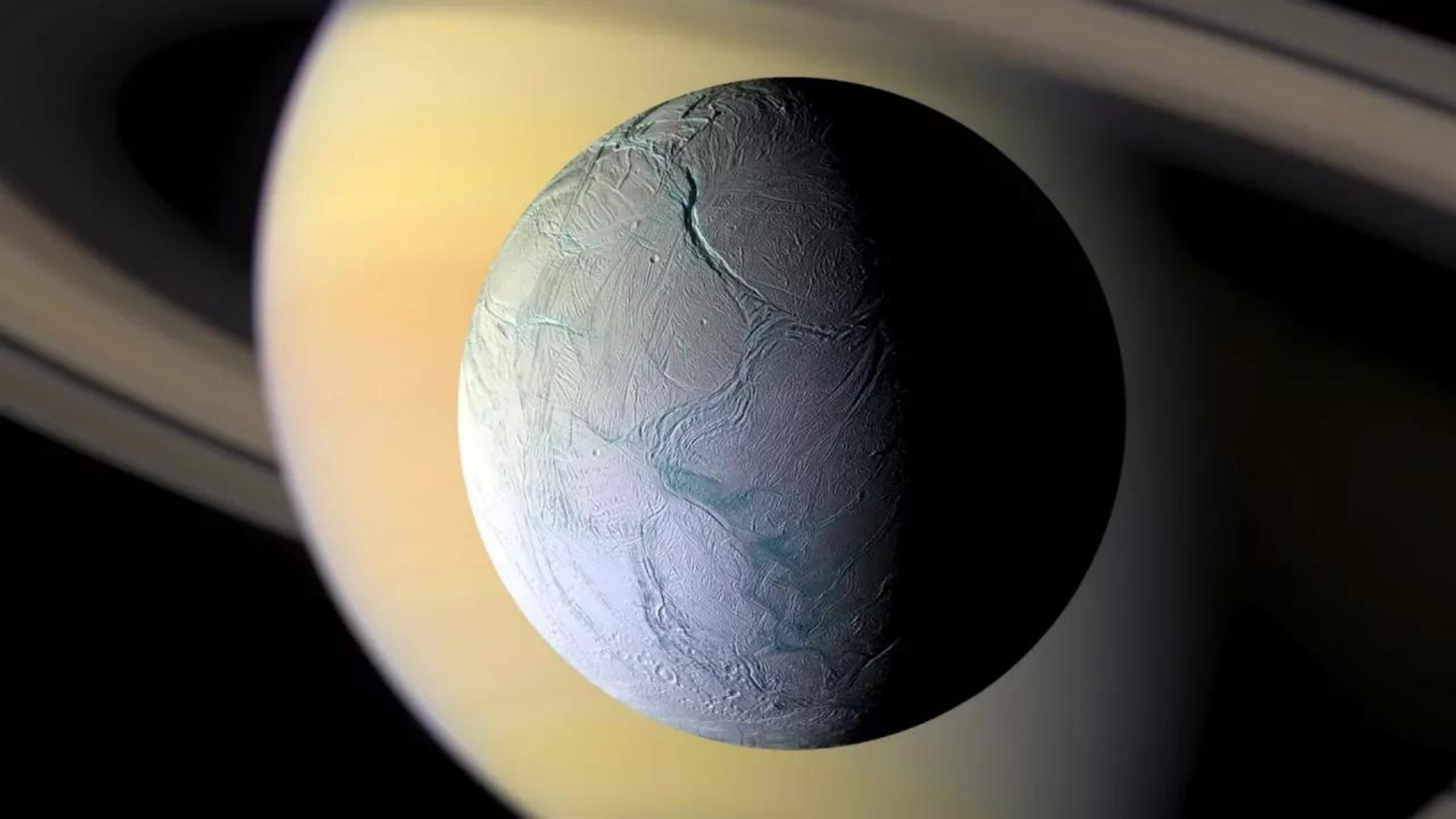

1
00:00:00,100 --> 00:00:06,006
[Music]

2
00:00:06,006 --> 00:00:07,841
My name is Michael
Flasar and I am the principal

3
00:00:07,841 --> 00:00:11,178
investigator of the Cassini
Composite Infrared Spectrometer,

4
00:00:11,178 --> 00:00:13,013
otherwise known as CIRS.

5
00:00:13,013 --> 00:00:14,147
My name is Conor Nixon.

