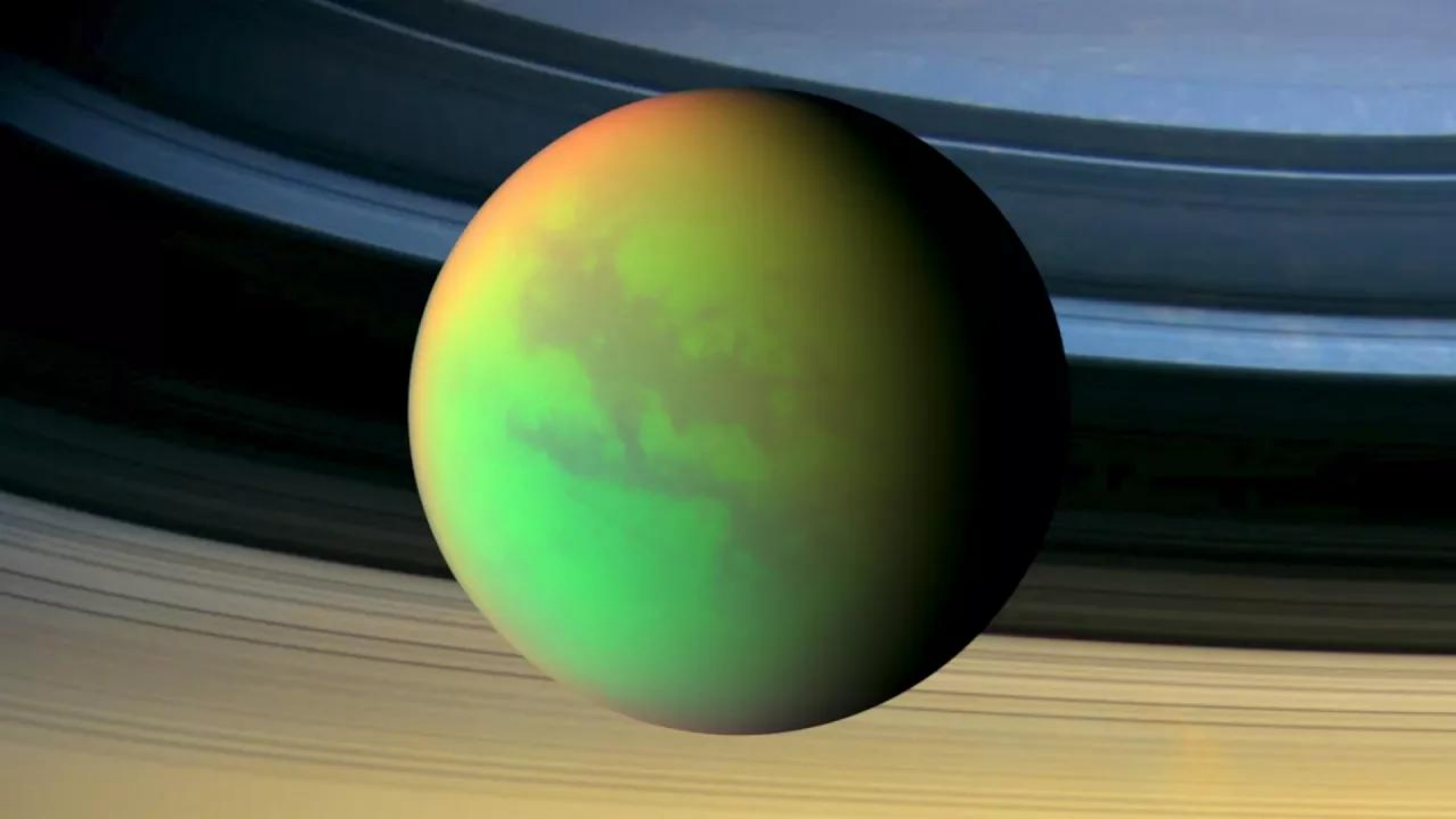

1
00:00:00,920 --> 00:00:04,860
TEXT ON SCREEN: NASA's Cassini
spacecraft arrived at Saturn in 2004.

2
00:00:05,180 --> 00:00:07,740
TEXT ON SCREEN: Cassini studied
Saturn and its moons in the

3
00:00:07,741 --> 00:00:10,444
infrared using its
CIRS instrument.

