotic past that may hold clues
to the origins of life.

6
00:00:17,550 --> 00:00:20,387
In October 2020,
a NASA spacecraft called

7
00:00:20,387 --> 00:00:23,857
OSIRIS-REx touched down on Bennu
and collected a sample

8
00:00:23,857 --> 00:00:25,592
for return to Earth.

9
00:00:25,592 --> 00:00:28,361
Scientists had expected
that this Touch-And-Go event,

10
00:00:28,528 --> 00:00:31,798
or TAG, would have little impact
on the asteroid.

11
00:00:32,165 --> 00:00:34,834

After a slow descent,
the sampler head would briefly

12

00:00:34,834 --> 00:00:36,169
make contact, inject

13

00:00:36,169 --> 00:00:38,905
a puff of gas, and capture
a handful of material.

14

00:00:39,439 --> 00:00:40,373
Perhaps it would also

15

00:00:40,373 --> 00:00:43,376
leave a small divot
at the sample site...a subtle

16

00:00:43,376 --> 00:00:46,146
footprint in the soil...or
so it was thought.

17

00:00:47,514 --> 00:00:50,283
When images of the TAG event
beamed back to Earth,

18

00:00:50,283 --> 00:00:52,485
they were far more dramatic
than anticipated.

19

00:00:53,253 --> 00:00:56,523
Despite its slow touchdown,
OSIRIS-REx had punched

20

00:00:56,523 --> 00:00:59,692
through the surface and set off
an explosion of loose material.

21

00:01:00,427 --> 00:01:02,662
Tons of rocks
and pebbles were ejected,

22

00:01:02,762 --> 00:01:05,131
radiating outward
in a wall of debris.

23

00:01:05,999 --> 00:01:09,002
The pictures were stunning,
but why did Bennu's surface

24

00:01:09,002 --> 00:01:10,703
behave so unexpectedly?

25

00:01:10,870 --> 00:01:12,939
[Music]

26

00:01:12,939 --> 00:01:14,974
The answer involves cohesion,

27

00:01:15,208 --> 00:01:18,211
an attractive force that can
bind molecules together.

28

00:01:19,079 --> 00:01:22,048
Cohesion gives water its surface
tension and keeps

29

00:01:22,048 --> 00:01:23,049
droplets together

30

00:01:23,049 --> 00:01:24,984
even in a microgravity
environment,

31

00:01:24,984 --> 00:01:27,454
like the International Space
Station.

32

00:01:27,454 --> 00:01:31,658
Granular materials like wheat

flour, cocoa, and dust can also

33

00:01:31,658 --> 00:01:35,261
exhibit cohesion, which pulls
individual grains into clumps.

34

00:01:36,162 --> 00:01:39,032
On Bennu, scientists
had expected cohesion

35

00:01:39,032 --> 00:01:41,134
to act like a bit of glue
between the rocks,

36

00:01:41,134 --> 00:01:43,770
making its loose surface
more solid.

37

00:01:44,270 --> 00:01:45,505
But the TAG event showed

38

00:01:45,505 --> 00:01:48,441
that Bennu's uppermost
layers are nearly cohesionless,

39

00:01:48,541 --> 00:01:50,643
deforming under stress
like a fluid.

40

00:01:51,444 --> 00:01:53,947
A good analogy is a ball pit.

41

00:01:53,947 --> 00:01:55,782
Although the plastic balls
are solid,

42

00:01:55,782 --> 00:01:58,618
they easily slide past one
another (and past

43

00:01:58,618 --> 00:02:01,554

boisterous children),
behaving en masse like a fluid.

44

00:02:01,754 --> 00:02:04,390

[Music]

45

00:02:04,390 --> 00:02:06,693

Thanks to OSIRIS-REx,
we now know

46

00:02:06,693 --> 00:02:09,696

Bennu's surface is not held
together by cohesion,

47

00:02:09,863 --> 00:02:14,634

but by gravity...or,
microgravity, with a minute tug

48

00:02:14,667 --> 00:02:17,003

less than 100,000th
the pull of Earth.

49

00:02:17,770 --> 00:02:21,541

On the Moon, gravity is 16%
as strong as it is on Earth,

50

00:02:21,808 --> 00:02:25,545

and more than 16,000 times
stronger than it is on Bennu.

51

00:02:25,945 --> 00:02:29,015

As a result, loose material
in the lunar subsurface

52

00:02:29,015 --> 00:02:30,717

is packed together more tightly,

53

00:02:30,717 --> 00:02:33,186

making the Moon's surface
relatively firm.

54

00:02:33,853 --> 00:02:37,023

If a 50 kilogram mass of solid
iron were to hit the Moon

55

00:02:37,023 --> 00:02:38,825

at the same speed
as the TAG event,

56

00:02:38,825 --> 00:02:41,794

it would sink into the ground
by only half a centimeter.

57

00:02:42,795 --> 00:02:43,997

Repeating this experiment

58

00:02:43,997 --> 00:02:46,666

at Bennu would yield
a dramatically different result.

59

00:02:47,133 --> 00:02:49,302

Though the mass would strike
with the same force,

60

00:02:49,302 --> 00:02:51,204

it would plunge 17 centimeters

61

00:02:51,204 --> 00:02:54,707

before stopping - over 30 times
deeper than at the Moon.