6
00:00:14,147 --> 00:00:16,516
I'm a planetary scientist here
at NASA's Goddard Space Flight

7
00:00:16,516 --> 00:00:19,353
Center, and I study Saturn and
its amazing system of moons and

8
00:00:19,353 --> 00:00:22,022
rings using the Composite
Infrared Spectrometer on the

9
00:00:22,022 --> 00:00:23,190
Cassini spacecraft.

10
00:00:23,190 --> 00:00:24,358
My name is Carrie Anderson.

11
00:00:24,358 --> 00:00:27,127
I work at NASA's Goddard
Space Flight Center and I'm a

12
00:00:27,127 --> 00:00:29,363
co-investigator
on the CIRS team.

13
00:00:29,363 --> 00:00:33,133
Cassini is the mission that was
to study the Saturn system, and

14
00:00:33,133 --> 00:00:34,701
has studied the Saturn system.

15
00:00:34,701 --> 00:00:37,838
It consisted of a spacecraft
that orbits Saturn and studies

16
00:00:37,838 --> 00:00:41,141
all the other satellites in
the system, and the rings.

17
00:00:41,141 --> 00:00:45,245
But it also had a probe, and
its probe landed on Titan.

18
00:00:45,245 --> 00:00:48,549
Before Cassini, the
previous flagship was Voyager.

19
00:00:48,549 --> 00:00:51,752
That flew by the Saturn
system in 1980, Voyager 1.

20
00:00:51,752 --> 00:00:54,154
In 1981 was Voyager 2.

21
00:00:54,154 --> 00:00:55,923
Those were just flyby missions.

22
00:00:55,923 --> 00:00:59,026
Cassini went into orbit around

Saturn, which was the first

23
00:00:59,026 --> 00:01:01,695
time, very historical,
this had never happened.

24
00:01:01,695 --> 00:01:04,998
Off-screen: And liftoff of
the Cassini spacecraft on a

25
00:01:04,998 --> 00:01:06,800
billion-mile trek to Saturn!

26
00:01:06,800 --> 00:01:10,837
The spacecraft launched in 1997
and after a long, seven-year

27
00:01:10,837 --> 00:01:14,608
cruise, it arrived at Saturn,
did a dramatic entry burn into

28
00:01:14,608 --> 00:01:17,110
orbit around Saturn, and
then commenced a wondrous,

29
00:01:17,110 --> 00:01:20,547
thirteen-year mission to explore
the entire system of moons and

30
00:01:20,547 --> 00:01:22,449
rings around Saturn.

31
00:01:22,449 --> 00:01:25,686
CIRS is Cassini's Composite
Infrared Spectrometer, built at

32
00:01:25,686 --> 00:01:28,255
NASA's Goddard Space Flight
Center, and this instrument is

33
00:01:28,255 --> 00:01:31,959
designed to measure thermal
infrared radiation, or heat, and

34
00:01:31,959 --> 00:01:34,561
split it up into different
wavelengths and measure the

35
00:01:34,561 --> 00:01:36,797
intensity of each one
of these wavelengths.

36
00:01:36,797 --> 00:01:39,299
The other thing is,
it's a chemical assayer.

37
00:01:39,299 --> 00:01:42,936
These molecules in the
atmosphere, ethane, methane,

38
00:01:42,936 --> 00:01:45,939
hydrogen, these molecules
have distinct signatures in the

39
00:01:45,939 --> 00:01:46,907
spectrum.

40
00:01:46,907 --> 00:01:49,242
They're their fingerprints.

41
00:01:49,242 --> 00:01:52,379
TEXT ON SCREEN: After arriving
in 2004, Cassini began observing

42
00:01:52,379 --> 00:01:55,215
Saturn and its moons in
the infrared using CIRS.

43
00:01:55,215 --> 00:01:57,651

CIRS carried out
over 1.4 million commands and

44
00:01:57,651 --> 00:01:59,886
collected terabytes of
data and image products.

45
00:01:59,886 --> 00:02:02,422
Here are some of
the instrument's greatest hits.

46
00:02:05,425 --> 00:02:08,462
So in 2010, there was a giant
outburst in Saturn's northern

47
00:02:08,462 --> 00:02:09,463
hemisphere.

48
00:02:09,463 --> 00:02:13,100
A giant storm eruption occurred,
and eventually this spread

49
00:02:13,100 --> 00:02:16,603
around to encircle the entire
globe at a latitude width about

50
00:02:16,603 --> 00:02:18,538
the extent of North America.

51
00:02:18,538 --> 00:02:21,942
Imaging first picked it up,
and it was, it was massive.

52
00:02:21,942 --> 00:02:26,079
From north to south it spanned
about nine thousand miles.