4
00:00:10,444 --> 00:00:13,313
TEXT ON SCREEN: CIRS is an
infrared spectrometer built and

5
00:00:13,313 --> 00:00:15,582
operated by NASA's
Goddard Space Flight Center.

6
00:00:15,582 --> 00:00:19,240
TEXT ON SCREEN: Here are some
of Cassini CIRS' Greatest Hits.

7
00:00:22,920 --> 00:00:24,920
TEXT: THE GREAT WHITE SPOT

8
00:00:25,160 --> 00:00:28,360
So in 2010, there was a giant
outburst in Saturn's northern

9
00:00:28,362 --> 00:00:29,229
hemisphere.

10
00:00:29,229 --> 00:00:32,833
A giant storm eruption occurred,
and eventually this spread

11
00:00:32,833 --> 00:00:36,336

around to encircle the entire
globe at a latitude width about

12
00:00:36,336 --> 00:00:38,272
the extent of North America.

13
00:00:38,272 --> 00:00:41,675
Imaging first picked it up,
and it was, it was massive.

14
00:00:41,675 --> 00:00:45,812
From north to south it spanned
about nine thousand miles.

15
00:00:45,812 --> 00:00:48,382
CIRS saw temperature increase
like we've never recorded

16
00:00:48,382 --> 00:00:49,383
before.

17
00:00:49,383 --> 00:00:53,153
CIRS, looking with its thermal
infrared eyes, was able to see

18
00:00:53,153 --> 00:00:57,357
two bright beacons of hotspot
temperatures shining about 150

19
00:00:57,357 --> 00:00:59,192
degrees brighter
than the surroundings.

20
00:00:59,192 --> 00:01:01,628
We, all of a sudden we
had these two bright spots.

21
00:01:01,628 --> 00:01:04,665
After a month or two they
merged, which was kind of

22
00:01:04,665 --> 00:01:08,201
curious, and then it
persisted for another two years.

23
00:01:08,201 --> 00:01:11,805
In fact, it persisted longer
than the tropospheric storm.

24
00:01:11,805 --> 00:01:14,408
Typically on Saturn these occur
about every twenty to thirty

25
00:01:14,408 --> 00:01:18,045
years, this is the sixth one
that's been seen since 1876.

26
00:01:18,045 --> 00:01:21,114
And Cassini was lucky enough to
be there at the right place at

27
00:01:21,120 --> 00:01:23,240
the right time to see
this storm eruption.

28
00:01:23,240 --> 00:01:24,184
TEXT: PAC-MAN MOONS

29
00:01:24,184 --> 00:01:27,955
Mimas and Tethys are two of I
believe the last count was about

30
00:01:27,955 --> 00:01:32,693
sixty-two moons that Saturn has,
and these are examples of these

31
00:01:32,693 --> 00:01:35,996
icy satellites, two of
Saturn's icy satellites.

32
00:01:35,996 --> 00:01:38,732
When you just take images
with Cassini they look normal.

33
00:01:38,732 --> 00:01:41,702
With Mimas it looks like the
Death Star, you know, and then

34
00:01:41,702 --> 00:01:44,304
you superimpose the
thermal maps from CIRS on it.

35
00:01:44,304 --> 00:01:47,040
And when you superimpose the
thermal maps, it looks like

36
00:01:47,040 --> 00:01:48,108
Pac-Man.

37
00:01:48,108 --> 00:01:51,311
Mimas was an example where
we saw very warm temperatures

38
00:01:51,311 --> 00:01:56,183
surrounding a very cold region,
as if it was going to, you know,

39
00:01:56,183 --> 00:01:57,184
chomp it up.

40
00:01:57,184 --> 00:02:00,520
Turns out the explanation
is kind of, is interesting.

41
00:02:00,520 --> 00:02:04,257
The way these are created is due
to their orbital orientation as

42
00:02:04,257 --> 00:02:05,625

they go around Saturn.

43
00:02:05,625 --> 00:02:08,929
They have a leading side, which
is always towards the front of

44
00:02:08,929 --> 00:02:11,098
its motion, and a trailing side.