62

00:02:54,707 --> 00:02:56,743

[Music]

63

00:02:56,743 --> 00:02:59,913

Bennu has consistently defied
scientists' expectations,

64

00:03:00,079 --> 00:03:03,616
as each new finding reveals
another facet of this small

65

00:03:03,650 --> 00:03:05,485
but surprising world.

66

00:03:05,485 --> 00:03:08,721
Using data from OSIRIS-REx,
we now have the ability

67

00:03:08,721 --> 00:03:12,025
to look back and accurately
recreate thirty seconds

68

00:03:12,025 --> 00:03:13,560
on asteroid Bennu.

69

00:03:14,093 --> 00:03:16,262
On October 20th, 2020,

70

00:03:16,262 --> 00:03:18,498
OSIRIS-REx made its
final descent

71

00:03:18,531 --> 00:03:20,934
to a sample site
called Nightingale.

72

00:03:21,401 --> 00:03:23,403
With its TAGSAM arm
outstretched,

73

00:03:23,503 --> 00:03:24,704
it approached the surface

74

00:03:24,704 --> 00:03:28,408
at ten centimeters per second -
the walking pace of an insect.

75

00:03:29,342 --> 00:03:31,077

One second after contact,

76

00:03:31,077 --> 00:03:33,813

it released a canister
of pressurized nitrogen,

77

00:03:33,880 --> 00:03:35,949

detonating
an explosion of particles

78

00:03:36,082 --> 00:03:37,283

and driving material

79

00:03:37,283 --> 00:03:39,819

into the TAGSAM head
for sample collection.

80

00:03:40,486 --> 00:03:42,188

Six seconds after contact,

81

00:03:42,188 --> 00:03:45,425

while it was still sinking
into Bennu, OSIRIS-REx fired

82

00:03:45,425 --> 00:03:47,927

its thrusters
to begin the back away maneuver.

83

00:03:48,728 --> 00:03:52,165

The engine burn lasted
for 24 seconds, continuously

84

00:03:52,165 --> 00:03:55,635

pushing against the spacecraft
and rapidly slowing its descent.

85

00:03:56,302 --> 00:03:59,305

Flying debris from the thrusters
and the gas release

86

00:03:59,305 --> 00:04:02,342
pelted the science instruments,
clogging them with dust.

87

00:04:03,042 --> 00:04:04,944
Nine seconds after contact,

88

00:04:04,944 --> 00:04:08,481
when OSIRIS-REx had sunk
nearly half a meter into Bennu,

89

00:04:08,581 --> 00:04:11,184
it reversed course and began
to rise.

90

00:04:11,851 --> 00:04:14,854
At sixteen seconds,
the TAGSAM head reemerged

91

00:04:14,854 --> 00:04:15,955
from the subsurface,

92

00:04:15,955 --> 00:04:18,391
as the spacecraft
continued to accelerate.

93

00:04:19,092 --> 00:04:22,262
Thirty seconds after contact,
OSIRIS-REx shut off

94

00:04:22,262 --> 00:04:25,632
its thrusters and drifted away
with its sample of Bennu.

95

00:04:25,632 --> 00:04:27,767
[Fade music]

96

00:04:27,767 --> 00:04:29,469

Almost six months later,

97

00:04:29,469 --> 00:04:32,605

on April 7th, 2021,

the spacecraft returned

98

00:04:32,605 --> 00:04:35,308

for one last flyover

to observe its footprint.

99

00:04:35,808 --> 00:04:38,444

At the point of impact

was a new crater, averaging

100

00:04:38,444 --> 00:04:41,848

eight meters across and reaching

68 centimeters in depth.

101

00:04:42,482 --> 00:04:45,685

Thruster marks overlapped

with this "TAG crater" in an X

102

00:04:45,685 --> 00:04:49,022

pattern, increasing its volume

by as much as 40%.

103

00:04:49,722 --> 00:04:52,292

A ridge of ejected material

that had been kicked up

104

00:04:52,292 --> 00:04:54,327

during sample collection

and then fallen

105

00:04:54,327 --> 00:04:57,697

back to the surface, circled

the crater like a campfire ring.

106

00:04:58,264 --> 00:05:01,734
With a puff of gas
and an engine burn, OSIRIS-REx

107
00:05:01,734 --> 00:05:05,071
had displaced 12 cubic meters
of granular material...

108
00:05:05,305 --> 00:05:07,940
six tons of loose rock
that may have been

109
00:05:07,940 --> 00:05:10,877
packed together as lightly
as a bowl of popcorn!

110
00:05:10,877 --> 00:05:13,680
[Music]

111
00:05:13,680 --> 00:05:17,250
After a final departure
maneuver in May 2021,

112
00:05:17,250 --> 00:05:20,153
OSIRIS-REx began a two-year
journey back to Earth.

113
00:05:20,787 --> 00:05:24,590
Stowed on board were about
250 grams of asteroid

114
00:05:24,590 --> 00:05:27,160
Bennu - a bounty of
scientific treasure

115
00:05:27,193 --> 00:05:29,128
destined for future discoveries.