53
00:02:26,079 --> 00:02:28,448
CIRS saw temperature increase
like we've never recorded

54
00:02:28,448 --> 00:02:29,516
before.

55
00:02:29,516 --> 00:02:33,420
CIRS, looking with its thermal
infrared eyes, was able to see

56
00:02:33,420 --> 00:02:37,624
two bright beacons of hotspot
temperatures shining about 150

57
00:02:37,624 --> 00:02:39,459
degrees brighter
than the surroundings.

58
00:02:39,459 --> 00:02:41,695
We, all of a sudden we
had these two bright spots.

59
00:02:41,695 --> 00:02:45,098
After a month or two they
merged, which was kind of

60
00:02:45,098 --> 00:02:48,468
curious, and then it
persisted for another two years.

61
00:02:48,468 --> 00:02:52,139
In fact, it persisted longer
than the tropospheric storm.

62
00:02:52,139 --> 00:02:54,741
Typically on Saturn these occur
about every twenty to thirty

63
00:02:54,741 --> 00:02:58,378
years, this is the sixth one
that's been seen since 1876.

64
00:02:58,378 --> 00:03:01,381
And Cassini was lucky enough to
be there at the right place at

65
00:03:01,381 --> 00:03:04,451
the right time to see
this storm eruption.

66
00:03:04,451 --> 00:03:08,221
Mimas and Tethys are two of I
believe the last count was about

67
00:03:08,221 --> 00:03:12,859
62 moons that Saturn has,
and these are examples of these

68
00:03:12,859 --> 00:03:16,229
icy satellites, two of
Saturn's icy satellites.

69
00:03:16,229 --> 00:03:18,999
When you just take images
with Cassini they look normal.

70
00:03:18,999 --> 00:03:21,968
With Mimas it looks like the
Death Star, you know, and then

71
00:03:21,968 --> 00:03:24,571
you superimpose the
thermal maps from CIRS on it.

72
00:03:24,571 --> 00:03:27,007
And when you superimpose the
thermal maps, it looks like

73
00:03:27,007 --> 00:03:28,175
Pac-Man.

74

00:03:28,175 --> 00:03:31,445
Mimas was an example where
we saw very warm temperatures

75
00:03:31,445 --> 00:03:36,149
surrounding a very cold region,
as if it was going to, you know,

76
00:03:36,149 --> 00:03:37,551
chomp it up.

77
00:03:37,551 --> 00:03:40,854
Turns out the explanation
is kind of, is interesting.

78
00:03:40,854 --> 00:03:44,591
The way these are created is due
to their orbital orientation as

79
00:03:44,591 --> 00:03:45,959
they go around Saturn.

80
00:03:45,959 --> 00:03:49,463
They have a leading side, which
is always towards the front of

81
00:03:49,463 --> 00:03:51,431
its motion, and a trailing side.

82
00:03:51,431 --> 00:03:54,935
And the leading side is
intensely bombarded by radiation

83
00:03:54,935 --> 00:03:56,369
from Saturn's magnetosphere.

84
00:03:56,369 --> 00:03:59,473
So the high-energy particle
bombardment is causing this

85
00:03:59,473 --> 00:04:04,144
fluffy surface, this icy, fluffy
surface, to be packed down to a

86
00:04:04,144 --> 00:04:09,216
very hard, solid ice surface,
and you're changing the way now

87
00:04:09,216 --> 00:04:13,320
the surface can heat up and cool
down over the course of a day

88
00:04:13,320 --> 00:04:14,421
for these moons.

89
00:04:14,421 --> 00:04:17,858
When we look at these in
infrared we see a cooler region

90
00:04:17,858 --> 00:04:21,261
on the leading hemisphere, and
a warmer region surrounding it.

91
00:04:21,261 --> 00:04:23,630
And this gives the exact
appearance of these Pac-Man

92
00:04:23,630 --> 00:04:25,632
features that we
so know and love.

93
00:04:28,969 --> 00:04:32,272
Enceladus is a very
small, icy moon of Saturn.

94
00:04:32,272 --> 00:04:34,741
It's about three
hundred miles in diameter.

95

00:04:34,741 --> 00:04:38,445
It's a moon that we weren't
expecting to see a lot from, and

96
00:04:38,445 --> 00:04:41,414
it's had a huge impact
on the Saturn system.

97
00:04:41,414 --> 00:04:44,518
Previously, we had hints
that this moon may be active

98
00:04:44,518 --> 00:04:46,586
stretching all the way
back to the Voyager mission.