45
00:02:11,098 --> 00:02:14,601
And the leading side is
intensely bombarded by radiation

46
00:02:14,601 --> 00:02:16,036
from Saturn's magnetosphere.

47
00:02:16,036 --> 00:02:19,139
So the high-energy particle
bombardment is causing this

48
00:02:19,139 --> 00:02:24,611
fluffy surface, this icy, fluffy
surface, to be packed down to a

49
00:02:24,611 --> 00:02:28,949
very hard, solid ice surface,
and you're changing the way now

50
00:02:28,949 --> 00:02:32,686
the surface can heat up and cool
down over the course of a day

51
00:02:32,686 --> 00:02:34,154
for these moons.

52
00:02:34,154 --> 00:02:37,591
When we look at these in
infrared we see a cooler region

53

00:02:37,591 --> 00:02:40,994
on the leading hemisphere, and
a warmer region surrounding it.

54
00:02:40,994 --> 00:02:43,363
And this gives the exact
appearance of these Pac-Man

55
00:02:43,363 --> 00:02:45,360
features that we
so know and love.

56
00:02:47,180 --> 00:02:48,720
TEXT: ENCELADUS OCEAN

57
00:02:48,720 --> 00:02:52,000
Enceladus is a very
small, icy moon of Saturn.

58
00:02:52,005 --> 00:02:54,474
It's about three
hundred miles in diameter.

59
00:02:54,474 --> 00:02:58,178
It's a moon that we weren't
expecting to see a lot from, and

60
00:02:58,178 --> 00:03:01,081
it's had a huge impact
on the Saturn system.

61
00:03:01,081 --> 00:03:04,184
Previously, we had hints
that this moon may be active

62
00:03:04,184 --> 00:03:06,253
stretching all the way
back to the Voyager mission.

63
00:03:06,253 --> 00:03:10,457

But when Cassini arrived, it was
able to detect curtains of icy

64
00:03:10,457 --> 00:03:12,859
material venting into space.

65
00:03:12,859 --> 00:03:15,996
Then using the CIRS instrument,
we were able to zoom in on the

66
00:03:15,996 --> 00:03:19,099
south pole, and see the south
pole was much warmer than we

67
00:03:19,099 --> 00:03:20,067
expected.

68
00:03:20,067 --> 00:03:24,304
The pattern of temperatures on
Enceladus did not match a simple

69
00:03:24,304 --> 00:03:27,307
inert body absorbing
sunlight and reradiating it.

70
00:03:27,307 --> 00:03:29,910
The question was what
to make of all this.

71
00:03:29,910 --> 00:03:32,979
The community decided it must be
tidal friction, tidal heating,

72
00:03:32,979 --> 00:03:35,082
as Enceladus orbits Saturn.

73
00:03:35,082 --> 00:03:38,218
This tells us that Enceladus is
being heated up by the action of

74
00:03:38,218 --> 00:03:39,419
Saturn's gravity.

75
00:03:39,419 --> 00:03:42,022
Inside Enceladus, we now know
that there's a liquid water

76
00:03:42,022 --> 00:03:45,025
ocean, and it's this ocean which
is venting through these cracks

77
00:03:45,025 --> 00:03:46,026
into space.

78
00:03:46,026 --> 00:03:47,994
Throughout the mission,
we've learned that it has a

79
00:03:47,994 --> 00:03:50,764
subsurface,
liquid-water environment.

80
00:03:50,764 --> 00:03:54,134
And with NASA, when you see
liquid water, it's "Follow the

81
00:03:54,140 --> 00:03:56,840
water," because
that's important for life.

82
00:03:57,940 --> 00:03:58,960
TEXT: TARGETING TITAN

83
00:03:58,960 --> 00:04:01,600
Titan was one of the
major objectives of Cassini.

84
00:04:01,608 --> 00:04:05,579
We knew from Voyager that

Titan was an organic molecule

85
00:04:05,579 --> 00:04:08,715
paradise, it just was
filled with organic molecules.

86
00:04:08,715 --> 00:04:11,985
But maybe one of the key things
about Cassini was, instead of a

87
00:04:11,985 --> 00:04:15,922
flyby past the Saturn system,
Cassini hung around for thirteen

88
00:04:15,922 --> 00:04:16,923
years.

89
00:04:16,923 --> 00:04:19,192
And during that time, even
though we were orbiting Saturn,

90
00:04:19,192 --> 00:04:23,296
we flew by Titan a
hundred and twenty-five times.

91
00:04:23,296 --> 00:04:27,033
Titan, at visible wavelengths,
looks like as everyone has seen,

92
00:04:27,033 --> 00:04:29,503
a orange-y, hazy moon.

93
00:04:29,503 --> 00:04:34,107
When Cassini was built, we put
on spectrometers that could see

94
00:04:34,107 --> 00:04:38,311
to longer wavelengths, outside
of the eye's visible range.

95
00:04:38,311 --> 00:04:42,616
And so we removed the veil of
this smog, we peeled it back.

96
00:04:42,616 --> 00:04:45,752
Lo and behold, we saw this
amazing, very active surface.

97
00:04:45,752 --> 00:04:50,524
River channels, and dunes,
and we found polar lakes.

98
00:04:50,524 --> 00:04:53,393
And we never saw this before
because we couldn't penetrate

99
00:04:53,400 --> 00:04:55,700
this very opaque,
hazy atmosphere.

100
00:04:57,840 --> 00:04:59,540
TEXT: A NEW HYDROCARBON

101
00:04:59,540 --> 00:05:02,235
In 2013, we made a fascinating
discovery about Titan's

102
00:05:02,235 --> 00:05:03,236
atmosphere.

103
00:05:03,236 --> 00:05:05,839
We discovered a new molecule,
which hadn't been previously

104
00:05:05,839 --> 00:05:06,840
detected.

105
00:05:06,840 --> 00:05:10,076
And this is called propylene,

and this molecule, on the Earth,

106
00:05:10,076 --> 00:05:11,311
serves a variety of purposes.

107
00:05:11,311 --> 00:05:14,414
In fact, it's one of the raw
ingredients that we use to make

108
00:05:14,414 --> 00:05:17,984
a type of hard rubbery plastic
commonly known as Tupperware,

109
00:05:17,984 --> 00:05:19,653
which we use in our lunchboxes.

110
00:05:19,653 --> 00:05:23,056
And it was really incredible to
find this molecule just floating

111
00:05:23,056 --> 00:05:24,491
around in Titan's atmosphere.

112
00:05:24,491 --> 00:05:27,327
Going all the way back to
the Voyager mission 32 years

113
00:05:27,327 --> 00:05:30,397
earlier, we'd seen a lighter
molecule and a heavier molecule

114
00:05:30,397 --> 00:05:32,065
in the same chemical family.

115
00:05:32,065 --> 00:05:34,834
But there was a gap at a
particular molecular mass, a

116
00:05:34,834 --> 00:05:37,170

particular size of molecule that
we just couldn't see anything

117
00:05:37,170 --> 00:05:38,205
in.

118
00:05:38,205 --> 00:05:41,975
So this discovery, using CIRS,
filled in this puzzle piece,

119
00:05:41,975 --> 00:05:44,878
which had been completely
outstanding for about thirty-two

120
00:05:44,880 --> 00:05:46,680
years.

121
00:05:47,620 --> 00:05:49,200
TEXT: THE GRAND FINALE

122
00:05:49,200 --> 00:05:52,752
Cassini's Grand Finale is now
underway as we dive repeatedly

123
00:05:52,752 --> 00:05:56,022
over the planet's north pole,
and through the gap between the

124
00:05:56,022 --> 00:05:57,490
planet and its innermost rings.

125
00:05:57,490 --> 00:05:59,326
We're making gravity
measurements and magnetic field

126
00:05:59,326 --> 00:06:01,261
measurements, and this is
information that we didn't get

127

00:06:01,261 --> 00:06:03,663
earlier in the mission so in
many ways it's like having a

128
00:06:03,663 --> 00:06:05,966
whole new spacecraft mission.

129
00:06:05,966 --> 00:06:10,370
Finally, on the very last orbit,
Cassini will go closer to Saturn

130
00:06:10,370 --> 00:06:12,572
and eventually burn up
in its upper atmosphere.

131
00:06:12,572 --> 00:06:15,575
The spacecraft will disintegrate
and become a permanent part of