99
00:04:46,586 --> 00:04:50,757
But when Cassini arrived, it was
able to detect curtains of icy

100
00:04:50,757 --> 00:04:53,193
material venting into space.

101
00:04:53,193 --> 00:04:56,329
Then using the CIRS instrument,
we were able to zoom in on the

102
00:04:56,329 --> 00:04:59,366
south pole, and see the south
pole was much warmer than we

103
00:04:59,366 --> 00:05:00,333
expected.

104
00:05:00,333 --> 00:05:04,571
The pattern of temperatures on
Enceladus did not match a simple

105
00:05:04,571 --> 00:05:07,541
inert body absorbing

sunlight and reradiating it.

106
00:05:07,541 --> 00:05:10,177
The question was what
to make of all this.

107
00:05:10,177 --> 00:05:13,246
The community decided it must be
tidal friction, tidal heating,

108
00:05:13,246 --> 00:05:15,415
as Enceladus orbits Saturn.

109
00:05:15,415 --> 00:05:18,485
This tells us that Enceladus is
being heated up by the action of

110
00:05:18,485 --> 00:05:19,686
Saturn's gravity.

111
00:05:19,686 --> 00:05:22,322
Inside Enceladus, we now know
that there's a liquid water

112
00:05:22,322 --> 00:05:25,292
ocean, and it's this ocean which
is venting through these cracks

113
00:05:25,292 --> 00:05:26,459
into space.

114
00:05:26,459 --> 00:05:28,328
Throughout the mission,
we've learned that it has a

115
00:05:28,328 --> 00:05:31,164
subsurface,
liquid-water environment.

116

00:05:31,164 --> 00:05:34,501
And with NASA, when you see
liquid water, it's "Follow the

117
00:05:34,501 --> 00:05:36,980
water," because
that's important for life.

118
00:05:39,200 --> 00:05:41,940
Titan was one of the
major objectives of Cassini.

119
00:05:41,942 --> 00:05:45,912
We knew from Voyager that
Titan was an organic molecule

120
00:05:45,912 --> 00:05:49,049
paradise, it just was
filled with organic molecules.

121
00:05:49,049 --> 00:05:52,319
But maybe one of the key things
about Cassini was, instead of a

122
00:05:52,319 --> 00:05:56,189
flyby past the Saturn system,
Cassini hung around for thirteen

123
00:05:56,189 --> 00:05:57,257
years.

124
00:05:57,257 --> 00:05:59,526
And during that time, even
though we were orbiting Saturn,

125
00:05:59,526 --> 00:06:03,563
we flew by Titan a
hundred and twenty-five times.

126
00:06:03,563 --> 00:06:07,300

Titan, at visible wavelengths,
looks like as everyone has seen,

127
00:06:07,300 --> 00:06:09,869
a orange-y, hazy moon.

128
00:06:09,869 --> 00:06:14,341
When Cassini was built, we put
on spectrometers that could see

129
00:06:14,341 --> 00:06:18,511
to longer wavelengths, outside
of the eye's visible range.

130
00:06:18,511 --> 00:06:22,749
And so we removed the veil of
this smog, we peeled it back.

131
00:06:22,749 --> 00:06:26,253
Lo and behold, we saw this
amazing, very active surface.

132
00:06:26,253 --> 00:06:30,790
River channels, and dunes,
and we found polar lakes.

133
00:06:30,790 --> 00:06:33,593
And we never saw this before
because we couldn't penetrate

134
00:06:33,593 --> 00:06:35,996
this very opaque,
hazy atmosphere.

135
00:06:39,833 --> 00:06:42,335
In 2013, we made a fascinating
discovery about Titan's

136
00:06:42,335 --> 00:06:43,403
atmosphere.

137
00:06:43,403 --> 00:06:46,006
We discovered a new molecule,
which hadn't been previously

138
00:06:46,006 --> 00:06:46,973
detected.

139
00:06:46,973 --> 00:06:50,410
And this is called propylene,
and this molecule, on the Earth,

140
00:06:50,410 --> 00:06:51,645
serves a variety of purposes.

141
00:06:51,645 --> 00:06:54,748
In fact, it's one of the raw
ingredients that we use to make

142
00:06:54,748 --> 00:06:58,318
a type of hard rubbery plastic
commonly known as Tupperware,

143
00:06:58,318 --> 00:06:59,719
which we use in our lunch boxes.

144
00:06:59,719 --> 00:07:03,323
And it was really incredible to
find this molecule just floating

145
00:07:03,323 --> 00:07:04,758
around in Titan's atmosphere.

146
00:07:04,758 --> 00:07:07,594
Going all the way back to the
Voyager mission thirty-two years

147
00:07:07,594 --> 00:07:10,664
earlier, we'd seen a lighter

molecule and a heavier molecule

148
00:07:10,664 --> 00:07:12,332
in the same chemical family.

149
00:07:12,340 --> 00:07:15,100
But there was a gap at a
particular molecular mass, a

150
00:07:15,100 --> 00:07:17,640
particular size of molecule that
we just couldn't see anything

151
00:07:17,640 --> 00:07:18,638
in.

152
00:07:18,638 --> 00:07:22,242
So this discovery, using CIRS,
filled in this puzzle piece,

153
00:07:22,242 --> 00:07:25,145
which had been completely
outstanding for about thirty-two

154
00:07:25,145 --> 00:07:26,980
years.

155
00:07:30,950 --> 00:07:34,587
Cassini's Grand Finale is now
underway as we dive repeatedly

156
00:07:34,587 --> 00:07:37,490
over the planet's north pole,
and through the gap between the

157
00:07:37,490 --> 00:07:39,059
planet and its innermost rings.

158
00:07:39,059 --> 00:07:41,061

We're making gravity
measurements and magnetic field

159
00:07:41,061 --> 00:07:43,096
measurements, and this is
information that we didn't get

160
00:07:43,096 --> 00:07:45,632
earlier in the mission so in
many ways it's like having a

161
00:07:45,632 --> 00:07:47,801
whole new spacecraft mission.

162
00:07:47,801 --> 00:07:52,138
Finally, on the very last orbit,
Cassini will go closer to Saturn

163
00:07:52,138 --> 00:07:54,174
and eventually burn up
in its upper atmosphere.

164
00:07:54,174 --> 00:07:57,344
The spacecraft will disintegrate
and become a permanent part of

165
00:07:57,344 --> 00:07:58,545
Saturn.

166
00:07:58,545 --> 00:08:00,180
It's a
bittersweet moment for us.

167
00:08:00,180 --> 00:08:02,882
We're so used to doing
Cassini, we'll miss it.

168
00:08:02,882 --> 00:08:05,485
As far as what CIRS has
accomplished, the excitement

169
00:08:05,485 --> 00:08:08,922
about the Enceladus
south pole has to rank high.

170
00:08:08,922 --> 00:08:12,792
The complex dynamics of
Saturn and its storms.

171
00:08:12,792 --> 00:08:15,128
Titan, just being
able to see Titan.

172
00:08:15,128 --> 00:08:18,965
The point is that if you don't
go up close and take the data,

173
00:08:18,965 --> 00:08:19,933
you get nothing.

174
00:08:19,933 --> 00:08:22,736
If you do take the data, there's
no guarantee you're going to

175
00:08:22,736 --> 00:08:25,338
solve all the problems, but on
the other hand at least you've

176
00:08:25,338 --> 00:08:27,307
made the effort to
acquire something and to ask

177
00:08:27,307 --> 00:08:28,842
other questions.

178
00:08:28,842 --> 00:08:33,179
This mission, and the amount of
data it's recorded, goes beyond

179

00:08:33,179 --> 00:08:34,447
just one object.

180
00:08:34,447 --> 00:08:37,450
Titan has always been my true
love, but I also have learned to,,

181
00:08:37,450 --> 00:08:40,720
really appreciate other moons
in Saturn's system, for example,

182
00:08:40,720 --> 00:08:41,788
Iapetus.

183
00:08:41,788 --> 00:08:45,325
It has this amazing dark-leading
hemisphere, but its trailing

184
00:08:45,325 --> 00:08:47,761
hemisphere is bright like snow.

185
00:08:47,761 --> 00:08:49,662
It's been called the
yin and yang moon.

186
00:08:49,662 --> 00:08:52,365
One of the moons called
Pan, it's embedded in Saturn's

187
00:08:52,365 --> 00:08:54,667
A-Ring, and it causes this gap.

188
00:08:54,667 --> 00:08:57,203
Pan looks like a flying saucer.

189
00:08:57,203 --> 00:09:01,141
These kind of things, you can't
have unless you're in orbit

190

00:09:01,141 --> 00:09:03,610
around such a
magnificent planet.

191
00:09:03,610 --> 00:09:06,279
And the data we've taken from
this system, I have no doubt

192
00:09:06,279 --> 00:09:08,748
will be used for decades to
come, and I only hope we can go

193
00:09:08,748 --> 00:09:11,117
back one day.